Crash Comparison of Single Point and Tight Diamond Interchanges

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Abstract: Although the single point interchange (SPI) has been around for approximately 3 decades, very few attempts have been made to evaluate its safety performance with a similar configuration, the tight diamond interchange (TDI). This paper provides a crash comparison between the TDI and the SPI interchanges for intersection related crashes on the cross road only. The SPIs considered in this study are without frontage roads. Data from 27 diamond interchanges (DIs) in Washington were used in building a negative binomial model to predict total crashes and injury/fatality based on the off-ramp flow, cross-road flow, and separation distance between left and right ramp terminals. Crash analysis of 13 SPI sites was used to compare with newly developed crash models of diamond interchanges. Wilcoxon signed-rank test was applied for safety comparisons between the SPI and TDI. The safety comparison did not reveal a significant difference between the two types of interchanges neither for total crash. However, the single point urban interchanges were found to be safer than the comparable DIs for injury/fatality frequencies.

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CE Database subject headings: Traffic accidents; Comparative studies; Interchanges; Traffic safety.

Introduction

Only one reference could be located comparing crash data of single point interchange (SPI) and diamond interchanges (DI), (Garber and Smith 1996). The study analyzed crashes at the intersection center, the on and off ramps, and the cross road of eight SPIs from four states and five DIs from three of the same states. Crashes were not classified as intersection related. Based on total crash rates (per million entering vehicles), a t-test could not reject the hypothesis of equality of crash rates of the SPI and DI. However, when taken separately, the proportion of on ramps, and off-ramp crashes are greater at the SPI. Crashes at the center of intersections are greater at DIs. The proportion and rates of rear-end and angle accidents are higher at DIs. A very recent paper by Bared et al. (private communication 2003) carried out a traffic analysis comparison between comparable geometric designs of single point urban interchange (SPUI) and tight diamond interchange (TDI) for multiple traffic scenarios in *CORSIM*. Results show that in general, when the flows are high [starting at 3,000 vehicles per hour (vph) total highest entering flows] a typical SPI will have lower control delay, stop time, and percent stops than a TDI. Significantly higher percent stops are estimated for TDIs because vehicles are more likely to slow down or stop at both signalized intersections of the TDI than at the single crossing of an SPI. The objective of this paper is to provide a crash comparison between the DI and SPI interchanges on the cross road only for intersection related crashes.

Characteristics of Single Point Interchange and Tight Diamond Interchange

The SPI illustrated in Fig. 1 is also known as the SPUI. It is similar to the TDI except that the ramp terminals are joined into one crossing with one signal. It is characterized by the ability to allow concurrent off-ramp left turns.

The TDI illustrated in Fig. 2 is characterized by two closely spaced intersections where the ramps terminate at the cross street. Generally, these ramps are perpendicular to the cross street. Two coordinated traffic signals are used one at each intersection.

In general diamond interchanges are the most common type of design, while SPIs are still gaining popularity. Tight diamond interchanges with off-ramp terminal offsets ranging from 200 to 400 ft are an alternative to the SPI with reduced construction cost and limited right-of-way requirements.

Methodology for Safety Analysis

In this study data were collected for 13 SPI sites (without frontage roads) from four states: Maryland (five sites), California (three sites), Missouri (three sites), Washington (one site), and Virginia (one site). Since crash data for comparable TDI or diamond interchange (DI) sites were not available, prediction models for total, and injury/fatal crashes were developed using Washington data. The sample size is composed of 27 typical DI sites from the State of Washington that include a few tight diamond interchanges. Data for DIs were acquired from the Highway Safety

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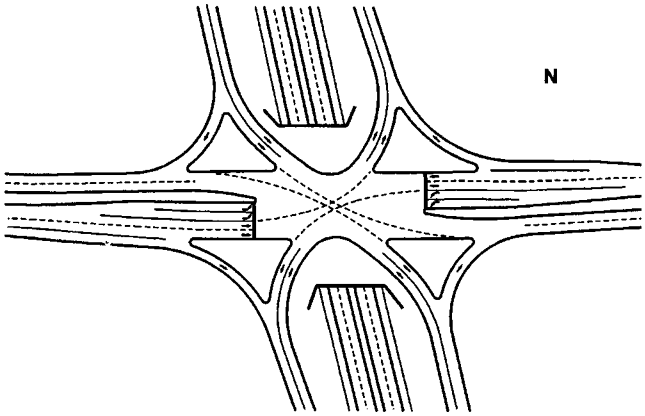

Fig. 1. Single point urban interchange (from Selinger and Sharp 2000, Institute of Transportation Engineers, used with permission)

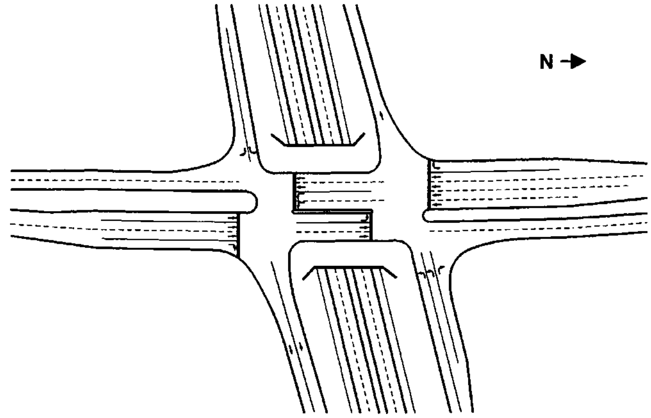

Fig. 2. Tight urban diamond interchange (from Selinger and Sharp 2000, Institute of Transportation Engineers, used with permission)

Information System in the Federal Highway Administration Office of Research and Development. Negative binomial models were fitted for crashes in relation to entering average daily traffic (ADT) on the cross road and the off ramps, and the ramp separation distance. For both samples of the DI and SPI, the considered crashes are strictly intersection related. The aggregate models from *SAS* are presented in Table 1.

Although the DI sample includes both urban (14sites) and rural (13 sites), and signalized (14 sites) and nonsignalized (13 sites) locations, the variables reflecting these differences were not significant in the modeling effort. The DI models for total, and fatal/injury crashes seem to have reasonable goodness-of fit based on the overdispersion parameters and the scaled deviance. The coefficients of the intercept and the ADT product are very significant.

All 13 SPI sites have three-phase signals, and the durations of crash data depended on the years of service and availability. For all Maryland and the Virginia sites (six), we collected hourly traffic volumes and converted them to ADT based on daily flow distribution from a Maryland State Highway Administration's report on traffic trends. The limitation of the sample is in combining data from various states. This implies some uniformity across states related to reporting, spatial, and temporal conditions. The assumption is necessary because of the dearth of typical SPI sites within one state. None of the 13 SPI sites allow through traffic from the off ramps onto corresponding on ramps. Table 2 shows only left-turn ADT for the six sites in Maryland, Virginia, and Missouri because the bypass lanes are removed from the main crossing of the ramp terminal with the cross road.

The safety analysis is conducted by comparing the observed crashes of the SPI sites with corresponding expected crashes derived from the models for diamond interchanges. Table 2 shows this comparison including data for all 13 sites of ADT on the cross road and entering flows from the off ramps.

Results and Conclusions

Most tests require certain assumptions of sample or population data distribution such as normal distribution. For less-stringent assumptions that cannot meet specific distributions, statisticians have developed what is known as nonparametric tests. A nonparametric Wilcoxon signed-rank test is applied to verify a hypothesis that the differences between the expected crashes of diamond interchanges minus the corresponding observed crashes of the SPIs are equal to zero ($\mu=0$ at the 0.05 level of significance).

The "Wilcoxon test for paired observations" proposed in 1945 by Wilcoxon is more sensitive than the sign test in detecting a difference in the population means. The sign test shows, by the assigned plus or minus sign, which member of a pair of observations is the larger, but it does not indicate the magnitude of difference. To test the hypothesis that $\mu=0$ using the Wilcoxon test, we first discard all differences equal to zero and then rank the remaining differences without regard to sign. When the absolute value of two or more differences is the same, we assign to each the average ranks that would have been assigned if the differences were not distinguishable. If there is no difference between the two population means, the total of ranks corresponding to the positive differences should be almost equal to the total of ranks corresponding to the negative differences. Representing the smaller of these totals by T, we find the probability of obtaining by chance

Table 1. Negative Binomial Model for Diamond Interchange Crossing

Variables (offset number of years)	Total crashes Coefficient	Total crashes Standard error	Total crashes *P* value	Injury/Fatal Coefficient	Injury/Fatal Standard error	Injury/Fatal *P* value
Intercept	$I=-8.6709$	1.5	0.00	$I=-9.5652$	1.89	0.00
Log of ($ADT_{cross} \times ADT_{off\text{-}ramps}$)	$a=0.5499$	0.08	0.00	$a=0.5571$	0.10	0.00
Dispersion	0.33	—	—	0.45	—	—
Scaled deviance	1.20	—	—	1.26	—	—

Note: ADT=average daily traffic; $A_D=N\ (ADT_{cross} \times ADT_{off\text{-}ramps})^a$ expo (I) where A_D=expected number of intersection related crashes at the cross road of a diamond interchange; I=intercept; N=number of years; ADT_{cross}=entering ADT on the cross road; and $ADT_{off\text{-}ramps}$=entering ADT on the off ramps.

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Table 2. Crash Comparison of Single Point Interchange (SPI) Sites and Expected Crashes of Corresponding Diamond Interchanges (DIs)

				SPI observed		DI expected	
SPI sites	Years of data	AADT cross street	AADT off-ramps	Total crashes	Injuries/fatal crashes	Total crashes	Injuries/fatal crashes
MD-A	6	16,685	7,755	7	1	29.7	13.9
MD-B	6	27,326	11,311	40	6	48.0	22.6
MD-C	3	29,175	7,289	11	6	19.5	9.2
MD-D	6	38,982	9,382	9	4	52.6	24.8
MD-E	3	21,004	7,640	4	2	16.7	7.8
WA	4	11,361	4,644	31	10	12.1	5.6
VA	5	31,848	7,071	58	20	33.6	15.8
CA-A	4	16,500	9,935	33	10	22.6	10.6
CA-B	6	6,600	6,079	7	4	15.6	7.2
CA-C	4	4,500	2,221	2	1	4.8	2.2
MO-A	1	42,540	13,310	3	0	11.2	5.3
MO-B	3	40,016	10,541	98	21	28.5	13.4
MO-C	3	52,395	22,460	59	16	50.0	23.8

Note: AADT=annual average daily traffic; MD=Maryland; WA=Washington; VA=Virginia; CA=California; and MO=Missouri.

alone, a value less than or equal to T when H_0 is true (Walpole and Myers 1978).

The analysis result for total crashes is $T=45>T_{0.05}=21$. It means we cannot reject the hypothesis that total crash frequencies of the DI and SPI are comparable. However, we have to reject the hypothesis stating similarity of injury/fatal crashes between the DI and SPI since $T=20<T_{0.05}=21$. When the right-turn ADTs for the Maryland, Virginia, and Missouri sites are included in the off-ramp ADT, total crashes are still not significantly different for the two interchange types, $T=24>T_{0.05}=21$. However, we have to reject the hypothesis stating similarity of injury/fatal crashes between the DI and SPI since $T=9<T_{0.05}=21$. When adding right-turn ADT, the crashes at DIs increase due to higher flows and absence of channelization for the right turning traffic from the off ramps and the fact that the bypass lanes are generally shorter than at SPIs. Besides, most SPIs have acceleration lanes for corresponding off-ramp right turns. In addition, most DIs allow through traffic from off to on ramps adding crossover movements that may cause more severe angle collisions.

The conclusion is that for a limited sample size of 13 SPI sites, observed total crash frequency of SPIs compared to corresponding expected total crash frequency of DIs reveals no significant crash difference between the two types of interchange. Nevertheless, observed injury/fatality frequency of SPIs compared to corresponding expected injury/fatality frequency of DIs does reveal a significant crash difference between the two types of interchange. Out of the 13 sites, between 10 and 11 SPIs (corresponding to cases without and with addition of right-turning ADT volumes) had fewer crashes than DIs. Although the sample of injury/fatal crashes is smaller, it is trustworthier when combining data from several states because injuries are more likely to be reported than property damage only.

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