A COMPARISON AND EVALUATION OF THE GEOMETRIC DESIGN PRACTICES WITH PASSING LANES, WIDE-PAVED SHOULDERS AND EXTRA-WIDE TWO-LANE HIGHWAYS IN CANADA AND GERMANY

Uwe Frost, Ingenieurbüro Sehlhoff
John Morrall, The University of Calgary

ABSTRACT

Passing Lanes (also known as three-lane highways), wide paved shoulders, and extra-wide highways are designed to enhance traffic operations on two-lane highways. These low-cost improvements bridge the gap between conventional two-lane highways and four-lane highways. This paper compares design practices and policies as well as the operational experience regarding passing lanes, wide paved shoulders, and extra-wide two-lane highways. Canadian and German warrants for upgrading a two-lane highway to a passing lane system and ultimately a four-lane motorway are examined. Geometric design standards such for cross-section elements such as lane width and shoulder width are compared. Design standards for the length and spacing of passing lanes as well as the length of merge and diverge tapers are examined. Design practices and policies concerning transition areas between, for example, conventional two-lane and extra-wide highways are discussed. The signing and marking practices for passing lanes, extra-wide highways and transition areas are also included in the paper.

The paper discusses the operational experience in terms of overtaking rates, speed-volume relationships, platooning, level-of-service, accident rates, and driver attitudes. Research studies in both Canada and Germany show that passing lanes, wide-paved shoulders, and extra-wide highways increase the quality of service and decrease the accident rates compared to conventional two-lane highways. Both Canadian and German studies have concluded that passing lanes and extra-wide highways offer a cost-effective alternative of enhancing the quality of service and safety on those two-lane highways that do not meet the warrants for motorways or where cost and environmental concerns rule out the four-lane option.

INTRODUCTION

The purpose of this paper is to compare and evaluate Canadian and German design practices and policies as well as the operational experience regarding passing lanes, wide paved shoulders, and extra-wide two-lane highways.

Canada has over 874,000 km of highways of which 20.3 percent or 177,000 km are paved rural roads (*1*). Eight of ten highway jurisdictions in Canada have climbing and passing lanes and there are approximately 1,700 installations of climbing and passing lanes reported in Canada (*3*). Alberta, for example, has a network of over 15,000 km of paved two-lane rural highways on which 220 km of climbing and passing lanes have been constructed (*3*). On the Trans-Canada Highway through the Mountain National Parks of Yoho, Glacier and Mount Revelstoke there are 25 climbing and passing lanes on 103 km of two-lane highway representing approximately 52 percent of system length. The average annual daily traffic (AADT) on this section of the Trans-Canada highway ranges between 3,830 and 4,270, however, during summer months average daily traffic volumes range between 7,520 and 8,650. The 105 km Kootenay Parkway with an AADT of 1,820 and average daily volumes in summer of 3,680 has an ultimate proposed climbing and passing lane system of 13 auxiliary lanes totalling 46 km.

In Canada a passing lane is defined as an auxiliary lane provided on a two-lane highway to enhance passing opportunities. Passing lanes are distinct from climbing lanes which are used in hilly or mountainous terrain. This distinction is that climbing lanes are provided to allow faster vehicles to pass slower vehicles on particular upgrades, whereas passing lanes are provided to increase passing opportunities on extended sections of highway. Passing lanes offer a low-cost and environmentally friendly alternative to major reconstruction of two-lane roads or "twinning" to a four-lane divided standard. Passing lanes are used as an intermediate level of road improvement on highway sections which may not meet warrants for four-laning but exhibit deteriorating levels of service and periods of reduced speeds, increased time spent following in platoons, and a demand for passing which exceeds passing opportunities. Depending on terrain and traffic composition passing lanes offer a low-cost alternative to major reconstruction or "twinning" on roads with traffic volumes of 2,500 AADT to a maximum of 10,000 AADT.

In Germany there are 24,500 km of two-lane highways classified as Bundesstrassen, which are major highways with an AADT from 5,000 to 20,000 and 5 - 20 percent heavy vehicles.

In Germany extra-wide highways are designed to fill the gap in the traffic supply provided by a two-lane highway and four-lane motorway. The range of application of an extra-wide highway is an AADT between 15,000 and 20,000. It is the objective in Germany to have a road category with a higher level of service and a higher traffic safety than the standard two-lane highway, but with less land use requirements and cost than a motorway.

Most of the extra-wide two-lane highways are just short sections of less than 4 km which operate as overtaking sections within standard Bundestrassen which provide very limited overtaking possibilities. This has led to risky overtaking manoeuvres and severe accidents mainly on those two-lane roads with narrow cross sections (less than 12 m) and high traffic volume (AADT > 15,000). This, however, is not a problem on extra-wide two-lane highways with the minimum design standard of 12 m cross-section, double-solid centre line, and a minimum length of 5 km as reported by Frost (*4, 5*). One major difference between three-lane and extra-wide two-lane highways is that the latter offer more or less continuous overtaking opportunities whereas on three-lane highways passing is only possible in three-lane sections which represent less than 50 percent of the total length.

Since the end of 1993, when research on extra-wide highways (b2s, b2+1, b2ü) was completed, the focus of German Road Authorities has been on the three-lane highway because of traffic safety (*7, 8, 9, 10, 11, 12, 13, 14, 15, 16*). These road types were mainly used for high volume highways (AADT 15,000 - 22,000), however, at the present time only the b2 + 1 is used.

In summary, the purpose of passing lanes in Canada and extra-wide highways in Germany is the same, namely, to fill the gap between conventional two-lane highways and four-lane highways. This paper presents the results from empirical data collected on several highways in Canada and Germany.

DETERMINING THE NEED FOR PASSING LANES AND EXTRA-WIDE HIGHWAYS

Highway agencies in Canada, in general, attempt to maintain level of service (LOS) C on primary two-lane highways. The Highway Capacity Manual (1985 HCM) does not incorporate procedures to determine the impact of passing lanes on level of service (*17*). However, by using the HCM platoon definition of 5 seconds, the TRARR simulation model output of percent time spent following can be directly related to the HCM LOS criteria. The TRARR simulation model, developed by the Australian Road Research Board, has been used extensively to examine the effect of systems of passing lanes on the level of service on many primary highways in Canada over the past decade as reported by Morrall et.al. (*18, 19, 20*). Specific warrants for passing lanes in Canada are still under development, however, warrants for twinning include volumes that are typically lower than volume warrants for twinning in Germany. For example, in one Canadian jurisdiction the highway agency has noted (*21*) that any decision to construct auxiliary lanes as an interim measure should be done in conjunction with developing plans for the ultimate highway cross section. In addition, twinning should be considered once AADT is in the 8,000 to 10,000 range or design hour volumes (DHVs) are in the 1,000 veh/h range. In Germany, three lane highways are considered for an AADT range of 10,000 to 18,000. The operational use for extra-wide highways is in the range of 10,000 to 20,000 AADT with a high percentage of heavy vehicles, typically more than 10 percent. The maximum capacity of extra-wide highways is considered to be in the range of 2,500 to 3,300 veh/h. Motorways are considered once the AADT reaches 18,000. Table 1 provides a summary of the design volumes and capacities of a range of two-lane highway types in Canada and Germany.

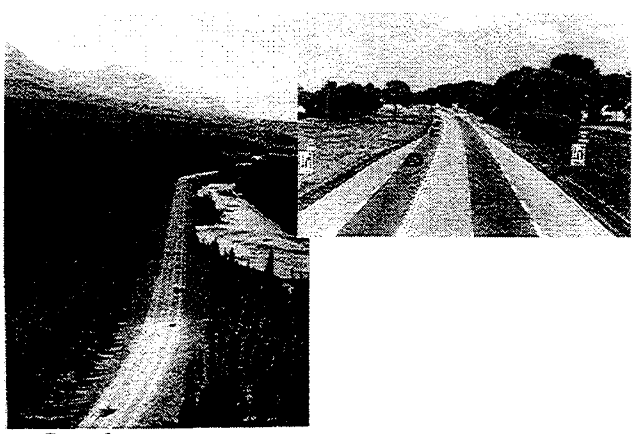
The following is a classification of German two-lane highways (Bundesstrassen):

BUNDESSTRASSEN	*CLASSIFICATION*	*LENGTH*
three-lane	(b2+1)	50 km
extra-wide two-lane	(b2ü)	215 km
with wide paved shoulders	(b2s)	220 km
standard	(b2)	≈24,000 km
total		≈24,500 km

GEOMETRIC DESIGN STANDARDS

Cross Sections

Figure 1 shows a section of a three-lane highway in Germany and a passing lane in Canada. Figure 2 compares different highway cross sections in Canada and Germany. The standard two-lane road in Germany has a classification of b2 and a cross section of 8.0 m. It is noted there was a road category called b2s in Germany, with a 1 m shoulder and with a solid continuous line demarking the travel lane and shoulder. However, the category is no longer used due to its limited effect on traffic flow and quality of service. The two-lane cross section shown for Canada is typical for primary highways in Alberta. The classification of RAU 213.4-130/120 stands for two-lane rural arterial undivided with a cross section of 13.4 m and a design speed of 120 to 130 km/h. This classification represents the highest class of two-lane highway found in Canada and is typical of the cross section on the Trans-Canada Highway. In both countries the defacto "shoulder lane" is used by a slower moving vehicle, typically a heavy truck or recreational vehicle (RV), as shown in Figure 3.



Canada *Germany*

FIGURE 1 Passing Lane in Canada and Three-Lane Highway in Germany

Also shown in Figure 2 are two examples of passing lane cross sections from Canada and a three lane highway cross section from Germany. A number of sections of primary highways with wide paved shoulders in Western Canada have been retrofitted with passing lanes. The retrofitting, which has resulted in a system of passing lanes on the Trans-Canada Highway in the Mountain National Parks, is accomplished by shifting the centre line 1.8 m. The resulting lane configuration provides two 3.7 m lanes, one 3.6 m lane and 1.2 m paved shoulders. If the highway is to be re-surfaced in mountainous terrain a passing lane section would be expanded to provide a minimum desirable shoulder width resulting in a cross section of 15.6 m, including concrete barriers. The German three lane highway has a cross section of 11.0 - 12.0 m and is operated in the same direction alternatively.

The standard cross section of the German extra-wide two-lane highway (b2ue) is 12.0 m and does not have any shoulders. The two directions of flow are divided by a solid double centre line or a broken centre line as shown in Figure 4 which shows two sections of extra-wide two-lane highways.

Length, Configuration, and Spacing of Passing Lanes

Figure 5 shows the general layout of a passing lane in the Trans-Canada Highway, while Figure 6 shows the corresponding layout for a three-lane highway in Germany. Figure 7 shows various configurations of passing lanes used in Canada. The following is a brief description of the design characteristics of each section of a passing lane and the three-lane and extra-wide highway.

Diverge Area

The primary function of the diverge area is to direct the slow-moving vehicles to the outside lane while the faster-moving vehicles move to the passing lane. The diverge treatment is similar in both Canada and Germany in that traffic is directed via roadway markings into the slower outside lane. Diverge taper lengths vary as shown in Table 1 and are dependent on the curve facilitates approach speed and pavement narrowing. In both countries the starting point of a passing lane is located where there is adequate sight distance for the fast and slower moving vehicles and platoons to diverge easily. In addition, studies in Canada (*22*) have found that developing the diverge taper around a horizontal separation of the fast and slow streams of traffic.

TABLE 1 Design Volume and Capacity of Different Highways in Canada and Germany

HIGHWAY TYPE		CROSS WIDTH [m]	DESIGN VOLUME [veh/hour]	AADT [veh/24h]	CAPACITY [veh/hour]	AADT[veh/24h]	SPEED LIMIT km/h
two-lane	Canada Germany	8.0 - 11.0 8.0	670 1,600	4,500 8,000	900 2,400	6,000 12,000	90 100
extra-wide two-lane	Canada 1) German	13.4 12 - 13.5	1,010 (790 2)) 1,900	6,730 (5,270 2)) 12,000	1,200 3,300	8,000 18,000	90 - 100 100 - 120
three-lane	Canada 3)	13.4 - 14.1	1,200	8,000	2,800	18,600	100
	Canada 4)	15.6	in mountainous terrain 540	in mountainous terrain 3,600			90 - 100
	Germany	11.5 - 13	1,800	12,000	2,500	15,000	100
motorway	Canada 5) Germany	 23.0	1,640 / lane 2,200 / lane	≈10,000 ≥18,000	2,200 / lane 2,600 / lane	>10,000 >35,000	110 no speed limit

1) level terrain; 10% trucks; 60/40 directional split, k=0.15; 2) rolling terrain; 3) ideal conditions, k=0.15; 4) 15% RVS, 6% trucks; 60/40 directional split, k=0.15; 5) ideal conditions, k=0.15

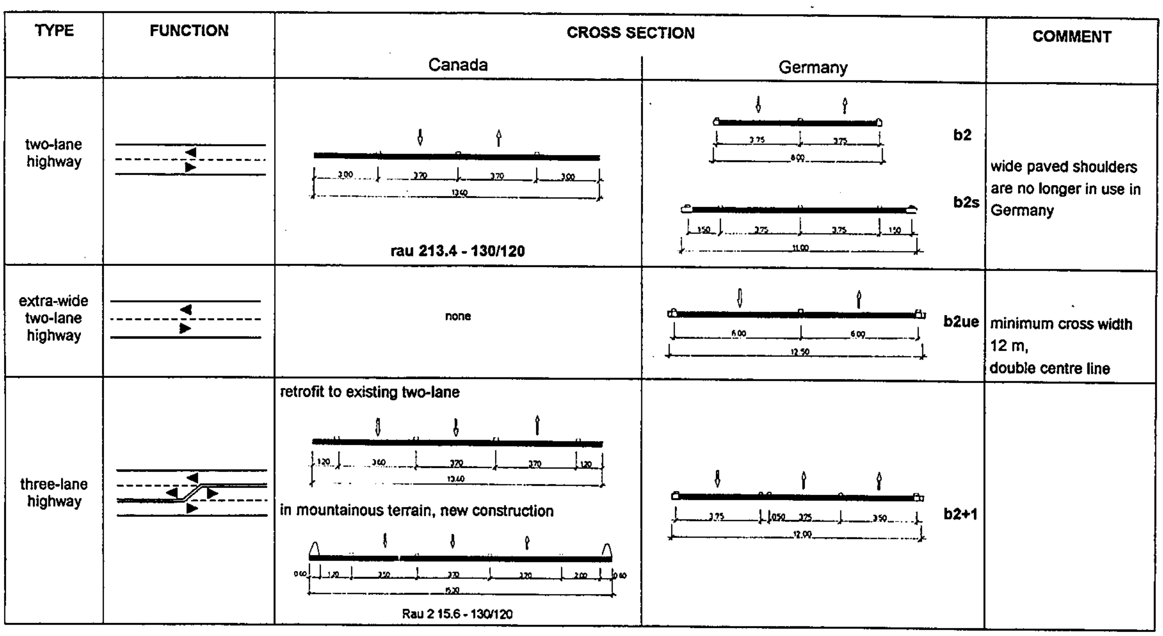


FIGURE 2 Cross Sections of Various Types of Two-Lane Highways in Canada and Germany

FIGURE 3 Examples of Shoulder Driving on Two-Lane Highways in Canada

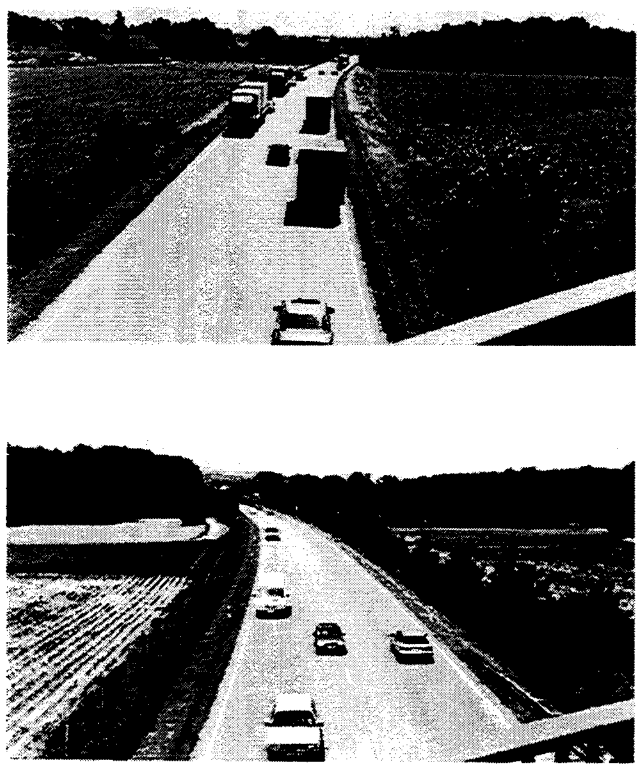


FIGURE 4 Sections of Extra-Wide Two-Lane Highway in Germany

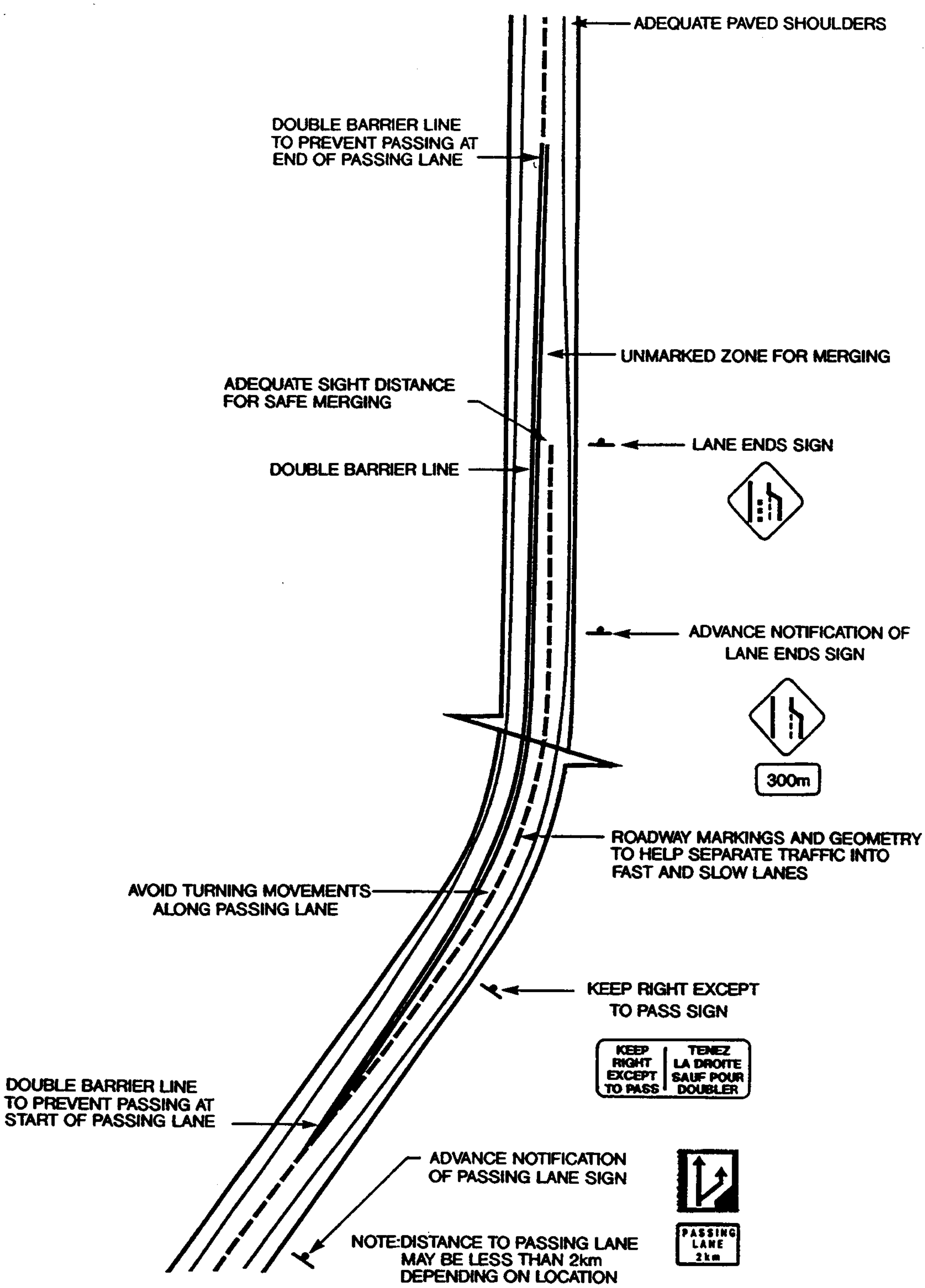


FIGURE 5 Signing and Marking for the Trans-Canada Highway Mountain National Parks Passing Lane System (AADT > 4,000)

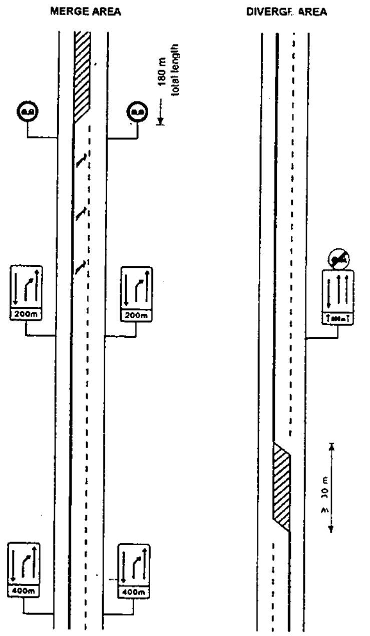


FIGURE 6 Signing and Marking for Three-Lane Highways in Germany

Passing Section

Recommended lengths for passing lanes for various highway planning agencies in Canada are shown in Table 2. The recommended length for passing lanes in Canada is generally about 2 km. In Germany the recommended length of three-lane highways is dependent on volume and percent heavy vehicles and varies between 1,000 m and 1,400 m. The minimum length is 800 m while the maximum length is 2 km. The minimum length of an extra-wide highway is 3 km, and minimum desirable length is 5 km (*4, 5, 11, 24*).Table 2: Comparison of Geometric Design Features of Passing Lanes and Extra-Wide Highways

Merge Area

The function of the merge area is to allow the fast and slow moving vehicle streams to form a single stream. The merge taper lengths for various highway agencies in Canada and Germany are shown in Table 2. Operational experience in Canada (*22*) and Germany (*4, 23*), has indicated that a taper length of approximately 200 m is required for the merge on high-volume two-lane highways, especially during peak holiday traffic with a high proportion of recreational vehicles.

One interesting difference between the two countries is that in Germany the high speed lane must merge into the slower speed outside lane, while Figure 5 shown for Canada, indicates that drivers must show a degree of common sense and co-operation when merging. Many Canadian highway jurisdictions place the onus on the driver in the outside (slow) lane to give way to drivers in the passing lane. It is noted that one highway jurisdiction in Canada, namely, Newfoundland, has a assigned right-of-way to the drivers in the outside (slow) lane at the merge area, similar to Germany. Properly designed and signed merge areas have not been found to be high accident locations in either Germany or Canada.

The Opposing Lane

One of the more vexing questions for some highway departments in Canada is whether or not overtaking should be permitted in the opposing lane where sight distance permits. Even when it is permitted, Canadian authorities have taken a cautious approach, informing drivers in the opposing lane to PASS ONLY WHEN CENTRE LANE IS CLEAR in Ontario and YIELD CENTRE LANE TO OPPOSING TRAFFIC in British Columbia, as shown in Figure 8. On overtaking lanes in Alberta, where the AADT is less than 4,000, opposing lane signs with the message DO NOT PASS WHEN TRAFFIC ONCOMING are placed on 500-m intervals. When the AADT is greater than 4,000 the symbolic sign for no passing and the educational tab DO NOT PASS are placed at 500-m intervals. The provision for overtaking in the opposing lane is subject to ongoing studies in Canada. Clearly, restricting overtaking in the opposing lane, especially at low volumes where sight distance is adequate, causes platooning, frustrates drivers and may create an environment where drivers tend to disregard the markings and pass anyway. In Germany passing is generally not permitted in the opposing lane, with DO NOT PASS signs placed every 500 m.

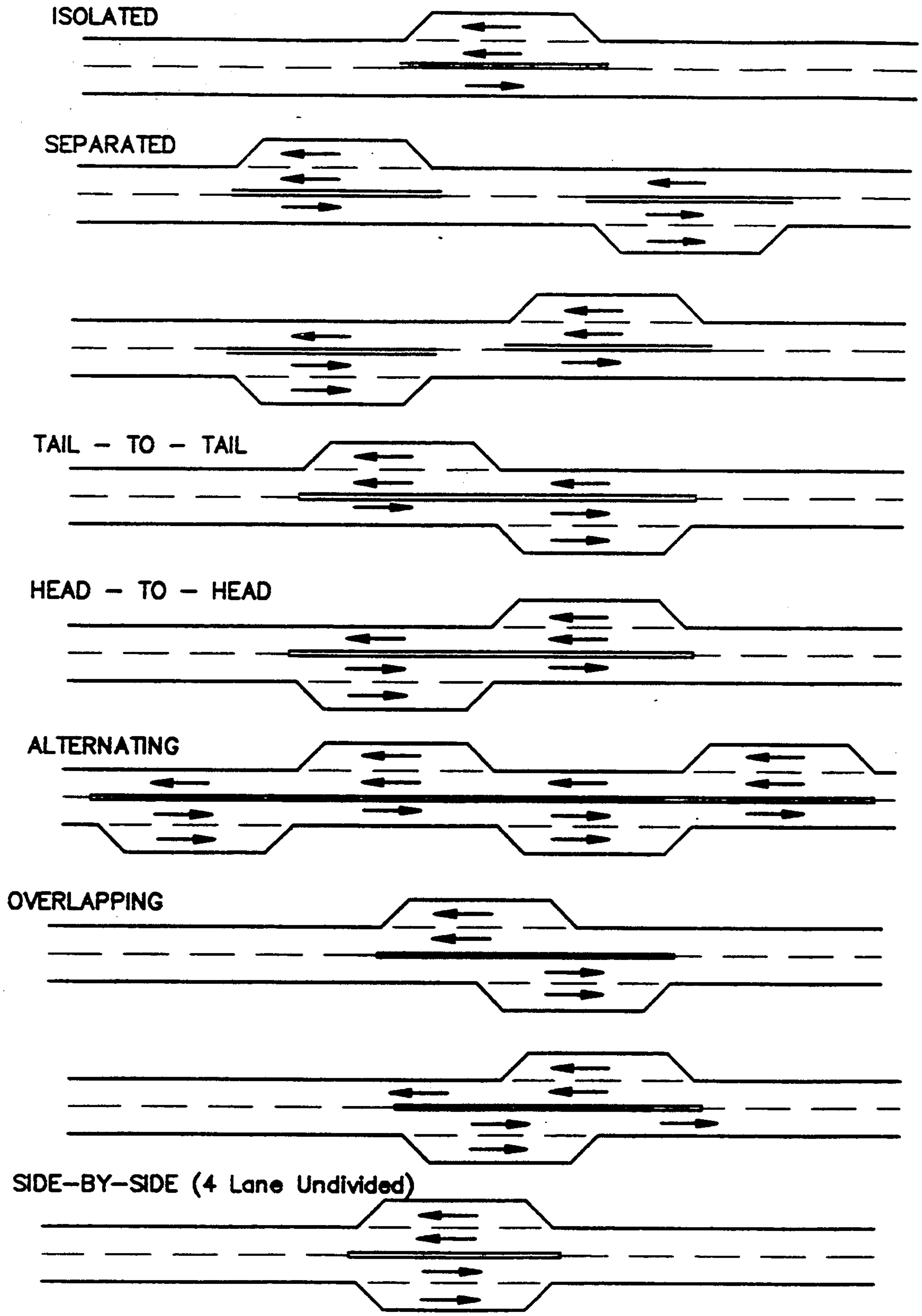


FIGURE 7 Alternative Configurations for Passing Lanes (AADT>4,000)

TABLE 2 Comparison of Geometric Design Features of Passing Lanes and Extra-Wide Highways

COUNTRY	HIGHWAY PLANNING AGENCY	LENGTH	TAPER LENGTH		LANE WIDTH	SHOULDER WIDTH	CONFIG-URATION	OTHER FACTORS
-	-	[m]	Diverge	Merge	[m]	[m]	-	-
CANADA passing-lanes	Ontario	1,500 - 2,000 m	200	200	Desirable: 3.4 m Minimum: 3.25m	Equal to the approach shoulder Minimum: 1m	Alternating preferred Spacing: 10-25 km	Taper length of broken line= SW/1.6*: 450m visibility to mid-point of merge taper
	British Columbia	Minimum: 800 m Desirable Minimum: 1,000 m	20:1	25:1	3.60 m	1.8 m paved	Mostly 4-lane	AADT> 4,000 overtaking prohibited in opposing lane
	Alberta	2,000 m (excl. tapers)	25:1	50:1	3.50 m	1.5 m paved	Alternating	AADT> 4,000 overtaking prohibited in opposing lane
	Parks Canada	2,000 m (incl. tapers)	100 m	200 m	3.65 m	1.2 m paved	Alternating	AADT> 4,000 overtaking prohibited in opposing lane
GERMANY three-lane highway	National Road Authority	Minimum: 800 m Maximum: 2,000 m	≥30 m	180 m	3.75 m	-	Alternating	AADT ≤ 20,000 overtaking prohibited in opposing lane
GERMANY extra-wide two-lane highway	Regional Authorities	≥ 5 km	≥ 0 m	200 m	6.50 m	-	Continuous	AADT ≤ 20,000

*S = speed limit (km/h), V= 85th percentile approach speed; W = lane width or amount of pavement widening

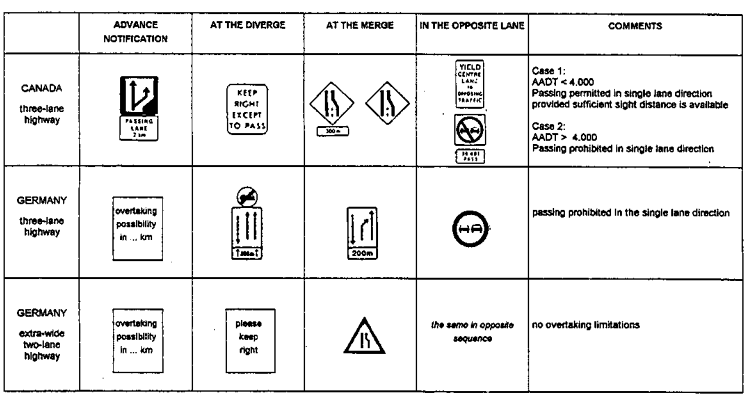


FIGURE 8 Comparison of Passing Lane Signing in Canada and Germany

SIGNING AND MARKING OF PASSING LANES, THREE-LANE HIGHWAYS, AND EXTRA-WIDE HIGHWAYS

Figure 8 compares the signing of passing lanes, three-lane highways, and extra-wide highways. Figures 5 and 6 show the markings and location of signs of passing lanes in Canada and Germany respectively.

As shown in Figure 8 advance notification is posted 2 km in advance of a passing lane. At the diverge the KEEP RIGHT EXCEPT TO PASS sign provides the most positive guidance in Canada, however, it is noted that some highway jurisdictions use the ambiguous SLOWER TRAFFIC KEEP RIGHT sign. In the passing lane sections the do not pass symbolic sign is used in both countries. In addition a symbolic sign indicating the direction of flow is used on three-lane highways in Germany, as shown in Figure 6.

In both countries advance notification of the merge is provided as shown in Figure 8. In Canada notification is provided 200 m to 300 m in advance of the merge while in Germany advance notification is given 200 m and 400 m in advance of the merge. At the merge area the lane drop sign is posted at the end of a passing lane as shown in Figures 5 and 8. A driver behaviour study in Germany (*4*) showed that the solid double centre line on extra-wide highways had a significant effect on safety provided the minimum design standards are followed.

OPERATIONAL EXPERIENCE

Good operational experience with passing lanes and extra-wide highways is reported by highway agencies in both Canada and Germany respectively. Drivers in both countries keep to the outside (slow) lane unless passing and merge safely into a single lane at the end of the passing lane.

Passing on Shoulders

In Western Canada it is common practice for some drivers to pull onto the 3 m wide paved shoulder, as a courtesy, to let following vehicles pass them and then return to the travel lane as depicted in Figure 3. In effect the wide paved shoulder acts as an informal passing lane which allows slower moving vehicles to be overtaken and queues to be dispersed. A field survey of passings on a 10 km section of the Trans-Canada Highway by Werner and Morrall (*25*) indicated that shoulder passings account for approximately 25 percent of passings at a two-way volume of 1,000 veh/h and 75/25 percent directional split, with almost all passings in the heavy direction of flow. Similar observations have been made in Germany but under lower volume conditions where wide paved shoulders, separated from the travel lanes by a solid continuous line demarking the travel lane and shoulder, are used as defacto auxiliary lanes. Clearly, wide paved shoulders aid in passing and dispersing platoons, but because shoulders are used only by some drivers in an informal fashion they cannot be considered as a substitute for passing lanes or extra-wide highways.

Effect of Passing Lanes and Extra-Wide Highway in Traffic-Flow

Empirical studies in Germany (*4, 5, 11, 24*) have shown that there are four times as much overtaking on an extra-wide highway as compared with a two-lane highway. As shown in Figure 9 speeds on extra-wide highways are on the average higher than on standard two-lane highways due to the fact that faster running cars are not delayed by heavy vehicles. The average increase in passenger car speeds is 25 km/h. The speed flow relationship for a high standard two-lane Canadian highway with a posted speed of 90 km/h is shown in Figure 9.

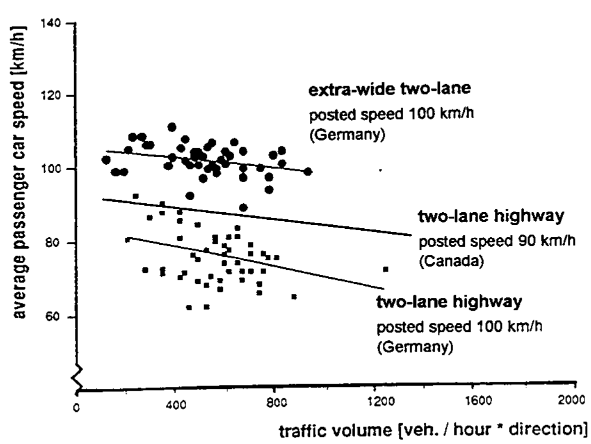


FIGURE 9 Speed-Volume Relations for Highways in Canada and Germany

The impact of extra-wide highways on the percent of vehicles of following in platoons is shown in Figure 10 which shows the percent of vehicles following in platoons (based on a 5 s headway criteria) vs volume. While on a standard two-lane highway in Germany 70 percent of the vehicles travel in platoons at a flow of 1,000 veh/h, on extra-wide highways there are only 55 percent travelling in platoons.

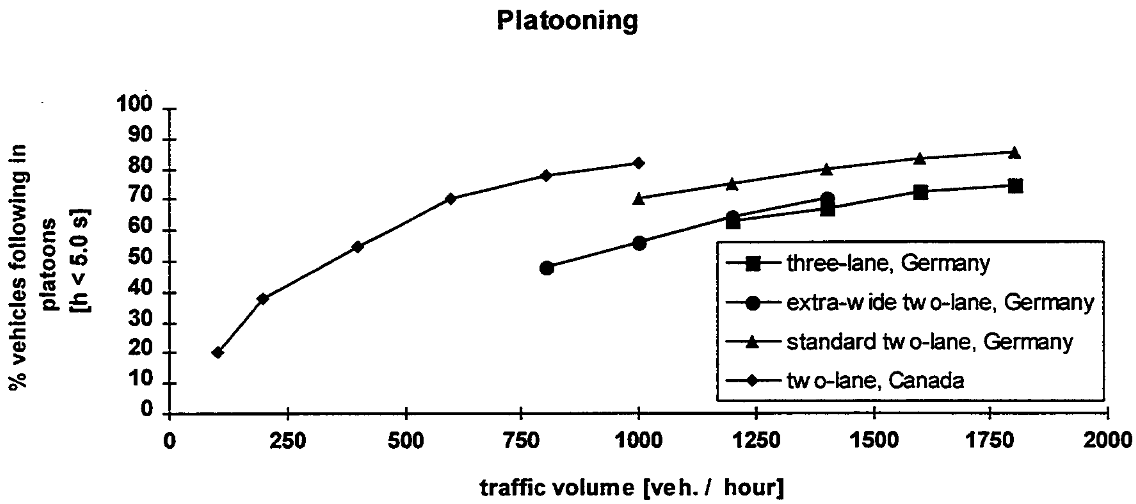


FIGURE 10 Percentage of Vehicles in Platoons as a Function of Traffic Volume

While the increase in speeds on passing lanes in Canada is not as pronounced as it is on extra-wide highways in Germany, the impact of passing lanes on the percent of vehicles following, and the increase in number of overtakings, is as pronounced in Canada as it is in Germany. A passing lane system increased the percent passing zones from 30 percent to 41 percent on a 46 km section of the Trans-Canada Highway in the Mountain National Parks with an AADT of approximately 5000. At a volume of 540 km/h, the passing lane system reduced percent time spent following by approximately 7 percent on one 16 km section and approximately 6 percent on another 30 km section. Passing lanes increased number of overtakings per km by 30 percent in the same 16 km section and by 72 percent in the 30 km section. In addition it is noted that passing lanes, and extra-wide highways provide assured passing opportunities which allow motorists to complete a passing manoeuvre in a safer, more relaxed fashion than overtaking in a conventional passing zone. In Canada, a level-of-service concept that is based on the supply of passing opportunities and demand for overtaking has been proposed by Morrall and Werner (*26*). Drivers are hypothesized to perceive level-of-service on a two-lane highway on the basis of their ability to overtake slower vehicles. The supply of opportunities for vehicles to overtake is a function of the number of gaps adequate for safe overtaking manoeuvres in the opposing traffic stream and the percentage of passing zones in a given highway section. The demand for overtaking is a function of volume and the speed distribution characteristics of the traffic stream. The relationship between supply and demand for overtaking forms the basis of a level-of-service measure defined by the overtaking ratio. The overtaking ratio is defined as the ratio of the achieved number of overtakings on a two-lane highway to the desired number (or to the actual number) of overtaking possible on a two-lane highway with continuous passing lanes and with vertical and horizontal geometry similar to a two-lane highway. The overtaking ratio decreases at a much faster rate than percent time delayed or speed with increasing volume. This finding suggests that opportunity to overtake is much more sensitive to volume than current measures of effectiveness. When given the opportunity to overtake in an assured or continuous fashion as provided by passing lanes or extra-wide highways, motorists greatly increase their overtaking rate as evidenced by observations made in both Canada and Germany.

COSTS

The cost of climbing and passing lanes varies widely with terrain and whether or not the auxiliary lanes are retrofitted to the existing highway or new construction of passing lanes is proposed. Current estimates for the retrofitting to the existing Trans-Canada Highway with 10 passing lanes in Yoho National Park is approximately $79,000/km. New construction of 22 passing lanes totalling 42 km in rolling and mountainous terrain on the Trans-Canada Highway in British Columbia has been estimated in the order of $16 million for an average cost of $380,000/km. In Germany the cost of extra-wide highways (exclusive of land) is 800,000 to 1,000,000 DM/km.

SAFETY BENEFITS

Passing lanes are considered to provide safety benefits both upstream and downstream in addition to along their length. Table 3 provides a comparison of the accident rates (fatal, injury and property damage) per million vehicle kilometres travelled. While detailed research documenting the impact of passing lanes on reducing the accident rate is currently not available, data suggests that passing lanes change the distribution of accident severity by reducing the number of collisions within its effective length as shown in Table 4 for Canada and Figure 11 for Germany, (*5, 8, 9, 27, 28*). The higher accident rate for Canada is partially explained by the fact that a property damage only accident in Canada is only approximately one-quarter the monetary value used to define an accident in Germany. Other factors contributing to the higher accident rate in Canada may include traffic characteristics (such as a higher percent of slow moving vehicles) and driver characteristics.

CONCLUSIONS

Germany

The results of empirical studies of traffic performance on extra-wide highways in Germany shows that an increase in the level of service can be achieved at an even higher level of safety than those of a standard two-lane highway. The operational use of extra-wide highways is seen for an AADT between 15,000 to 20,000 with a high percentage of heavy vehicles. Maximum capacity is considered to be in the range of 2,500 to 3,300 veh/h. Extra-wide highways are well suited to fill the gap of highway supply between the standard two-lane highway and motorway in Germany. In the future, however, the National Road Authority has recommended only the three-lane highway (b2 + 1) be used to fill the gap between standard two-lane highways and motorways.

Canada

Similarly in Canada, passing lanes offer a cost-effective alternative for enhancing the level of service on those two-lane highways that don't meet warrants for twinning. A system of passing lanes on the Trans-Canada Highway, for example, will extend the design life of the existing facility until twinning is justified. Passing lane systems are seen for use on two-lane highways with volumes up to 8,000 AADT, although there are sections of two-lane highway with passing lanes in Canada with AADTs in excess of 15,000. The passing lane system now under construction on the Trans-Canada Highway in the Mountain National Parks will ensure that all highway sub-sections will not exceed a maximum of 60 percent time spent following, corresponding to LOS C, at volumes expected towards the end of the design life of the facility.

TABLE 3 Accident Rates for Highways in Canada and Germany

COUNTRY	ACCIDENT RATE [accidents per MvkmT]			
	two-lane highway	extra-wide two-lane highway	three-lane highway	motorway (two-lane / direction)
CANADA	**1.60** [1] **1.10** [2]	**0.90**	**0.90**	**0.75 - 1.37**
GERMANY	**0.53**	**0.42**	**0.35**	**0.35**

[1] low standard; [2] medium standard; source (*5,8,28*)
Fatal, injury and property damage accidents per million vehicle kilometres travelled

TABLE 4 **Typical Accident Rates and Severity Distribution for Canadian Highways**

HIGHWAY TYPE	ACCIDENT RATE	ACCIDENT SEVERITY DISTRIBUTION (%)		
	[acc. / MvknT]	Fatal	Injury	Property Damage
two-lane	**1.10**	**1.6**	**30.0**	**68.4**
two-lane with passing lane	**0.90**	**1.4**	**27.8**	**70.8**
Motorway low-volume [1)] high-volume [2)]	 **0.75** **1.09**	 **1.0** **1.3**	 **17.4** **32.3**	 **81.6** **66.4**

[1)] AADT: 8,000; 4-lane rural freeway (Trans-Canada Highway in Banff National Park)
[2)] AADT: 5,000 - 10,000; 4-lane divided arterial, (*28*)

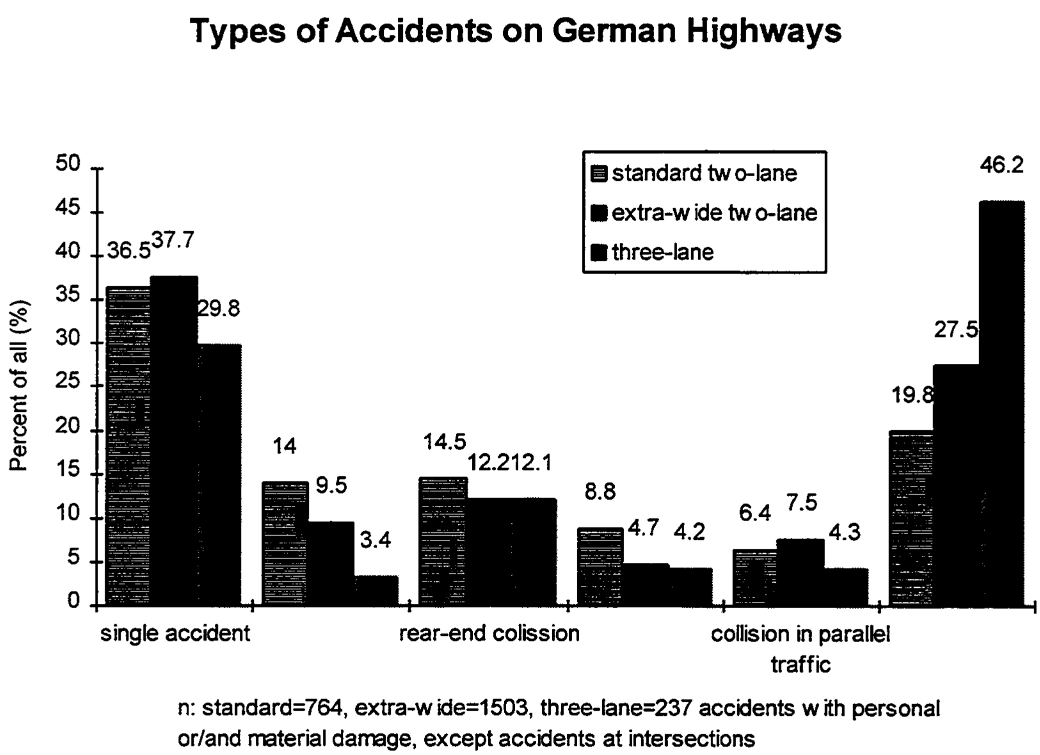


FIGURE 11 **Types of Accidents on German Highways**

Canadian-German Comparison

Both countries have had a similar experience with passing lanes (three-lane highways) namely that they offer a cost-effective

alternative of enhancing the quality of service and safety on those two-lane highways that do not meet the warrants for motorways or where cost and environmental concerns rule out the four-lane option. The two most notable differences in geometric design practice between the two countries are the maximum service volumes for three-lane highways and merging practices. Maximum service volumes for three-lane highways in Germany are 12,000 as compared to 8,000 in Canada. At the end of three-lane sections in Germany merging is from the passing lane to the outside lane while in Canada vehicles in the outside side lane must merge with the passing lane which is typical for most highway jurisdictions through North America. Comparisons between extra-wide German highways and highways with wide-paved shoulders indicate a much higher degree of overtaking in Germany which is to be expected as overtaking on such highways occurs only in an informal fashion. Although traffic volumes on three-lane highways is typically much higher in Germany than Canada, a lower accident rate is reported for Germany. The authors suspect the higher accident rate for Canada may be due to factors such as the comparatively low monetary value used to define an accident in Canada, and differences in traffic and driver characteristics. It is also noted that there are differing opinions regarding the safety benefits of extra-wide highways in Europe, for example the Nordic countries report good operational experience and safety with extra-wide highways.

Future Research

It is recommended by the authors that accident research be undertaken to determine the safety benefits of passing lanes and wide-paved shoulders compared to two-lane highways in Canada and three-lane highways and extra-wide highways compared to two-lane highways in Germany.

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