IMPLICATIONS OF REDUCING THE TARGET HEIGHT USED TO DELINEATE PASSING ZONES

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Abstract

The current standard for establishing thresholds of passing zones on two-lane roads is based on target heights of 115 cm [Transportation Association of Canada, 1976]. As the percentage of Canadian vehicles equipped with daytime running lights continues to increase, it may become appropriate to lower the target height to 60 cm to correspond with the minimum height standard for headlights. The revision would recognize a possible change in behavior where the driver may become accustomed to identifying oncoming vehicles by the presence of headlights. With such a revision there will be a corresponding reduction in the number of passing opportunities on two-lane roads resulting in decreased operational levels. The net reduction will depend on prevailing terrain (level, rolling, mountainous) and operating speeds.

A sample of arterial and collector highways was surveyed using a decreased target height of 60 cm to quantify the changes in passing opportunities which may result from a decreased target height. Results showed that a target height reduction would decrease the capacity utilization on facilities by an overall average of only 1% and in most cases there was no change in the of level of service grade assigned to a facility.

INTRODUCTION

The research included an analysis of the operational impacts associated with changing the design criteria for marking no-passing zones on two-lane rural highways. The study explores the premise that the striping guidelines, defined by the Uniform Traffic Control Devices manual for Canada (UTCD) [Transportation Association of Canada, 1976], should be changed to reflect a lowered target height equivalent to the standard minimum height of passenger vehicle headlights of 60 cm. The net result would be reductions in passing opportunities which could directly influence operational service levels.

An underlying assumption of this research was that as daytime running lights (DRL) become more prevalent, drivers will grow more accustomed to identifying oncoming vehicles by the presence of DRLs before initiating passing manoeuvres. Safety is a primary issue in highway design and it is proposed that the target height used to define the no-passing zones could increase safety if reduced from 115 cm to 60 cm. The current target height assumes that a driver can recognize an on-coming vehicle if at least the windshield/roof is visible. The trade-off would be a reduction in operational service levels. Note that the minimum height standard for DRLs is 38 cm as dictated by Canadian Motor Vehicle Safety Standard #108 [Transport Canada, 1996], however, since most vehicle manufacturers incorporate DRLs into the headlight assembly, the headlight height standard of 60 cm was used for this study.

Highway capacity utilization, average travel speed, and percent time delays are operational measures that describe the quality of service provided by a two-lane facility. The impacts that a change in the target height used to delineate passing zones had on these measures of effectiveness were quantified through a series of Level of Service (LOS) analyses.

The data from a stratified sample of sections of rural arterial and collector roads within the New Brunswick provincial highway network were tested to evaluate the implications of adopting the study premise. Sample sections were stratified according to the proportion of no-passing zones present to reflect the diversity of vertical alignments and terrain within the study area. Field surveys were conducted to determine the changes in passing opportunity if the target heights were reduced from the current standard of 115 cm to 60 cm.

STUDY DESIGN

A stratified sample of rural two-lane arterial and collector highways was selected from the highway network in New Brunswick and data from the sample was used for analysis. Due to time and resource constraints, local roads were not included as part of this study. The New Brunswick Department of Transportation (NBDoT) Highway Control Section manual, Road Life Study diagrams, and Passing Sight Distance (PSD) manual provided input information required for sample design and level of service analyses. Each arterial and collector roadway is divided into control sections (CS), which are further subdivided into rating sections (RS). A control section is delineated by an obvious fixed marker on the roadway (e.g. an intersection), while a rating section is delineated by a change in roadway characteristics (e.g. pavement surface width). Each rating section has the percent no-passing opportunity recorded from previous road inventories.

Data were stratified in order to choose a proportional representation of roads having different terrain characteristics, and therefore different no-passing zones. The roadway population was further stratified into percent no-passing zones. No-passing zones were subdivided into the 10 stratifications shown in

Table 1. This sampling scheme ensured that the sample would be representative of the provincial highway population and it allowed the changes in LOS to be associated with the varying terrain classifications. The original intent was to achieve a 10 percent sample for each category, however, as shown in Table 1, actual sample percentages varied between stratifications. The design enabled over 11 percent of the arterials to be sampled, with just over 7 percent of the collectors included. Due to time and resource constraints, the road sections sampled were within relatively close proximity to Fredericton so that travel time could be minimized and daylight hours more fully utilized. Therefore, the sample of routes chosen was not a true random sample, but a *convenience* sample. Possible bias was minimized by sampling relatively equivalent percentages within each "percent no-passing" category.

TABLE 1 - Study Sample

Percent No-Passing Zones	Arterials (km)			Collectors (km)		
	Provincial Total	Sample Total	Sample as % of Total	Provincial Total	Sample Total	Sample as % of Total
0-10<	148.5	1.3	0.8%	10.6	-	0.0%
10-20<	60.5	6.0	10.0%	34.4	-	0.0%
20-30<	227.4	22.6	10.0%	96.9	3.6	3.7%
30-40<	238.7	34.8	14.6%	129.8	-	0.0%
40-50<	456.9	44.0	9.6%	300.9	41.5	13.8%
50-60<	232.8	27.1	11.6%	263.2	19.1	7.2%
60-70<	250.8	23.1	9.2%	336.9	22.6	6.7%
70-80<	143.9	25.2	17.5%	541.2	42.0	7.8%
80-90<	160.9	32.4	20.1%	469.3	31.8	6.8%
90-100	71.1	8.5	11.9%	416.5	24.2	5.8%
Total	**1991.3**	**224.9**	**11.3%**	**2599.7**	**184.7**	**7.1%**

METHODOLOGY

The study required the sample roads to be surveyed by a striping crew to determine changes in passing opportunities which would result from a reduction in the target height used. Two vehicles are used to pre-mark the highway striping. Pre-marking is done simultaneously for both sides of a two-lane highway. An observation vehicle follows a target vehicle while maintaining a separation distance equal to the minimum passing sight distance defined in the UTCD manual for delineating no-passing zones. The minimum distances used for striping are dependent on the prevailing roadway speed. The manual stipulates that the driver's eye height in the observation vehicle and the target, on the target vehicle, both be set at 115 cm [Transportation Association of Canada, 1976].

The beginning of a no-passing zone will be marked at the point where the sight distance first becomes less than the minimum passing sight distance specified. The zone will end at a point where the sight distance again exceeds the minimum. The sampled roadway sections were surveyed using this procedure. However, a 60 cm target height was used in addition to the standard 115 cm height. This resulted in two specific striping plans for each section of road.

The minimum passing sight distance must be maintained throughout a passing zone. A no-passing zone will be extended if a passing zone is less than 100 metres in length [Transportation Association of

Canada, 1976]. The minimum sight distance between the vehicles is maintained throughout the section or until the design speed changes.

Following the field data collection phase, changes in the operational performance of the sample roads were determined. A measure of the operational performance of a highway facility is its Level of Service (LOS) which is the quality of service that a roadway section provides the user. LOS is divided into six categories ranging from A to F. A level of service 'A' is considered the best service that a facility can provide, while 'F' is the least desirable. Operational characteristics which define the LOS categories for two-lane roads are percent time delay, speed, and capacity utilization. Capacity utilization is defined as the ratio of the demand flow rate to the capacity of the facility, or the v/c ratio [Transportation Research Board, 1994]. The only measurable parameter of LOS is capacity utilization so it was chosen as the parameter for determining the operational effect of decreasing the target height used to define passing zones on the sampled roads. The v/c ratio is directly related to the percent no-passing opportunity available on a roadway.

The Highway Capacity Software (HCS) package is a computer automation of the procedures outlined in the 1994 Highway Capacity Manual (HCM) [Transportation Research Board, 1994]. This software was used to estimate the changes in operational characteristics of the sampled road sections using the program's Two-Lane Highways module. Each roadway rating section was analysed with this software using percent no passing opportunities corresponding to the 115 cm and 60 cm target heights.

The HCS uses other roadway characteristics including shoulder and surface widths, speeds, volumes, directional distribution of traffic, terrain type, traffic composition, and v/c ratios to calculate the service flowrates (SF) of a facility. The SF's essentially define levels of traffic volumes which can be accommodated for each individual LOS (A through F). The v/c ratios are determined directly from the existing percent no passing opportunity but are also influenced by flowrates. Once SF's are calculated for a specific road they are compared with the actual traffic flowrate of the facility to determine the prevailing LOS.

For the purpose of this study, percent no-passing was the only input variable that was changed, as a result of decreasing the target height standard, within a rating section. The HCS uses ranges of the percent no-passing zone values to approximate the v/c ratio values found in the HCM.

STUDY RESULTS

The results from the level of service analyses for the sampled arterial and collector highways are presented in Tables 2 and 3, respectively. The tables quantify the reductions in passing opportunities associated with a reduction in the target height standard being proposed, changes in capacity utilization (v/c ratios), and finally, the corresponding decreases in the Level of Service grade.

The data in Table 2 document that the average increase in no-passing zones for the arterials sampled is 8.6 percent, while the collectors averaged 7.1 percent. The combined (weighted) average increase in percent no-passing for arterials and collectors, was found to be 8.0 percent. Although this average decrease in passing opportunities does not directly translate into significant changes in levels of service, the freedom to manoeuvre and travel speeds will likely decrease somewhat on many routes. Furthermore, specific sections of roads were found to deviate significantly from these overall averages. For example, a reduction in passing opportunities of nearly 41 percent was found for route 10, control section 4, rating section 2, while others experienced no change.

TABLE 2 - Summary of LOS Analyses Output for Arterial Sections

Arterials			No-Passing Zones (%)			Volume/Capacity Ratio			Levels of Service	
			Target Heights			Target Height				
Route	CS	RS	60 cm	115 cm	% change	60 cm	115 cm	% v/c change	60 cm	115 cm
3	3	1	90.6	87.4	3.1	0.1394	0.1426	0.3	B	B
3	4	1	51.2	39.4	11.8	0.1788	0.1912	1.2	B	B
8	3	2	74.9	57.1	17.9	0.4651	0.4858	2.1	D	D
8	4	1	84.8	82.8	2.0	0.2952	0.2972	0.2	C	C
8	4	2	58.1	48.6	9.5	0.3229	0.3371	1.4	C	C
8	4	3	94.3	93.6	0.7	0.2857	0.2864	0.1	C	C
8	6	1	61.8	47.7	14.1	0.1682	0.1823	1.4	B	B
8	7	1	91.5	81.9	9.5	0.2885	0.2981	1.0	C	C
8	7	2	42.3	31.9	10.4	0.3466	0.3662	2.0	C	C
8	7	3	80.4	62.8	17.6	0.2996	0.3106	1.1	C	C
8	9	2	36	29.5	6.5	0.1980	0.2110	1.3	B	B
8	9	3	54.2	45	9.2	0.1758	0.1850	0.9	B	B
8	10	1	47.2	37.9	9.4	0.1828	0.1942	1.1	B	B
8	10	2	66.3	53.8	12.5	0.1637	0.1831	1.9	B	B
8	11	1	42	31.5	10.4	0.1880	0.2070	1.9	B	B
8	12	2	54	41.5	12.5	0.3290	0.3478	1.9	C	C
8	13	1	37.1	29.5	7.6	0.3558	0.3710	1.5	C	C
8	14	1	16.5	14.5	2.0	0.3953	0.3983	0.3	C	C
8	14	2	15.6	14.2	1.4	0.3966	0.3987	0.2	C	C
8	14	3	100	100	0.0	0.4300	0.4300	0.0	D	D
8	17	2	63.8	50.4	13.4	0.3162	0.3344	1.8	C	C
10	1	1	77.7	71.6	6.2	0.4623	0.4684	0.6	D	D
10	2	1	70.7	64.5	6.2	0.3093	0.3155	0.6	C	C
10	2	2	47.5	45.1	2.3	0.3388	0.3424	0.4	C	C
10	3	1	49.4	36.6	12.8	0.1806	0.1968	1.6	B	B
10	4	1	64.5	55.5	9.0	0.3155	0.3268	1.1	C	C
10	4	2	99	58.3	40.8	0.2810	0.3226	4.2	C	C
10	4	3	100	100	0.0	0.2800	0.2800	0.0	C	C
10	5	1	77.4	75.1	2.3	0.3026	0.3049	0.2	C	C
10	6	1	24.8	4.8	20.0	0.0928	0.1380	4.5	B	A
10	6	2	0	0	0.0	0.1500	0.1500	0.0	A	A
10	6	3	77.9	69.3	8.6	0.1521	0.1607	0.9	B	B
10	7	1	78.9	75.7	3.2	0.1511	0.1543	0.3	B	B
10	7	2	48.4	47.1	1.3	0.1816	0.1829	0.1	B	B
10	7	3	92.8	92.7	0.1	0.2872	0.2873	0.0	C	C
Average					8.6%			1.1%		

TABLE 3 - Summary of LOS Analyses Output for Collector Sections

Collectors			No-Passing Zones (%)			Volume/Capacity Ratio			Levels of Service	
			Target Heights			Target Heights				
Route	CS	RS	60 cm	115 cm	% change	60 cm	115 cm	% v/c change	60 cm	115 cm
101	1	2	31.2	26.9	4.3	0.9088	0.9131	0.4	E	E
101	2	1	100	100	0.0	0.9000	0.9000	0.0	E	E
101	2	2	73.9	59.9	14.1	0.3061	0.3202	1.4	C	C
101	3	1	64.2	59.8	4.4	0.1658	0.1702	0.4	B	B
101	3	2	50.9	38.4	12.5	0.1791	0.1932	1.4	B	B
101	3	3	75	60.5	14.5	0.0425	0.0500	0.7	A	A
101	4	1	66.7	63.2	3.5	0.1633	0.1668	0.4	B	B
102	8	1	72.7	67.9	4.8	0.1573	0.1621	0.5	B	B
102	9	1	79.2	72.2	7.0	0.1508	0.1578	0.7	B	B
102	10	1	92.5	88.9	3.6	0.1375	0.1411	0.4	B	B
102	11	1	76.2	71.3	4.9	0.1538	0.1587	0.5	B	B
102	11	2	69.4	61.2	8.2	0.0453	0.0494	0.4	A	A
102	11	3	84.2	77.5	6.8	0.1458	0.1525	0.7	B	B
102	12	1	90.5	88.4	2.1	0.1395	0.1416	0.2	B	B
112	4	1	43.6	36.9	6.7	0.1864	0.1962	1.0	B	B
112	5	1	67.7	58.3	9.4	0.3123	0.3226	1.0	C	C
112	5	2	56.7	56.6	0.2	0.3250	0.3251	0.0	C	C
112	6	1	64.9	57.7	7.2	0.3151	0.3235	0.8	C	C
112	6	2	66.5	64.7	1.8	0.1635	0.1653	0.2	B	B
112	7	1	60.1	59.2	0.9	0.1699	0.1708	0.1	B	B
112	7	2	69	63.4	5.6	0.1610	0.1666	0.6	B	B
112	8	1	69.8	60.8	9.0	0.1602	0.1692	0.9	B	B
112	8	2	71.4	66.8	4.6	0.1586	0.1632	0.5	C	B
127	1	1	51.4	36.1	15.3	0.0586	0.0760	1.7	A	A
127	2	1	57	46.9	10.1	0.1730	0.1831	1.0	B	B
Average					7.1%			0.6%		

The v/c ratios, as expected, were found to decrease in response to a lowered target height standard. The decreases, however, are not significant enough to change the service levels for the majority of road sections. It should be noted that each LOS grade actually encompasses relatively broad ranges of service flowrates. Consequently, it may require significant changes in the v/c ratio to cause a change in the service level rating unless the prevailing condition was bordering on a threshold to another rating. As an example, section 112, control section 8, rating section 2 had a decrease in LOS despite a reduction in its v/c ratio which was much smaller than many of the other sections. It is for this reason that changes in capacity utilization are a more appropriate means of describing operational impacts associated with a reduction in target height.

Capacity Utilization

The capacity utilization (v/c ratio) has a direct impact on the calculation of service flowrates and thus LOS. The percent no-passing input variable will determine the value of v/c assigned to a rating section, however, the exact change will also depend on the levels of prevailing traffic volumes. Table 4 presents a summary of the weighted average reduction in v/c ratio for arterial and collector roads according to different ranges of traffic volumes. This table is presented to serve as a general reference for agencies interested in estimating changes in operational characteristics of two lane highways if the target height used to delineate no-passing zones is reduced from 115 cm to 60 cm.

The overall results do not indicate significant reductions in v/c ratios and thus changes in LOS ratings will be unlikely to occur. Overall, the largest observed reduction in any v/c ratio was 1.89% while several sections show no change. On average, the capacity utilization of the arterials dropped by 1.14 percent, while collectors decreased by only 0.76 percent. The overall weighted average reduction in capacity utilization for the sampled arterials and collectors was found to be 0.97 percent.

TABLE 4 - Capacity Utilization Reductions

Percent No-Passing (%)	Avg. Increase in Percent No-Passing[1] (%)	AADT	Weighted Average Reduction in v/c Ratio (%)		
			Arterial:	Collector:	Arterials and Collectors Combined:
0 - 30<	6.0	0 - 1500	-	-	-
		1500 - 3000	1.54	-	1.54
		3000 +	0.21	0.43	0.31
30 - 60 <	10.4	0 - 1500	0.95	1.73	1.35
		1500 - 3000	1.52	1.00	1.31
		3000 +	1.89	-	1.89
60 - 100	4.8	0 - 1500	0.32	0.46	0.43
		1500 - 3000	0.84	0.59	0.69
		3000 +	0.49	0.00	0.29
Weighted Average	**8.0%**		**1.14%**	**0.76%**	**0.97%**

[1] resulting from a reduction in target height from 115 cm to 60 cm
Note: Dashed lines indicate that no data were collected within this AADT category

As a general observation, it would seem that the category of roads which are exposed to the greatest changes in capacity utilization as a result of the reduction in target height are those which have 30 to 60 percent no-passing. Sections of road over aggressive terrain (60 to 100 percent no-passing) exhibit relatively small changes in capacity utilization. In fact, it would appear that terrain types which yield no-passing zone percentages which are either relatively high or low (0 to 30 percent) are influenced the least by the proposed reduction in target height.

Level of Service

At the onset of the study there existed an intuitive opinion that a decrease in the target height would have a negative impact on passing opportunities, v/c ratios, and LOS. However, the overall LOS grade assigned for each section generally did not change, with the exception of two routes. The only input variable influenced for each target height was the percent no-passing. The percent no-passing affected the values of v/c, which in turn affected the resulting service flowrates. Each LOS grade is assigned on the basis of a broad range of service flowrates. Since the v/c ratios were only minimally impacted, the net effect was that the LOS grades generally did not change. Route 10, control section 6, rating section 1; and route 112, control section 8, rating section 2 were the only sample road sections which showed a decrease in their respective LOS grades. Results indicate that capacity of the facility was never approached for any of the sampled road sections.

Road Safety Issues

Safety is a primary concern in the design and operation of highways and should be maintained at all times. As indicated in Tables 2 and 3, when the target height is reduced from 115 to 60 cm, no-passing zones are extended. Table 4 presented a summary of the average reductions in passing opportunities associated with the different terrain categories of roads. An examination of the data in the table suggests that the largest reduction in passing opportunities would occur on facilities which currently have 30 to 60 percent no-passing.

By employing more conservative methods to delineate no-passing zones, the potential for accidents in hazardous areas should be reduced. However, the safety impact of reduced passing opportunities should also be considered to more fully evaluate the net impacts of reducing the target height standard for the delineation of passing zones. Although safety may increase on sections with hazardous horizontal and vertical curves with a target height reduction, a lack of appropriate passing opportunities may result in platoon formation, driver frustration, and an increase in passing manoeuvres occurring within no-passing zones. These adverse effects on the operational characteristics of a roadway could increase, rather than reduce, the accident rate of a facility.

Increased driver frustration due to a decrease in target height may be an issue for a number of routes surveyed given the moderate reductions in the percentage of passing opportunities. Freedom to manoeuvre may decrease on some sections of roadway, as indicated by the decreases in v/c ratios. As a result, travel speeds will decrease and congestion could increase as free flow conditions are impeded. Unfortunately, little is known surrounding the relationship between passing opportunities, driver frustration, and risk taking.

CONCLUSIONS

To reflect the changes in vehicle standards and driver behaviour, a reduced target height from the present 115 cm used in the UTCD manual to 60 cm, the national standard for minimum passenger vehicle headlight height, was proposed. Conclusions drawn from analyses of the data obtained in this study which quantified the operational impacts of this change include:

- A decrease in the target height from 115 cm to 60 cm would result in an increase in the percent no-passing zones by an average 8.0 percent, thus decreasing the available passing opportunities on a facility.

- The average decrease in capacity utilization (v/c ratio) resulting from a reduction in target height from 115 cm to 60 cm was found to be only 1 percent. Consequently, the effects on travel speeds, freedom to manoeuvre, and driver behaviour will be minimal. Furthermore, a target height reduction will result in minimal changes in LOS since it is directly related to the magnitude of the change in v/c ratio.

RECOMMENDATIONS

The need to maintain safe and efficient operations has always served as an impetus for improvements to design standards and guidelines for use on Canadian roadways. With the introduction of daytime running lights as standard equipment on all vehicles sold or manufactured in Canada, consideration of the affect of this standard on driver behaviour for passing manoeuvres should be reflected in the design of roadways. Greater conspicuity provided by this safety feature has proven that accident rates on highways were reduced since approaching vehicles can be detected more easily at greater distances [White, 1991].

The UTCD manual provides guidelines used by many agencies across Canada for developing standards for passing sight distance. These guidelines influence the decisions of agencies relative to providing safe operations. It is suggested that a target height reduction from 115 cm to 60 cm be considered in the guidelines used for establishing no-passing zones on two-lane rural highways. This would recognize headlight height as the standard target height used to establish passing sight distance. The basis for the use of headlight height relates to the recently adopted daytime running light standard.

Further research is needed to clarify the relationship between DRLs and accident reduction, specifically during the performance of passing manoeuvres on two-lane highways. Furthermore, the relationship between frequency of passing opportunities and risk-taking needs to be explored.

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REFERENCES

Province of New Brunswick. (1996) New Brunswick Motor Vehicle Act, sections 209 (3) through 209 (5), Fredericton, NB, Canada.

Transportation Association of Canada. (1976). **Uniform Traffic Control Devices for Canada**. Ottawa. ON, Canada.

Transportation Association of Canada. (1994) **Manual of Geometric Design Standards for Canadian Roads.** Ottawa, ON, Canada.

Transportation Research Board. (1994) **Highway Capacity Manual, Special Report 209.** National Research Council, Washington, D.C.

Transport Canada. (1996) Motor Vehicle Safety Act; Motor Vehicle Safety Regulations. Road Safety and Motor Vehicle Regulation Directorate, Ottawa, ON, Canada

White, J. (1991) Daytime Running Lights in **Critical Information Issue/Publication de renseignements essentiels.** Transport Canada, Road Safety and Motor Vehicle Regulation Directorate, Ottawa, ON, Canada.