NZTA Passing Lane Research

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New Zealand Transport Agency

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1 Introduction

MWH was engaged by the New Zealand Transport Agency (NZTA) National Office to undertake an investigation into intersection crashes associated with passing lanes, particularly with respect to the effect of intersections within or near passing lanes. This was a preliminary assessment of literature and available data with a limited budget, which comprised a literature review, collection of data relating to rural passing lanes, statistical analysis of the passing lanes with intersection crashes over a five year period, related to various road-related elements.

The Passing and Overtaking Policy was introduced in October 2006 and replaced the previous Passing Lanes Strategy. The Provisional Passing and Overtaking Guidelines (version 4, July 2008) containing Attachment F Planning Notes Table F2 were effective from July 2008 (Appendix D). There were no previous New Zealand guidelines for passing lanes. Therefore, the majority of passing lanes having intersections along or nearby were completed before Table F2 came into effect.

The purpose of this research is to verify if Table F2 Recommended Location & Sight Distance Relative to Existing/Proposed Passing Facility or Overtaking Zone is adequate in terms of sight distance and location:

- Identify key influences or combinations of key influences resulting in an adverse crash history.
- Identify any side road/access driveway location configurations that may cause adverse crash situations.
- Where appropriate, identify and recommend any changes to Table F2 location and sight distances (Appendix D).

The project was undertaken over a two and a half year period owing principally to the effort needed to collate and analyse the passing lane data.

2 Literature Search

2.1 Background

This chapter outlines the results from the initial literature search undertaken by ARRB Transport Research information services. The search as requested by MWH focused on the following key words: intersection, junction, passing lane, major access, overtake, operation, design, safety, separation, location and subsequently “passing lane design”.

The results for the over 60 documents matching the search criteria were provided by ARRB in three documents, the first pertaining to search of the ATRI database, and others to international databases. Table 2-1 gives a summary of all the documents from 1986 onwards, with the relevancy field subjectively determined based on the abstract and the key goal of this project.

2.2 Relevant References

We conducted an Internet search of the references which were probably or possibly relevant using Google Scholar, TRB and FHWA (including ‘All DOT’) search engines. We then read those that we were able to source to ascertain to what degree they had detailed information and findings of relevance to this study and to what degree any such information could be transferrable to the New Zealand context.

While the information we examined is interesting, there is no specific material relating to the effect of intersections along passing lanes, other than the general and not unexpected finding that accidents increase with more accesses per kilometre (or per mile), and that the provision of passing lanes helps to reduce the number of (principally overtaking) accidents.

Table 2-1: Summary table of literature search results (1986 onwards)

Ref	Search	Data base	Year & area	Report / Conf	Author(s)	Title	Relevancy. Examined	Note
0			2009/10	AGRD04/09		Guide to Road Design: Part 4 – intersections, interchanges and crossings		Downloadable from Austroads
1	Main	ATRI	2009 NZ	TRB 88th ann. meeting	Koorey	Road data aggregation and sectioning considerations for crash analysis	Low	
2	Main	ATRI	2008 NZ	ARRB 23rd ann. Conf.	Cameron, Wanty	Passing and overtaking on New Zealand two-lane state highways: policy to practice		Downloadable
3	Main	ATRI	2007	AP-R311/07	Green, Karl	Tools that impact network performance: road space allocation tools	Low	Downloadable from Austroads
4	Main	ATRI	2007	AP-R312/07	Green, Karl	Tools that impact network performance: dynamic traffic management tools	Low	Downloadable from Austroads
5	Main	ATRI	2007 OZ & NZ	AGTM06/07	Bennett et al (ARRB)	Guide to Traffic Management: Part 6 – intersections, interchanges and crossings		Downloadable from Austroads
6	Main	ATRI	2006 Auckland	ARRB 22nd ann. Conf.	Cleaver et al (GHD,Dunn)	Safety implications of flush medians in Auckland City	Low	
7	Main, design	Id l	2006	TRR 1961	Gattis et al	Alternating passing lane lengths	Low	
8	Main	ATRI	2005	AP-G11.5/05	Veitch et al (ARRB)	Guide to Traffic Engineering Practice: Part 5 – intersections at grade	Low	
9	Main	ATRI	2005 Poland	3rd ISHGD	Szagala	Analysis of 2+1 roadway design alternatives	Low. NCHRP cf TWOPAS	
10	Main	ATRI	2005 Canada	TAC ann. conf. & exh.	McGuire et al	Downgrade passing lanes on the Canada Trans-Mountain Highway System	Low	
11	Design	Int'l	2005	3rd ISHGD	Irzik, Dammann	Passing Process on 2+1 roads in Germany	Low	
12	Design	Int'l	2004 Kansas	RDT 04-008, TI 02-218	Potts, Harwood	Benefits and design/location criteria for passing lanes	Possibly. See extract.	Downloadable from Berkeley
13	Main	ATRI	2004 OZ	AP-R247/04	Imberger et al (ARRB)	Guidelines for setting-up and operation of signalised intersections with red light cameras	Low	Downloadable from Austroads
14	Main	ATRI	2004 NZ	IPENZ TG Conf	Roozenburg, Nicholson	Estimating passing demand	Low.	Downloadable from IPENZ TG
15	Main	ATRI	2003 NSW	ARRB 21st ann. Conf.	Prisloo, Goudanas	Development of a crash prediction model for rural roads in NSW	Possibly. Low	Also REAAA 11th conf
16	Main	Int'l	2003 USA		Sen et al	Analysis of lane change crashes	Low	
17	Main	Int'l	2002	TRB	Daganzo (Berkeley)	A behavioural theory of multi-lane traffic flow. Part II: merges and the onset of congestion	Low.	
18	Main	ATRI	2002 OZ & NZ	AP-G69/02	Arup Group	Urban road design: a guide to the geometric design of major urban roads	Low.	Downloadable from Austroads
19	Main	ATRI	2002 NZ	NZTA (TF) RR 220	Koorey, Gu (Opus)	Assessing passing opportunities : stage 3	Low. EEM; simulation	
20	Main	ATRI	2001 Q'ld OZ	RSETF 2001	Cox (Qld DMR)	Determining the level of service on roads with multiple overtaking lanes	Low	
21	Main, design	ATRI, Int'l	2001 Texas	FHWA/TX-02/4064-1	Wooldridge et al	Design guidelines for passing lanes on two-lane roadways (Super2)	Possibly. See extract	Downloadable tti.tamu.edu
22	Main	ATRI	2000	TSoTC 1999 VTI 13A Pt4	Russell et al (KSU)	Development of guidelines for location of passing lanes on two-lane roadways	Probably but see 25 below	
23	Main, design	ATRI, Int'l	1999 USA	TRR 1658	Mutabazi et al (KSU)	Location and configuration of passing lanes	Possibly. TWOPAS	
24	Main	ATRI	1999 NZ	NZTA (TF) RR 146	Koorey et al (Opus)	Assessing passing opportunities : stage 2	Low.	LJC supplied a copy - Dec'10
25	Main, design	ATRI	1999 Kansas	K-TRAN: KSU-97-1	Mutabazi et al (Russell)	Review of the effectiveness, location, design and safety of passing lanes in Kansas	Probably. See extract	Downloadable from Berkeley
26	Main	ATRI	1999 Minnesota	MN/RC-2000-22	Preston, Schoenecker	Bypass lane safety, operations, and design study	Low?	
27	Main	Int'l	1999		Lerner et al	Development of countermeasures for driver manoeuvre errors	Low	
28	Main	Int'l	1999	TEC 1999-02	Willoughby, Emmerson	Network interaction – a review of existing modelling techniques	Low	
29	Main	Int'l	1998		Clarke et al (Nottingham)	Overtaking accidents	Low	

Ref	Search	Data base	Year & area	Report / Conf	Author(s)	Title	Relevancy. Examined	Note
30	Main, design	ATRI	1998 Kansas	REAAA 9th conf.	Russell et al (KSU)	Safety and operational performance of passing lanes in Kansas	Probably but see 25 above	
31	Main	ATRI	1998 NZ	ARRB 19th ann. conf.	Koorey et al	New Zealand research into assessing passing opportunities	Low	
32	Main	ATRI	1998 NZ	AAP 30.4	Turner, Nicholson	Intersection accident estimation: the role of intersection location and non-collision flows	Low.	See Turner, ARRB 2008
33	Main, design	ATRI	1998 Kansas	TRR 1628	Mutabazi et al	Drivers' attitudes, understanding, and acceptance of passing lanes in Kansas	Low	
34	Design	Int'l	1998 Kansas	PhD Thesis	Mutabazi (KSU)	Analysis of passing lanes	Low	
35	Main, design	ATRI	1998 NZ	RSRPE Conf	Koorey et al (Wanty, PC)	Applications of road geometry data for highway safety in New Zealand	Low	
36	Main	ATRI	1998	1995 ISHGD Practices	Harwood et al	International sight distance design practices	Low	
37	Main, design	ATRI	1998 Canada, Germany	1995 ISHGD Practices	Frost, Morrall	A comparison of the geometric design practices with passing lanes, wide-paved shoulders and extra-wide two-lane highways in Canada and Germany (chapter 34)	Low	Downloadable from Berkeley.
38	Main	ATRI	1997 NZ	NZTA (TF) RR 89	McLarin (Opus)	Typical accident rates for rural passing lanes and unsealed roads	Possibly but see (vii) below	
39	Design	Int'l	1997 California	CA-TO-OR-97-1	Rooney	Passing lanes at rolling and slightly mountainous areas	Low	
40	Design	Int'l	1997 Arkansas	TRR 1579	Gattis et al	Rural two-lane passing headways and platooning	Low. Less freq passing >2s	
41			March 1996	TRB Circular 456	TRB	Driveway and street intersection spacing	Low?	
42	Design	Int'l	1996 Quebec	1996 TAC conf.	Baass et al	Design, pavement markings and signing of climbing and passing lanes	Low	
43	Main	Int'l	1996		Clarke et al (Nottingham)	A clear road ahead: beyond the problems of accident causation research	Low	
44	Main	ATRI	1996		Uloth Pty; Evangelisti	Great Eastern Highway Sawyers Valley to Northam: planning study of overtaking lanes and intersection treatments	Possibly	
45	Main, design	ATRI	1995	JoTE 121.1	Morrall et al	Planning and design of passing lanes using simulation model	Low	
46	Main	ATRI	1995 USA	TRR 1512	Zageer, Council	Safety relationships associated with cross-sectional roadway elements	Possibly	
47	Main	ATRI	1993	1993 TAC conf.	Smith et al (Morrall)	Determining the need for and location of passing lanes on two-lane highways	Possibly. TRARR	
48	Design	Int'l	1993 California	UCB-ITS-RR-93	Lovell et al (Berkeley)	Using the TRARR model to investigate alignment alternatives and passing lane configurations on the Buckhorn grade	Low	
49	Design	Int'l	1991	TRR 1303	May (Berkeley)	Traffic performance and design of passing lanes	Low	
50	Design	Int'l	1991 Michigan	TRR 1303	Jain, Taylor	Warrants for passing lanes	Low. TWOPAS	
51	Design	Int'l	1991 Michigan	ITE Journal 1991/2	Jain, Taylor	Criteria for passing lane relief on two-lane highways	Low.	
52	Main	ATRI, Int'l	1991	UCB-ITS-RR -90-1, -91-2	Staba et al (Berkeley)	Development of comprehensive passing lane guidelines. Volume 1: final report; 2 app	Low. TRARR, TWOPAS	
53	Main	ATRI	1990	ARRB 15th ann. conf.	Okura, Matsumoto	Traffic simulation study for two-lane rural highway overtaking improvements	Low.	
54	Design	Int'l	1989 Alberta		Morrall et al	Planning and design guidelines for the development of a system of passing lanes for Alberta highways	Low	
55	Design	Int'l	1988	UCB-ITS-RR-88-13	Emoto, May (Berkeley)	Operational evaluation of passing lanes in level terrain	Low. TRARR and RURAL	
56	Main	ATRI	1988 Victoria		Road Constn. Authority	East Gippsland region overtaking lane strategy: Princes Highway East, Rosedale to	Low. TRARR LOS B (<40%	

Ref	Search	Data base	Year & area	Report / Conf	Author(s)	Title	Relevancy. Examined	Note
					(RCA)	NSW border	foll), 30th vph	
57	Main	ATRI	1988 Victoria	ARRB 14th ann. conf.	Mariager (RCA)	Overtaking lanes on rural highways: statewide strategy planning	Low	
58	Design	Int'l	1988	TRR 1195	Kaub, Berg	Design guide for auxiliary passing lanes on rural two-lane highways	Low. TWOWAF	
59	Design	Int'l	1988	TRR 1195	Harwood et al (Hoban)	Effective use of passing lanes on two-lane highways	Possibly	
60	Main	Int'l	1988 UK	2nd int'l conf. on road safety, 1987	Harris	The subjective probability of involvement in an overtaking accident in the vicinity of a junction	Low	
61	Main	ATRI	1986, OZ, Canada	Transportn Forum 2-4	Morrall, Hoban	A comparison of Canadian and Australian passing lane design practice	Low	
62	Main	ATRI	1986, OZ, Canada	ARR 144	Hoban, Morrall	Overtaking lane practice in Canada and Australia	Low	
A	LJC		2005 Wisconsin			Facilities Development Manual. Section 11.5.5 Access Control Refer http://roadwaystandards.dot.wi.gov/standards/fdm/index.htm	LJC – possibly Low	Hardcopy from LJC (5 pages)– downloadable
B	LJC		2003	TRB AMM03		Access Management Manual. Chapter 9 Access Spacing. Refer http://www.accessmanagement.info/manual.html	LJC – possibly Low.	Hardcopy from LJC (21 pages)
C	LJC		2002 Wisconsin			Facilities Development Manual. Section 11.15.10 Passing Lanes and Climbing Lanes– (Warrant from Washington State DoT)	LJC – possibly See extracts	Hardcopy from LJC - (7 pages) downloadable
D	LJC		2003	Transit NZ HO 02-59	Working Grp (Review Grp)	A review of Access Management on State highways in New Zealand (draft)	LJC – possibly Low	Hardcopy from LJC (28 pages)
E	LJC		2001? Wisconsin	WIS 23 Proj 1440-13/15-00	Unknown	Appendix A Traffic Information for Project 1440-13/15-00 WIS 23	LJC – possibly Low	Hardcopy from LJC (2 pages)
F	LJC		2000?	TRB circular E-C019 USS	Papayannoulis et al	Access Spacing and Traffic Safety	LJC – possibly Low	Hardcopy from LJC (15 pages)
G	LJC		1998 British Columbia	MoTn&Hwys Tech Bulletin DS98003	Coulter (Eng Branch)	Passing Lane Warrants and Design	LJC – possibly See extract	Hardcopy from LJC (16 pages)
(i)	MWH		2001	TNZ	(BCHF)	Simplified Procedures for Passing Lanes – Further analysis (draft) – also review comments by FNT and I Bone response	Low	Hardcopy from FNT (23 pages)
(ii)	MWH		2001	Transfund NZ RR220	Koorey, Gu (Opus CL)	Assessing Passing Opportunities: Stage 3	Low	Hardcopy from FNT (120 pp)
(iii)	MWH		1999	IPENZ Trans v26 #1/CIV	Koorey, Tate	Road infrastructure assessment model – incorporation of passing-lane sections	Low	Hardcopy from FNT (8 pages)
(iv)	MWH		1999	FHWA-RD-99-172	Fitzpatrick et al (TTI)	Alternative Design Consistency Rating Methods for Two-Lane Rural Highways	Low	Hardcopy from FNT (170 pp)
(v)	MWH		1998	FHWA-RD-98-133	Vogt, Bared	Accident Models for Two-lane Rural Roads: Segments and Intersections	Low	Hardcopy from FNT (189 pp)
(vii)	MWH		1997	Transfund NZ RR220	McLarin (Opus CL)	Typical Accident rates for rural passing lanes and unsealed roads	Low	Hardcopy from FNT (30 pages)
(viii)	MWH		1997 NZ	TNZ PR3 0128	WCS	Warrants for No-Overtaking Lines (draft)	Low	Hardcopy from FNT (78 pages)
(ix)	MWH		1995	TNZ PR3 0128	Thrush (WCS)	Assessing Passing Opportunities: Literature Review	Low	Hardcopy from FNT (78 pages)
(x)	MWH		1995	TNZ PR3 0097	Tate (WCS)	Assessing Passing Opportunities: Stage 1	Low	Hardcopy from FNT (112 pp)
(xi)	MWH		1991 Canada	Ontario MoT TDS-91-02		Cost-effectiveness of Passing Lanes: safety, Level of Service, and Cost Factors	Low	Hardcopy from FNT (6 pages)
(xii)	MWH		1990 Canada	Canada. Jrnl Civ Eng V17	Morrall, Thompson	Planning and design of passing lanes for the Trans-Canada highway in Yoho national park	Low. TRARR	Hardcopy from FNT (8 pages)

Ref	Search	Data base	Year & area	Report / Conf	Author(s)	Title	Relevancy. Examined	Note
(xiii)	MWH		1989 NZ	RRU NRB TM/20	Bone (BCHF)	Waipawa Passing Lanes After Study	Low	Hardcopy from FNT (35+apps)
(xiv)	MWH		1988/89 S Africa	unknown	Bester, Wolhuter	The economics of climbing lanes	Low	Hardcopy from FNT (15 pages)
(xv)	MWH		1988 S Africa	CSIR Tech Rpt RT/110	Kennedy, Bester	CLIM – A computer program to evaluate climbing lanes in mountainous terrain	Low	Hardcopy from FNT (29 pages)
(xvi)	MWH		1987	FHWA-IP-87-2	Harwood, Hoban	Low cost methods for improving traffic operations on two-lane roads: informational guide	LJC – Probably See extracts	Hardcopy from FNT (107 pp)
(xvii)	MWH		1986	TRR 1052	Khasnabis	Operational and safety problems of trucks in no-passing zones on two-lane rural highways	Low	Hardcopy from FNT (9 pages)
(xviii)	MWH		1982	ARRB conf 1982 V11Pt4	Hoban	The two and a half lane rural road	Low	Hardcopy from FNT (12 pages)
(xix)	MWH		1981 OZ	TEC Apr 81	McLean (ARRB)	Driver speed behaviour and rural road alignment design	Low.	Hardcopy from FNT (4 pages)

KSU = Kansas State University (Mutabazi, Russell and Stokes); ISHGD = International Symposium on Highway Geometric Design; TAC= Transportation Assn. of Canada; RSETF = Road System and Engineering Technology Forum; TSoTC = Traffic Safety on Two Continents; AAP = Accident Analysis and Prevention; JoTE = Journal of Transportation Engineering; TEC = Traffic Engineering and Control; USS = Urban Street Symposium

2.3 Specific References

In addition there were five references to be specifically examined, one of which was only recently posted on the Austroads website, and was added to the summary table as reference #0. The other specific references are 5 and 8 (also Austroads Guides), 25 (Kansas) and 41 which was also added to the summary table[1].

In examining the three Austroads Guides specific references, GTM Part 6 (reference #5), which along with GRD Part 4 (reference #0) replaced GTEP Part 5 (reference #8), does not have any relevant material although GTEP Part 5 outlines sight distance requirements. Sight distance requirements should be included in GRD Parts 3 and 4, which are available for downloading from the Austroads publications site[2].

Section 13 of the Austroads 2003 *Rural Road Design: Guide to the Geometric Design of Rural Roads*, gives guidance on when passing (auxiliary or overtaking) and climbing lanes should be considered, minimum merge sight distances, their length (including tapers) and basic advice on the spacing of passing lanes. It does not give information pertaining to the specific location of passing lanes with respect to intersections (and neither does its replacements).

Extracts of ten selected references are given in Appendix A.

2.4 Other References

Other reference documents also include information of some relevance to this research. These are outlined below:

(a) The relationship between slow and overtaking vehicle speed is given below[3], which assists in establishing when there could be a need to provide a passing lane or slow vehicle bay (turnout).

[1] For completeness details of this publication are appended, as downloaded from the TRB website advanced search http://pubsindex.trb.org/default.asp?p=adv&kw=&date1=&date2=&datetype=1&serial=&issue=&agency=&conference=&author=&terms=&code=&codename= http://pubsindex.trb.org/document/view/multi.asp?pub=1&recordlist=461876|

[2] http://www.onlinepublications.austroads.com.au/script/Home.asp

[3] Refer email from Larry Cameron to David Wanty dated 17 June 2009 – original source is unknown.

Table 2-2: Relationship between slow and overtaking vehicle speed

Slow vehicle (km/h)	Overtaking vehicle (km/h)
20	65
30	65
40	70
45	75
50	75
55	80
60	80
65	85
70	85
75	90
80	100
85	110

(b) Information relating the level of service to the percent time-spent-following (PTSF), for which the percent following could be considered a surrogate, is given in Chapters 12 and 20 of the Highway Capacity Manual 2000 for different types or classes of two lane highways.

(c) Section A7.3 of the NZTA Economic Evaluation Manual (first edition, October 2006) gives some general guidance on passing lane locations and the limiting length of climbing lanes. It also states that the use of a simulation package (such as TRARR or TWOPAS) should be used for detailed assessments.[4]

(d) Information relating to when NZTA consider the need for four-laning rather than passing lanes is given in section 3.4.3.2.2 of the August 2007 draft Planning Policy Manual. This states that four-laning will generally become a likely option on *national* State Highways[5] where the projected (30 year) flow is 20,000-25,000 vehicles per day, and is unlikely to be undertaken on *regional* and *sub-regional* state highways or where not supported by the Regional Land Transport Strategy.

In conducting the searches, we uncovered other material, extracts of which are attached in Appendix A for convenience.

2.5 Conclusion

The literature was unable to identify any research that quantifies the effect of intersection location and form on passing lane crashes. Therefore it is concluded that there is a need to undertake specific research into the safety effect of intersections on passing lanes on state highways in New Zealand.

3 Passing Lane Analysis

3.1 Data collection

An analysis spreadsheet was created with a list of all the passing lanes on the rural state highway network. Substantial effort was undertaken to check and enhance the data relating to the passing lanes. For example the state highway video was used to confirm the start and end route positions, the diverge

4 The EEM procedure 2 is stated as being acceptable for prefeasibility studies and when passing lanes do not comprise the majority of benefits

5 Refer to Figures 9 and 10 of the June 2007 National State Highway Strategy which show the State Highway hierarchy categories and probable/possible four-laning or "2+1" for the 30 year concept. Refer http://www.nzta.govt.nz/resources/national-state-highway-strategy/docs/national-state-highway-strategy-2007.pdf

and merge lengths, the direction of the passing lane, confirm whether the facility was marked and signposted as a slow vehicle bay (SVB) or passing lane (PL), the posted speed limit, and on which side a side road was located.

The location of the side roads was obtained from survey information conducted as part of the KiwiRAP project but unfortunately while this survey recorded such information pertaining to the type of intersection, turn bays, sight distances and other data, it did not record on which side (increasing or decreasing direction) the side road was located (naturally both sides for a crossroad intersection). Accordingly we had to check the video records to identify on which side (increasing/decreasing) the intersecting side road was located (naturally both sides for crossroads).

From this laborious exercise it was established that with only a few exceptions, there were no more than two public road intersections located within a passing lane and a maximum of two intersections before or after a passing lane, where the latter comprised 300 m before the (100 m) diverge zone or 300 m after the (150 m) merge area for passing lanes (shorter distances[6] for slow vehicle bays). The odd passing lane with more than two intersections along its length was excluded because the passing lane was either partly within an urban area or essentially part of a four length section.

A number of features were identified for each passing lane. These features were: AADT, length, number of side roads, side road on left or right hand side, gradient / terrain, intersection lighting or not, right turn bay or not and sight distance. The passing lane length was coded into four length ranges, namely SVB, <0.5, 0.5-1.2 and >1.2 km, and location into three zones relative to the direction of the passing lane proper, namely ‘Before’, ‘Within’ (or ‘Mid’), and ‘After’.

To simplify the analysis spreadsheet by having only one column for each feature considered, since there could be up to two intersections in either the Before, Within or After sections (when combined for the ‘Entire’ passing lane there could be more than two intersections), for features related to the intersection or side road, the integer portion related to the first intersection and the fractional portion related to the second intersection (if applicable). This was applied to features such as the form of the intersection (e.g. T, Y, X), the presence of turn bays, street lighting, and side road AADT.

The AADT of the side road was not populated enough to be of use in the statistical analysis. It was initially thought that the side road AADT was likely to be correlated with the form of the intersection turning treatments, (i.e. none, shoulder widening, right turn bays, left turn deceleration lanes) and extent of intersection street lighting (none, flag, full). After analysis and discussion with NZTA staff, these features were not correlated and this matter is discussed later within the report under Section 3.4. Similarly the side road characteristics (unsealed, local, minor, major), intersection form / type (e.g. priority T, priority crossroads), channelisation (yes/no), and speed environment features were also initially considered as possible parameters but were subsequently rejected and not analysed.

The lack of AADTs for the side roads made it impractical to compare intersection-related crashes along and near to passing lanes with typical rural intersection crash rates under similar traffic conditions.
As well as the passing lane details, details of all injury and non-injury crashes for the five calendar year period 2004 to 2008 that occurred at or near passing lanes were downloaded from the NZTA Crash Analysis System (CAS). These were linked with the passing lanes using the running distance field, and attributed to the before, within or after passing lane segment (and in some cases to a second nearby passing lane in the opposite direction).

There were about 16 passing lanes that began immediately after a right turn bay for a side road on the opposite side of the passing lane (Tee intersection). Any crash recorded at those intersections were assigned to the ‘Before’ passing lane zone rather than the ‘Within’ passing lane zone.

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[6] For Slow Vehicle Bays, from inspection of the video images a 30 m diverge and 50 m merge length was assumed plus 120 m before and 150 m after lengths due to the slower speeds and shorter available sight distances associated with SVB, which were mainly located in mountainous terrain. Note also that generally speaking the merge area taper length for 100 km/h highways would be expected to be about 165 m but from the videos a number were somewhat less than this so 150 m was chosen.

3.2 Statistical Analysis

A total of 366 passing lanes (including slow vehicle bays) were assessed of which 162 passing lanes (including SVBs) had crashes, comprising 396, 852, and 335 crashes in the 'Before', 'Within' and 'After' zones of the passing lanes respectively. From those 162 passing lanes (including SVBs) with crashes, the sample of passing lanes (PLs) and slow vehicle bays (SVBs) with crashes and at least one intersection (public side road) was obtained and its crash distribution is shown in Table 3-1 below (refer also the beginning of Appendix B).

Table 3-1: Crash distribution on the 40 passing lanes with crashes and at least one intersection

Description	Before PL	Within PL	After PL
Crashes on the 40 PLs (including SVBs) with at least one intersection.	58	168	53
Crashes on the 2 SVBs with at least one intersection.	2	2	0

Appendix B contains the detailed results for the statistical analyses. While the analysis was undertaken in two parts, the second part being further analysis relating to the side of the side road and type of turn bay, the results have been recompiled (and thus differ slightly from the initial analysis results).

Table 3-2 summarises the statistical analysis results based on the standard null hypothesis that this feature has no impact on passing lane crashes. Considering the entire passing lane (Before+Within+After zones), higher AADTs and side roads on the opposite side to the PL will generate increased crashes. Before the PL (i.e. diverge area plus up to 300 m upstream), increased AADT (5.01), increased number of side roads and shorter PL length are associated with more crashes. Within and After the PL, only increased AADT are associated with significantly (95% confidence level) more crashes, although for the After PL zone (i.e. merge area plus up to 300 m), side roads on the opposite side to the PL and shorter PL length are significant at the 90% confidence level.

Table 3-2: Summary of Student's *t* Values for each passing lane feature

Feature	Before PL	Within PL	After PL	entire PL
AADT	5.01	2.98	4.60	5.02
Number of side roads	2.23	0.11	-0.97	0.38
PL length code	-2.41	0.82	-1.67	-0.56
Sight distance at start of zone	-2.05	-0.49	-0.62	-1.09
Side road on opposite side of PL	2.48	1.19	1.73	2.10
PL gradient (terrain)	-0.60	0.62	0.60	0.12
Provision of night lighting	0.02	-1.26	-0.22	-1.01
Provision of RT turn bays	-0.30	0.99	-0.08	0.64
Note: Student's *t* values that are <-1.96 or >1.96 are significant at 95% confidence (dark shading) While *t* values < -1.645 or >1.645 are significant at 90% confidence level (light shading).				

The general lack of features that are statistically significant at the 95 % confidence level in the 'Within' and 'After' passing lane zones may be due to NZTA's current approach of either avoiding intersections in those locations or if intersections are present, providing mitigating measures. With respect to right turn bays and sight distance, the lack of effect is discussed later respectively under Section 3.3 Discussion headings Side of Intersecting Road and Site Selection and Design Processes.

3.3 Discussion

The above results are generally not unexpected.

Tack-On (widening of existing) versus Passing Lanes with realignments

From a sample of 21 tack-on (0.84 km average length), 5 realignment (1.42 km average length) and 8 mixed tack-on/realignment passing lane sites (1.08 km average length), Transfund NZ Research Report

No. 146 Assessing Passing Opportunities - Stage 2 Tables 3.4 and 3.5 indicate that intersection-related crashes at all passing lanes increased for traffic in the same (treated) direction (5%) and decreased for traffic in the opposite (untreated) direction (4%). However, for tack-on passing lanes, intersection-related crashes at passing lanes reduced for the same direction (8%) and increased for the opposite direction (22%). For the intersection-related crash results from all passing lanes to be opposite for tack-on passing lanes, the smaller proportion of intersection-related crashes on passing lanes that are partly/fully on realignments must have increased in the same direction and strongly decreased in the opposite direction.

The majority of NZ's passing lanes are tack-on as opposed to fully or partly within carriageway realignments. The analysis reviewed all of NZ's passing lanes and considered only passing lanes with at least one intersection-related crash within either the "Before", 'Within" or "After" zones. It is likely that intersections along or near to passing lanes within part/full realignments would have been upgraded if required, have better sight distance and be located on or near to longer passing lanes. All of these features should help to reduce the number of intersection-related crashes associated with part/full realigned passing lanes. Therefore, the selection method may have a bias towards choosing tack-on passing lanes.

Driver Behaviour

The "Before" results might partly indicate the effect of anxious drivers overtaking somewhat prematurely or motorists following too closely and not allowing for a vehicle turning out of the side road just ahead of the lead vehicle in the platoon, recognising also that bunching is likely to be worst immediately prior to a passing lane. Particularly for drivers that regularly drive the route, those drivers would be aware if the passing lane is short and may be utilising right turn bays immediately before the passing lane diverge to artificially extend the passing lane length.

Another possible explanation is that for those passing lanes without double yellow lines, some motorists overtaking in the opposite direction might be caught out by shorter passing lane lengths than expected or by turning vehicles. However, overtaking in the opposite direction is not necessarily a widespread behaviour and is more likely where there has been little previous opportunity for vehicles to overtake.

Site Selection and Design Processes

The results for the "Before" and "After" zones are the most interesting, given that they both had similar numbers of intersection-related crashes. The site selection and design processes for passing lanes may have a mitigating effect on both the number of side roads and the sight distance after the passing lane compared to before the passing lane.

For the "Before" results, statistically significant effects are i) the AADT, ii) the number of side roads, iii) passing lane length, iv) sight distance and v) side road on opposite side. By comparison, the key influences on the ‘After' zone, at the 90% confidence level are i) the AADT and ii) passing lane length and iii) side road on opposite side and are common to both zones. However, the number of side roads (0, 1 or 2) and sight distance are significant to the "Before" zone but not significant for the "After" zone.

For the "After" zone based on passing lane site selection practices, if there are two intersections in the ‘After' zone, these intersections (or at least one of them if considering the entire passing lane) are more likely to be on the left (treated) side of the passing lane rather than on the right (untreated) side. After discussion with NZTA, the passing lane site selection criteria has been less critical of intersections within the ‘Before' zone compared to the "After" zone.

Also downstream intersections within the "After" zone were more likely to have turning treatments than upstream intersections within the "Before" zone. Therefore, for "Before zones", there may be a greater likelihood that either at least one intersection will be in the "Before" zone and/or on the right hand side (i.e. untreated side) of the passing lane or the intersection will be multiple intersections (i.e. close spaced

T-junctions or cross roads). Therefore, this practice might account for the finding that the number of side roads for the 'After' zone is not significant whereas it is for the 'Before' zone.

For the "After" zone, the lack of significance for sight distance is not surprising since having good sight distance for both the merge area and the road downstream of the merge area is a standard design requirement for passing lanes. Also, the sight distance for intersections within the "Before"' zone is more likely to be insufficient, as a fair proportion of passing lanes tend to begin their diverge taper tangential off a right hand curve. Passing lanes are less likely to finish close to a left or right hand horizontal curve or a vertical curve as this would provide insufficient advance sight distance at the end of the merge, which is one of the site selection criteria for passing lanes. Therefore, this practice might then account for the finding that the sight distance for the "After" zone is not significant whereas it is for the "Before" zone.

Side of Intersecting Road

The significance of the side (i.e. treated or untreated side) of the intersecting road for the 'Entire' passing lane also suggests that left hand side intersections are safer than right hand side intersections. From discussions with NZTA staff, the side of the intersecting road may not be significant for the 'Within' zone as mitigating measures are more likely to have been applied for a right hand intersection within the passing lane than for both the 300 m approx upstream and downstream of the passing lane.

While the side of the intersecting road is statistically significant, right turn bays were not considered to be statistically significant. This is most likely due to the right turn bays for the left hand intersections also being included. Therefore, right turn bays (for both the treated and untreated directions) was not a conclusive mitigating measure. Some of these turning bays may not be based on turning volumes and have been provided as a standard treatment, especially if located within the passing lane. Also, for intersections located within the "Before" or "After" zones, shoulder-widened intersections may be adequate at lower AADTs.

Passing Lane Length

While the statistical analysis subdivided crashes on passing lanes into the 'Before', 'Within' and 'After' zones, no analysis was undertaken for passing lanes of a particular length, relative to a particular range in AADT. Undertaking such analyses might be useful to test the idea that crashes rates on a say 0.6-0.8 km passing lane might be acceptable at lower traffic volumes of say 4,000-5,000 vehicles per day (vpd) but be less likely to be acceptable at higher volumes of 10,000-12,000 vpd. Passing lanes greater than 1.2 km long (the threshold used for the upper PL length code) are more likely to be located on higher volume State highways, and the longer passing lane results in any intersection within the passing lane being more likely to be located a sufficient distance away from the diverge and merge zones (refer Table F2 reproduced in Appendix D).

After discussions with NZTA staff, it would appear that there may be a number of under-length passing lanes say 600-800 m or less that would be located on both low-volume and high-volume State highways. While passing lane length was considered, it did not take into account the passing lane length with respect to AADTs. Therefore, short passing lanes may still be appropriate at lower AADTs but intersections should be avoided within these short 600-800 m passing lanes, as merging and deceleration activity will be mixed with passing activity.

3.4 Implications for Planning Notes Table F2

Before versus After Zones

Table F2 places similar emphasis on intersection separation distances from both the diverge start and merge end of the passing lane. The difference in results between the two zones is probably because this similar emphasis has not always been the case under the previous Passing Lanes strategy.

Therefore, the separation distances at both ends should remain within Table F2 but possibly more flexibility should be provided for left hand intersections compared to right hand intersections intersecting with high-volume access driveways and minor/collector district roads. Suggested wording would be that within the upstream and downstream areas, the current separation distance of 500 m is desirable for both minor/collector road as well as major arterials. However, reduced separation could be considered for left hand intersections down to a minimum 300 m rather than 500 m and right hand intersections could be considered down to 300 m rather than 500 m provided mitigating effects were satisfied.

AADT

Table F2 should continue to take into account the traffic volumes on the state highway or the likelihood of traffic volumes increasing over the 30 year analysis period for the passing lane and to consider if intersection upgrades should be undertaken either as part of or linked to the provision of either new or upgrading/extended passing lanes. Note 2 of Table F2 currently requires that access and intersection capacity is to be based on 25-30 year projected AADTs. While not stated, it is assumed that district road volumes would be pro-rated the same as the State highway flows. Note 2 should be adequate.

Multiple Intersections

Where possible, the number of intersections should be reduced, especially in the “Before” zone, with preferably only T-junctions on the left hand (untreated) side remaining. Table F2 does specify only T-junctions on the treated side and centrally located along the passing lane. Table F2 does not distinguish between single intersections and multiple intersections (e.g. close spaced T-junctions/crossroads) especially within the "Before" and "After" zones.

An additional note would seem appropriate. The suggested wording might want to consider avoiding, reducing or eliminating multiple intersections. Other suggested mitigation measures include: access controls on applications for high volume driveways along passing lanes, restricting turning movements using central median cables or intersection leg closures.

Length

It is suggested that the Passing and Overtaking Policy's long-term layout table is used as a reference for passing lane length relative to road gradient and AADT. Table F2 does not distinguish between under length passing lanes that do not comply with the Policy's long-term layout table and shorter length passing lanes (i.e. 600-800 m length) that do comply with the long-term layout table. An additional note would seem appropriate. Suggested wording is that the passing lane length satisfies the Passing and Overtaking Policy's long-term layout table and that SVB lengths comply with MOTSAM.

Sight Distance

For new passing lane sites, intersections with poor sight distance should be located greater than 300 m upstream of the diverge mid point and more than 300 m downstream of the merge taper end or alternatively the sight distance should be improved. The intersection distance should be improved if existing intersections, especially within the "Before" area, were to remain.

Note 4 of Table F2 requires 300 m sight distance for all accesses up to 100 vpd and desirably 500 m for all other cases with 300 m as a minimum sight distance based on 110 km/hr. Note 4 is adequate but could refer to AUSTROADS sight distance criteria, although intersection sight distances are based on these lengths.

Right versus Left-Hand side intersections

It would be good practice not to locate both right-hand and left-hand intersections within either the diverge or merge area. Therefore, Table F2 is adequate by recommending that access/intersection are not located within the diverge and merge tapers. However, it would seem appropriate that a reduced location spacing is required for left hand intersections compared to right hand intersections. Possibly, a desirable and minimum location distance could be provided.

As currently stated within Table 2, left-hand intersections located within the middle of the passing lane are generally adequate. Care should be taken if these left hand intersections with high-volume access and minor to collector district roads have high turning volumes or is likely to have high turning volumes. However, all district roads may have traffic increases. Therefore, it would seem appropriate to assume that all intersections may eventually operate at higher turning volumes. An additional note highlighting the potentially adverse situation of combined SH and side road turning traffic volumes would seem appropriate.

Also, Note 5 of Table F2 does differentiate between crossings in both the treated and untreated directions but does not take into account state highway/district road intersections. Note 5 should be amended to include District road intersections. Suggested wording for mitigation measures from right hand intersections, especially if turning volumes are high, would include: i) access controls on crossing applications for high-volume driveways along passing lanes as well as 0-300 m upstream and 0-300 m downstream, ii) restricting turning movements using central median cables or iii) intersection leg closure.

Passing Lane Gradient

Table F2 does not have to differentiate between operating speed environments and one set of criteria for intersection location and sight distances is adequate. Note 4 on sight distance is based on the operating speed environment and should be adequate.

Night Lighting

The night lighting was not statistically significant and could not be considered as a mitigating measure. Night lighting is usually an indicator of an intersection of two rural state highways or a rural state highway (SH) /major district arterial intersection but the lighting requirement is neither turning volume nor AADT based. Therefore, night lighting was not a good indicator of high volume SH/SH and SH/major district arterial intersections and also not a conclusive mitigating measure.

Right Turn Bays

Right turn bays are usually an indicator of high turning movements but were not statistically significant compared to other right turn treatments, mainly due to left hand intersections being included. Therefore, it would be good practice to provide a right turn bay, if right hand intersections (which are statistically significant) were allowed within a passing lane. However, an additional note would seem appropriate. Suggested wording might involve left and right turn treatments complying with AUSTROADS turning volumes and safety criteria (noting the New Zealand exclusion of choosing the “intermediate” type of right turn treatment).

4 Summary and Conclusions

4.1 Summary

This research project has investigated the effect of specific features on intersection-related crash rates within and near passing lanes on rural state highways in New Zealand. The research findings suggest that having a T-junction intersection with the intersecting road on the left hand side of the passing lane (when travelling in the treated direction), preferably with low volumes, generally does not infer a safety concern. More attention should be given to the "Before" zone within NZTA's site selection processes, particularly for sight distance and the number of intersections.

The research generally supports the current NZTA operational review of passing lanes and overtaking opportunities, including Table F2 but some amendments to this table would seem appropriate. Table F2 can be used to provide guidance on any possible safety problems associated with intersections currently located either within or close to existing passing lanes as well as possible future passing lane sites. Table F2 is also useful for evaluating access crossing applications and land use development applications that might be located close to existing or possible future passing lane sites.

Influencing factors on passing lane crash rates include the AADT, number of intersections, length of passing lanes, sight distance and on which side of the State highway that the intersecting road was located. Other factors or elements did not have any statistically significant effect, namely passing lane gradient, right turn bays and night lighting. In addition, other elements were considered but not incorporated into the statistical analysis due to insufficient sample size, too much missing data or insufficient variation within the element.

4.2 Conclusions

In accordance with the research purpose, the following concluding points and recommendations are made for NZTA's consideration:

1. Site features that will cause adverse safety problems are listed in order of importance, namely:

    - higher AADTs (for the "Before", "Within" and "After" zones and generally along the "Entire Passing Lane"),
    - under-length passing lanes (relative to AADTs and road gradient within the Policy's long-term layout table) (for the "Before" and "After" zones),
    - poor advance sight distance to intersections (for the "Before" zone),

2. Intersection configurations that will cause adverse safety problems are listed in order of importance, namely:

    - intersections located on the right hand (untreated) side (for the "Before" and "After" zones and generally along the "Entire Passing Lane"),
    - multiple intersections (i.e. cross roads or closely spaced staggered T-junctions count as two intersections) (for the "Before" zone).

3. The following features were not found to be statistically significant on reducing intersection-related crashes at passing lanes but should be considered as part of good practice:

    - location and sight distance criteria is not dependant on passing lane gradient but should take into account the operating speed environment.
    - right turn treatments should comply with AUSTROADS criteria for turning volumes and safety (noting the NZ exclusion of “intermediate” type intersections).

- night lighting to continue being applied to SH/SH and SH/major district arterials intersections, particularly if channelisation is provided.

4. It is recommended to create a database relating solely to passing lanes, slow vehicle bays and marked wide shoulders, noting that changes should be updated regularly.

5. It is recommended to monitor all passing lanes that begin at an intersection with a right turn bay to examine in more detail the effect of this passing lane arrangement.

6. It is recommended to undertake a 'Before and After' study for any passing lane that is substantially extended or significantly modified.

Finally, for convenience, possible changes to Planning Notes Table F2 of the Provisional Passing and Overtaking Guidelines as provided by NZTA are included (refer Appendix D).

5 Acknowledgements

MWH would like to acknowledge the statistical analysis work undertaken by Kelly Mara, consultant statistician. Larry Cameron of NZTA assisted with the review and part of the written text of this report, including the discussion, the implications for Table F2 and the conclusions.

Appendix A Literature search selected results

Search Results for specific reference #41

Title:	**DRIVEWAY AND STREET INTERSECTION SPACING**
Accession Number:	00721450
Record Type:	Component
Language 1:	English
Abstract:	This Circular on driveway and street intersection spacing has been developed in response to the need for information that may be applied in the development of sound spacing practices. It is a compilation of the contemporary practice that illustrates the basic considerations for spacing standards and guidelines and that describes current state, county, and local spacing requirements. The Circular begins with an overview on access management and a look at access management benefits. Section 2 presents general considerations in establishing spacing and the number of driveways; section 3 identifies the various technical considerations associated with setting spacing requirements for signalized intersections, corner clearance, and unsignalized intersections; section 4 contains regulations, policies, and standards for state highway systems; section 5 presents regulations, policies, and standards for local highway systems; and section 6 sets forth the conclusions.
Supplemental Notes:	This report was developed by a TRB Committee on Access Management task force.
TRIS Files:	HRIS
Pagination:	44 p.
Features:	Figures; References; Tables
Monograph Info:	See related components
Corporate Authors:	• Transportation Research Board 500 Fifth Street, NW Washington, DC 20001 USA
Availability:	• Transportation Research Board Business Office 500 Fifth Street, NW Washington, DC 20001 US • Find a library where document is available Order URL: http://worldcat.org/issn/00978515
Publication Date:	199603
Serial:	Transportation Research Circular Issue Number: 456 Publisher: Transportation Research Board ISSN: 0097-8515
Index Terms:	Access; Counties; Crossovers; Driveways; Guidelines; Intersections; Local government; Median openings; Medians; Policy; Regulations; Signalized intersections; Spacing; Specifications; Standards; States; Unsignalized intersections; Access management (highways); Requirements
Subject Areas:	Design Highways Law Planning and Forecasting Policy Safety and Human Factors I21: Planning of Transport Infrastructure I82: Accidents and Transport Infrastructure

Extracts from FHWA-RD-99-207, *Prediction of the Expected Safety Performance of Rural Two-Lane Highways*, December 2000 (pages 40-43; 56-58; 112)

Driveway Density

The nominal or base condition for driveway density is three driveways per km (five driveways per mi). The AMF [accident modification factor] for driveway density is based on the following equation derived from the work of Muskaug:(17)

$$AMF = \frac{0.2 * [0.05 + 0.005\, ln\,(ADT)]\, DD}{0.2 * [0.05 + 0.005\, ln\,(ADT)]\,(5)} \qquad \textbf{(22)}$$

where:
ADT = annual average daily traffic volume of the roadway being evaluated (veh/day); and
DD = driveway density (driveways per mile). [1 mile = 1.61 km]

The Muskaug study deals with injury accidents only but the expert panel made a judgment that the AMF shown in equation (22) can be applied to total roadway accidents of all severity levels.
The expert panel considered the Norwegian study by Muskaug to be the best available study on the safety effects of driveway density on rural two-lane highways. The panel was concerned, however, about reliance on an international data source and undertook a further review of relevant U.S. literature. The most applicable U.S. reference appeared to be *Transportation Research Circular 456*, and an analysis concluded that its results were consistent with the findings of Muskaug.(18) Still another review of [Highway Safety Information System] HSIS data from Minnesota concluded that the effect of driveway density in accidents is consistent with the results of the Muskaug study. Therefore, the Muskaug results were retained as the basis for the driveway density AMF.

Passing Lanes

The nominal or base condition for passing lanes is the absence of a lane (i.e., the normal two-lane cross section). The AMF for a conventional passing or climbing lane added in one direction of travel on a two-lane highway is 0.75 for total accidents in both directions of travel over the length of the passing lane from the upstream end of the lane addition taper to the downstream end of the lane drop taper. This value assumes that the passing lane is operationally warranted and that the length of the passing lane is appropriate for the operational conditions on the roadway. An [Interactive Highway Safety Design Model] IHSDM procedure other than the accident prediction algorithm should be used to warn users if a passing lane is not operationally warranted or if an inappropriate passing lane length is used. Passing lanes are known to have traffic operational effects that extend 5 to 13 km (3 to 8 mi) downstream of the passing lane; while it might be presumed that these operational effects provide analogous safety benefits over a similar length of highway, no such effect is included in the accident prediction algorithm for lack of quantitative evidence of such a benefit.

The AMF for short four-lane sections (i.e., side-by-side passing lanes provided in opposite directions on the same roadway section) is 0.65 for total accidents over the length of the short four-lane section. This AMF applies to any portion of roadway where the cross section has four lanes and where both added lanes have been provided over a limited distance to increase passing opportunities. This AMF does not apply to extended four-lane highway sections.

The AMF for passing lanes is based primarily on the work of Harwood and St. John, with consideration also given to the results of Rinde and Nettleblad.(19, 12, 20) The AMF for short four-lane sections is based on the work of Harwood and St. John.(19) These AMFs apply to total roadway segment accidents within the passing lane and short four-lane sections.

Two-Way Left-Turn Lanes

The installation of a center two-way left-turn lane (TWLTL) on a two-lane highway to create a three-lane cross section can reduce accidents related to turning maneuvers at driveways.
The AMF for installation of a TWLTL is:

$$AMF = 1 + 0.7P_D\, P_{LT/D} \qquad \textbf{(23)}$$

where:
P_D = driveway-related accidents as a proportion of total accidents; and
$P_{LT/D}$ = left-turn accidents susceptible to correction by a TWLTL as a proportion of driveway-related accidents.

The value of P_D is estimated from the work of Hauer as: (21)

$$P_D = \frac{0.0047DD + 0.0024DD^2}{1.199 + 0.0047DD + 0.0024DD^2} \qquad \textbf{(24)}$$

The value of $P_{LT/D}$ was estimated by the expert panel as 0.5.

The expert panel considers that equations (23) and (24) provide the best estimate of the AMF for TWLTL installation that can be made without data on the left-turn volumes within the TWLTL. Realistically, such volumes are seldom available to highway agencies for use in such analyses. The AMF, as adjusted in equation (23), applies to total roadway segment accidents. Equation (24) was initially developed to represent total access point density (driveways plus unsignalized intersections). However, it is used here to determine an AMF for driveway density alone, because the effects of left-turn lanes at intersections are considered separately below.

The AMF for TWLTL installation should not be applied unless the driveway density is greater than or equal to three driveways per km (five driveways per mi). If the driveway density is less than three driveways per km (five driveways per mi), the AMF for TWLTL installation is 1.00. TWLTL installation would, in any case, be inappropriate for roadway segments with driveway densities lower than this threshold.

Driveway Density

Table 12 presents the sensitivity of safety to driveway density for roadway segments while all other factors remain at their nominal or base conditions. The table shows that a roadway segment with 19 driveways per km (30 driveways per mi) can experience up to four times as many accidents as a similar roadway segment with no driveways. The sensitivity of safety to driveway density is greater at lower ADTs than at higher ADTs, although the absolute magnitudes of the predicted accident frequencies at low ADT are very low. Nevertheless, it might be more reasonable to expect greater sensitivity of accidents to driveways at higher ADTs than at lower ADTs. Further research on this issue would be desirable.

Table 12 also shows the predicted accident frequency and accident rate for two-lane highway sections with two-way left-turn lanes (TWLTLs). The AMF for TWLTLs is based on equations (23) and (24). The accident reduction effectiveness of a TWLTL ranges from 2 to 23 percent as a function of driveway density.

Table 12. Sensitivity of Safety to Driveway Density on Roadway Segments.

Driveway Density (driveways per mile)							
ADT	0	5	10	15	20	25	30
(veh/day)		BASE					
ACCIDENTS PER MILE PER YEAR							
400	0.06	0.09	0.12	0.15	0.18	0.21	0.24
1,000	0.16	0.22	0.29	0.35	0.41	0.47	0.54
3,000	0.54	0.67	0.81	0.94	1.08	1.21	1.34
5,000	0.95	1.12	1.30	1.47	1.65	1.82	2.00
10,000	2.04	2.24	2.45	2.65	2.85	3.05	3.25
ACCIDENTS PER MILLION VEHICLE-MILES							
400	0.41	0.61	0.82	1.03	1.23	1.44	1.64
1,000	0.44	0.61	0.79	0.96	1.13	1.3	1.47
3,000	0.49	0.61	0.74	0.86	0.98	1.11	1.23
5,000	0.52	0.61	0.71	0.81	0.90	1.00	1.10
10,000	0.56	0.61	0.67	0.73	0.78	0.84	0.89
ACCIDENTS PER MILE PER YEAR—WITH TWLTL							
400	0.06	0.09	0.11	0.13	0.15	0.17	0.18
1,000	0.16	0.22	0.27	0.31	0.34	0.38	0.41
3,000	0.54	0.66	0.75	0.83	0.9	0.97	1.04
5,000	0.95	1.10	1.21	1.30	1.38	1.46	1.54
10,000	2.04	2.19	2.28	2.33	2.38	2.44	2.50

ACCIDENTS PER MILLION VEHICLE—MILES							
400	0.41	0.60	0.76	0.9	1.03	1.15	1.26
1,000	0.44	0.60	0.73	0.84	0.94	1.04	1.13
3,000	0.49	0.60	0.69	0.76	0.82	0.88	0.95
5,000	0.52	0.60	0.66	0.71	0.76	0.80	0.84
10,000	0.56	0.60	0.62	0.64	0.65	0.67	0.69

Passing Lanes

Table 13 presents the sensitivity of safety to passing lanes and short four-lane sections on roadway segments. The table shows that, as explained in section 4 of this report, installation of passing lanes to increase passing opportunities reduces accidents by 25 percent and installation of short four-lane sections to increase passing opportunities reduces accidents by 35 percent.

Table 13. Sensitivity of Safety to Presence of Passing Lanes & Short Four-Lane Sections on Roadway Segments.

	Passing Lane Present?		Short Four-Lane Section Present?	
ADT	No	Yes	No	Yes
(veh/day)	BASE		BASE	
ACCIDENTS PER MILE PER YEAR				
400	0.09	0.07	0.09	0.06
1,000	0.22	0.17	0.22	0.15
3,000	0.67	0.50	0.67	0.44
5,000	1.12	0.84	1.12	0.73
10,000	2.24	1.68	2.24	1.46
ACCIDENTS PER MILLION VEHICLE-MILES				
400	0.61	0.46	0.61	0.40
1,000	0.61	0.46	0.61	0.40
3,000	0.61	0.46	0.61	0.40
5,000	0.61	0.46	0.61	0.40
10,000	0.61	0.46	0.61	0.40

References:

17. Muskaug, R., *Accident Rates on National Roads*, Institute of Transport Economics, Oslo, Norway, 1985.
18. Transportation Research Board, "Driveway and Street Intersection Spacing," *Transportation Research Circular 456*, March 1996.
19. Harwood, D. W., and A. D. St. John, *Passing Lanes and Other Operational Improvements on Two-Lane Highways*, *Report No. FHWA/RD-85/028*, Federal Highway Administration, July 1984.
20. Nettelblad, P., *Traffic Safety Effects of Passing (Climbing) Lanes: An Accident Analysis Based on Data for 1972-1977*, Meddelande TU 1979-5, Swedish National Road Administration, 1979.
21. Hauer, E., "Two-Way Left-Turn Lanes: Review and Interpretation of Published Literature," unpublished, 1999.

NOTE:
The downloaded PDF did not accurately reproduce the equations - the "=" and "+" symbols were all represented by a "." Accordingly they should be checked before use. In addition "The value of P_D is" was stated in the PDF as "The value of P_{AP} is". The FHWA report also outlined the Empirical Bayes (EB) procedure to adjust the accident rates, calculated by the prediction equations, based on the actual site-specific accident history.

It would appear that the US material is now being 'gathered' into the Interactive Highway Safety Design Model (IHSDM) which is coordinated with two related initiatives: the SafetyAnalyst under development by FHWA; and the Highway Safety Manual under development by the Transportation Research Board. Refer http://www.tfhrc.gov/safety/ihsdm/ihsdm.htm

Extracts from #21, FHWA/TX-02/4064-1, *Design guidelines for passing lanes on two-lane roadways (Super2)*, September 2001 (pages 40-43; 56-58; 112)

Background

Many research studies conducted in the past have recognized the ability of passing lanes to improve traffic opportunities by providing dependable passing opportunities in all volume conditions *(9)*. The following model developed by Harwood and St. John predicts the passing rate at a given passing lane section using a set of input values which are explained below *(1)*:

$$PR = 0.127 FLOW - 9.64 LEN + 1.35 UPL;\ for\ 50vph \le FLOW \le 400vph \quad (R^2 = 0.83) \tag{1}$$

where

PR = passing rate in passes per mile per hour,

FLOW = flow in one direction in vph,

LEN = length of passing lane in miles,

UPL = percentage of vehicles platooned upstream, and

vph = vehicles per hour.

DESIGN GUIDELINES

Guidelines published regarding the location and design of passing lane sections on two-way, two-lane rural highways are discussed in the following sections.

Guidelines

Research conducted by the Kansas Department of Transportation suggests that improvements to two-lane rural highways in the form of adding passing lanes should be accomplished in a two-level process: i.e., network and project levels *(9)*.

The study recommends that, at the network level, two-lane rural highway segments operating below a predefined level-of-service should be identified for improvements. At the project level, highway segments identified at the network level should be ranked for the purpose of prioritization *(9)*. The study also recommended minimum average annual daily traffic (AADT) values that warrant the addition of passing lanes at the network level, based on the *HCM* level-of-service procedures for rural two-lane highways *(9)*. Table 3 presents these warrants.

Table 3. Suggested Minimum AADT Values for Rural Two-Lane Highways for Levels-of-Service B and C in Level Terrain–Justification for Passing Lanes.

		Projected Design Year AADT									
% Trucks		10		15		20		30		40	
LOS		B	C	B	C	B	C	B	C	B	C
% No Passing Zones	0 %	3900	6200	3700	5890	3520	5600	3210	5110	2950	4690
	20 %	3460	5630	3290	5340	3130	5080	2850	4630	2620	4260
	40 %	3030	5190	2880	4930	2740	4690	2500	4280	2290	3930
	60 %	2740	4900	2600	4660	2480	4430	2260	4040	2080	3710
	80 %	2450	4760	2330	4520	2220	4300	2020	3920	1860	3600
	100 %	2310	4620	2190	4380	2090	4180	1900	3800	1750	3490
Assumptions: K=0.15, directional split = 60/40, peak hour factor = 0.92, lane width ≥ 12 ft, shoulder width ≥ 6 ft.											

Length

The literature does not provide a specific definition for the length of a passing lane. Some studies consider the passing lane length to include tapers, while others exclude tapers from the definition of passing lane length. In this report, the length of a passing lane refers to the length of the two-lane passing section excluding the transition tapers.

Earlier research conducted by Harwood and Hoban suggested the optimal passing lane lengths for respective two-way volumes as shown in Table 4 (*10*). Subsequent research generally supported these recommendations (*8,9*). However, these studies were conducted during the period (1974-1996) when the national maximum speed limit was 55 mph.

Table 4. Optimum Lengths for Passing Lanes.

Two-Way Flow Rate (veh/hr)	Optimal Passing Lane Length (mi)
200	0.5
400	0.5-0.75
800	0.75-1.0
1400	1.0-2.0

Spacing

Harwood and Hoban (*10*) suggest that the Australian approach of long initial spacing of 10-15 miles should be followed for passing lane installations. If volumes continue to grow such that additional improvements are warranted, the spacing may be reduced to 3-5 miles by adding intermediate passing lanes.

A comparison of recommended design guidelines regarding length and spacing of passing lanes in Canada, Australia, and the United States is listed in Table 5 *(9)*.

Table 5. Comparison of Design Guidelines for Passing Lanes Among Canada, Australia and the United States (2).

Jurisdiction	Spacing (mi)	Length (mi)	Taper Length	
			Diverge	Merge
British Columbia	-	Minimum 0.5; desirable 0.65	20:1	25:1
Alberta	-	1.3	25:1	50:1
Canadian Parks Service	Determined from warrants	Trans-Canada 1.3; other highways minimum 0.3	100 m	200 m
Ontario	6.2-15.5	0.9-1.3	$\frac{V \times W}{1.6}$	$\frac{V \times W}{1.6}$
Federal Highway Administration (USA)	3.1-8.0	Minimum 0.2; 0.5-1.0 optimal	$\frac{2 \times V \times W}{3}$	$V \times W$
Australia	2.2-3.1 to 6.2-9.3	Depends on design speed; normal maximum length 0.75	$\frac{V \times W}{3}$	$\frac{V \times W}{2}$

$V = 85^{th}$ Percentile Speed.
W = Lane Width.
Length does not include transition tapers.

MEASURE OF OPERATIONAL PERFORMANCE SELECTED

Percent time delay was chosen as the measure of operational performance in this project, as the *HCM* uses percent time delay as the primary measure of effectiveness in determining the LOS of a two-lane highway. The level-of-service for a two-lane highway is related to the average percent time delay as shown in Table 6 (*14*).

Table 6. Level of Service and Corresponding Percent Time Delay (*11*).

Level of Service	Percent Time Delay
A	30
B	45
C	60
D	75
E	> 75

References

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9. Mutabazi, M. I., Russell, E. R., and Stokes, R. W. *Review of the Effectiveness, Location, Design, and Safety of Passing Lanes in Kansas*, Report No. K-TRAN: KSU-97-1, Kansas State University, Manhattan, Kansas, October 1999.
10. Harwood, D. W. and Hoban, C. J. *Low Cost Methods for Improving Traffic Operations on Two-Lane Roads*, Report No. FHWA-IP-87-2, McLean, Virginia: Federal Highway Administration, December 1985.
11. Messer C. J. *Two-Lane, Two-Way Rural Highway Capacity,* NCHRP Report 3-28 A, Texas Transportation Institute, February 1983.
14. *Highway Capacity Manual*, Transportation Research Board, Special Report 209, Washington, D.C., 1985.

Extract from FHWA-RD-01-103, *Highway Design Handbook for older drivers and pedestrians,* May 2001 (http://www.tfhrc.gov/humanfac/01103/ch3.htm#c)

D. Design Element: Passing Zone Length, Passing Sight Distance, and Passing/Overtaking Lanes on Two-Lane Highways

Table 41. Cross-references of related entries for passing zone length, passing sight distance, and passing/overtaking lanes on two-lane highways.

Applications in Standard Reference Manuals		
MUTCD (2000)	**AASHTO Green Book (1994)**	**Traffic Engineering Handbook (1999)**
Table 2B-1 Sects. 2B.24 & 2B.25 Tables 2C-1 through 2C-5 Sects. 2C.06 & 2C.32 Sect. 3B.02	Pg. 44, Para. 3 Pgs. 128-136, portion of Sect. on *Passing Sight Distance for Two-Lane Highways* & all of Sect. on *Frequency and Length of Passing Sections* Pg. 223, Sect. on *Passing Sight Distance* Pgs. 262-268, Sects. on *Passing Lane Sections on Two-Lane Roads, Three-Lane Sections, Turnouts, Shoulder Driving,* & *Shoulder Use Sections* Pgs. 286-288, Sect. on *Design Controls -- Passing Sight Distance* Pgs. 446-447, Sect. on *Passing Sight Distance* Pgs. 461-462, Sect. on *Sight Distance* Pg. 485, Sects. on *Sight Distance & Alignment* Pgs. 490-491, Sect. on *Provision for Passing* Pg. 500, Sect. on *Climbing Lanes on Multilane Arterials*	Pg. 224, Sect. on *No-Passing Zones* Pg. 374, Sect. on *Passing Sight Distance (PSD)* Pg. 399, Sect. on *Special Features* Pg. 427, Para. 3 & Table 12-7

The safety and effectiveness of passing zones depend upon the specific geometric characteristics of the highway section, as well as on how drivers receive and process information provided by signs and pavement markings, integrate speed and distance information for opposing vehicles, and control their vehicles (brake and accelerate) during passing maneuvers. As the number of older drivers in the population increases dramatically over the years 1995-2025, many situations are expected to arise where not only the slower-moving vehicle, but also the passing vehicle, is driven by an older person.

The capabilities and behavior of older drivers, in fact, vary with respect to younger drivers in several ways crucial to this discussion. Studies have shown that while driving speed decreases with driver age, the sizes of acceptable headways and gaps tend to increase with age. While motivational factors (e.g., sensation seeking, risk taking) have been shown to play a major role in influencing the higher speeds and shorter headways accepted by young drivers, they seem to play a less important role in older driver behavior. Instead, the relatively slower speeds and longer headways and gaps accepted by older drivers have been attributed to their compensating for decrements in cognitive and sensory abilities (Case, Hulbert, and Beers, 1970; Planek and Overend, 1973).

The ability to judge gaps when passing in an oncoming lane is especially important. For some older drivers, the ability to judge gaps in relation to vehicle speed and distance is diminished (McKnight and Stewart, 1990). Depth perception--i.e., the ability to judge the distance, and changes in distance, of an object--decreases with age (Bell, Wolfe, and Bernholtz, 1972; Henderson and Burg, 1973, 1974; Shinar and Eberhard, 1976). One study found that the angle of stereopsis (seconds of visual arc) required for a group of drivers age 75 and older to discriminate depth using a commercial vision tester was roughly twice as large as that needed for a group of drivers ages 18 to 55 to achieve the same level of performance (Staplin, Lococo, and Sim, 1993). McKnight and Stewart (1990) reported that the inability to judge gaps is not necessarily associated with a high crash rate, to the extent that drivers can compensate for their deficiencies by accepting only inordinately large gaps. This tactic has a negative impact on operations as traffic volumes increase, however, and may not always be a feasible approach.

Judging in-depth motion is made difficult by the fact that when no lateral displacement occurs, the primary depth cue is the expansion or contraction of the image size of the oncoming vehicles (Hills, 1980). Studies of crossing-path crashes, where gap judgments of oncoming vehicle speed and distance are critical as in passing situations, indicate an age-related difficulty in the ability to detect angular movement. In laboratory studies, older persons required significantly longer to perceive that a vehicle was moving closer (Hills, 1975). Staplin and Lyles (1991) reported research showing that, relative to younger drivers, older ones underestimate the speed of approaching vehicles. Similarly, Scialfa, Guzy, Leibowitz, Garvey, and Tyrrell (1991) showed that older adults tend to overestimate approaching vehicle velocities at lower speeds and underestimate at higher speeds, relative to younger adults. Older persons also apparently accept a gap to cross in front of an oncoming vehicle that is a more-or-less constant distance, regardless of the vehicle's speed. Analyses of judgments of the "last possible safe moment" to cross in front of an oncoming vehicle showed that older men accepted a gap to cross at an average constant distance, whereas younger men allowed a constant time gap and thus increased distance at higher speeds (Hills and Johnson, 1980). A controlled field study showed that older drivers waiting (stationary) to turn left at an intersection accepted the same size gap regardless of the speed of the oncoming vehicle (48 km/h and 96.5 km/h [30 mi/h and 60 mi/h]), while younger drivers accepted a gap that was 25 percent larger for a vehicle traveling at 96.5 km/h (60 mi/h) than their gap for a vehicle traveling at 48 km/h (30 mi/h) (Staplin et al., 1993).

The minimum passing sight distances listed in table 3B-1 of the MUTCD (FHWA, 2000) for marking passing zones are shorter than AASHTO's minimum passing sight distance values for the design of two-lane highways, as listed in table III-5 of the Green Book (AASHTO, 1994). Although the minimum passing sight distances specified by AASHTO are based on observations of successful car-passing-car observations, Hughes et al. (1992) commented that the model does not take into account the abortive passing maneuver, nor does it consider the length of the impeding vehicle. Saito (1984) determined that the values specified by the MUTCD for minimum passing distance are inadequate for the abortive maneuver, while Ohene and Ardekani (1988) asserted that the MUTCD sight distance requirements are adequate for the driver to abort if the driver decelerates at a rate of 3.2 m/s^2 for a 64-km/h passing speed (10.5 ft/s^2 for a 40-mi/h passing speed) and at a rate of 3.9 m/s^2 for a passing speed of 80 km/h (12.8 ft/s^2 for a 50-mi/h passing speed). In any event, it cannot be assumed that drivers will always use the maximum acceleration and deceleration capabilities of their vehicles, particularly older drivers.

Consistent with the AASHTO operational model (AASHTO, 1994), passing sight distance is provided only at places where combinations of alignment and profile do not require the use of crest vertical curves. For horizontal curves, the minimum passing sight distance for a two-lane road is about four times as great as the minimum stopping sight distance at the same speed (AASHTO, 1994). By comparison, the MUTCD defines passing sight distance for vertical curves as the distance at which an object 1.07 m (3.50 ft) above the pavement surface can be seen from a point 1.07 m (3.50 ft) above the pavement. For horizontal curves, passing sight distance is defined by the MUTCD as the distance measured along the centerline between two points 1.07 m (3.50 ft) above the pavement on a line tangent to the embankment or other obstruction that cuts off the view of the inside curve (MUTCD, 2000). The length of passing zones or the minimum distance between successive no-passing zones is specified as 120 m (400 ft) in the MUTCD. As Hughes, Joshua, and McGee (1992) pointed out, the MUTCD sight distance requirements were based on a "compromise between a delayed and a flying passing maneuver, traceable back to the AASHTO 1940 policy that reflected a compromise distance based on a passing maneuver such that the frequency of maneuvers requiring shorter distances was not great enough to seriously impair the usefulness of the highway."

The basis for the minimum length of a passing zone (120 m [400 ft]) is unknown, however, because research has indicated that for design speeds above 48 km/h (30 mi/h) the distance required for one vehicle to pass another is much longer than 120 m (400 ft) (Hughes et al., 1992). Weaver and Glennon (1972) reported that, in limited studies of short passing sections on main rural highways, most drivers do not complete a pass even within a 244-m (800-ft) section; and use of passing zones remains very low when their length is shorter than 274.3 m (900 ft). Not surprisingly, it has been mentioned in the literature (Hughes et al., 1992) that the current AASHTO and MUTCD passing sight distance values are probably too low. Several studies have indicated that both the MUTCD and AASHTO passing sight distances are too short to allow passenger cars to pass trucks and for trucks to pass trucks (Donaldson, 1986; Fancher, 1986; Khasnabis, 1986).

Several research studies have been performed that have established and evaluated passing sight distance values for *tangent* sections of highways. As early as 1934, the National Bureau of Standards measured the time required for passing on level highways during light traffic and found that the time to complete the maneuver always ranged between 5 and 7 s regardless of speed. Passing maneuvers were observed at speeds ranging from 16 to 80 km/h (10 to 50 mi/h). They concluded that 274.3 m (900 ft) of sight distance was required for passing at 64 km/h (40 mi/h). Harwood and Glennon (1976) reported that drivers are reluctant to use passing zones under 268 m (880 ft). They recommended that design and marking standards should be identical and include both minimum passing sight distances and minimum length of passing zones, with minimum passing sight distance values falling between the AASHTO and MUTCD values. Kaub (1990) presented a substantial amount of data on passing maneuvers on a recreational two-lane, two-way highway in northern Wisconsin. Under low and high traffic volumes, respectively, he found that 24-35 percent and 24-50 percent of all passes were attempted in the presence of an opposing vehicle; the average time in the opposing lane (96 km/h [60 mi/h]) was 12.2 s under low-traffic conditions and 11.3 s with high-traffic volumes.

Passing lanes, also referred to as overtaking lanes, are auxiliary lanes provided on two-lane highways to enhance overtaking opportunities. Harwood, Hoban, and Warren (1988) reported that passing lanes provide an effective method for improving traffic operational problems resulting from the lack of passing opportunities, due to limited sight distance and heavy oncoming traffic volumes. In addition, passing lanes can be provided at a lower cost than that required to construct a four-lane highway. Based on Morrall and Hoban (1985), the design of overtaking lanes should include advance notification of the overtaking lane; a KEEP RIGHT UNLESS OVERTAKING sign at the diverge point; advance notification of the merge and signs at the merge; and some identification for traffic in the opposing lane that they are facing an overtaking lane. They reported that there is general agreement that providing short overtaking lanes at regular spacing is more cost-effective than providing a few long passing lanes. This feature becomes increasingly attractive as the diversity of driving styles and driver capability levels grows, with more aggressive motorists accepting greater risks to overtake slower-moving vehicles.

Finally, the benefits of fluorescent retroreflective sheeting for increased daytime and nighttime conspicuity are reported by Jenssen, Moen, Brekke, Augdal, and Sjøhaug (1996). They conducted a controlled field study of daytime and nighttime visibility performance of fluorescent and non-fluorescent yellow traffic signs, both fabricated with retroreflective sheeting that provides for high brightness at wide observation angles (ASTM D4956-01,Type IX). The subjects included younger (ages 18-25) and older (ages 55-75) drivers. Under daytime conditions, the fluorescent yellow signs with Type IX sheeting provided a 90 m (295 ft) increase in sign shape recognition distance over the non-fluorescent yellow signs with Type IX sheeting for the older driver sample, and a 57 m (187 ft) increase for the younger driver sample. At a speed of 100 km/h (62 mi/h), this additional detection distance would translate to 3.2 s of extra reaction time for the older drivers and 2.1 extra seconds of reaction time for the younger drivers. At nighttime, the signs fabricated with Type IX sheeting provided an additional sign shape recognition distance of 288 m (945 ft) over signs fabricated with engineering grade sheeting (Type I), and an additional 149 m (489 ft) of shape recognition distance over signs made with high intensity sheeting (Type III) for the older driver sample. The younger driver sample performed similarly, with increased sign shape recognition distances for the signs made with Type IX sheeting (308 m [1,010 ft] over the signs made with Type I engineering grade sheeting, and 147 m [482 ft] over the signs fabricated with Type III high intensity sheeting). These increased distances translate to an additional 5 to 10 seconds of reaction time, at a speed of 100 km/h.

The age differences in driver capability and behavior noted earlier--i.e., age-related difficulties in judging gaps and in increased perception-reaction time, coupled with slower driving speeds--support a recommendation for use of the more conservative passing sight distance values specified by AASHTO (1994). In addition, a raised treatment to improve drivers' preview of the end of a passing zone--the widely recognized NO PASSING ZONE pennant, either oversized or fabricated with fluorescent yellow retroreflective sheeting that provides for high brightness at wide observation angles (e.g., Type IX) for added daytime and nighttime conspicuity-- can reasonably be expected to facilitate older drivers' decisions and responses in situations where safe operations dictate that they should abort a passing maneuver. Finally, a recommendation to implement passing/overtaking lanes may be justified in terms of overall system safety and efficiency.

Extract from FHWA, *Project Development and Design Manual,* May 2001

(http://flh.fhwa.dot.gov/resources/manuals/pddm/Chapter_09.pdf)

Extract from Section 9.3.9.8.2 Passing Lanes of the PDDM Chapter 9 Highway Design.

When determining where to locate passing lanes, consider the following factors:

1. ***Costs and Impacts.*** *Locate passing lanes to minimize costs and impacts. Difficult terrain will generally increase the costs and impacts for construction of passing lanes.*
2. ***Appearance.*** *The passing lane location, and its value, should appear logical and be obvious to the driver.*
3. ***Horizontal Alignment.*** *Where practical, avoid locating passing lanes on segments with lower-speed horizontal curves that restrict the speed for all vehicles.*
4. ***Vertical Alignment.*** *Where practical, construct passing lanes on a sustained upgrade. The upgrade will generally cause a greater speed differential between slow moving vehicles and passing vehicles. However, passing lanes in level terrain still should be considered where the demand for passing opportunities exceeds supply.*
5. ***Intersections.*** *Locations should be avoided that include major intersections or high volume access points (over 500 ADT). Use special care when designing passing lanes through minor intersections and commercial entrances.*
6. ***Structures.*** *Avoid placing passing lanes where structures (e.g., large culverts, bridges) may restrict the overall width of the travelled way, passing lane and shoulder.*
7. ***Tapers.*** *Avoid locating the ending or merging taper within 150 m [500 ft] prior to an intersection or major side approach road. The merging taper should be located to avoid side approach roads or driveways on either side of the highway.*

Separate left-turn lanes may be provided in a passing lane section when left turn volumes are significant. Refer to Section 9.3.14.6

Extracts from FHWA–IP-87-2, Low-cost Methods for improving traffic operations on two-lane roads: informational guide*,* 1987

The above differs little from the seven bullet points given in section 3.3.1 Location and Configuration of the FHWA-IP-87-2 information guide. The 1987 guide elaborates more with regard to intersections as follows:

- *The location of major intersections and high-volume driveways should be considered in selecting passing lane locations, to minimise the volume of turning movements on a road section where passing is encouraged. Low-volume intersections and driveways do not usually create problems in passing lanes. Where the presence of higher-volume intersections and driveways cannot be avoided, special provisions for turning vehicles should be considered. The prohibition of passing by vehicles travelling in the opposing direction should also be considered on passing lane sections with higher-volume intersections and driveways.*

Section 3.4.1 Turnouts of the guide states

To maximise usage, turnouts should be located where the drivers of slow-moving vehicles do not consider use of the turnout to involve substantial delay to themselves. For example it is better to locate a turnout in the middle of a sustained grade where the speed of trucks and recreational vehicles (RVs) are depressed, that at or near the crest of the grade where the truck and RV drivers are intent on recovering their lost speed.

A driver approaching a turnout should have a clear view of the entire turnout in order to determine whether the turnout is available for use and in order to anticipate whether a vehicle sing the turnout is about to re-enter the traffic stream. Operational experience suggests that turnouts that cannot be seen for some distance by approaching drivers are less likely to be seen.

Extract from the British Columbia Ministry of Transportation and Highways, Technical Bulletin DS98003, Passing Lane Warrants and Design,1998

Location Guidelines:

Intersections should be avoided within the passing lane, particularly on the right side and in the vicinity of the merge and diverge tapers. Avoid intersections within the decision sight distance (DSD) upstream of the merge end of the passing lane, or with 300 metres downstream of the diverge taper.

When an intersection in the passing lane cannot be avoided, the intersection should be in the middle of the passing lanes section away from the merge and diverge areas where other weaving manoeuvres are occurring and driver workload is high. The intersection should have a separate right turn lane regardless of traffic volume since a stopped right turn vehicle in the passing lane represents a high hazard to overtaking traffic. "T" intersections on the passing lane side are more desirable than intersections on the opposing side; they do not generate right turn movements to or from the fast lane.

Extracts from the Wisconsin Department of Transportation, December 2002, Facilities Development Manual, Section 11-15-10 Passing Lanes and Climbing Lanes

Refer http://roadwaystandards.dot.wi.gov/standards/fdm/index.htm

Passing Lanes: Location

When selecting a site for a passing lane facility, avoid side roads with 500 ADT or over. Driveways and field entrances should be avoided in the merge taper area on either side of the highway... No driveway or intersections should be located closer than 500 feet (152 m) from the end of the downstream [merge] taper.

A widened segment of roadway , with protected right turn lanes, may be constructed in a passing lane section to provide for the right turning traffic when right turn volumes are significant [see below]... In those limited areas where 4-lane undivided passing lanes sections are required, crossing intersections are not permitted and tee intersections are not desirable.

Avoid passing lanes on horizontal curves greater than 3 degrees, if possible

Climbing Lanes: Taper lengths and Locations

The climbing lane should be carried well beyond the crest to a point where trucks are able to regain a speed within 10 mph (15 km/h) of the speed of other vehicles.

Access is undesirable on either side of the highway in merge areas... Provide a minimum of 500 feet (152 m) of space downstream from the end of the taper to the nearest access point.

From Section 11-25-5 Left-turn [NZ Right-turn] Lanes

Exclusive left-turn NZ [right-turn] lanes are provided in order to enhance the safety and to facilitate the movement of through traffic. Generally, consider providing an exclusive left-turn [NZ right-turn] lane if the construction year AADT on the main road exceeds 7,000 and the side road AADT exceeds 1,000 [see also Table 1 Operational Warrants (based on vph and 60 mph operating speed) of this section]

Extracts from the Review of ... Passing lanes in Kansas, 1999

6.2.4 Location of Passing Lanes

It is recommended that crossroad intersections be avoided within a passing lane section if possible, especially along high traffic volume segments. Where a low volume side road intersection is inevitable within a passing lane, the passing lane should be located so that the intersection is as close as possible to the middle of the passing lane. High volume side roads should be avoided. High volume side roads are defined as those crossroads where left-turn [NZ right-turn] volume from the main highway would warrant a separate left-turn [NZ right-turn] lane on a conventional two-lane section. Side road intersections within lane-drops and lane-additions should be avoided. Further, right turn [NZ left turn] lanes are recommended at high volume crossroads. These turn lanes act as a bypass lane for through traffic in the event that the through lane is occupied by left [NZ right] turning vehicles waiting for a suitable gap in the opposing traffic.

6.2.5 Implementation Plan

Implement developed written design guidelines regarding a) minimum length of a passing lane, b) minimum lengths of tapers, c) avoiding major intersections where the left-turn movement from the major road is such that a left-turn lane would be warranted, d) locating minor intersections near the middle of the passing lane, and e) providing right-turn lanes at crossroad intersections.

It would seem that the Guidelines were subsequently written as noted in References 22 (and 23).

Extracts from the Design of ... Super 2 Highways, 2001

Recommendations

Passing lanes should be located to best fit existing terrain and field conditions. Uphill grades are preferred sites over downhill grades. Passing lanes on significant uphill grades should extend beyond the crest of the hill. Passing lane sections should be placed to avoid major intersections. If present, minor intersections that do not require deceleration lanes should be located near the midpoint of passing lane sections, avoiding transition areas.

Extracts from the Benefits and design/location criteria for passing lanes, 2004

Recommendations

8. The locations of major intersections and high-volume driveways should be considered in selecting passing lane locations, to minimize the volume of turning movements on road sections where passing is encouraged. Where major intersections or high-volume driveways are present in a passing lane, provision of left-turn lanes should be considered.
9. In locating passing lanes, other physical constraints, such as bridges and culverts, should be avoided if they restrict the provision of a continuous shoulder.
10. Climbing lanes on steep upgrades should be considered where the climbing lane warrants in the AASHTO *Green Book* are met. NCHRP Report 505 provides a spreadsheet program that can be used to determine the speed profile for heavy trucks on specific upgrades.

This report did not appear to specifically investigate the effect of intersections within a passing lane. The AASHTO *Green Book* and NCHRP 505 references are as below.

4. American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets*, 2001.
5. Harwood, D. W., D. J. Torbic, K. R. Richard, W. D. Glauz, and L. Elefteriadou, *Review of Truck Characteristics as Factors in Roadway Design*, NCHRP Report 505, Transportation Research Board, 2003.

Appendix B Statistical analysis results

Initial Overview:

(A) Incidence of Crashes (2004-08) in entire PL – influenced only by Side of Side Road
(B) Number of Crashes (2004-08) in 'Before' PL influenced by AADT, Number of Side Roads, coded PL Length, Sight Distance (both Decreasing and Increasing) and Side of Side Road.
(C) Number of Crashes (2004-08) in 'Mid' PL influenced only by AADT.
(D) Number of Crashes (2004-08) in 'After' PL influenced by AADT (plus PL length & Side of Side Road)
(E) Number of Crashes (2004-08) in entire PL influenced only by AADT and Side of Side Road.

162 Passing Lanes (including Slow Vehicle Bays) with crashes in either the 'Before', 'Mid' or 'After' zone
124 passing lanes where crashes occurred in the 'Before' PL zone;
142 passing lanes where crashes occurred in the 'Mid' PL zone;
105 passing lanes where crashes occurred in the 'After' PL zone.
204 Passing Lanes with 0 crashes in 2004-2008 (either Before, Mid, After PL)

1. PL Length: 1= 1200m+; 2= 500-1200m; 3= <500m 4= Slow Vehicle Bay (SVB)
2. Terrain: 1= Flat; 2= Rolling; 3= Mountainous
3. Intersection Lighting
4. Incr. Sight Distance
5. Decr. Sight Distance

Note that the 'entire' Passing Lane includes the 'Before', 'Mid' and 'After' zones, whereas the PL length pertains only to the 'Mid' zone (which excludes any tapers).
Altogether there were 43 Slow Vehicle Bays (14 with crashes, of which 2 had one or more side roads) and 323 other rural passing lanes included (148 with crashes, of which 40 had one or more side roads).

(A) Response –Indicator : Presence or Absence of Crash in the 'entire' Passing Lane

GLM Summary (Occurrence of Crash Events)
Crash (Yes or No): ~ PL Length + AADT + Number Side Roads + Terrain + Intersection Lighting + Incr. Sight Distance + Decr. Sight Distance + Side of Side Road

Coefficients:

Parameter	Value	Standard Error	*t* value
(Intercept)	0.3972	0.1053	3.771
PL Length	-0.0341	0.0293	-1.164
AADT	0.0000	0.0000	1.481
Number Side Roads	0.1009	0.0829	1.217
Right Turn Bay	0.0575	0.0728	0.790
Terrain (gradient)	0.0161	0.0343	0.468
Intersection Lighting	-0.0771	0.0751	-1.027
Incr. Sight Distance	0.0001	0.0004	0.343
Decr. Sight Distance	-0.0002	0.0004	-0.587
Side of Side Road	0.0553	0.0274	2.020

Null Deviance: 85.96 on 346 degrees of freedom
Residual Deviance: 82.91 on 337 degrees of freedom
19 observations deleted due to missing values

Significant relationship with the likelihood of a crash (or crashes) for the 'entire' passing lane (including before and after zones) is measurable only with side of side road (just at 95%).

(B) Response : Number of Crashes 2004-08 in the 'Before' Passing Lane

Number of Crashes Before PL: ~ PL Length + AADT + Number Side Roads + Terrain + Intersection Lighting + Side of Side Road

Coefficients:

Parameter	Value	Standard Error	*t* value
(Intercept)	0.8122	0.4362	1.862
PL Length	-0.2918	0.1212	-2.408
AADT	0.0001	0.0000	5.012
Number Side Roads	0.7653	0.3433	2.229
Right Turn Bay	-0.0908	0.3016	-0.301
Terrain (gradient)	-0.0855	0.1421	-0.602
Intersection Lighting	0.0058	0.3109	0.019
Incr. Sight Distance	0.0020	0.0015	1.381
Decr. Sight Distance	-0.0030	0.0015	-2.047
Side of Side Road	0.2815	0.1133	2.484

Null Deviance: 1633.96 on 346 degrees of freedom
Residual Deviance: 1421.91 on 337 degrees of freedom
19 observations deleted due to missing values

Length, AADT, Number of Side Roads, Decreasing Sight Distance and Side of Side Road have a significant effect on Crashes in the 'Before PL' zone.

(C) Response : Number of Crashes 2004-08 in the 'Mid' Passing Lane

Number of Crashes Mid PL ~ PL Length + AADT + Number Side Roads + Terrain + Intersection Lighting + Side of Side Road

Coefficients:

Parameter	Value	Standard Error	*t* value
(Intercept)	0.7122	1.2091	0.589
PL Length	0.2769	0.3360	0.824
AADT	0.0002	0.0001	2.975
Number Side Roads	0.1000	0.9518	0.105
Right Turn Bay	0.8275	0.8361	0.990
Terrain (gradient)	0.2456	0.3940	0.623
Intersection Lighting	-1.0853	0.8617	-1.260
Incr. Sight Distance	-0.0020	0.0041	-0.487
Decr. Sight Distance	-0.0018	0.0040	-0.453
Side of Side Road	0.3727	0.3141	1.187

Null Deviance: 11480.32 on 346 degrees of freedom
Residual Deviance: 10926.18 on 337 degrees of freedom
19 observations deleted due to missing values

Only AADT has a measurable effect on the number of crashes in the 'Middle' Passing Lane zone.

(D) Response : Number of Crashes 2004-08 in the 'After' Passing Lane

Number of Crashes After PL: ~ PL Length + AADT + Number Side Roads + Terrain + Intersection Lighting + Side of Side Road

Coefficients:

Parameter	Value	Standard Error	*t* value
(Intercept)	0.9411	0.5053	1.862
PL Length	-0.2348	0.1404	-1.672
AADT	0.0001	0.0000	4.599
Number Side Roads	-0.3850	0.3978	-0.968
Right Turn Bay	-0.0265	0.3494	-0.076
Terrain (gradient)	-0.0993	0.1647	-0.603
Intersection Lighting	-0.0794	0.3602	-0.221
Incr. Sight Distance	-0.0007	0.0017	-0.423
Decr. Sight Distance	-0.0010	0.0017	-0.620
Side of Side Road	0.2271	0.1313	1.730

Null Deviance: 2075.729 on 346 degrees of freedom
Residual Deviance: 1908.663 on 337 degrees of freedom
19 observations deleted due to missing values

Only AADT has a measurable effect on the number of crashes in the 'After' Passing Lane zone at the 95% confidence level, but PL length and Side of Side Road are significant at a 90% confidence level.

(E) Response : Number of Crashes 2004-08 in the 'entire' (Before+Mid+After) Passing Lane

Number of Crashes entire PL: ~ PL Length + AADT + Number Side Roads + Terrain + Intersection Lighting + Side of Side Road

Coefficients:

Parameter	Value	Standard Error	*t* value
(Intercept)	2.4655	1.6153	1.526
PL Length	-0.2497	0.4489	-0.556
AADT	0.0005	0.0001	5.018
Number Side Roads	0.4803	1.2715	0.378
Right Turn Bay	0.7102	1.1170	0.636
Terrain (gradient)	0.0609	0.5264	0.116
Intersection Lighting	-1.1589	1.1512	-1.007
Incr. Sight Distance	-0.0007	0.0054	-0.124
Decr. Sight Distance	-0.0059	0.0054	-1.086
Side of Side Road	0.8813	0.4197	2.100

Null Deviance: 21591.44 on 346 degrees of freedom
Residual Deviance: 19502.19 on 337 degrees of freedom
19 observations deleted due to missing values

AADT and Side of Side Road have a measurable effect on the number of crashes along the entire Passing Lane.

Appendix C Planning Policy Manual (PPM) extract

Appendix 3E– Passing and overtaking

Table App3E/4 - Long-term framework for passing and overtaking treatments

Projected AADT (vpd)	Road Gradient		
	Flat	**Rolling**	**Mountainous**
0-2,000	**Overtaking (OT)** (OT sight distance improvements, OT enhancements, possible isolated shoulder widening/crawler shoulder/SVBs[1]/short PLs.		
2,000-4,000	**Overtaking** (As above).	**Mainly OT, as above but possibly some SVB[1] or short PLs @ 10 km.**	
4,000-5,000 (General transition to PLs)	**Mainly OT, as above but possibly some SVBs[1] or short PLs @ 10 km.**	**PLs @ 10km** 1.2 km + tapers **& OT enhancements.**	**PLs @ 5 km** 1 km+tapers **& possible OT enhancements.**
5,000-7,000	**PLs @ 5 or 10 km[2]** 1.2 km + tapers **& OT enhancements.**		
7,000-10000	**PLs @ 5 or 10[2] km** 1.5 km + tapers **& OT enhancements.**		**PLs @ 5 km** 1.2 km+tapers **& possible OT enhancements.**
10,000-12,000 (General transition to 2+1 lanes)[3]	**PLs @ 5 km** 1.5 km + tapers **& possible OT enhancements**	**2+1 lanes (subject to four-lane comparison)**	**PLs @ 5 km** 1.2-1.5 km + tapers.
12,000-20,000	**2+1 lanes (subject to four-lane comparison).**		
20,000-25,000 (General transition to 4 lanes)			

Key – strategy type	**Overtaking**	**Mainly overtaking**	**Passing and overtaking**	**Passing**

Notes: 1. Where appropriate, a SVB is able to be easily altered to a short PL or PL at a later date.
2. Along the same road section, a mixed layout with 5 km spacings in higher demand locations and 10 spacings in lower demand locations.
3. For flat or rolling road gradient, the combination of passing lane length and spacing may not be sufficient to dissipate vehicle queues and a more frequent provision of passing opportunities would be required. Therefore, passing treatments, such as 2+1 lanes (subject to comparison with four-lanes), are likely to be required for state highways with a flat or rolling gradient and projected 10,000-25,000 vpd.
4. 10,000-12,000 vpd represents a general upper limit for passing lanes in series with flat or rolling gradient. Above this threshold, treatments such as 2+1 lanes (subject to comparison with four-lanes), are likely to be required. Some locations may have a higher upper limit of about 14,000 vpd depending on other factors, such as proportion of directional flow and traffic composition.

There will be some flexibility in determining the level of infrastructure and supporting measures for specific sections of state highway. Passing/overtaking demand may vary due to other factors (e.g. available overtaking sight distance, the length of affected state highway section and the proportion of HCVs) and this will be taken into account in determining the appropriate treatment. The provisions within the National State Highway Strategy may also affect some locations.

Temporary passing lane closure

Passing and 2+1 lanes may restrict overall traffic flow at times of high demand (typically 1,200-1,400 vph one way, depending on passing facility length), compared to single lane carriageways, because of delays at merge points. Transit may temporarily close passing lanes where this is predicted to occur (e.g. during holiday peak periods).

Note that the version 2 revision of the PPM was due for release at the end of 2010.

Appendix D Passing & Overtaking Guidelines extract

ATTACHMENT F. PLANNING NOTES **F/C. INTERSECTIONS & DRIVEWAYS**

Separation & Clear Sight Distance

Table F2 shows the separation and clear sight distance for passing facilities and overtaking zones relative to intersections and driveways. Most planning issues should be resolved by complying with Table F2.

Any distance less than the minimum specified distances within Table F2 does not necessarily mean that the location is unsatisfactory but should be assessed on a case-by-case basis with input from a road safety expert.

Supporting evidence may be required from the applicant to ensure than any reduced distance will be safe and not adversely affect the operation of the passing facility or overtaking zone.

Similarly, if the passing lane/slow vehicle bay is closer than the specified distances, Transit Regions applying for SAR approval of passing lanes or slow vehicle bays will be required to explain the basis of locating closer than the recommended distances, have input from a road safety expert and should have been considered within any safety audit process.

Table F2. Recommended Location & Sight Distance[1] Relative to Existing/Proposed Passing Facility or Overtaking Zone

Type of Access/ Intersection [2, 3, 4]	Before Diverge (upstream section) [5, 6]	Diverge [6]	Within PL or OT length	Merge [6]	AfterMerge (downstream section) [6, 7]
30 vpd or less access [7] (PPM Diagram C or D required).	At least 300 m before mid point of diverge taper.	Access not allowed. Case-by-case for access tapers.	From end of diverge taper to at least 300 m before merge taper ends At least crossing spacing separation.	Access not allowed.	Greater of at least 300 m after taper end OR crossing spacing.
31-100 vpd access (PPM Diagram D or E required).	At least 300 m before mid point of diverge taper.	Access not allowed.	From end of diverge taper to at least 300 m before merge taper ends. To be on the treated side & preferably located near middle.[8]	Access not allowed.	Greater of at least 300 m OR crossing spacing after taper end.
High-volume access, minor to collector District Roads (Priority controlled with shoulder widening or turning bays required).	Greater of at least 500 m OR crossing spacing before mid point of diverge taper.	Access not allowed.	Case-by-case. T-junction only. To be on the treated side and near the middle.	Access not allowed.	Minimum greater of at least 500 m OR crossing spacing after taper end. Preferred 1,000 m.
Major intersection between two SHs or SH and District arterial (Rural roundabout or grade-separation required)	Minimum 500 m before mid point of diverge taper for rural roundabouts. Preferred 1,000 m for grade separation.	Access not allowed.	Access not allowed.	Access not allowed.	Minimum 1,000 m after taper end. During interim strategy stage, preferred 5,000 m for 2+1 lanes & PLs.[9]

Notes.
1. Location distances assume clear sight distance. If clear sight distance is not available, location distance is to be increased.
2. Access and intersection capacity is to be based on projected flows over the next 25-30 years.
3. If an intersection treatment is required above what projected flows suggest, separation distances will be for the higher level type of access or intersection.
4. For all accesses up to 100 vpd, provide at least the safe intersection stopping distance (SISD) of 300 m approx sight distance in each direction, based on 110 km/hour operating speed at 2 second reaction time along the passing facility or overtaking zone. For all other cases, the entering sight distance (ESD) of 500 m is desirable, with SISD of 300 m approx as a minimum sight distance based on 110 km/hour operating speed.
5. Where overtaking in the untreated direction occurs or is likely to occur, avoid crossings in the untreated direction from 300 m upstream of opposite diverge taper start until 300 m downstream of opposite diverge taper start.
6. Consider possible adverse restriction on access for properties with short frontages within or close to diverge or merge areas.
7. Excludes farm gate access to paddocks or similar with occasional use less than once per day on average.
8. If there is/would be a high number of right turn movements (either in or out) across the passing facility, a central location is preferred.
9. During interim development stages for a road section, a separation of 5 or 10 km will enable downstream benefits to be maximised before encountering a major intersection.

H:\Passing and Overtaking Policy\Key Documents\Guidelines\Version 4\Attachment F Planning Notes V4 17-6-08.doc 9

Note that these draft guidelines have not been formally approved by NZTA and are currently unavailable (not posted on the NZTA website).

Possible Revised Table F2. Recommended Location[1] Relative to Existing/Proposed Passing Facility (or Overtaking Zones as Possible Future Passing Facility Sites)

Type of Access/ Intersection [2, 3, 4]	**Before Diverge (upstream section)** [5, 6, 10, 11, 13]	**Diverge** [6,]	**Within PL or OT Length** [10, 11, 12, 13]	**Merge** [6,]	**After Merge (downstream section)** [6, 7, 10, 11, 13]
30 vpd or less access[7] **(PPM Diagram C or D required).**	**Desirable** - At least 300 m before mid point of diverge taper. **Minimum** –Within upstream section.	**Desirable** - Access not allowed incl. tapers. **Minimum** - Case-by-case for access tapers.	**Desirable** - From end of diverge taper to at least 300 m before merge taper ends At least crossing spacing separation. **Minimum** – Within 300 m from merge, on case-by-case basis	Access not allowed.	**Desirable** - Greater of at least 300 m after taper end OR crossing spacing. **Minimum** –Within upstream section.
31-100 vpd access **(PPM Diagram D or E required).**	**Desirable** - At least 300 m before mid point of diverge taper. **Minimum** – Within upstream section, on case-by-case basis	Access not allowed.	**Desirable** - To be on the treated side & located near middle.[8] **Minimum** –From end of diverge taper (excluding access tapers) to at least 300 m before merge taper ends, on case-by-case basis, preferred on treated side.	Access not allowed.	**Desirable** - Greater of at least 300 m OR crossing spacing after taper end. **Minimum** –Within downstream section, on case- by-case basis, preferred on treated side.
High-volume access, minor to collector District Roads **(Priority controlled with shoulder widening or turning bays required).**	**Desirable** - Greater of at least 500 m OR crossing spacing before mid point of diverge taper. **Minimum** – For right hand T-junctions, 300 m approx before mid-taper point of diverge. For left hand T- junctions, 200 m approx.	Access not allowed.	**Desirable** - Left hand T-junctions only. To be on the treated side and near the middle to allow sufficient acceleration before start of merge. **Minimum** - Right hand T-junctions only with right turn bay, on case-by-case basis. Same location as for left hand T-junctions intersections. Right turn bay marking to start at least 500 m after start of PL excluding diverge taper. [13]	Access not allowed.	**Desirable -** Greater of at least 500 m OR crossing spacing after taper end. Use 1 km separation after merge taper end, if allowing for future grade separation. **Minimum** – For right hand T-junctions, 300 m approx after merge taper. For left hand T-junctions, 200 m approx.
Major intersection between two SHs or SH and district arterial **(Roundabout or grade-separation required)**	**Desirable -**Use 1 km if allowing for grade separation. **Minimum** - 500 m before mid point of diverge taper for T-junctions. For upstream rural roundabouts, on case-by –case basis.	Access not allowed.	Access not allowed.	Access not allowed.	**Desirable** Use 1 km after merge taper end for grade separation. During interim strategy stage, preferred 5-10 km for PLs and 3 km for 2+1 lanes.[9] **Minimum** 500 m separation for T-junctions. For rural roundabouts, on case-by-case basis.

Notes.
1. Location distances assume clear sight distance. If clear sight distance is not available, location distance is to be increased. AUSTROADS guidelines provide advice on intersection sight distance relative to the operating speed environment.
2. Access and intersection capacity is to be based on projected flows over the next 25-30 years
3. If an intersection treatment is required above what projected flows suggest, separation distances will be for the higher level type of access or intersection.
4. For all accesses up to 100 vpd, provide at least the safe intersection stopping distance (SISD) of 300 m approx sight distance in each direction, based on 110 km/hour operating speed at 2 second reaction time along the passing facility or overtaking zone. For all other cases, the entering sight distance (ESD) of 500 m is desirable, with SISD of 300 m approx as a minimum sight distance based on 110 km/hour operating speed.
5. Where overtaking in the untreated direction occurs or is likely to occur, avoid intersections and crossings in the untreated direction from 300 m upstream of opposite diverge taper start until 300 m downstream of opposite diverge taper start.
6. Consider possible adverse restriction on access for properties with short frontages within or close to diverge or merge areas.
7. Excludes farm gate access to paddocks or similar with occasional use less than once per day on average.
8. If there is/would be a high number of right turn movements (either in or out) across the passing facility, a central location is preferred.
9. During interim development stages for a road section, a separation of 3-10 km will enable downstream benefits to be maximised before encountering a major intersection.
10. For multiple intersections (including close spaced staggered T-junctions and cross roads) and right-hand intersections along and near to passing lanes and to a lesser extent OT zones, possible mitigating features include: avoidance during site selection, access controls for high-volume access crossings, eliminating intersection legs and restricting movements to left in and out using central median cables as AADTs increase.
11. The long-term layout table within the PO Policy provides advice on passing lane/SVB lengths relative to AADT, bearing in mind that the SVB length is restricted to about 300 m under MOTSAM. Where 600-800 m passing lanes are recommended, intersections within the passing lane should be avoided.
12. If right hand intersections are located within passing lanes, the provision of a right turn treatment is desirable. For upstream and downstream locations, the right turn treatment doesn't necessarily have to a right turn bay to be effective. AUSTROADS guidelines provide advice on the appropriate level of treatment, with respect to turning movements and safety criteria. Note that type B intersections are excluded within New Zealand.

Note that this provisional table was prepared by NZTA subsequent to the conclusion of the research study.