EFFECTS OF ROADWAY GEOMETRY CONDITIONS ON HEAD-ON COLLISIONS

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1. Introduction

Many studies have addressed the relationship between traffic and geometric variables and accident frequency but few studies have tried to address the causes of head-on collisions. The factors causing such accidents vary considerably as the causes for the accident type are numerous and level of severity that they cause remains different. Head-on collisions are the most fatal traffic accidents in Hokkaido as compared to the proportions of the accidents. A study on the effects of road conditions and drivers' attention on head-on collisions in Hokkaido indicates that slippery and rutted road surfaces were major factors contributing to crossing the centerline in winter[5.] The objective of this study is to develop a statistical model to determine the effects of annual average daily traffic volume, the location of the highway (urban or rural), curve radius, grade, shoulder width and number of lanes on head-on collision frequencies on national highway route 5 (NR-5) in Hokkaido. Poisson regression models were used to evaluate the effects of the traffic and highway features on the number of head-on collisions.

2. Methods

2.1 Poisson Regression Models

The relationship between traffic and geometric variables and accident occurrences has been the focus of many researchers and their findings have been influential in citing the specific countermeasures for the problems identified. A study by Wong and Nicholson (1992) indicates that modifications to roadway geometrics were important because of the strong association between adverse geometric elements and high accident locations[7]. Miaou and Lum (1993) evaluated the statistical properties of two conventional and linear regressions models to determine their suitability for modeling vehicle accidents and highway geometric design relationships. They concluded that the Poisson regression models possessed the most desirable statistical properties in describing vehicle accident events, but noted the limitation of the model in that the variance of the accident data is constrained to be equal to the mean[4]. According to Cameron and Trivedi (1986) [1], count data (such as traffic accidents) are often modeled by assuming poisson distributions[1]. The Poisson distribution is a useful starting point because (i) it lends itself well to the modeling of count data by virtue of its discrete, nonnegative integer distribution characteristics and (ii) can be generalized to more flexible distributional forms of regression models. Another problem associated with Poisson regression is the implicit assumption that there is no unobserved heterogeneity in the data. Overdispersion, which occurs when the variance of the accident frequency data is greater than its mean, can result in a biased model coefficients and erroneous standard errors. The biased coefficients can result in an under or overstatement of accident likelihood. They also point out that the negative binomial or the double poisson distributions must be used to overcome the overdispersion concern. When the overdispersion parameter (α) is not significantly different from zero, the Poisson model remains acceptable [(2,3,6)].

For the Poisson model, the probability of having a specified number of accidents at some road section $i\ (n_i)$ per year (where n_i is a nonnegative integer) is

$$P(n_i) = \frac{\exp(-\lambda_i)\lambda_i^{n_i}}{n_i!} \qquad (1)$$

Where $P(n_i)$ = probability of an accident occurring on road section i, n_i times per year; and λ_i = Poisson parameter for the road section i, which is equal to the road section i 's expected accident frequency per year [i.e.; $E(n_i)$].

$$\ln \lambda_i = \beta_i X_i + \beta_0 \qquad (2)$$

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Where X_i = a vector of explanatory variables; and β = a vector of estimable coefficients.

The Poisson regression, as defined in (1) and (2), is estimable by standard maximum likelihood methods with the likelihood function

$$L(\beta) = \Pi_i \frac{\exp[-\exp(\beta X_i)][\exp(\beta X_i)]^{n_i}}{n_i!} \quad (3)$$

2.2 Head-on Collision data on Route 5

The study begins with the analysis of a three-year crash data records (2001 to 2003). NR-5 covers an area that extends from Hokodate to Sapporo. 278 sections each with a uniform length of 1 km section were prepared on the basis of the kilo post location for the analysis. The monthly distribution of head-on collisions along route5 indicates that high number accidents occurred in the winter months. For the analysis we divide the highway sections into two parts. Part 1 from Hakodate to Oshamanbe covering 106 sections, and part 2 from Oshamanbe to Sapporo having 172 sections. The classifications are based on the topographic nature of the area. Part 1 is found mostly on the pacific coast and it is relatively less mountainous as compared to Part 2, which is found in mountainous areas. The Annual Average Daily Traffic (AADT) along NR-5 has the highest record from the remaining national highways in Hokkaido. The AADT shows an average decrease of approximately 30% in winter months. The numbers of head-on collisions are lower in summer months in contrary with increasing AADT. The sections in part 1 have less number of head-on collisions in winter as compared to those in part 2, which have high accident record, that correspond to the sections with high AADT. Figure 1 shows the distribution of the head-on collisions and the AADT for the sections in part 1 and 2 for both winter and summer.

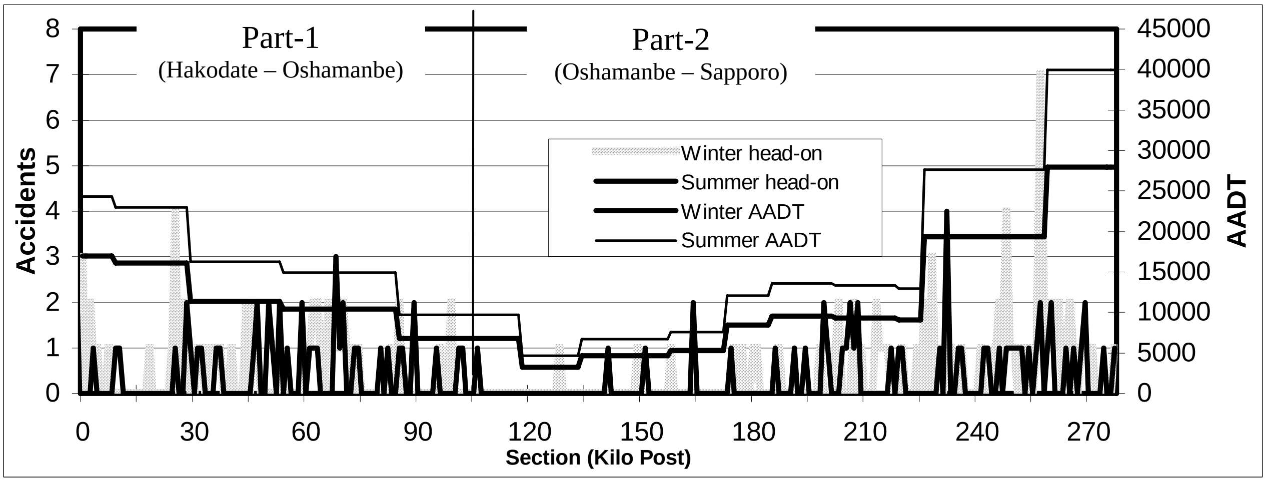

Figure 1 AADT and distribution of head-on collisions along NR-5

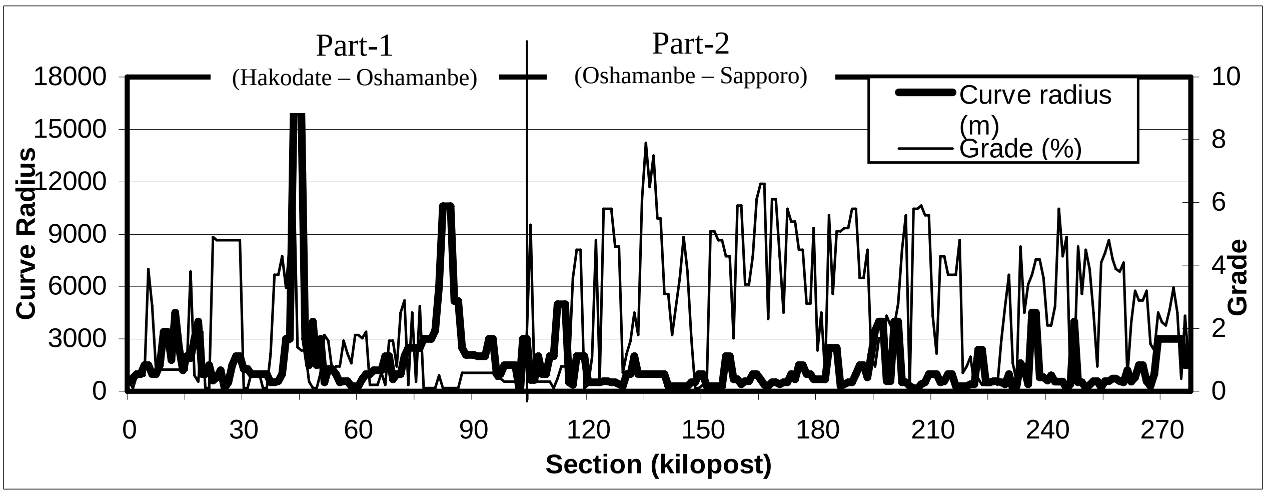

Figure 2 Distributions of shoulder width and number of lanes along NR-5

The sections under the study are comprised of different types of shoulder widths. The dominant shoulder widths that are observed are 1 and 2 meters having a proportion of 22% and 31% of the total respectively. 75% of the sections are single-lane highways and 24% are comprised of two-lanes and the remaining 1% has three-lanes. The curve radius along NR-5 ranges between 150 and 16,000 meters and the dominant curve radius is 1000 meters covering 16%of the total. The highway grade in the sections ranges from 0.1% to 7.9%. From Figure 3 it can be observed that the sections in part two have sharp grades indicating the mountainous nature of the area but part 1 has relatively lower grades

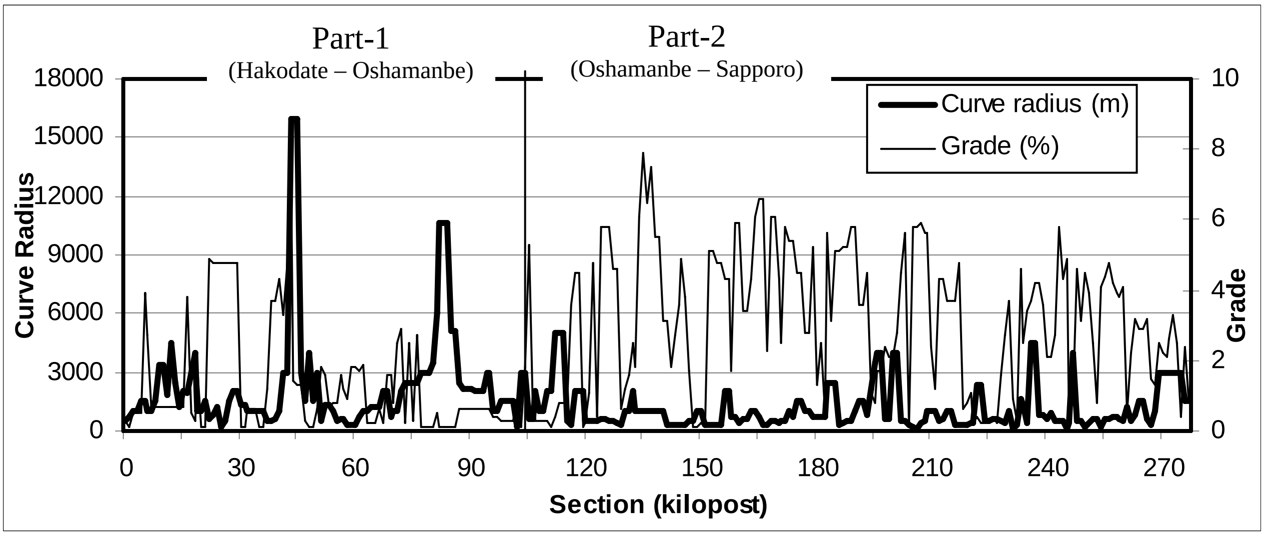

Figure 3 Distribution of curve radius and grades along NR-5

3. Results

The econometric software package LIMDEP 7.0 was used for modeling the Poisson regression model for the count data as a function of the geometric features and traffic variables. We have used a significance level of 10% to evaluate for each factor. Based on this, the results of the estimation indicate that in winter for part 1 (Hakodate – Oshamanbe), all the factors are not found to be significant in causing head-on collisions. For this part, in summer, the shoulder width and the number of lanes are with in the significance level. The increases in shoulder width, increases the probability of head-on collisions. Whereas the number of lanes has a positive effect indicating that the higher the number of lane, would result in high probability for head-on collisions to occur. For part 2 (Oshamanbe – Sapporo), the curve radius has a significance effect on the probability of head-on collisions in winter. But for the case in summer, the AADT, shoulder width and curve radius have significance effects on the probability of head-on collisions. As the AADT increases, the probability of a head-on collision increases and vice versa. The other factors such as grade and location of the highway do not have significant effect on the probability of head-on collisions in both seasons.

Table 1 Poisson regression Model estimates for part 1 (Hakodate – Oshamanbe)

	Summer			Winter		
Variables	Coefficient	t-value	P-value	Coefficient	t-value	P-value
Constant	-1.971	-1.216	0.224	0.085	0.080	0.936
Annual Average Daily Traffic (AADT)	0.000	-0.451	0.652	0.000	0.077	0.939
Grade	0.056	0.463	0.6434	0.053	0.546	0.585
Curve Radius	0.000	0.273	0.785	-0.000	-0.337	0.736
Location indicator *(1 if rural; 0 otherwise)	0.471	0.419	0.675	-0.363	-0.692	0.489
Number of lanes indictor (1 if single lane; 0 otherwise)	1.375	1.711	0.087	-0.300	-0.739	0.460
Shoulder width indicator (1 if greater than 1.5 m; 0 otherwise)	-0.713	-1.999	0.046	-0.468	-1.461	0.144
Number of observations		106			106	
Log likelihood at zero		-87.526			-103.015	
Log likelihood at convergence		-80.033			-100.103	
Likelihood Ratio (ρ^2)		0.085			0.028	

(*) Note: Location indicator is the place where the highway passes through (rural or urban)

Table 2 Poisson regression models Estimates for part - 2 (Oshamanbe - Sapporo)

	Summer			Winter		
Variables	Coefficient	t-value	P-value	Coefficient	t-value	P-value
Constant	-2.052	-1.587	0.113	-0.573	-0.547	0.585
Annual Average Daily Traffic (AADT)	0.000	1.650	0.099	0.000	1.082	0.28
Grade	0.064	0.754	0.451	0.040	0.526	0.599
Curve Radius	-0.001	-1.976	0.048	-0.002	-2.363	0.018
Location indictor (1 if rural; 0 otherwise)	-0.039	-0.052	0.959	-0.491	-0.759	0.448
Number of lanes indictor (1 if single lane; 0 otherwise)	0.308	0.677	0.499	-0.534	-1.385	0.167
Shoulder width indicator (1 if greater than 1.5 m; 0 Otherwise)	-0.562	-1.814	0.07	-0.224	-0.853	0.394
Number of observations		172			172	
Log likelihood at zero		-121.03			-150.836	
Log likelihood at convergence		-107.396			-124.361	
Likelihood Ratio (ρ^2)		0.113			0.176	

4. Conclusion and Discussions

The results presented that Poisson regression modeling of head-on collisions can be used to identify the significance of some geometric features. Understanding the significance of geometric features can help to find out the level of effects that each factors has on the probability of head-on collisions to occur. Based on this results it can be said that curve radius, shoulder width, as well as the number of lanes, can contribute a significance level for margin for a head-on collisions to occur. The values obtained as a result of the likelihood ratio are relatively small and indicates that this factors are not the major probable factors for head-on collisions to occur on the roadway sections. Head-on collisions are rare accidents and the small values that are obtained from the model estimation could emerge from small nature of the accidents. This implies that other contributing factors for head-on collisions should be assessed and addressed. In the future of this study, to know the specific effects of winter head-on collisions, we will include the environmental factors associated with weather.

References

1) Cameron, A. C.; Trivedi, P. K. Econometric models based on count data: Comparisons and applications of some estimators and tests. *Journal of Applied Econometrics*1: 29-53; 1986
2) Hoong C. C. and Mohammed A. Q., Modeling count data with excess zeros. *Sociological methods and research*, Vol. 32 No. 90-116, 2003
3) Mark Poch and Fred Mannering, Negative Binomial analysis of intersection-accident frequencies. *Journal of Transportation engineering* /March/April, 1996
4) Miaou, S. -P.; and Harry Lum, Modeling vehicle accidents and highway geometric design relationships. *Accident analysis and prevention* Vol. 25, No. 6, pp. 689-709, 1993
5) Toru Hagiwara and et al; Effects of road condition and Driver’s attention on Head-on Collision, *submitted for TRB annual meeting*, 2004
6) Shankar, V.N., F. Mannering. Effects of roadway geometric and environmental factors on rural freeway Accident frequencies. *Accident Analysis and prevention* Vol. 27 No. 3, pp 371-389, 1995.
7) Wong, Y.D.; Nicholson, A. Driver behavior at horizontal curves: risk compensation and the margin of safety. *Accident Analysis and prevention* Vol. 24 No. 4, pp 425-436, 1992