EVALUATING THE POTENTIAL FOR CENTRELINE RUMBLE STRIPS ON ARTERIAL TWO-LANE HIGHWAYS OF RURAL NEW BRUNSWICK

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Abstract

This study represents a digital mapping approach to identify the potential for establishing centreline rumble strips on arterial two-lane highways in rural New Brunswick. Right-hand side rumble strips are employed on four-lane highways in New Brunswick, but the province currently does not employ any centreline rumble strips on its arterial two-lane network. This project employed TAC centreline rumble strip guidelines, in concert with GIS mapping, Google Maps, and collision data to estimate the number of kilometres (by route number) that would be eligible for centreline rumble strips and, by extension, the number of collisions that may have been prevented.

There are a total of 1257 km of arterial two-lane highway in New Brunswick, with 466.6 km and 11.5 km falling outside of municipal boundaries (i.e. away from urban areas and communities) and on bridge decks respectively. Based on estimates of passing/no-passing zones on select arterial highways, approximately 273 km of centreline rumble strips would be needed. A total of 135 head-on and opposite-direction sideswipe collisions (where vehicles crossed the centreline) were recorded between 2007 and 2012 on the two-lane arterial highway network, and research suggests that up to 30% of such collisions may be prevented by centreline rumble strips. Due to the relatively low cost of rumble strip installation, in concert with prospective benefits of reduced collisions, centreline rumble strips have considerable potential in New Brunswick and should be considered for installation.

1 Introduction

Longitudinal rumble strips are meant to alert inattentive or errant drivers that they have left or are leaving the travel lane, and may be placed on the shoulder, edge line, or centre line (Federal Highway Administration, 2014). Several jurisdictions have been using rumble strips due to their effectiveness at reducing run-off-road collisions (ROR) at a relatively low cost. Centre line rumble strips (CLRS) have been found to have considerable potential in some research for reducing target total crashes and target fatal and injury crashes (up to 30% and 44% respectively) on rural two-lane roads (Torbic, et al., 2009).

Organizations considering implementing CLRS will likely want to have a clearer understanding of costs and benefits of implementation tailored to their specific highway network and collision history. The simplest way to calculate costs would be to apply a per km construction rate to the total length of roadway as determined from a National Road Network (NRN) Geographic Information System (GIS) layer. The challenge is that according to TAC's *Synthesis of Best Practices for the Implementation of Shoulder and Centreline Rumble Strips*, centreline rumble strips are not appropriate for use in certain locations (e.g. within 200 m of a residential or urban area; on bridge decks; in passing zones on two-lane roads; across an intersection). Each of those locations would need to be excluded from the total length of roadway in order to provide a better estimate of costs, which is possible with a GIS, except for "passing zones". The presence of "passing zones" is not an attribute recorded in the NRN, which would lead to overestimation of CLRS-eligible road sections and costs.

This paper describes an exercise to estimate the length of CLRS-eligible road sections on New Brunswick two-lane arterial highways using a combination of GIS analysis and estimation of percent "passing zones" from the Highway Capacity Manual, confirmed with satellite imagery. This approach was used in concert with a review of relevant collision data for the candidate roadways to develop an initial estimate of costs and benefits associated with installing CLRS on New Brunswick rural arterial highways.

2 Background

The main purpose of rumble strips is to reduce the occurrence rate of run-off-road crashes (ROR) (Arnebeck, 2008). According to a study conducted in the State of Michigan, crashes involving drowsy or distracted drivers are classified as DOR, a subset of ROR crashes and may be as high as three to five times more severe (Morena, 2002). CLRS may reduce the frequency of DOR crashes occurring on the left side of the roadway and frontal collisions. The Federal Highway Administration in the United States highlights that CLRS can reduce head-on fatal and injury collisions on rural two-lane roads by 44% (Federal Highway Administration, 2014).

Errant drivers, whether they are inattentive, drowsy or sleepy are involved in many collisions every year. It is estimated that 16% of fatal collisions and 20% collisions with injuries in the U.S. involved driver distraction (Transport Canada, 2011). Furthermore, it is estimated that about 20% of fatal collisions are due to driver's fatigue, excluding other possible accident causes such impaired driving, driving over the speed limit and unsafe passing (Transport Canada, 2011). In the United States, 56,000 crashes, resulting in 71,000 injuries and 1,500 deaths are associated to drowsy drivers every year (Noyce & Elango, 2003). ROR are the most common type of crash fatalities in single-vehicle crashes, accounting for two-thirds of all traffic fatalities on rural highways (Liu & Subramanian, 2009).

Numerous states reported reductions in cross-over crashes leading to injury and fatal crashes (Transportation Research Board, 2005). A study conducted at the University of Massachusetts concluded that the installation of CLRS is an effective method to reduce the cross-over crashes in areas where they are frequent (Noyce & Elango, 2003). Another benefit that may arise that has not been investigated, is the reduction of near misses, although this may be difficult to determine accurately as these events are not recorded.

Some issues were raised about the installation of CLRS. Motorcyclists have expressed concerns that rumble strips damage their motorcycles if crossing the rumble strip (Transportation Research Board, 2005). Other concerns were raised about increased wear due to snowplowing operations, snow and rain accumulation in the grooves, accelerated degradation of the pavement and reduced visibility of the centreline once the rumble strip installed. TAC has reported that the service life of CLRS is typically the same as the pavement itself and can be replaced along with the pavement as needed (Bahar, Wales, & Longtin-Nobel, 2001).

A previous study conducted at the University of Massachusetts found concerning results about the driver's first exposure reaction when encountering CLRS (Noyce & Elango, 2003). Using a driving simulator, it was observed that some driver's reaction is to steer left, towards the incoming traffic, when encountering CLRS. This reaction was attributed to the familiarity users have developed with right shoulder rumble strips that have been in use since the 1960s (Noyce & Elango, 2003). In real life situations, there is generally no evidence of users steering the vehicle into the wrong direction (Transportation Research Board, 2005).

As of 2005, British Columbia, Alberta and Saskatchewan have had installed CLRS, Alberta being the first Canadian province to install CLRS in 1999 (Bahar & Parkhill, 2005). Manitoba first issued a called for tenders for the installation of CLRS in 2009 (Manitoba Heavy Construction Association, 2009) and has since issued standard construction specifications for CLRS in 2013 (Manitoba Infrastructure and Transportation, 2013). Ontario issued drawings for CLRS in 2004 and installed its first test section in 2007 (Offert, 2014). Quebec has also been using CLRS since 2008 (Ouimet, 2008) and Nova Scotia since at least 2011 (Department of Transportation and Infrastructure Renewal, 2012). Other provinces do not have documented installation of CLRS.

New Brunswick does not have any CLRS on any of its roadways (MacLean, 2014). Furthermore, New Brunswick does not currently have any intentions to install CLRS on rural two-lane highways in the foreseeable future. Currently in New Brunswick, right shoulder rumble strips for four-lane highway facilities (and select two-lane undivided facilities) remain the exclusive practice. Research has shown that left shoulder rumble strips could produce tangible benefits for users of New Brunswick's four-lane highways (Mulkern and Hildebrand, 2013), which raises questions whether similar benefits may be accrued from the consideration of CLRS for two-lane arterial highways in New Brunswick.

3 Estimating the potential for CLRS in New Brunswick

This study used TAC's *Synthesis of Best Practices for the Implementation of Shoulder and Centreline Rumble Strips* that describe locations not appropriate for centreline rumble strips (e.g. within 200 m of a residential or urban area; on bridge decks; in passing zones on two-lane roads; across an intersection). These criteria were used as a filter to estimate the total kilometres of rural arterial highway in New Brunswick that would be eligible for CLRS.

3.1 Isolating eligible two-lane arterial highway sections with GIS

The first step was to use ArcGIS 10.2 to isolate the New Brunswick road network from the NRN, then to isolate the two-lane arterial highways from the New Brunswick road network. New Brunswick arterial highways (as defined by the New Brunswick Department of Transportation and Infrastructure) are numbered from 1 to 95, and includes highways that are access controlled four-lane divided facilities for part or all of their entire length, as well as some that are community main streets. The "Select by Attributes" tool was used to isolate "Freeway", "Expressway/highway" and "Arterial" routes, and then all four-lane sections were removed to create an arterial road network layer.

TAC criteria indicate that CLRS should not be installed within 200 m of a residential or urban area. Since there was no available map layer that isolated residential or urban areas specifically, a municipal boundary layer available through Service New Brunswick's GeoNB Map Viewer was used to permit the removal of two-lane arterial highways within municipal boundaries (and 200 m on either side). All bridges were also identified and removed from the layer. The result was an arterial highway layer where CLRS would be eligible for installation. The data in Table 1 below summarizes the three steps taken to find the total eligible route length to install CLRS. Values are reported in Table 1 in terms of route length and not two-lane equivalent km.

Table 1 Summary of procedure

Total route length of arterial highways	Route length of four-lane highways	Route length of arterial highways in urban or municipal areas	Route length of bridge decks	Remaining length of two-lane arterial eligible for CLRS
2097.7 km	840.4 km	466.6 km	11.5 km	779.2 km

Figure 1 illustrates the output from the GIS showing the routes eligible for CLRS.

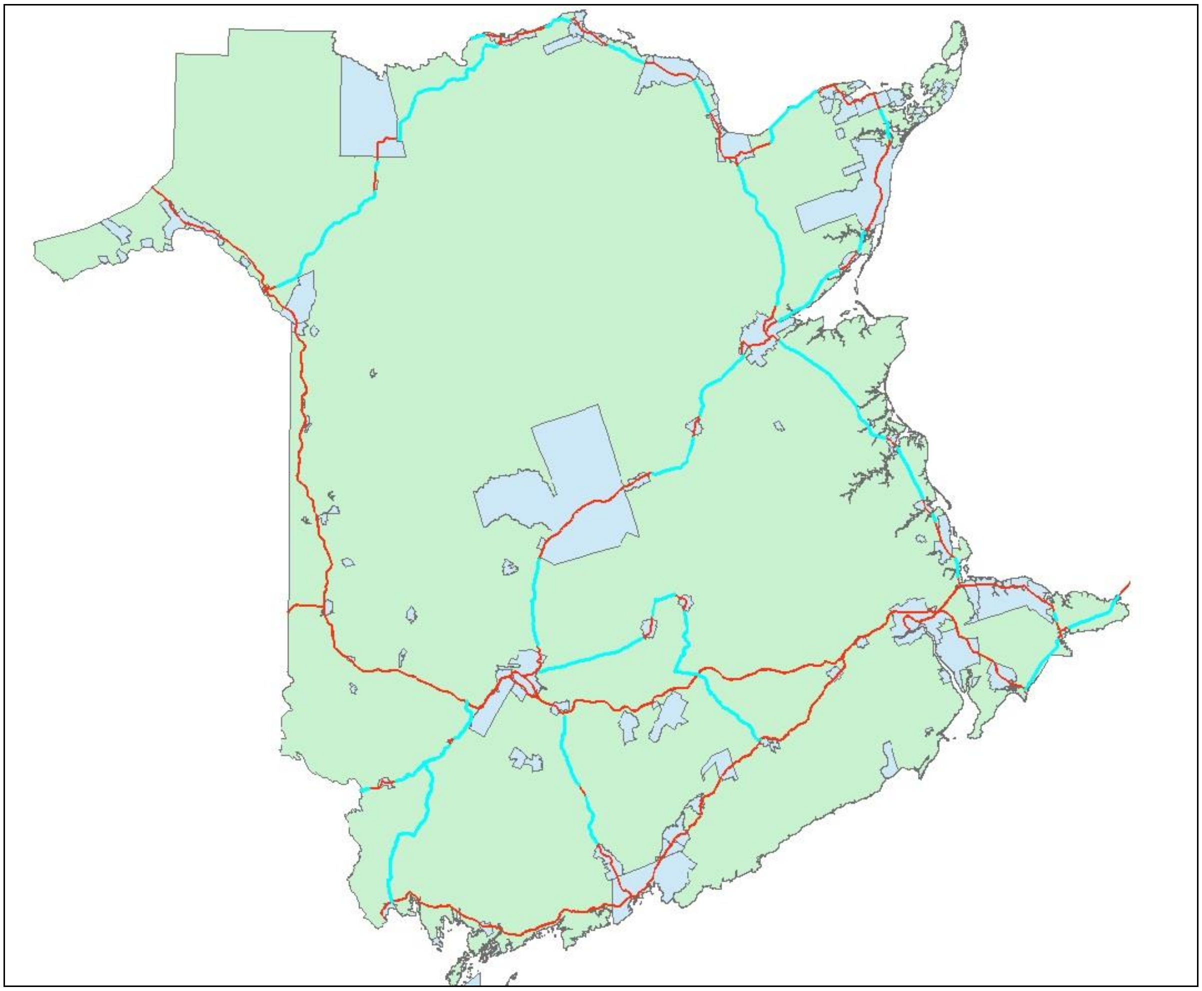

Figure 1: Two-lane arterial highways estimated to be eligible for CLRS (in blue)

3.2 Estimating need for CLRS on eligible two-lane arterials

Since CLRS are typically only installed in no-passing zones, the next step involved determining a reduction factor that could be applied to the remaining length of eligible two-lane arterial highways to account for this. The challenge is that the NRN data does not include attribute information regarding passing/no passing zones, nor does the information appear on NBDTI road life diagrams. Exhibit 12-11 of the *Highway Capacity Manual (HCM) 2000* assigns default values for percent no passing zones of 20% and 50% for level and rolling two-lane roads respectively. Applying these values based on a subjective assessment of the operating terrain of each route could be a straightforward means to develop a quick estimate, though without corroborating data, it was not known if applying these defaults would be appropriate for New Brunswick.

Satellite imagery was used (Google Maps and Google Street View) to measure the proportion of passing/no-passing zones on select routes in more detail. Routes were subjectively assessed as either in "rolling" or "level" terrain; there is no mountainous terrain in New Brunswick. Segments reviewed ranged in length from 26.6 km to 40 km, which was maximum length of CLRS-eligible routes uninterrupted by municipal boundaries or classification changes (e.g. two-lane to four-lane). Any sections of no-passing zones less than 50 metres in length in between two passing zones was considered as a passing zone regardless as it would have been too difficult to measure and would not have a major effect on the results. In some cases, it was not possible to analyze a route in its entirety given the resolution of the satellite imagery was not sufficiently high to permit visual measurement. The results of the sample are outlined in Table 2 which shows the no-passing ratios are consistent with the HCM defaults expected from a subjective assessment of operating terrain.

Table 2 Summary of the Routes Studied

	Subjective assessment of operating terrain	**Total (m)**		**Ratio**		**Assessment consistent with HCM default?**
		Passing	**No pass**	**Passing**	**No pass**	
Route 7	Rolling	10100	16500	0.38	0.62	Yes
Route 11	Level	24000	5500	0.81	0.19	Yes
Route 11	Rolling	14000	16000	0.47	0.53	Yes
Route 3	Rolling	15450	24550	0.39	0.61	Yes
Route 17	Rolling	20400	19600	0.51	0.49	Yes

The results detailed in Table 2 provided confidence that conducting a subjective assessment of the operating terrain of CLRS eligible routes in New Brunswick, then using HCM no-passing percentage defaults as a reduction factor, would be appropriate for estimation purposes (Table 3).

Table 3: Total Length Where CLRS could be Installed Based on Level and Rolling Categories

Route	**Eligible Length (km)**	**Terrain Type**	**No-passing Factor**	**Estimated length of CLRS (km)**
3	89.9	Rolling	0.50	45.0
4	15.9	Rolling	0.50	8.0
7	45.3	Rolling	0.50	22.7
8	139.8	Level	0.20	28.0
10	122.3	Rolling	0.50	61.2
11	199.2	Level	0.20	39.8
15	3	Level	0.20	0.6
16	45.9	Level	0.20	9.2
17	117.9	Rolling	0.50	59.0
Total	**779.2**			**273.2**

The data in Table 3 show that based on a subjective assessment of New Brunswick highway topography, approximately 35% of the length of eligible arterial highways (273 km) could be candidates for CLRS.

3.3 Estimating potential benefits from collision reduction

Sanitized provincial collision data for 2007-2012 inclusive were acquired from NBDTI for the purposes of quantifying (to a limited degree and at a high-level) the potential benefits associated with collision reduction on two-lane arterial highways in New Brunswick. Relevant collisions were isolated to those with a major contributing factor (MCF) where a vehicle has crossed the centerline, and excluded collisions in urban areas, on collector and local roads, and four-lane highways. This represented a total of 157 relevant collisions (Table 4). Though the collision data provided by NBDTI did not differentiate collisions by injury severity, it can be expected that the majority of frontal collisions resulted in at least an injury collision.

Table 4: Collision Configuration Summary

Collision Configuration	Count
Frontal collision (head on and left side)	135
ROR to the left	14
Other	4
Opposite direction sideswipe	3
Collision with fixed object	1
Total	**157**

Research by Persaud, Retting, & Lyon suggests that up to 30% of frontal collisions (head on and left side) could be prevented by CLRS; by extension, approximately 41 collisions may have been prevented on these routes over the past 6 years (or approximately 7 per year) with the installation of CLRS. The Federal Highway Administration reports an even higher percentage, 44% of head-on collisions, that could be avoided with CLRS (Federal Highway Administration, 2014). In Ontario, the average social collison cost involving injury in 2004 was $82,000 (Vodden, Smith, Eaton, & Mayhew, 2007). Another study completed in Alberta found that the average collision cost for collisions involving injuries was $81,000, including direct cost and human capital cost (Leur, 2010).

The estimated unit price for CLRS installation is $500/km for rolled in CLRS and $1000 to $1500/km for milled in CLRS. As the CLRS would be installed on existing pavements, $1000 would be a reasonable assumption (Kenny, 2011). In Kansas, it was determined that the installation cost of CLRS is approximately $2,175 per km (Karkle, Rys, & Russell, 2013).

By multiplying the total length (273 km) by the unit cost ($1000/km), the optimistic project completion cost is estimated to be about $273,000 and have a service life of between two and eight years (Bahar, Wales, & Longtin-Nobel, Synthesis of Best Practices for the implementation of Shoulder and Centerline Rumble Strips, 2001). Assuming that CLRS can prevent 7 injury collisions per year, each bringing $80,000 in social benefits, CLRS would bring up to $560,000 in social benefits every year for their entire service life. Benefits would be considerably higher if fatalities were considered.

4 Discussion and Caveats

This research presents a method to develop an informed estimate of the need for CLRS in New Brunswick. It was not accompanied by an over-the-ground assessment of passing/no-passing zones or the presence of urban areas, rather it employed a tool (GIS) using TAC geographic and geometric criteria from *Synthesis of Best Practices for the Implementation of Shoulder and Centreline Rumble Strips*, to develop an estimate for planning purposes. Unlike recommended in TAC's synthesis, a gap of 45 m at each intersection was not removed during the GIS exercise. This assumption was made in order to simplify the data processing and was not antcipated to impact the results significantly.

The use of the HCM 2000 defaults for terrrain-based passing/no-passing zone percentages (e.g. level, rolling, mountainous) seemed appropriate for New Brunswick given a satellite imagery assessment of route segments, though it should be possible to develop an additional attribute for the NRN GIS layer that includes passing/no-passing zones and would simplify analysis. There would be considerable benefit to this, particularly in the support of collision analysis, which could be done in concert with modernizing New Brunswick's approach to recording collision data. The Province of New Brunswick continues to employ labour-intensive processes for collecting and transcribing collision data and has yet to adopt GPS-based referencing.

The discussion of costs and benefits was at a high level and was only intended to be exploratory. Nevertheless, the seemingly positive results highlights the need to explore this issue in more detail.

5 Conclusions and Recommendations

Many studies in various jurisdictions have led to the conclusion that CLRS are an effective means to reduce motor vehicle collisions. In many states, a significant reduction in crash rates has been observed although a few negative impacts were observed from a serviceability and a facility degradation point of view. Some states also recorded isolated complaints from users about vehicle manoeuvres over the rumble strips. In general, the positive impacts arising from the installation of CLRS appear to outweigh the negative impacts.

This study estimates it would be appropriate to install CLRS on approximately 1/3 of the route-km of rural two-lane arterial highways in New Brunswick. The remaining 2/3 of the route-km are in passing zones, urban areas, or are on bridges. The cost would be approximately $273,000 (at an estimated $1,000 per km) and the service life can range between two to eight years, though appear to have the potential to prevent seven collisions per year on rural arterial highways in New Brunswick.

The results from this study suggest that centerline rumble strips would improve road safety and bring social and economic benefits in excess of the costs. It is highly recommended that given the relatively low cost and perceived high benefit, NBDTI install CLRS where appropriate. At a minimum, NBDTI could begin with a test highway and conduct a before and after study. Further research could explore the potential of CLRS on two-lane collector highways in New Brunswick.

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