Safety Performance Assessment of Freeway Interchanges, Ramps, and Ramp Terminals

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ABSTRACT

The paper describes the development of new safety performance functions for interchanges, ramps and ramp terminals for Ontario freeways, using negative binomial regression modelling that relates collision frequency to traffic volumes and basic entity characteristics. Also presented is the application of these safety performance functions for network screening using two varieties of the potential for safety improvement (PSI) index method, one based on expected collision frequency and one based on expected collision frequency in excess of what is considered normal. The rankings of screened sites based on the two methods are compared. A third method, which is based on an index of a high proportion of a specific collision type, is applied to ramp terminals by way of illustration to identify those sites with high proportions of specific collision types. This method does not require safety performance functions or traffic volumes but does require the application of some fairly intricate statistical methodology. A comparison of the rankings so obtained with those derived by applying the PSI methods for a specific collision type suggests that the method of screening for high proportions of specific collisions can be a useful alternative to the PSI index method where safety performance functions and/or traffic volumes are not available since, unlike the PSI Index method, it does not require these inputs in doing network screening for specific collision types. This work has been developed as part of the continuing efforts of the Ministry of Transportation Ontario to establish a state-of-the-art knowledge base on the interaction of human factors, highway design and highway safety that can be put into practical use. The body of knowledge that is being assembled is referred to as the "The Science of Highway Safety".

INTRODUCTION

Rational road safety management requires the efficient screening of the road network to identify those elements (e.g., ramps, interchanges, ramp terminals) where there is a high potential for safety improvement. It is important that this process be efficient since an inefficient process could cause resources to be wasted on unsafe elements while safe ones are left untreated. Conventional techniques utilizing collision counts and/or rates, often in a statistical quality control framework, are not as efficient as desired. Using collision counts could produce a bias in favour of high-volume elements; and using collision rates could produce a bias in favour of low volume ones because of the inherent non-linearity in the relationship between collisions and traffic volume, a relationship that has been confirmed by numerous researchers. In addition, the regression-to-mean effect could result in elements with temporarily-high observed collision frequencies and/or rates to be incorrectly identified as unsafe, and vice-versa.

To overcome the difficulties with the conventional techniques, an approach based on operational or safety performance functions[1] has been developed as part of the continuing efforts of the Ministry of Transportation Ontario (MTO) to establish a state-of-the-art knowledge base concerning the interaction of human factors, highway design and highway safety that can be put into practical use. The body of knowledge that is being assembled is referred to as "The Science of Highway Safety". This approach compensates for random fluctuations in collision occurrence

[1] "Operational" performance function is a term used by MTO for what is commonly referred to as "Safety" performance function.

by using an empirical Bayesian technique that combines the collision count of an element with an estimate of its expected safety performance derived from a safety performance function (SPF). An SPF is a calibrated relationship between collision frequency, traffic volume and other characteristics of a site.

The selection and ranking of sites suitable for further investigation and treatment are based on a PSI_{index} (Potential for Safety Improvement Index) that was proposed and explored by Persaud et al. (1999). The PSI_{index} provides a measure of the how much a site can be improved with appropriate treatment. This index, in the existing MTO methodology, is the difference between a site's expected number of collisions and that expected at sites with similar characteristics, weighted to account for collision severity. (More recently, Hauer (2002) has suggested that the index should be merely the site's expected number of collisions rather that it's "excess" collisions).

This paper documents the data collection and SPF development, with illustrative network screening applications. In addition, for ramp terminals, SPFs for specific collision types are presented to enable a comparison to a pre-diagnosis procedure developed to identify those terminals with a high propensity for a particular collision type (e.g., left-turn, rear-end, angle). Of necessity, this paper is a summary. Further details on all aspects are given in (1)

PROJECT OVERVIEW

The main objectives of this project were to use data from 1997 to 2003 from Central, Southwest and Northeast Regions of Ontario as follows.

1. To develop SPFs for interchanges. These SPFs were for the mainline portion of the freeway within the influence zone of the interchange operation. Interchanges were combined into groups based on similar geometrics, and SPFs were developed for each group separately. The SPFs included models for fatal and injury collisions combined (F+I) and for property damage only (PDO) collisions.

2. To develop SPFs for different classifications of ramps as follows:
    i. Flared on ramps
    ii. Flared off ramps
    iii. Loop on ramps
    iv. Loop off ramps
    v. Freeway to freeway ramps
    vi. Flared and loop combined on ramps
    vii. Flared and loop combined off ramps
    viii. Other on ramps
    ix. Other off ramps

Note that ramps that split from the main ramps were placed in the "other" category.

3. To develop SPFs for ramp terminals. Ramp terminals were identified as the intersections where off-ramps meet the side road. Four categories of ramp terminals were identified:

i. Three-legged signalized ramp terminals
ii. Three-legged stop controlled ramp terminals
iii. Four-legged signalized ramp terminals where the 4th leg is the origin of an entrance ramp
iv. Four-legged stop-controlled ramp terminals where the fourth leg is the origin of an entrance ramp

4. To develop and apply a method to screen ramp terminals for high proportions of specific collision types. Separate rankings are produced for four categories of ramp terminals:
    i. Three-legged signalized ramp terminals
    ii. Three-legged stop controlled ramp terminals
    iii. Four-legged signalized ramp terminals where 4th leg is origin of entrance ramp
    iv. Four-legged stop controlled ramp terminals where 4th leg is origin of entrance ramp

5. To compare the ranking of ramp terminal sites based on the SPF screening method and the screening for high proportions method.

DATA COLLECTION

Data used in this study were taken from MTO's Central, Southwest and Northeast regions. In these regions, 311 interchanges, 1545 ramps and 380 ramp terminals had the minimum data required for SPF development and network screening, namely, traffic flows and collision counts from 1997 to 2003. Geometric, collision and traffic data compiled for this study are discussed under separate headings below.

Geometric Data

These data included interchange configuration, number of lanes on mainline, ramp length, number of lanes on ramp, ramp configuration, and configuration of exit ramp approaching the ramp terminal. A description of these elements follows.

<u>Interchange Configuration</u>

Each interchange location was identified by the unique identifier based on the linear highway referencing system (LHRS). The identifier is a 5-digit reference number followed by an offset distance from the starting point of the LHRS section.

The 11 types of interchanges as shown in Figure 1 were grouped into three logical categories to facilitate sufficiently large sample sizes for SPF development. These were:

Group 1: interchange types 1, 2, 4 and 8
Group 2: interchange types 3, 5 and 6
Group 3: interchange types 7, 9, 10 and 11

The influence length of each interchange was considered as one kilometer on either side of the interchange. However, where two interchanges were closely spaced (less than 2 kilometres), the influence length for each was taken as one half of the distance between them.

Number of Lanes on the Mainline

The number of lanes on the mainline refers to the total number of through lanes at the interchange in both the directions. Acceleration and deceleration lanes were not considered. The number of lanes on the mainline varied from four to eight.

Ramp Configuration

A total of 2,444 ramps were identified in the three regions for this study. The 16 configurations shown in Figures 2a and 2b were grouped into five logical categories to facilitate adequate sample sizes for SPF development. The ramp types in each group were as follows:

Flared ramps (Types 1, 4, 5 and 7): There were 797 ramps in this category. These ramps were further subdivided into on-ramps and off-ramps. There were 364 on-ramps and 433 off-ramps.

Loop ramps (Types 2, 3 and 6): There were 277 on-ramps and 121 off-ramps.

Freeway to freeway ramps (Type 8): These include those ramps that connect one freeway to the other freeway.

Flared and loop combined: Both flared and loop ramps were combined together in this group. This group contained 641 on-ramps and 554 off-ramps.

Others: This category included those ramps that did not fall into any of the above groups. These were mainly split ramps for which each portion was considered individually in the analysis. There were 89 on-ramps and 135 off-ramps.

Ramp ID

Ramps associated with a given interchange are identified by the LHRS number of the interchange and a unique 2-digit number used to identify the ramp at the interchange level. The first digit of the ramp ID identifies the origin direction and the second digit identifies the destination direction.

Ramp Length

Ramp length refers to the bullnose to bullnose distance of the ramp. These lengths were compiled by three methods.

1. GIS maps:

GIS maps were available from Central and Southwest Regions for scaling using GIS Arc Reader software. All the ramps of Southwest region and some of the Central Region ramps were scaled using the GIS Arc Reader software.

2. Scaling the hard copies of drawings:
Scaled hard copies of drawings were obtained from Northeast Region. These drawings were scaled using the digital scale master to determine ramp length.

3. Scaling ortho photos:
Ortho photos were obtained for most of the ramps in the Simcoe County of Central Region. These were scaled using a digital scale master to determine ramp length. However, in many cases these maps were not very clear, in which case method 2 was used to determine ramp length.

Number of Lanes on Ramp

The numbers of lanes on ramps were obtained from MTO in Excel format with the exception of some of the Northeast Region ramps, for which the determination was made by scaling hard copies of drawings. Where the ramp widths were greater than or equal to 7 meters, the number of lanes was assumed to be 2 and where the widths were less than 7 meters, the number of lanes was assumed as one. Most ramps had widths of 4.5 meters and 7.5 meters. The observed number of lanes ranged from one to three.

Ramp Terminal Configuration

Ramp terminals are defined as the intersections of exit ramps and the side roads. A total of 572 ramp terminals were identified in the three regions. Schematic diagrams of interchanges were used to identify the configuration of ramp terminals according to whether or not the approach was split to provide a slip lane for right turning traffic. There were 146 ramp terminals with this split ramps and 426 without.

Ramp terminals were further classified by number of legs and by type of traffic control. There were 409 three-legged ramp terminals while 163 were four-legged. 246 of the ramp terminals were signalized and 307 were stop controlled. No data on traffic control were available for 19 locations.

Collision Data

Collision data pertained to the mainline, ramps and ramp terminals. A description of each aspect follows. All the collision data for the purpose of this study were obtained electronically, extracted in Excel format. Separate files were obtained for mainline, ramp and ramp terminal-related collisions.

Mainline Collision Data

Mainline collision data from the three regions during the period 1997 to 2003 were obtained from MTO in Excel format. These data were classified by severity level. Collisions for each highway are recorded at an interval of 100 metres. A collision influence length of an interchange was considered to be one kilometre on either side of the interchange. Thus, collisions occurring within one kilometer on either side of an interchange were assigned to that interchange. However, several of the interchanges under study were closely spaced and had influence lengths less than 2 kilometres. In such cases, as noted earlier, the spacing between the interchanges was equally divided for the purpose of assigning collisions to the interchanges.

To have sufficient sample sizes for statistical analysis, mainline interchanges were grouped into three logical categories based on reasonable similarity in interchange configurations as described earlier. Data in each group were further divided into fatal and injury collisions and PDO collisions. A summary of each group of collision data is presented in Table 1.

Table 1 Summary Statistics of Mainline Collisions

	Sites	Total Collisions	Mean	Median	Min. Value	Max. Value	Variance
Group 1							
Total FI	136	4986	36.66	15.00	2	611	5560.37
Total PDO	136	16546	121.66	46.00	3	1304	42041.65
Group 2							
Total FI	105	10906	103.87	47.00	5	855	20852.04
Total PDO	105	39303	374.31	230.00	15	2474	203341.64
Group 3							
Total FI	70	3270	46.71	19.50	3	472	6982.21
Total PDO	70	12169	173.84	69.50	8	1625	94492.13

Ramp Collision Data

Ramp collision data were also made available in electronic in Excel format. These data consisted of ramp and ramp terminal-related collisions. There was no separate record of ramp terminal related collisions. However, the database showed the road locations where the collision occurred. After studying the collision reports and the collision database, it was decided that those collisions with road location coded as “intersection related” and “at intersection” were in fact ramp terminal related. These collisions were predominantly rear-end in type.

A separate ramp collision data file that contained only “intersection related” and “at intersection” collisions was obtained from MTO. Net ramp related collisions were calculated by excluding those collisions assumed to be ramp terminal related. Summary statistics of collision data associated with each ramp category identified earlier are presented in Table 2.

Table 2 Summary Statistics of Ramp Collisions

	No of Sites	Total Collisions	Mean	Median	Min. Value	Max. Value	Variance
Flared On-ramps							
Total FI	354	311	.88	0	0	13	2.2
Total PDO	354	1408	3.98	2	0	58	39.66
Flared Off-ramps							
Total FI	413	645	1.56	1	0	20	6.36
Total PDO	413	2645	6.4	3	0	65	69.86
Loop On-ramps							
Total FI	270	180	.67	0	0	5	1.04
Total PDO	270	824	3.04	2	0	25	14.76
Loop Off-ramps							
Total FI	116	130	1.12	0	0	10	3.85
Total PDO	116	503	4.34	2	0	46	45.06
Freeway to Freeway Ramps							
Total FI	124	409	3.3	1	0	33	29.48
Total PDO	124	1725	13.91	7	0	106	392.59
Flared and Loop Combined On-ramps							
Total FI	624	491	0.79	0	0	13	1.71
Total PDO	624	2232	3.58	2	0	58	29.05
Flared and Loop Combined Off-ramps							
Total FI	529	775	1.47	1	0	20	5.84
Total PDO	529	3148	5.95	3	0	65	65.06
Other On-amps							
Total FI	87	15	0.17	0	0	6	0.52
Total PDO	87	86	0.99	0	0	17	6.03
Other Off-ramps							
Total FI	134	37	0.28	0	0	5	0.56
Total PDO	134	169	1.26	0	0	15	5.91

Ramp Terminal Collision Data

As mentioned earlier, there were no separate data for ramp terminal related collisions, so these were assumed to be those that occurred “at the intersection” or that were identified as “intersection related”. Summary statistics of these data are presented in Table 3.

Table 3 Summary Statistics of Ramp Terminal Collisions

	Sites	Total Collisions	Mean	Median	Min. Value	Max. Value	Variance
3-legged Signalized Ramp Terminals							
Total FI	140	565	4.03	2	0	33	31.85
Total PDO	140	2669	19.06	14	0	84	361.35
3-legged stop controlled Ramp Terminals							
Total FI	124	77	0.62	0	0	6	1.31
Total PDO	124	276	2.22	1	0	16	9.37
4-legged Signalized Ramp Terminals							
Total FI	23	120	5.21	3	0	22	31.72
Total PDO	23	436	18.95	12	0	62	341.95
4-legged Stop Controlled Ramp Terminals							
Total FI	20	10	0.5	0	0	3	0.68
Total PDO	20	29	1.45	1	0	6	2.16

A separate set of data was prepared for screening ramp terminals based on a high proportion of a specific collision type. These data were also of type “intersection related” or “at intersection” and were categorized by 9 initial impact types.

Traffic Volume Data

Traffic volume data pertained to the mainline, the ramp and the ramp terminals. A description of each aspect follows. Traffic volume data for the mainline were available in the Excel format and for ramp and ramp terminals in hard copies. For the mainline, the average annual daily traffic (AADT) from 1997 to 2002 was available and for ramps and ramp terminals, AADTs from 1997 to 2004 were available.

Mainline Traffic Volume

The mainline AADTs for the period of 1997 to 2002 were extracted from the provincial volume data file which contains the AADTs of all locations under MTO’s jurisdiction. All the traffic volumes were in terms of AADT. These traffic volumes referred to flows in both directions at the interchange locations. Mainline interchanges were grouped in three main categories as described earlier. In group 1, there were 136 interchanges with a mean AADT of 82,194, minimum AADT of 8,833 and maximum AADTs of 383,833. Group 2 had total of 105 interchanges with mean, minimum and maximum AADTs of 135,374, 9,250 and 428,633 respectively. Likewise, group 3 had a mean AADT 85,157, and minimum and maximum AADTs being 6,858 and 373,000 respectively.

Ramp Traffic Volume

All of the ramp traffic volumes were extracted and compiled from the hard copy data obtained from the MTO regional traffic offices. The ramp traffic volumes were either in the form of average daily traffic (ADT) or average weekday (AWD) traffic. In some cases 8-hour turning movement counts were used to get the ramp volumes. ADT and AWD were converted to AADT by using MTO's conversion factors. These factors vary, depending on the location and time of year. The AADTs used in the models were the average of all available AADTs during the study period. Table **4**4 summarizes the AADT characteristics of each ramp group.

Table 4 Summary of Ramp Volume Data

Ramp type	No of ramps	Mean AADT	Min. AADT	Max. AADT
Flared	797	6199	63	62842
Loop	398	4787	40	33543
Freeway to freeway	126	12170	320	43692
Flared & loop	1195	5728	40	62842
Others	224	4368	13	24934

Ramp Terminal Traffic Volume

Traffic volumes used in the ramp terminal models were obtained from 8 hour turning movement counts available in hard copy format for the period from 1997 to 2004. The turning movement counts were used to calculate the approach volumes. Total approach volumes for the cross roads and the ramps were calculated separately. Ramp approach volumes included the sum of approach volumes from ramp and service roads, where these exist. The cross road approach volume consisted of the sum of approach volumes from two approaches of the side road. All the turning movements were in 8-hour counts (from 7 hr to 11 hr and 15 hr to 19 hr). 8-hour counts were converted into AADT using a conversion factor of 2.3. This factor was estimated from continuous hourly counts on the mainline for a month at two locations on Highway 401 and the QEW. A summary of ramp terminal volumes in each group is presented in Table 5.

Table 5 Summary of Ramp Terminal Volumes

Terminal type	Sites	Avg. approach AADT		Min. approach AADT		Max. approach AADT	
		Ramp	Cross-road	Ramp	Cross-road	Ramp	Cross-road
3-legged signalized	140	13641	39972	1148	7360	57590	116969
3-legged stop controlled	124	3261	13171	83	283	14552	65801
4-legged signalized	23	11351	37452	1971	8793	34677	76431
4-legged stop controlled	20	4026	10997	1394	4384	11495	31756

SPF DEVELOPMENT

SPF parameters were estimated using the SAS statistical analysis software. The key variables used in the models were traffic flow, segment or ramp length and some dummy variables for geometric configurations. This section summarizes the SPFs developed for mainline segments, ramps and ramp terminals.

Mainline SPFs

The mainline SPFs are of the form:

$$Collisions / year = a(AADT)^{b}\ e^{c(length)}$$

where length is measured in kilometres and, a, b and c are parameters estimated from data using SAS, which also estimates ϕ an overdispersion parameter that is such that, for a given dataset, the smaller value of ϕ is, the better is the model fit.

Table 6 provides the parameter estimates and standard errors of these for each group.

Table 6 Parameter Estimates of Mainline SPFs

Collision Type	Parameter	Group 1 (133 Sites)		Group 2 (104 Sites)		Group 3 (70 Sites)	
		Estimate	Std. error	Estimate	Std error	Estimate	Std error
FI	ln(a)	-7.0564	0.7881	-10.9230	0.6720	-10.0818	0.9062
	b	0.7732	0.0578	1.1302	0.0484	0.9898	0.0685
	c	0.1407	0.1780	0.1801	0.1617	0.5680	0.2002
	ϕ	0.2634	0.0369	0.1632	0.0251	0.3072	0.0563
PDO	ln(a)	-8.4681	0.6107	-11.3698	0.6222	-10.6217	0.8347
	b	0.9949	0.0467	1.2212	0.0459	1.1301	0.0639
	c	0.2834	0.1292	0.5871	0.1409	0.7248	0.1831
	ϕ	0.1784	0.0233	0.1458	0.0208	0.2944	0.0500

Ramp SPFs

The ramp SPFs are of the form:

$$Collisions / year = a(AADT)^{b}\, e^{c(length)}$$

where length is measured in kilometres.

Table 7 provides the parameter estimates and standard errors of these for each group, including the estimated overdispersion parameters.

Table 7 Parameter Estimates of Ramp SPFs

Collision Type	Parameter	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
		Flared On-ramps (354 Sites)		Loop On-ramps (270 Sites)		Flared and Loop Combined On-ramps (624 Sites)	
FI	ln(a)	-8.9013	0.7744	-8.4405	0.8568	-8.7880	0.5826
	B	0.7962	0.0883	0.6741	0.0987	0.7561	0.0664
	C	0.0968	0.3422	1.2251	0.4130	0.5259	0.2910
	ϕ	0.6617	0.1508	0.2939	0.1522	0.5665	0.1116
PDO	ln(a)	-7.4134	0.5149	-6.0394	0.492	-6.8203	0.3589
	B	0.7535	0.0579	0.5630	0.0573	0.6717	0.0410
	C	0.9483	0.3487	1.3569	0.3201	1.1316	0.2386
	ϕ	0.8262	0.0920	0.4623	0.075	0.6863	0.0611
		Flared Off-ramps (413 Sites)		Loop Off-ramps (116 Sites)		Flared and Loop Combined Off-ramps (529 Sites)	
FI	Ln(a)	-9.1476	0.5910	-8.3723	1.2133	-8.9626	0.5258
	b	0.8510	0.0662	0.7002	0.1425	0.8148	0.0592
	c	0.3564	0.3206	1.4753	0.7227	0.6489	0.3036
	ϕ	0.6073	0.1034	1.2532	0.3874	0.7158	0.1058
PDO	Ln(a)	-8.0417	0.3645	-8.1072	0.7905	-8.0689	0.3306
	b	0.8911	0.0415	0.8478	0.0932	0.8847	0.0037
	c	0.1980	0.1877	0.9718	0.5124	0.3426	0.1870
	ϕ	0.3796	0.0430	0.6811	0.1427	0.4357	0.0431
		Freeway-Freeway ramps (124 Sites)		Other Off-ramps (87 Sites)		Other Off-ramps (134 Sites)	
FI	Ln(a)	-8.3446	0.9828	-12.8018	3.5616	-10.5913	2.1429
	b	0.7742	0.1055	1.0653	0.4019	0.8505	0.2453
	c	0.4447	0.2457	0.9403	4.7567	2.5585	4.7026
	ϕ	0.9077	0.1872	2.6718	2.1477	1.9855	1.04
PDO	Ln(a)	-7.8696	0.7589	-6.5062	1.142	-8.7222	1.259
	b	0.8694	0.0820	0.4832	0.1376	0.7763	0.144
	c	0.5529	0.2129	4.9637	2.4673	5.1396	2.9624
	ϕ	0.7466	0.111	1.489	0.5102	1.403	0.365

Ramp Terminal SPFs

SPFs were estimated for the following four ramp terminal categories:
1) Three-legged signalized ramp terminal
2) Four-legged signalized ramp terminal
3) Three-legged stop controlled ramp terminal
4) Four-legged stop controlled ramp terminal
For categories 1 and 2, the SPF form is:

$$Collisions / year = a(AADTramp)^b (AADTcross)^c e^{d(split)}$$

For categories 3 and 4, the SPF form is:

$$Collisions / year = a(AADTtotal)^b e^{c(split)}$$

where AADTcross is the sum of approach volumes from two approaches of the side road
AADTramp is the sum of approach volumes from ramp and the service roads
AADTtotal is the total AADT approaching the terminal from all approaches
'split' is a dummy variable taking a value of zero if the approach ramp is non split and 1 if the approach ramp is split.

Table 8 provides the parameter estimates and standard errors of these for each group, including the estimated overdispersion parameters.

Table 8 Parameter Estimates of Ramp Terminal SPFs

Collision Type	Parameter	3-Legged Signalized (140 Sites)		4-Legged Signalized (23 Sites)		3-Legged and 4-Legged Stop-Controlled (144 Sites)	
		Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
FI	ln(a)	-12.7762	1.9129	-17.1286	3.9417	-6.9588	1.9920
	b	0.6187	0.1776	0.7150	0.2558	0.5028	0.2077
	c	0.6114	0.1946	0.9685	0.4299	-1.1066	0.3405
	d	-0.7555	0.1478	-2.4316	1.0432	1.173	0.4364
	ϕ	0.8132	0.1072	0.1501	0.1235	-6.7506	1.2659
PDO	ln(a)	-11.5143	1.312	-14.4269	4.1520	0.6087	0.1319
	b	0.7360	0.1123	0.9566	0.2382	-1.0104	0.1976
	c	0.5351	0.1181	0.6219	0.4321	0.5499	0.124
	d	-0.7636	0.1465	-1.3896	0.4710	-	-
	ϕ	0.4257	0.0606	0.3328	0.1418	-	-

An SPF was also developed for 'angle' and 'turning' collisions combined at 3-legged signalized ramp terminals. The SPF was of the form:

$$Angle\ plus\ Turning\ Collisions / year = a(AADTramp)^b (AADTcross)^c e^{d(split)}$$

where,

AADTramp refers to the AADT at the ramp approach;
AADTacross refers to the AADT at the cross road; and
"split" is a dummy variable that is 0 for ramp terminals without a split ramp and 1 for those with split ramps

The SPF parameter estimates and standard errors of these, including the estimated overdispersion parameter are shown in Table 9.

Table 9 Parameter Estimates for Ramp Terminal Collision Models at 3-legged Signalized Ramp Terminals Considering ‘Turning’ and ‘Angle’ Collisions’

Parameter	Estimate	Std. Error
ln(a)	-9.5549	1.7852
b	0.3359	0.1522
c	0.6425	0.1716
d	-1.222	0.2046
ϕ	0.6258	0.0981

ILLUSTRATIVE NETWORK SCREENING APPLICATION

For this illustration, 3-legged signalized ramp terminals were ranked by the potential for safety improvement (PSI) method with respect to their frequency of angle and turning collisions in ten 5 year period. The rankings so obtained are compared to those obtained by a method that estimates the probability of the site having a high proportion of this collision type and ranks sites by this “pattern score”. Full details of this probability estimation process are provided in (1), based on theory originally presented in (4).

The SPFs presented in Table 9 were used in the PSI method to rank the 144 three-legged signalized ramp terminals with respect to angle and turning collisions combined. In this method, an empirical Bayes (EB) collision frequency is calculated as a weighted average of the SPF prediction and the collision count at the site. In one variation of the PSI method, sites are ranked by this EB expected frequency. In another variation, sites are ranked based on an EB expected excess frequency, calculated as the difference between the EB estimate and the SPF estimate. Full details are provided in (1) and in other sources (2).

As mentioned above, the rankings by the two PSI methods were compared to that obtained by a method that ranks sites by the probability of having a high proportion of angle and turning collisions. The 144 terminals had a total of 1206 such collisions in the 5 year period, constituting 29.6% of all collisions.

Table shows a comparison of ranking by the three different methods for the sites subjected to this ranking procedure comparison. The second and third columns show the ranking by the PSI methods for the top 10 sites ranked by the pattern score method. It is seen that 7 of the 10 sites ranked highest by the pattern score method and by the PSI excess method were the same. However, by the PSI expected ranking method, only 4 of the10 top ranked sites matched the ranking based on the pattern score. Based on the site and collision types considered for comparison, the ranking by PSI excess method currently adopted by MTO and that by pattern score method gave reasonably consistent results. Hence, the pattern score could be a reasonable alternative to the PSI excess method for site screening for specific collision types, which is convenient since for the pattern score method, neither traffic volumes nor SPFs are required – only collision counts.

Table 10 Ranking Comparison of Turning and Angle Collisions at 3-legged Signalized Ramp Terminals Based on Three Different Methods

Ranking of sites by Pattern Score	Ranking of the pattern score top sites by PSI "Excess" Method	Ranking of the pattern score top sites by PSI "expected" Method
1	1	2
2	20	21
3	6	3
4	2	1
5	15	16
6	7	15
7	14	24
8	8	18
9	10	11
10	7	7

References

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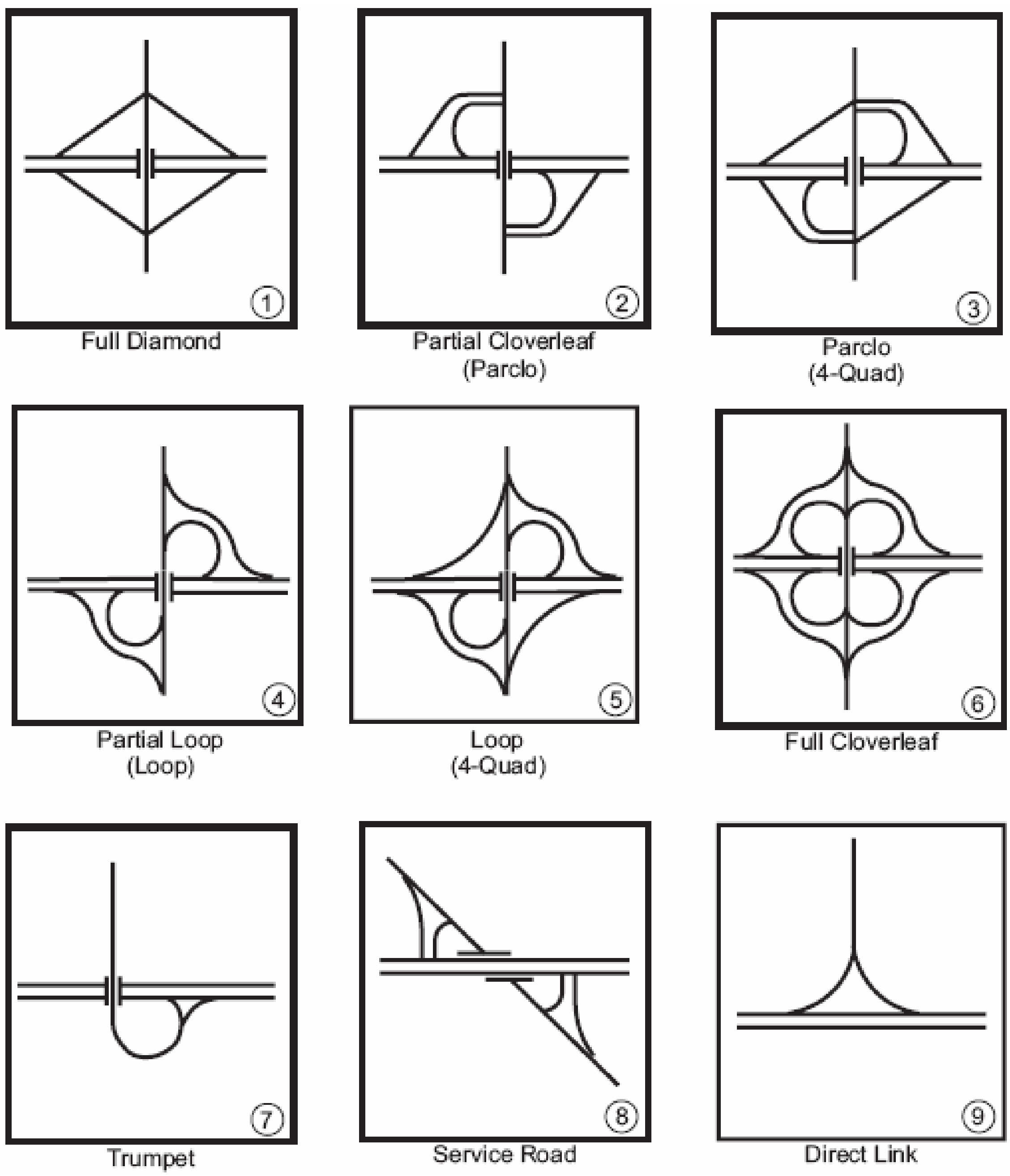
2. Hauer, E (2002): Screening the Road Network for Sites with Promise, Transportation research Record 1784, Washington D.C.

3. Bahar, G. and Persaud, B. (2000), Prioritization of Central Region Interchanges and Ramps Final Report, Ministry of Transportation, Toronto.

4. Heydecker, B. J. and Wu, J. (1991), Using the Information in Road Accident Records, Proceedings, 19th PTRC Summer Annual Meeting, London.



Any combination of two ramps that is not identified as a typical ramp according to other ten categories
(10)

Freeway to Freeway Interchanges
(11)

Figure 1 Interchange configurations
Source: Reference (3)

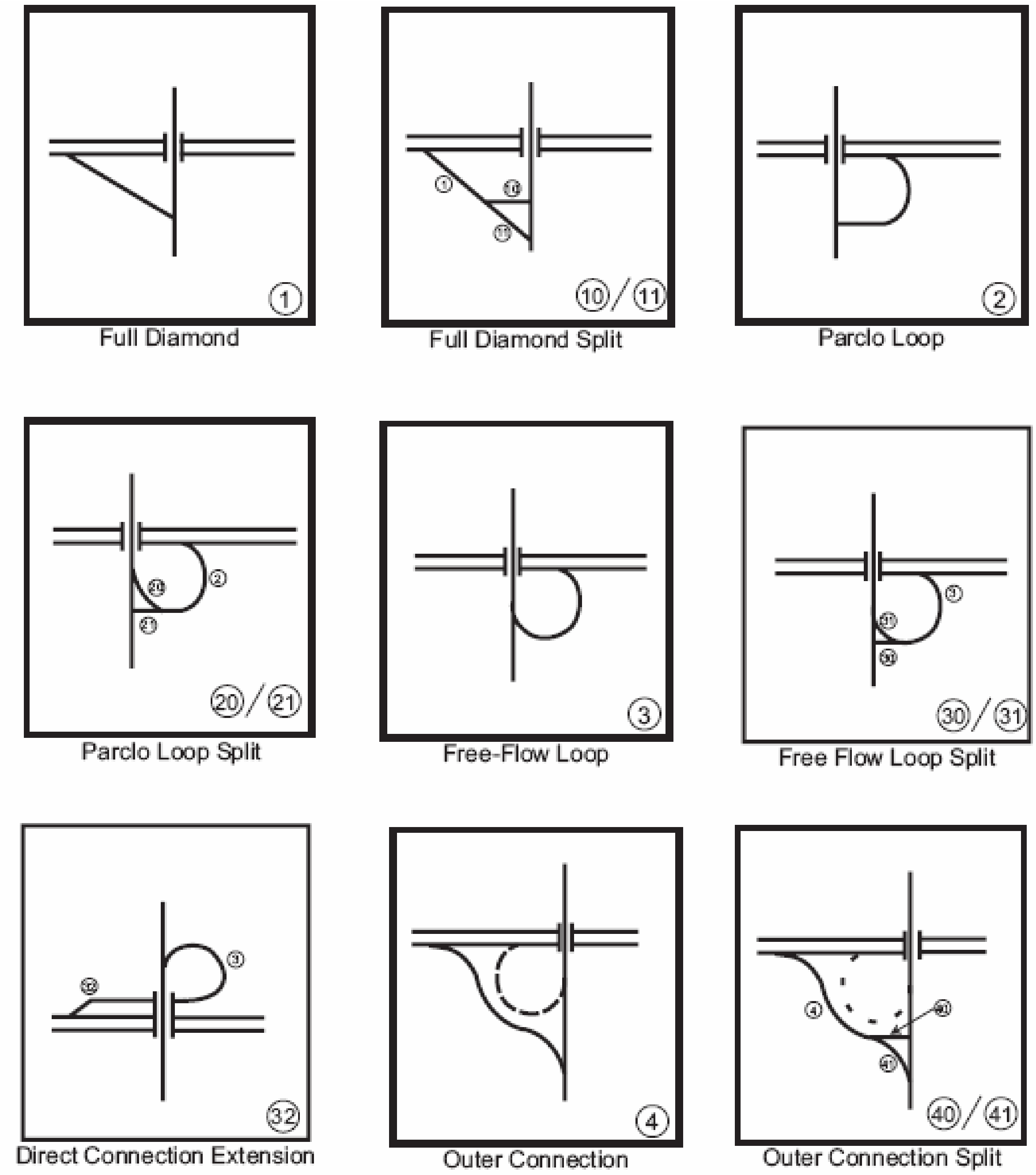


Figure 2 (a) Ramp configurations – Part 1
Source: Reference (3)

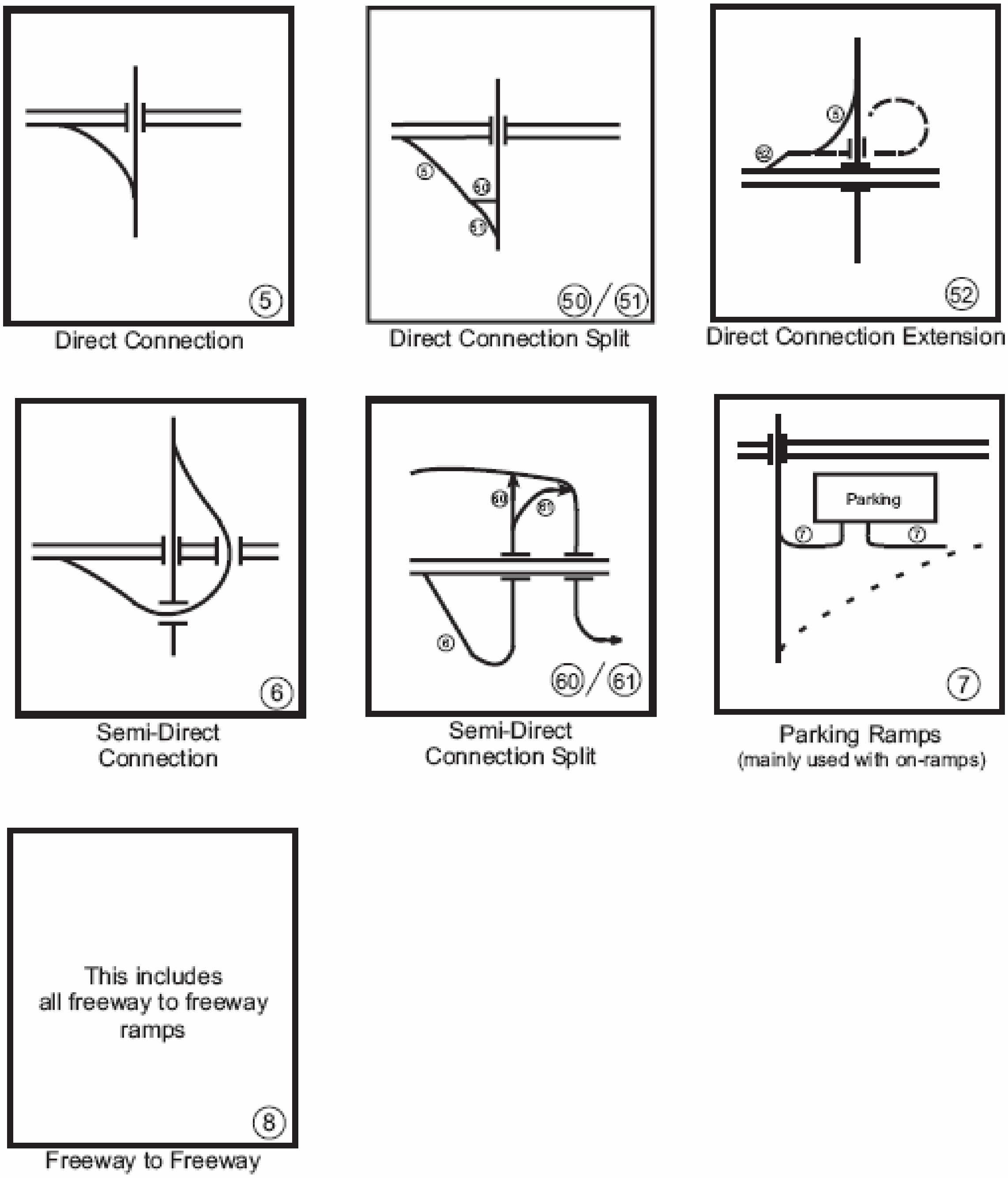


Figure 2 (b) Ramp configurations – Part 2
Source: Reference (3)