Updating the Saskatchewan Passing Lane Design Guide for Planning and Prioritization Purposes

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ABSTRACT

Over the past five to ten years, Saskatchewan has seen above average vehicular and truck traffic growth in a number of areas throughout the province. This increase in traffic, coupled with public safety concerns, has led the Ministry of Highways and Infrastructure (MHI) to investigate the implementation of passing lanes on its two-lane highways as a way to improve overall traffic operations. Typically, a passing lane is a third lane added to a two-lane highway in level or rolling terrain for the exclusive purpose of providing additional passing opportunities where passing is otherwise limited by sight distance and opposing traffic. This can improve overall traffic operations by breaking up traffic platoons and reducing delays and collisions caused by inadequate passing opportunities. Passing lanes normally have high driver compliance, positive driver response, and may be an economically feasible solution to improve level of service and defer twinning of a highway.

MMM Group Limited (MMM) was retained by MHI to complete a passing lane location study on Highway 10 between Regina and the Fort Qu'Appelle Valley. The study purpose was to assess the need, configuration and existing roadway geometry of the corridor to identify timely and cost effective passing lane locations. During the study it was determined that the Saskatchewan passing lane design guide required updating and MMM therefore reviewed passing lane design guidelines from British Columbia, Alberta, Manitoba and the Transportation Association of Canada in order to gauge practices in other jurisdictions and their potential applications in Saskatchewan. Subsequently, the MHI design guide was updated to incorporate implementation warrants based on collisions and level of service. The updated guide was used to assess passing lane systems, locations and benefits/costs on Highway 10, and eventually expanded to include the Highway 7 corridor between Saskatoon and Rosetown.

Potentially, the updated design guide could be used to evaluate the effectiveness of passing lanes for a number of highway segments throughout the provincial network. This could, in turn, lead to the development of a high level passing lane and twinning prioritization strategy for the Ministry. This paper relates the MHI passing lane design guide update to transportation planning objectives for the provincial highway network.

INTRODUCTION

Over the past five to ten years, Saskatchewan has seen above average vehicular and truck traffic growth in a number of areas throughout the province. This increase in traffic, coupled with public safety concerns, has led MHI to investigate the implementation of passing lanes on its two-lane highways as a way to improve overall traffic operations. Typically, a passing lane is a third lane added to a two-lane highway in level or rolling terrain for the exclusive purpose of providing additional passing opportunities where passing is otherwise limited by sight distance and opposing traffic. This can improve overall traffic operations by breaking up traffic platoons and reducing delays and collisions caused by inadequate passing opportunities. Passing lanes normally have high driver compliance, positive driver response, and may be an economically feasible solution to improve level of service and defer twinning of a highway.

BACKGROUND INFORMATION

Passing Lanes

A passing lane is the introduction of an additional lane, having sufficient length to allow faster moving vehicles to safely pass slower moving vehicles. Passing lanes improve the overall traffic operations on two-lane highways by reducing delays and collisions caused by inadequate passing opportunities. Passing lanes may be an economically feasible solution to improve level of service and delay twinning of a highway. Ideally, passing lanes should have a useful life of at least 10 and preferably 20 years (a typical road design period). Any of the following conditions can lead to conditions that may require consideration of a passing lane:

- High percentage of no-passing zones
- Traffic volumes high enough to restrict assured passing opportunities
- High percentage of long distance, high speed trips
- High percentage of slow moving vehicles

A typical passing lane configuration is illustrated in Figure 1.

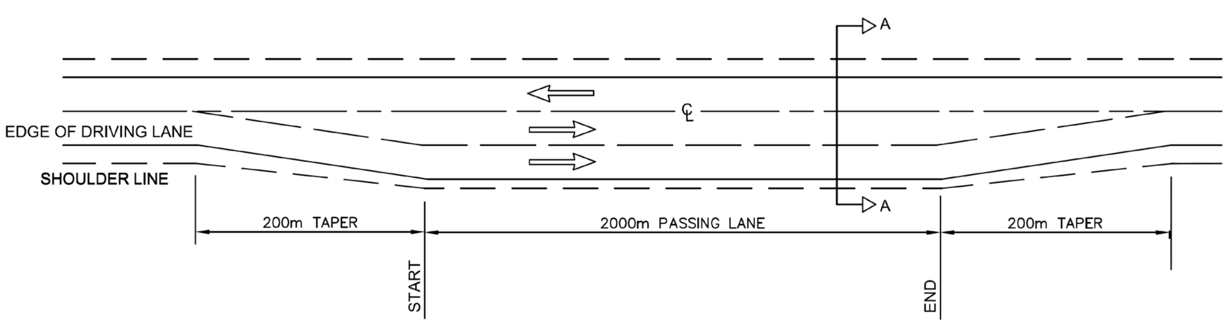

Figure 1: Typical Passing Lane Configuration

Guideline Warrant

During the study of Highway 10, it was determined that the MHI passing lane design guide required updating and thus MMM reviewed passing lane guidelines from British Columbia, Alberta, Manitoba and the Transportation Association of Canada. The MHI passing lane design guide was subsequently updated to reflect a combination of practices in Manitoba and Saskatchewan and development of a warrant analysis spreadsheet template to determine passing lane feasibility and implementation. The warrant analysis incorporates evaluation of passing lanes based on collisions and level of service.

Calculation of level of service is based on percent of vehicles following which in turn is a function of headway factor, opposing/advancing traffic volumes and net passing opportunities. A significant amount of background information is required and entails:

- Plan/profile of project
- Passing restriction zones
- Speed restriction zones
- Intersections and access configurations and location
- Traffic volumes - average annual daily traffic (AADT) or peak-hour
- Traffic volumes for existing intersections along the control section
- Truck percentage
- Traffic Accident Information System data

If either the level of service or benefit/cost indicator warrant is met, then the designer must conduct a life-cycle benefit/cost analysis using MicroBENCOST or a similar methodology. If neither is met, passing lanes are not warranted and the review terminates at this point.

MicroBENCOST is utilized to prepare a benefit/cost analysis to assist in assessing priorities. Inputs into the benefit/cost analysis include:

- Traffic volumes by direction
- Forecast traffic growth rate
- Collision records in order to develop collision rates by class of collision
- Vehicle mix making up the traffic
- Unit collision costs by class (fatality, personal injury, and property damage)
- Construction cost estimates
- Project discount rate

- Anticipated pavement resurfacing schedule

The analysis projects the net present value of costs, the net benefit/cost ratio and internal rate of return.

Highway 10 Review

MHI requested an analysis and recommendations as part of a passing lane location study on Highway No. 10 between Balgonie and the crest of the south side of the Qu'Appelle River valley, near Fort Qu'Appelle. This portion of the Highway 10 corridor is a two lane facility which serves a high volume of recreational vehicles and seasonal traffic. The topography of the area results in limited passing opportunities and the frequent platooning of multiple vehicles. MHI wished to assess the potential of passing lanes to improve the level of service of the highway by lowering the percentage of vehicles platooning and thus defer the need for twinning.

The study assessed the need, configuration, and existing roadway geometry of the corridor to identify timely and cost effective passing lane locations. The proposed passing lane location report recommended staging opportunities, timing, and estimated costs for the construction and implementation of passing lanes, as well as sensitivity analysis of the Benefit/Cost ratio.

Highway No. 10 is being planned as an ultimate four lane highway facility for the long term. The study area has recently been reassessed and the general location of the proposed four lane facility is recommended in the *Four Lane General Location Report*, Stantec, 2009. The passing lane location report applied industry recognized standards for rural passing lanes including those outlined by the Transportation Association of Canada. The analysis included collision history, traffic volumes, expected growth, standard spacing, topography, and roadway geometry. Prioritization of potential passing lane locations, single line location drawings, staging for construction, and cost estimate of proposed options were included in the report. Justification of recommendations considered the existing two lane structure and proposed four lane structure to evaluate opportunities to effectively implement passing lanes as an interim feature to future four laning. The recommended single line drawing locations and staging were based on the optimal safety and cost efficiency of the passing lane locations.

The study had the following primary objectives:

1. To determine if passing lanes are warranted on the corridor and if so, determine the locations to provide optimal performance of the passing lanes along the corridor;
2. If the passing lanes are warranted, development of a business case as part of the study scope and will be relative to twinning the corridor;
3. The recommendations for potential future passing lanes will incorporate sound engineering assessment of the current and future (25 years) traffic operational

needs, mitigation of potential collisions and the potential to implement the lanes, in light of a future four lane facility;

4. To consider the geometric features of the highway and the opportunity to improve any substandard or geometrically constrained portions through the addition of passing lanes;
5. To determine prioritized passing lane locations based on the aforementioned factors;
6. Reference Ministry standards as set out for Passing Lanes in the Ministry of Highways *Design Manual I*, sections on vertical and horizontal alignment.
7. To review the preliminary desktop review of environmental and heritage resources included in the 2009 *Four Lane General Location Report* in determining locations for passing lanes. Where necessary, revise the preliminary desktop review of environmental and heritage resources for all locations; and
8. To review utility locations and determine if existing locations will impact any potential passing lane locations.

HIGHWAY 10 PASSING LANE LOCATION STUDY

Passing Lane Warrants

The Highway 10 study first assessed the corridor using a warrant assessment developed for Manitoba Infrastructure and Transportation. The Manitoba Design Guide for passing lanes presents a simplified system that directly relates to the improvement of level of service. The warrant assessment is done by calculating the projected level of service, measured by percent of vehicles following, to determine if it falls within the warrant limits. The warrant for the installation of passing lanes on an arterial highway is met if the current level of service is C or worse (more than 45 percent of vehicles following); that guide indicated that passing lanes are warranted.

The corridor was then analyzed using the warrant assessment from the Saskatchewan Design Manual. The MHI Design Manual uses benefit/cost analysis as a planning tool to screen potential passing lane projects. The objective of this warrant is to determine whether a detailed analysis at the operational level is necessary. Two conditions should be met prior to applying the warrant:

1. The highway examined should be experiencing a level of service of C or less. A level of service assessment for the study section of Highway 10 was conducted using the Highway Capacity Software HCS+ and found an existing (2010) level of service (LOS) C (v/c of 0.24).

2. The AADT on the highway should be more than 3,000 vehicles. The 2010 weighted average AADT is 3,740. Passenger car equivalents (pcu) was used in the calculation.

The MHI Design Manual Warrant Calculations were completed and indicated that a detailed analysis at the operation level was warranted. The number of passing lanes calculation was then determined, as summarized in the table below.

Table 1: Number of Passing Lanes Calculation (Year 2010)

Base Conditions		
Section Length (L) km		46.6
Traffic Volume Two-Way PCU		672
Traffic Volume Opposing (V_{opp})		269
Traffic Volume Advancing (V_{adv})		403
Passing Allowed (P)		0.8
Reduction Coefficient (F_{pl})		0.61
Calculations	**Formula**	**Result**
Effective Downstream Length (L_{eds}) km	$-9.2089*(LnV_{adv})+69.177)$	13.9
Headway Factor (HF)	$HF = e^{(-.008*Vopp)}$	0.116
Net Passing Opportunity (NPO)	NPO = P*HF	0.093
Base Percent Following ($PFOLL_{base}$)	$PFOLL_{base} = 0.000365*V_{adv}-0.89278*NPO+.53$	59%
Passing Lane Percent Following ($PFOLL_{pl}$)	$PFOLL_{pl} = F_{pl}*PFOLL_{base}$	36%
One PL Impact ($Area_1$)	$Area_1 = (PFOLL_{base}-PFOLL_{pl})*(2+L_{eds}/2)$	2.08
Average Impact (Δ_1)	$\Delta_1 = Area_1/L$	0.045
Total Desired Impact (Δ_T)	$\Delta_T = PFOLL_{base}-0.45$	0.14
Number of Passing Lanes (N)	$N = \Delta_T/ \Delta_1$	3.11

The results indicate that approximately three passing lanes are required for each direction in order to attain a LOS B at 2010 traffic volumes. However, with three passing lanes, the level of service would immediately deteriorate to LOS C with any further traffic growth. Therefore, a minimum of four passing lanes are required to provide LOS B for a reasonable (economic) service life.

A passing lane was considered after 7.7 km, with a 2.0 km passing lane length. On this basis the percent following (PFOLL) was 44.9 percent, with LOS B and a Benefit Index of 2.32 percent. As a test, the study section was re-analyzed with five passing lanes to compare the PFOLL and Benefit Index over the study period forecast traffic. The comparison in summarized in Table 2.

Table 2: Comparison of Four- and Five-Lane System Effectiveness

Year	$PFOLL_{base}$	Factor	Passing Lane System	
			Four-Site	Five-Site
2011	59% (LOS C)	$PFOLL_{system}$	41.2%	39.9%
		Benefit Index	2.224%	1.909%
2023	63% (LOS D)	$PFOLL_{system}$	44.9%	43.3%
		Benefit Index	2.322%	2.011%
2029	66% (LOS D)	$PFOLL_{system}$	46.8%	45.1%
		Benefit Index	2.360%	2.055%
2035	68% (LOS D)	$PFOLL_{system}$	48.7%	46.8%
		Benefit Index	2.390%	2.094%

Minor improvements are forecast with the five site system and it was concluded that a four site system would be sufficient. The cost difference was $6.5M vs. $8.1M in 2010 dollars; that compared to $66M to twin the study corridor to a four lane divided facility (costs only include road works, earth and base works).

Benefit/Cost Analysis

The benefit/cost analysis was undertaken for the various scenarios using MicroBENCOST software developed by the Texas Transportation Institute for the Highway Research Program. The model determines the net benefits for roadway users resulting from reduced vehicle operating costs and travel times as well as the net costs of improvements including the capital costs and the maintenance associated with the infrastructure. All costs in the model were discounted to (at the time) present day 2010 dollar values.

The MicroBENCOST analysis was divided into segments by roadway type (i.e., undivided versus divided, no passing lanes versus passing lanes). All segments were treated by MicroBENCOST as 'rural arterial'.

In addition to the estimated construction costs of the project, specific MicroBENCOST inputs as they relate to the project were also required and included:

- Discount rate
- Salvage Value (varies according to the proposed road works)
- Operating, maintenance and depreciation costs
- Daily traffic volumes and distribution (existing and forecast)
- Fleet composition
- Collision rates
- Emission and temperature data

Sensitivity Analysis

To provide a base for assessing the study results, an analysis was done to show the sensitivity of the model output to the input parameters. The system average level of service, $PFOLL_{system}$, is the key parameter guiding the design of the passing lane system. The sensitivity of $PFOLL_{system}$ to various input parameters was therefore analyzed, using the EXCEL passing lane design template. This was supplemented with a review of input parameters on the benefit/cost ratios determined with the MicroBENCOST model.

Model runs were made using typical range of values, varying one parameter at a time and holding all others constant at the value used in the study (base value). The detailed analysis is summarized in Table 3 below.

Table 3: Summary of Sensitivity Analysis

Parameter	Base Value	∆ Range	$PFOLL_{system}$ Impact	Comments
Annual Growth Factor (%)	1.15	1 to 2.5	0.445 to 0.492	Direct Linear
Percent Trucks (%)	11	0 to 15	0.414 to 0.462	Direct Linear
Truck Factor	2.5	1 to 2.5	0.414 to 0.461	Direct Linear
Peak Direction Split (%)	60	50 to 70	0.443 to 0.450 to 0.442	Convex Curve Peaks at 60%
Percent Passing Zones (%)	80	0 to 100	0.487 to 0.440	Inverse Linear
Length of Passing Lane (km)	2	1.5 to 2.1	0.487 to 0.440	Inverse Linear
			B/C Ratio Impact	
Discount Rate (%)	5	3 to 7	3.13 to 2.14	Inverse Concave Curve
Percent Trucks (%)	11	9 to 13	2.75 to 2.41	Inverse Linear
Annual Growth Factor (%)	1.15	0.85 to 1.45	2.46 to 2.66	Direct Linear

The results of the analysis can serve as a guide in selecting appropriate values for the model parameters in future studies. Two parameters are worthy of specific note. Firstly, it can be seen that a 60/40 percent peak-hour directional split is the critical split leading to the worst level of service; assuming this split should lead to the most conservative results. Secondly, in this theoretical analysis, it appears that the level of service will continue to increase (or $PFOLL_{system}$ decrease) linearly as the length of individual passing lanes increases; in practice, it has been found that there are diminishing returns from passing distances greater than 2 kilometres.

PASSING LANE LOCATION STUDY

Following the Highway 10 study and passing lane warrant update, MHI expanded use of the process to test other highway segments to test twinning vs. passing lanes as a possible (in some cases, first stage) solution. The benefits of considering passing lanes include:

- Application as part of the capital planning process/spending strategies
- Identifying the benefit/cost of implementing passing lanes in order to defer the need for twinning
- Determining if specific highway segments will not gain a benefit from implementing passing lanes
- Address public perception and concerns over the type of highway improvement that would be beneficial and cost effective

In 2013 MHI asked MMM to examine a number of highway segments, throughout the provincial network, to determine if the segments warrant implementation of passing lanes using the updated design guide manual. Each of the study highway segments were evaluated, in order to determine a high level priority of twinning based on equal weighting of the return on investment (benefit/cost analysis), collision rates and level of service (passing opportunities).

Three sets of rankings are then developed based on the above information; benefit/cost ranking; collision rate ranking; and level of service ranking. These are then combined to develop an overall ranking of possible projects. A generic example is given below.

Table 4 – Segment Rankings

	Benefit / Cost Ranking	Collision Rate Ranking	Level of Service Ranking	Overall Rank
Highway 1				
Section A1	4	3	6	4
Highway 2				
Section A2	1	1	2	1
Highway 3				
Section A3	3	6	1	3
Highway 4				
Segment A4	5	4	7	T5
Segment B4	7	8	4	7
Segment C4	6	5	5	T5
Segment D4	2	2	3	2

Passing Lane System Analysis

Each segment of the study highways identified as a potential passing lane candidate, was analyzed using updated traffic volume and growth rates provided by MHI. The passing lane system analysis is theoretical in that it assumes that passing lanes can be sited as required, with no field site restrictions. The warrant analysis is done in one direction only, assuming am/pm directional peaks are balanced. For example, when mention is made of a four-site passing lane system, there are a total of eight sites for both directions. Level of service is discussed in terms of percent of time spent following (P_{FOLL}) with an assumption that it is desired to provide LOS B to highway traffic and to consider highway upgrade when the LOS drops to C, or P_{FOLL} = 45 percent. Passing lanes will improve the LOS for some time, and the end of their design life is defined as the point in time when P_{FOLL} again reaches 45 percent.

Since the investment in passing lanes is mostly throw-away, in a highway upgrade to four-lane divided, it is assumed that passing lanes will not be considered unless they have at least ten years' useful life. The analysis calculated a service life for the system based on traffic volumes and projected level of service for the highway. If a passing lane system was found to have a service life of less than 10 years, it was designated as a candidate for twinning. If the passing lane system returned a service life of 10 years or more, it was determined to be a viable passing lane implementation candidate.

As well as level of service, a basic benefit/cost indicator warrant is also applied using the collision rate of the segments. Highways with a collision rate higher than 0.3 incidents per million vehicle kilometres traveled (MVKT) are warranted for further detailed economic analysis using software such as MicroBENCOST. None of the study segments exceeded the indicator warrant level with the exception of one sub-segment. The sub-segment has a collision rate of 0.56 collisions/MVKT compared to the overall segment considered for passing lanes with a combined rate of 0.24 collisions/MVKT.

Table 5 summarizes each highway segment's traffic volumes, existing level of service ($PFOLL_{base}$), number and approximate location of passing lanes and passing lane system level of service ($PFOLL_{system}$). Some study segments were determined, based on 2012 data, to no longer be feasible candidates for passing lane systems and thus should be considered for twinning. As such, these segments were incorporated into the twinning prioritization objectives of the study.

Table 5 – Summary of Passing Lane System Analysis

Corridor	Length		Design Yr	AADT (vpd)		AADT (pcu)		$PFOLL_{base}$		Passing Lane Sites			$PFOLL_{system}$	Comments
	Corridor	Segment		2013	Design Yr	2013	Design Yr	2013	Design Yr	Number	Start Location	Length		
Highway D														
Segment D1	40.90			3413		4683								NB system has 6-year life. SB system has 5-year life. Passing lanes not a feasible solution.
NB		40.90	2019		3958		5431	0.592	0.644	4	D1.1	2.0	0.454	
											D1.2	2.0		
											D1.3	2.0		
											D1.4	2.0		
SB		40.90	2018		3862		5536	0.608	0.651	4	D1.5	2.0	0.455	
											D1.6	2.0		
											D1.7	2.0		
											D1.8	2.0		
Segment D2	23.07			4136		5563								NB system has 2-year life. SB system is not feasible. Passing lanes not a feasible solution.
NB		23.07	2015		4345		5844	0.655	0.671	3	D2.1	2.0	0.450	
											D2.2	2.0		
											D2.3	2.0		
SB		23.07	2013		4136		5563	0.653	0.653	2	D2.4	n/a	0.450	
											D2.5	n/a		
Segment D3	82.92			4090		5403								NB system has 1-year life. SB system is not feasible. Passing lanes not a feasible solution.
NB		82.92	2014		4192		5538	0.644	0.653	8	D3.1	2.0	0.452	
											D3.2	2.0		
											D3.3	2.0		
											D3.4	2.0		
											D3.5	2.0		
											D3.6	2.0		
											D3.7	2.0		
											D3.8	2.0		
SB		82.92	2013		4090		5403	0.645	0.645	8	D3.9	n/a	0.451	
											D3.10	n/a		
											D3.11	n/a		
											D3.12	n/a		
											D3.13	n/a		
											D3.14	n/a		
											D3.15	n/a		
											D3.16	n/a		
Segment D4+D5	34.65			3680		5396								NB system has 2-year life. SB system has a 2-year life. Passing lanes not a feasible solution.
NB		34.65	2015		3866		5670	0.506	0.665	4	D4/5.1	2.0	0.451	
											D4/5.2	2.0		
											D4/5.3	2.0		
											D4/5.4	2.0		
SB		34.65	2015		3866		5670	0.649	0.665	4	D4/5.5	2.0	0.451	
											D4/5.6	2.0		
											D4/5.7	2.0		

Benefit/Cost Analysis

The highway sections in this study underwent a benefit/cost analysis using MicroBENCOST based on the following assumptions:

- Collision rates are reduced by 35 percent for twinning.
- Maintenance costs for all scenarios were provided by MHI as $2,800/lane-km/yr.
- Fleet composition (percentage of vehicle type) varies for each of the highways in the study. However, detailed fleet composition data was not available and sensitivity analysis of the benefit/cost calculations showed a minor (<2 percent) variation in economic user benefits with variation of fleet composition. As such, basic vehicle parameters (value of time, size and weight, etc.) and fleet composition values were taken from previous projects, completed by MMM in 2010.
- Unit/collision costs (provided by MHI) were as follows:

- Fatality = $3,300,000/incident.
- Personal injury = $144,000/incident (MicroBENCOST can only accept a maximum value of $99,999/incident for injuries).
- Property damage only = $7,800/incident.

- There are no major intersections requiring speed reduction within the study segments.
- Construction cost estimates are based on typical capital planning costs per kilometre provided by MHI.
- The analysis period is equal to 20 years.
- Twinning improvements are completed by 2015.
- Collision rate percentage breakdown (fatality, injury, property damage only) provided by MHI for the years 2001 to 2012.
- The project discount rate is 4.05 percent to reflect the current Government of Saskatchewan long-term borrowing rate.
- Salvage value for the work is 20 percent after 20 years.
- Existing pavement is assumed to be resurfaced in 15 years with no resurfacing for new pavement within the analysis period.

The net present values (NPV), net benefit/cost (NB/C) and internal rate of return (IRR) of the study highway segments are summarized in Table 6.

Table 6 – Summary of Benefits, Costs and Economic Measures

	NPV	Net B/C Ratio	IRR	Construction Cost	Rank
Highway A					
Segment A1	$21,200,000	1.41	3.6%	$55,100,000	4
Highway B					
Segment B1	$37,200,000	2.10	8.8%	$35,700,000	1
Highway C					
Segment C1	$29,100,000	2.06	8.4%	$29,300,000	3
Highway D					
Segment D1	$1,800,000	1.03	0.3%	$61,400,000	5
Segment D2	$(3,100,000)	0.90	-0.9%	$34,600,000	7
Segment D3	$(2,500,000)	0.98	-0.2%	$124,400,000	6
Segment D4	$17,400,000	3.58	21.3%	$11,600,000	2
Segment D5	$(26,200,000)	0.30	-8.3%	$40,400,000	8

All values of costs and benefits are discounted to 2013 dollars. Items to note regarding the summary tables:

- Net present value is the discounted user benefits seen by the improvement minus the discounted total agency costs to implement.
- Net benefit/cost ratio is the combined discounted user benefits seen by the improvements, salvage value of the infrastructure at the end of the design period and the increase in maintenance costs divided by the discounted construction costs to implement. As benefit/cost ratios achieve relatively high values (greater than 2.00), the internal rate of return climbs rapidly in a non-linear fashion and can result in a very high value.
- Internal rate of return is the rate of return that brings the net present value of all cash flows for the proposed project to zero.
- There are a variety of approaches to economically evaluate any given project, and each approach (i.e., NPV vs. IRR, IRR vs. NB/C, etc.) has advantages and disadvantages. For this study, the economic indicators of NPV, NB/C and IRR were weighted equally to determine the ranking of twinning projects. Therefore, the rank shown in Table 6 is based on an equally weighted ranking of IRR, NB/C and NPV for each segment.
- The economic results for twinning of a number of segments return negative net present values and benefit/cost ratios below 1.0. These results are typically due to a combination of the length of a number of the segments (high capital costs) and a relatively low traffic volume or collision rate which do not create enough user benefits to counteract the initial high construction cost. A more detailed analysis of each segment with appropriate maintenance/deterioration/collisions, as well as a longer service life, would return more accurate economic indicators for twinning. Also, in cases where twinning of a segment returns an acceptable level of service for the roadway where passing lanes do not, passing lanes may be an interim solution if MHI policy can accept a less than desirable level of service.

Collision Analysis

A collision analysis involves a review of the collision history of a facility through an assessment of multiple years of collision statistics. Collision data was provided by MHI, including a summary of the number and severity of collisions for various time periods (mainly 2006 to 2012). Average annual daily traffic (AADT) volumes were also provided by MHI for the various years and road segments.

The number of collisions, collision severity and collision rate for the study highway segments are summarized in Table 7. Collision rates exceeding 1.5 incidents per MVKT are typically considered as locations that warrant further review. There are no segments within the study highways that had a collision rate greater than 0.61 incidents per MVKT. The rankings are based on the collision rates in descending order from highest to lowest.

Table 7 – Collision Analysis Summary

	Length (km)	Analysis Period	Collisions				Collision Rate (MVKT)	Rank
			PDO	Injury	Fatal	Total		
Highway A								
Segment A1	36.7	2006 to 2011	67	33	8	108	0.34	3
Highway B								
Segment B1	36.1	2001 to 2012	421	121	9	551	0.61	1
Highway C								
Segment C1	28.7	2001 to 2012	102	46	5	153	0.21	6
Highway D								
Segment D1	36.1	2006 to 2012	53	30	4	87	0.29	4
Segment D2	23.1	2006 to 2012	20	9	1	30	0.15	8
Segment D3	82.9	2006 to 2012	89	51	8	148	0.21	5
Segment D4	9.5	2006 to 2012	19	21	2	42	0.56	2
Segment D5	26.9	2006 to 2012	11	7	0	18	0.20	7

Level of Service

The capacity analysis for the study segments was undertaken using Highway Capacity Software (HCS) 2010 software. This software calculates the level of service for two-lane and multilane roadways based on the methodology of the Highway Capacity Manual 2010.

The relative performance of an intersection or highway segment is measured in terms of LOS and ranges from A (excellent) to F (beyond capacity). In general, LOS E is considered to be at capacity. The volume to capacity (v/c) ratio is used to determine the level of congestion for each lane group.

AADT traffic volumes for the highway segments were provided by MHI for the years 2001 to 2012 and were used to determine historical annual growth rates and forecast traffic volumes to the analysis year 2034. Five and ten-year growth rates for the road segments were generally high (up to 10 percent) due to high development rates and mining operations in the province. Although these high growth rates may continue over the next several years they are generally not sustainable over a 20-year analysis period. Therefore, a growth rate of 2.5 percent was assumed for all road segments. This growth rate allows for continued rapid traffic growth over the next several years then stabilizing to a more typical growth rate of zero to two percent.

The HCS 2010 level of service capacity analysis for the study highway segments is summarized in Table 8. The study segments are ranked based on the 2-lane LOS and v/c ratio. All of the highway segments have forecast LOS of D or higher and LOS A when twinned. Typically, a LOS B is desired for a highway segment.

Table 8 – Level of Service Analysis Summary

	Annual Growth Rates (%)			AADT Volume		LOS			Rank
	5-Year	10-Year	Analysis	2012	2034	2-Lane	v/c Ratio	4-Lane	
Highway A									
Segment A1	2.3	1.8	2.5	4,180	7,195	C	0.305	A	6
Highway B									
Segment B1	6.4	2.4	2.5	5,715	9,840	D	0.410	A	2
Highway C									
Segment C1	7.3	5.3	2.5	7,510	12,930	D	0.520	A	1
Highway D									
Segment D1	4.6	3.1	2.5	3,330	5,735	C	0.270	A	7
Segment D2	4.8	3.7	2.5	4,030	6,940	C	0.320	A	4
Segment D3	5.6	5.5	2.5	4,135	7,120	C	0.310	A	5
Segment D4	10.7	4.7	2.5	5,570	9,590	D	0.400	A	3
Segment D5	8.9	4.4	2.5	1,615	2,785	B	0.160	A	8

IMPLEMENTATION STRATEGY

Overall Ranking

The road segments analyzed were prioritized and ranked equally based on their economic, collision and level of service analysis results summarized in earlier sections of the paper. Table 9 summarizes the analysis rankings for each segment and the corresponding overall ranking.

As noted in Table 9, Highway B, Segment B1 is the top ranked highway section based on an equal rating of return on investment, collision rates and level of service. Following the Highway B section, Segment D4 of Highway D ranked second and Highway C, Segment C1 ranked third.

However, Segments D2, D3 and D5 of Highway D were identified to require twinning but return net present values less than zero and thus require no action at this time:

Table 9 – Overall Segment Rankings

	Benefit/Cost Ranking	Collision Rate Ranking	Level of Service Ranking	Overall Rank
Highway A				
Segment A1	4	3	6	**4**
Highway B				
Segment B1	1	1	2	**1**
Highway C				
Segment C1	3	6	1	**3**
Highway D				
Segment D1	5	4	7	**T5**
Segment D2	7	8	4	**7**
Segment D3	6	5	5	**T5**
Segment D4	2	2	3	**2**
Segment D5	8	7	8	**8**

Implementation Plan

Based on the overall economic/collision/LOS analysis and ranking shown in Table 9, the following twinning implementation strategy is recommended based on a program staged in three years:

Year 1:

- Highway B – Segment B1 (approximate cost $35.7 million, NPV $37.2 million)
- Total approximate construction cost of $35.7 million
- Total approximate net present value of $37.2 million

Year 2:

- Highway D – Segment D4 (approximate. cost $11.6 million, NPV $17.4 million)
- Highway C – Segment C1 (approximate. cost $29.3 million, NPV $29.1 million)
- Total approximate construction cost of $40.9 million
- Total approximate net present value of $46.5 million

Year 3:

- Highway A – Segment A1 (approximate cost $55.1 million, NPV $21.2 million)
- Total approximate construction cost of $55.1 million
- Total approximate net present value of $21.2 million

DETAILED STUDY

A subsequent detailed study of each highway segment is necessary for functional and detailed designs. The detailed assessment requires the following for each segment:

- Detailed collision analysis.
- Actual peak hour traffic counts and intersecting roadway traffic volumes.
- Detailed review of existing profile and horizontal sight lines.
- Site investigation to confirm assumptions for construction cost estimates.
- Determination of site conditions, utility conflicts and required realignment and/or modifications to existing intersections and accesses.

CONCLUSIONS

The analysis conducted in these studies indicated that passing lanes can be a cost-effective way of deferring a highway twinning project while maintaining a good level of service to the travelling public.

The benefits of considering passing lanes include:

- Application as part of the capital planning process/spending strategies
- Identifying the benefit/cost of implementing passing lanes in order to defer the need for twinning
- Determining if specific highway segments will not gain a benefit from implementing passing lanes
- Address public perception and concerns over the type of highway improvement that would be beneficial and cost effective

The passing lane systems presented in this report are deemed to be near optimal at a functional design level. However since the functional work was mainly an office exercise, with limited field information, site locations need further review in detailed design.

REFERENCES

1. MMM Group Limited, *Passing Lane Location Study: Highway 10 – Balgonie to Fort Qu'Appelle*; Saskatchewan Ministry of Highways and Infrastructure; June 2010.
2. MMM Group Limited, *MHI Twinning Prioritization*; Saskatchewan Ministry of Highways and Infrastructure; November 2013.