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Effect of Different Median Barriers on Traffic Speed

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Abstract

This study assesses the impact of the types of median barriers installed on the comfort speed of drivers traveling in the median lane. Current guidelines and practices in most jurisdictions across the world assume that the types of barriers used do not have any impact on drivers' choice of speed. However, anecdotal evidence suggests that different drivers react differently to the presence of different types of median barriers due to differences in risk perceptions. If drivers do adapt their behaviors according to the types of barriers installed, then this relationship should be explicitly considered in the selection criteria. A speed study was therefore undertaken at selected sites with different median barriers such as ditch, curb, w-beam, Thrie-beam, F-barrier, and F-barrier with chain-link fence. Also, sites were selected in both 70km/h and 80km/h posted speed zones to determine if effects would be consistent across different speeds. By comparing the mean speeds obtained at the barrier sites to those at non barrier sites, consistent differences in comfort speed were found for both speed zones considered. Discussion of implication to road safety and capacity is discussed and some recommendations on future barrier selection are provided.

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1.0 Introduction

Collisions involving left-of-centre and run-off-the-road vehicles constituted about 41.2% and 19.8% of all fatal collisions in Alberta in 2003 (AIT, 2004). Most of these fatal collisions, however, can be effectively prevented by simple engineering measures. The safest alternative to mitigate or prevent these types of crashes is to have a wide clear zone and median. Nevertheless, these options are often not the favoured choice, particularly in an urban setting where land values are high, and existing infrastructures preclude their provisions. One simple alternative to providing a wide median is to install median barriers, which are a very common treatment in many urban areas and mountainous terrains. These road-side features are introduced to mitigate potential dangers associated with collisions involving opposing traffic flows (AASHTO, 2004; PIARC, 2003; Elvik & Vaa, 2004).

With the increased use of barriers, much attention has been focused on making them as safe as possible and research continues to improve the performance of barriers and reduce the severity of collisions (Ross et al., 1993). Warrant procedures for the placement of barriers are very well documented and regulated. The majority of the procedures take into consideration variables such as highway geometrics, traffic volume and design speed (e.g. AASHTO, 2002; TAC, 1999; AIT, 1998; Calgary Roads, 2002). For the case of median barriers, the main warrant factors are the median separation and the average daily traffic. Once the warrant process has identified the need for a barrier, the choice of a barrier type is left to the judgement of the designer and cost is usually one of the main factors determining the type of barrier chosen. Little or no attention is given to the potential effects of different barrier types on driver behaviour in general and driver speed choice in particular.

Research regarding traffic speed adjacent to barriers has largely been approached from a roadway capacity perspective. The Highway Capacity Manual (HCM) produced by the Transportation Research Board identifies some geometric effects on free flow speed (TRB, 2000). The two main adjustments for free flow speed identified by the HCM are the lane width and the lateral clearance to an obstruction such as a median barrier. Expected speed reductions for lane width and lateral clearance of freeways are presented in Tables 1 and 2 respectively (TRB, 2000).

Table 1
Lane width adjustment to free flow speed

Lane Width (m)	Reduction in Free Flow Speed (km/h)
$\geq$ 3.66	0.0
3.35	3.06
3.05	10.62

Table 2
Lateral clearance adjustment to free flow speed

Shoulder Lateral Clearance (m)	Reduction in free flow speed (km/h)	
	Lanes in one direction	
	2	3
≥ 1.83	0.00	0.00
1.52	0.97	0.64
1.22	1.93	1.29
0.91	2.90	1.93
0.61	3.22	2.57
0.35	3.86	3.22
0.00	5.79	3.86

The HCM states that a reduction in the width of the driving lane is expected to slow drivers, as they will be less comfortable. The expected reduction in free flow speed will become significant when the lane widths become relatively small. The predicted speed reductions for the lateral clearance are smaller, indicating that lane width is assumed to have a larger impact on free flow speed. The expected reduction in speed for lateral clearance is attributed to shy distance. If the shy distance desired is not provided, drivers will compensate by lowering their speed to reduce their perceived risks.

The Transportation Association of Canada Geometric Design Guide for Canadian Roads provides some suggestions for shy line offset values but no explicit speed reduction values were given (TAC, 1999). For a design speed of 90km/h, which would be posted at 80km/h in the City of Calgary, an offset of 2.2 metres is suggested. For a design speed of 80km/h, which would be posted at 70km/h in Calgary, an offset of 2.0 metres is suggested. Since these values are both larger than the upper limit of the HCM values as shown in Table 2, we would expect no speed reduction to occur along 70 km/h or 80 km/h roads in Calgary. Neither of these documents, however, refers to the type of barrier installed or suggests that there may be a differential reduction due to different types of barriers installed.

Barrier related speed studies are generally done as part of an overall safety evaluation of barrier installation, and these are primarily before and after type studies for a particular barrier. In one of the few studies that examined this issue, Bergh and Carlsson (1999) evaluated the safety effects of the installation of a cable median barrier on the Swedish 2+1 road network. The 2+1 network is a highway system of 13m wide roadways with alternating sections of two lanes in one direction and one lane in the opposing direction. There were about 100 deaths and 400 injuries per year on these roads (half of them from head on collisions), so the installation of a median barrier was adopted. Following the convention of the HCM discussed earlier, the Swedish National Road Association expected that the installation of a barrier would reduce driver comfort and result in lower speeds. The study showed that, contrary to expectations, the barrier resulted in increased speeds. This case study evaluated only one type of barrier and therefore added little to the barrier type discussion, but it did indicate that perceived safety improvement could result in higher speeds even though the HCM indicated that a free flow speed reduction is expected due to driver discomfort.

By comparing the observed speeds adjacent to various barrier types with a comparison site (grass median with no barrier), the validity of assuming that driver reaction is the same for all barrier types can be examined. If the barrier type is shown to affect the traffic speed, a further dimension of the warrant and design process would be recommended. Moreover, if a given barrier type is shown to slow drivers more than others, it could be used as a traffic calming device to reduced speeds, resulting in a reduction in collision severity.

2.0 Measurement Method

In order to determine if the median barrier type effects traffic speed, spot speed was measured along sections of freeways in the City of Calgary, Alberta. The sites had different types of longitudinal median barriers but otherwise the sites had similar characteristics. Several factors were considered in the development of the spot speed study in order to maximize uniformity in measurement. To ensure that the comfort speed of drivers was measured, a long enough section of the road at a constant offset was required. This consideration limited the number of possible locations within the Calgary area but if steady state traffic speeds were not reached, then meaningful comparisons would be difficult. In addition, the speed of impeded or rushed drivers would have been influenced by others and were therefore not included in the sample in order to measure only the comfort speed under free flow condition. To maximize the sample of observed vehicles with adequate headway and tailway, measurements were taken mainly during off peak periods.

To reduce the variations in speed due to time of day and day of week effects, speed measurements were only taken during mid week evenings. A further benefit of taking measurements at night is that the darkness reduces the visibility of the researcher taking the measurements. Moreover, since weather and road surface conditions affect traffic speed, measurements were only taken under dry conditions.

There were three main options to measure the speed of vehicles travelling in the median lane: automated measurement under the lane (e.g., induction loops), radar or laser measurement from the side of the road, and radar or laser measurement from above the road. Measurements using induction loops were discarded due to cost considerations. Measurement from the side of the road was considered but not preferred due to the relatively higher obtrusiveness of the method. In addition, measuring from above the road on vehicle or pedestrian overpasses provided a safe work zone for data collection, had an unobstructed view of the median lane, was unlikely to be mistaken for an enforcement activity, and allowed a better view of vehicle flow. By having an improved overhead view of traffic flow, sufficient headways and tailways of vehicles could be easily assessed. Finally, choosing as many sites on the same roadway as possible would help to reduce the differences due to driver characteristics that may affect the free flow speed.

With the selection of overpasses as the location for measurement, the speed measuring tool had to be portable and easily operated from an overpass. The Ultralyte 20-20 laser speed gun was chosen for the study. This battery operated, light, portable and tripod mountable speed gun was also backlit, which aided night readings. The quoted accuracy was +/- 2km/h (Laser Tech, 2005), which was adequate for this study. More importantly, the readings are not expected to have a systematic bias when measuring relative vehicle speed along roads with different barrier types.

3.0 Site Selection

The last important issue was the selection of sites with various barrier types. Further geometric considerations for individual sites were horizontal alignment, vertical grade and weave zones, which could affect the local flow and speed patterns. The most desirable geometric conditions are straight horizontal and flat vertical alignments. Since these conditions are rare in Calgary sites that approximated these conditions (no slope or curve to naked eye) were deemed close enough to provide similar conditions across all sites. Sites were selected for 80 and 70 km/h posted speed zones in the Calgary area because most low speed roads do not have median barriers. Both these categories of roads were chosen so that the results obtained in the 80km/h zones could be compared to 70 km/h zones to see if the reactions to barriers were similar. Two roadways with the greatest variety of barrier and highest concentrations of overpasses, Crowchild Trail and Glenmore Trail, were chosen for this study. There were six sites with an 80km/h speed limit and three sites with a 70km/h speed limit.

The barrier conditions at the 80km/h sites selected were:

1. Wide ditch median
2. Raised curb median
3. Thrie beam barrier
4. F-shape concrete barrier
5. F-shape concrete barrier, topped with chain link fence
6. F-shape concrete barrier, topped with chain link fence

The barrier conditions at the 70km/h sites selected were:

7. Raised curb median
8. W-beam barrier
9. F-shape concrete barrier

These nine sites were the most compatible sites with the measurement method chosen and with one another in terms of design geometry, traffic characteristics and shy distances. Measuring speed from overpasses was not feasible for the Thrie beam barrier in the 80km/h zone, and the F-shape concrete and W-beam barriers in the 70km/h zone due to the lack of an overpass nearby, so measurements were taken from the roadside instead.

The collection of the speed data from the nine sites took place in the evenings during the months of March and April of 2005, as the weather and road conditions permitted. The sample sizes for all sites except one exceeded the minimum required to ensure a 95% accuracy for a +/-

1 km/h tolerance. Site #6 was only collected at the 89.12% confidence level with a +/-1km/h tolerance due to time and weather constraints. It was added to the list to supplement the readings from site 5, which has the same type of barrier, to support and confirm the readings from Site 5.

Calculations of all descriptive statistics were performed in Microsoft Excel which also allowed for the easy graphing of the results. As expected, all samples fitted the normal distribution well when they were graphed (Roess et al., 2004). Therefore, unless otherwise stated, all computations and statistical tests used will be based on the assumption of a normal distribution.

4.0 Results

Descriptive statistics of results from each site are presented in Table 3. At the time of collection, the distances to the vehicles were also measured with the intent of correcting for the cosine effect, which results from taking a measurement of a vehicle that is not approaching directly toward the laser gun. Since the nearest readings were at a distance of 70 metres or more, this correction resulted in a very small difference of about 1/3 km/h.

Table 3
Descriptive Statistics of Speed Measurements

Barrier	Sample Size	Speed Measurements					Speeding (%)	
		Mean	SD	Max	Min	85th	Over Limit	10km/h Over
80 km/h								
Wide ditch	300	90.8	7.9	146.0	73.0	98.2	94.7	47.3
Raised curb	350	89.6	9.2	139.0	65.0	98.0	85.4	41.7
Thrie beam	286	90.2	8.6	118.0	69.0	99.0	89.9	44.1
F-barrier	350	93.6	9.3	139.0	75.0	103.0	94.3	58.8
F-barrier & fence	288	84.9	8.5	148.0	59.0	91.9	70.8	19.4
F-barrier & fence	156	85.5	7.8	108.0	59.0	94.0	74.4	21.2
70 km/h								
Raised curb	289	71.9	7.0	96.0	53.0	79.0	52.9	11.4
W-beam	300	75.3	8.5	106.0	52.0	84.0	69.3	26.7
F-barrier	462	79.6	10.8	125.0	59.0	90.0	42.1	14.5

It is interesting to note that relative to the ditch and raised curb (no barrier configurations), the mean speed and 85th percentile speed along sections of the roads with Thrie beam, F-barrier and W-beam are generally higher. This result is in contrast to those predicted by the HCM. On the other hand, the mean speed and the 85th percentile speed along roads with F-barriers and fence are lower; a result that is consistent with those predicted by the HCM.

As a comparison, the speed reduction predicted by applying the recommendations of the Highway Capacity Manual (see Tables 1 & 2) for different lane width and lateral clearance was computed and the expected mean speeds at the various sites obtained by subtracting these reductions from the observed mean speed without barrier. The expected and observed mean speed for the different barrier types are presented in Table 5 and their differences are also computed and shown. It is interesting to note that except for the Thrie beam configuration, the speed predictions using the HCM recommendations did not perform very well.

Table 4
HCM Predicted Reductions in Mean Speed

Barrier type	Lane width (m)	Lateral clearance (m)	Total Reduction (km/h)	Predicted speed (km/h)	Observed speed (km/h)	Diff (km/h)
80 km/h						
No Barrier	-	-	-	-	90.83	-
Thrie beam	4.8	1.5	1.29	89.54	90.19	0.65
F-barrier	6.34	1.34	1.29	89.54	93.55	4.01
F-barrier w/	3.23	1.26	11.91	78.92	84.89	5.97
F-barrier w/	3.66	0.93	1.93	88.9	85.53	-3.37
70 km/h						
No Barrier	-	-	-	-	71.86	-
W-beam	3.87	0.45	3.22	68.64	75.28	6.64
F-barrier	3.64	1.34	4.35	67.51	79.56	12.05

To determine if there is a difference in driver behaviour adjacent to various barrier types, it is necessary to compare the mean speeds of the test sites and obtain a confidence interval for the difference of the means. Confidence intervals for the means were calculated using the sample means, standard deviations and sample sizes, and a Z-value corresponding to a 95% confidence level (Walpole et al., 2002). The 80km/h zone barrier comparisons are made relative to the ditch configuration (site #1) and shown in Figure 1 as well as to the curb configuration (site #2) and shown in Figure 2. The 70km/h zone barrier comparisons are made relative to the curb configuration (site #7) and are presented in Figure 3. In all figures, positive values indicate faster speeds relative to the comparison site, and the tails drawn represent the 95% confidence interval.

Figure 1

Mean Speed Relative to Ditch Section

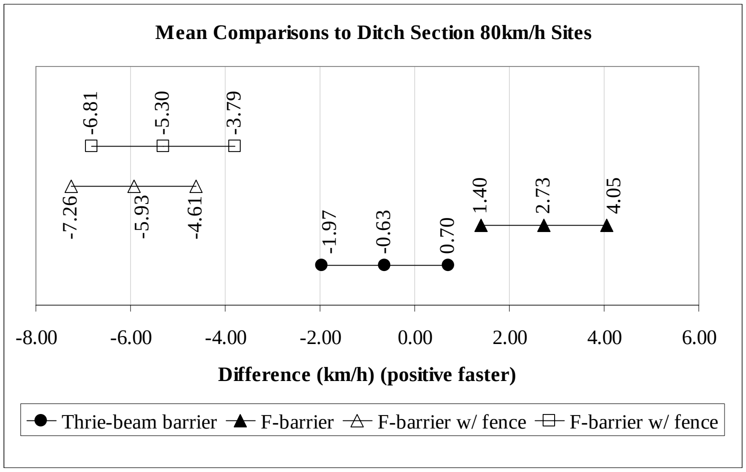


Figure 2

Mean Speed Relative to Raised Curb Section

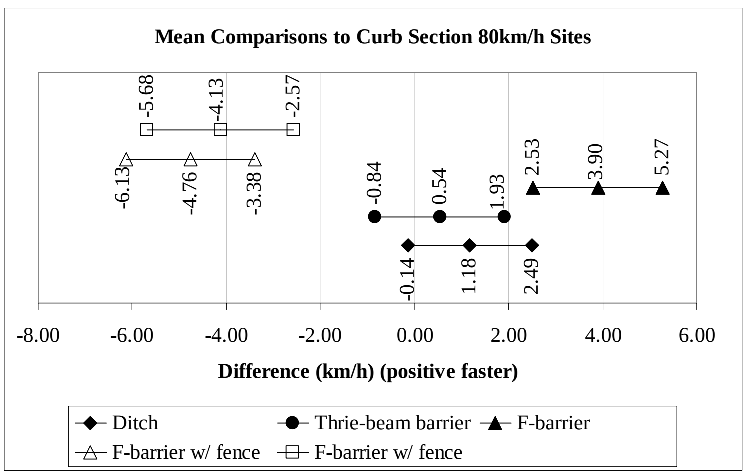
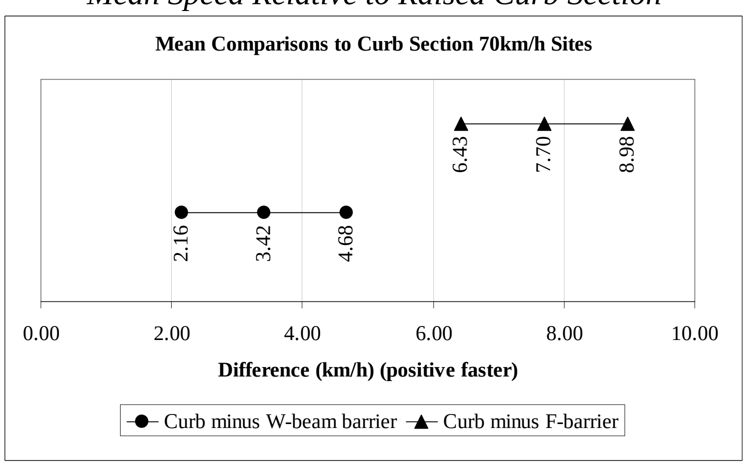


Figure 3

Mean Speed Relative to Raised Curb Section



5.0 Discussion

Road crashes are a leading cause of deaths and injuries in Canada (Transport Canada, 2004) and around the world (Peden et al, 2004). Many of these deaths and injuries, however, can easily be prevented with simple engineering measures. In the Province of Alberta, for example, more than 60% of the fatal crashes involved a vehicle running off the road or crossing the centre line (AIT, 2004). These types of crashes can effectively be mitigated by proper road design through the provision of wide medians and clear zones, and by the installation of appropriate median and road side barriers where space is an important constraint (AIT, 1995; TAC, 1999; ASSHTO, 2002; PIARC, 2003; Elvik & Vaa, 2004).

It is therefore not surprising that median barriers are a common sight on many urban freeways. Despite their widespread use, little research has been conducted to examine the effect of different barrier types on driver behaviour. The HCM suggested that, relative to road segments without barriers, vehicle speed along sections of roads with barriers would be reduced due to increased drivers' discomfort. The manual, however, does not differentiate between different types of barriers, although it does provide some guidelines on the expected reductions in speed according to the lane widths and lateral clearances of the roads.

This study attempts to examine the effect of barrier types on driver behaviour by measuring the speed of vehicles travelling along different segments of two major urban expressways in the City of Calgary. The HCM predicts speed reductions from the no barrier free flow speed while the observed speeds of vehicles along the roads with different barriers indicated that, in all cases but one (F-barrier with fence), the observed speeds were higher than the predicted speeds. More importantly, in contrast to the suggestions of HCM, the mean traffic speeds along most sections of the roads with barriers were actually higher than the base free flow speed along road segments without barriers.

These results suggest that the HCM speed adjustments method may not be a good approach to predict the actual change in traffic speed due to the installation of barriers. Our results are consistent with those found in Sweden where the traffic speed increased after the installation of a rope barrier (Bergh & Carlsson, 1999). It can be inferred from these results that drivers perceived the median barriers more as a protective device than as a hazard and therefore adapt to their presence by increasing their speed to compensate for the perceived reduction in risks. This inference is also supported by anecdotal evidence from drivers who reported feeling safer driving along roads with median barriers.

With respect to the differentiate speed effects of different barrier types, the Thrie beam in the 80km/h zone was relatively neutral with the confidence interval overlapping the no barrier cases. The W-beam in the 70km/h, on the other hand, had adjacent speeds 2.2 to 4.7 km/h faster than the no barrier case. In both the 80 and 70km/h zones, drivers travelled the fastest along the F-shape concrete barriers. These speeds are 1.4 to 4.7 km/h faster than along the ditch site and 2.5 to 5.3 km/h faster than along the curb section.

In contrast, the two F-shape barriers with a chain link fence placed on top both had noticeably slower speeds than the sections with no barriers. Comparing to the ditch section, the mean speed at one site was 3.8 to 6.8 km/h slower while the mean speed at the other site was 4.6 to 7.3 km/h slower. Similarly, compared to the curb section, the mean speed was 2.6 to 5.7km/h and 3.4 to 6.1 km/h slower respectively. These results indicate that adding a fence on top of the concrete barrier may slow drivers significantly, given that the F-shape barriers alone were found to be associated with the greatest speed increase. This result suggests that the height of the barrier may play a greater role in determining the comfort speed of drivers than the lateral clearance to the barrier. Also, the addition of a fence above the concrete barrier may give drivers the impression that there may be people or animals nearby attempting to cross the freeway.

Overall, our results suggest that design guides such as the HCM should be revised to reflect changes in driver behaviour and risk perception that have taken place since the barriers were introduced as roadside appurtenances. When longitudinal barriers were introduced nearly 50 years ago, they might have reduced traffic speed because they might have increased driver's discomfort. From the literature review, little recent research has been found that examined driver behaviour in response to median barriers.

Further investigations into driver response may change the way barriers are used. If the findings of this investigation hold elsewhere, barrier design could be used for two purposes. Tall barriers could be used as a traffic calming device and reduce the variations of speeds which generate collisions as well as the mean speed which would reduce the severity of the collisions. The other possibility is the use of shorter barriers which will provide the same crossing protection as a taller barrier but will allow drivers to maintain a higher comfort speed thereby allowing a higher flow which will improve the level of service of the road.

6.0 Conclusions

The objective of this investigation was to explore the effect of different median barrier type on traffic speed. Through a speed study at several sites, the observed speeds in most sites were found to be higher than the expected speed predicted by HCM. Compared to the no barrier configurations, F-shape concrete median barriers were found to increase the comfortable speed of drivers in both 70km/h and 80km/h sites included in the study. Thrie beam barriers were found to have little effect on driver speed in the 80km/h site while the W-beam barrier was found to increase the speed of drivers. In contrast, F-shape concrete barriers on which a chain link fence was installed were found to reduce driver speed.

These results have serious implications for the selection of appropriate barrier types which have not yet been discussed in the literature or documented in the major design guides. Therefore, more research using a larger sample is needed to confirm the speed effects of different barriers. If these findings are shown to hold, then a review of the current best practice relating to barrier selection and installation is required as the recommendations in the HCM did not predict the expected change in speed very well. Median barriers are an integral part of our roadway infrastructure and a better understanding of their effects on driver behaviour may allow better use of these roadway appurtenances.

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