Truck Accident Models for Interstates and Two-Lane Rural Roads

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Truck travel increased from 668 billion km (400 billion vehicle mi) of travel to 1,002 billion vehicle km (600 billion vehicle mi) from 1980 to 1989, a staggering 50 percent increase. If this trend continues, truck travel will exceed 1.67 (1 trillion vehicle mi) trillion vehicle km by the end of the year 2000. This increase poses operational and safety problems for both passenger vehicles and trucks. To improve the safety of existing highway facilities and to determine the design standards for new truck facilities, an understanding of the relationship between truck accidents and the geometry of the highway is required. The objectives of this study were to identify the roadway variables that affect truck accidents and to develop mathematical models of their relationships. Data from the Highway Safety Information System were used in this analysis. The Highway Safety Information System is a new data base developed by the Federal Highway Administration. It contains accident, roadway, and traffic data from five states. Models for truck accidents on Interstates and two-lane rural roads were developed using data from the state of Utah. The Interstate model indicates that truck accidents are primarily affected by horizontal curvature and vertical gradient. For two-lane rural roads, the model indicates that truck accidents are affected by the shoulder width and the horizontal curvature. Gradient was not found to have an effect on truck accidents on two-lane roads, although this may be because of inadequate data.

The economy of the United States is largely based on freight transportation and most of this freight movement takes place through highways by means of trucks. Travel data show that truck travel increased from 668 billion vehicle km (400 billion vehicle mi) to 1,002 billion vehicle km (600 billion vehicle mi) from 1980 to 1989, a staggering 50 percent increase (*1*). If this trend continues, truck travel will exceed 1.67 trillion vehicle km (1 trillion vehicle mi) by the end of this century. This increase in truck travel causes a number of operational and safety problems on the highway. These problems result from the shear dimension of the trucks as well as their acceleration and deceleration characteristics.

To improve the safety of existing highways, a clear understanding of the relationship between truck accidents and the design of the highway is needed. To achieve this, a mathematical model of the relationship between truck accident rates and roadway design variables is required.

A number of models have been developed in the past. However, they are single variable models based on only one or two years of accident data and on a limited amount of roadway mileage. Hence their ability to explain truck accidents is limited. Documented in this paper is the development of a truck accident model for different highway types using a data base recently developed by the Federal Highway Administration (FHWA) called the Highway Safety Information System (HSIS).

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PREVIOUS RESEARCH

An extensive literature review was conducted to determine the causes of truck accidents, identify the critical variables affecting accidents in general and truck accidents in particular, and examine the accident models developed in the past.

Truck Characteristics

The occurrence of truck accidents is different from that of passenger vehicle accidents because of the special characteristics of trucks (*2*):

1. Trucks are much heavier and larger in dimension compared with passenger cars;
2. Trucks have less effective acceleration capabilities than passenger cars and have greater difficulty maintaining their speeds on upgrades; and
3. Trucks have a lower deceleration in response to braking than do passenger cars.

Because of these differences, trucks are affected differently by roadway characteristics, and truck accidents tend to be more severe than those involving passenger cars. Although studies of passenger car accidents can provide insights into important highway variables, a complete understanding of truck-highway relationships requires the use of truck accident data.

Critical Geometric Features

Several studies have examined the critical geometric features affecting truck accidents. In an FHWA report (*3*) on improving truck safety, six major design deficiencies for interchanges causing rollover and jackknifing truck accidents have been identified. Examples are (a) abrupt changes in compound curves, (b) short deceleration lanes on tight radius, and (c) steep downgrade at the exit ramp. In a report on hazardous material (HAZMAT) accidents by FHWA (*4*), several geometric features that cause truck accidents have been identified, such as (a) number of lanes, (b) lane width, (c) shoulder width, (d) median width, (e) alignment, (f) surface condition and (g) pavement condition.

Out of these geometric features, the most important in truck accident occurrence are vertical gradients and horizontal curves. Downgrades may lead to an excessive increase in truck speeds resulting in runaway accidents and rear ending of slow-moving vehicles, whereas on upgrades the truck moves slowly, resulting in rear ending of trucks by fast-moving vehicles. Horizontal curves can contribute to rollover problems for trucks with high centers of gravity or when the load shifts while negotiating the curve. On two-lane roads, trucks may encroach on the opposite lane while negotiating a curve, posing a hazard for opposing vehicles (C. V. Zeeger, J. Hummer, and F. Hanscom. *Operational Effects of Larger Trucks on Rural Roadways*. Presented at TRB Annual Meeting, January 1990).

Truck Exposure Data

A particular problem in truck accident analysis is the unavailability of truck exposure data. Truck exposure is not available by truck types and hence it becomes extremely difficult to study the impact of different types of trucks in an accident. In a recent report on data requirements for monitoring truck safety, it is emphasized that greater quality control is required in collecting truck data to get better truck exposure, especially by truck types (*5*).

A significant finding from previous research was the method of calculating truck accident rates. In a number of studies, truck accident rates are calculated by considering an accident a truck accident if at least one vehicle involved is a truck. The truck accident rate is determined by dividing the total number of truck accidents by truck annual daily traffic (ADT), resulting in artificially high truck accident rates. The reason behind this is that multivehicle accidents involving trucks and nontrucks are only counted as truck accidents. To get a true picture of truck accident occurrence, truck involvement rates should be used. That is, the total number of trucks involved in an accident divided by truck ADT.

Accident Models

A number of accident models have been developed for truck accidents exclusively. One of the truck models developed by Garber (*6*) established a loglinear relationship among truck involvement rate, slope change rate, ADT, and truck percentage variables. Three-year data were considered from Virginia and the road types used include divided and undivided, two- and four-lane, and primary and Interstate highways. In another attempt by the same author (*7*), an equation was developed to calculate the truck involvement using only truck volume. These are the only two significant models that deal with truck involvements.

In a study of truck accident modeling, Chang and Jovanis (*8,9*) have shown that truck accidents could be modeled at a disaggregate level as a survival process. Several truck accident models were developed using variables pertaining to truck characteristics, driver characteristics, roadway geometry and environmental factors. The significant variables in all of the models were weather condition, day and night condition, age and experience of the driver, the weight of the cargo carried, and the number of off and on duty hours worked by the driver.

In another study done by the Saccomanno and Buyco (*10*), a loglinear modeling approach is used to assess the effect of the traffic environment on truck accident rates. It should be noted that neither this model nor the previous work by Jovanis found any significant relationships between geometric variables and truck involvement rate.

Other models, although not developed exclusively for truck accidents, can provide a foundation for the development of a truck model. Zeeger et al. (*11*) developed a model that predicts single vehicle plus opposite direction head-on collisions, opposite direction sideswipe collisions, and same-direction sideswipe accidents/mi/year. The variables in this model included ADT, lane width, paved and unpaved shoulder widths, median roadside rating and terrain condition. The correlation coefficient (R^2) was 0.456. Data were collected from seven states on 8,350 km (5,000 mi) of two-lane rural roads.

In developing a relationship between rural highway geometry and accident rates in Louisiana, Dart (*12*) found that the percentage of trucks, traffic volume ratio, lane width, shoulder width, pavement cross slope, horizontal alignment, vertical alignment, percentage of continuous obstructions, marginal obstructions/mi, and traffic access points/mi were significant variables. The study was carried out on approximately 1,670 km (1,000 mi) of rural highway. Various models were developed and the model for total accidents had an R^2 of 0.46.

The studies noted previously are important as they have identified the variables that affect accidents and have narrowed down to a handful those that are most significant. The important variables that emerge from these studies are shoulder width, shoulder type, median width, median type, ADT, and lane width, supplemented by variables indicating the curvature and gradient of the roadway segment.

BRIEF DESCRIPTION OF HSIS

The data base used for the model development in this study is called HSIS. It has been developed by the FHWA and the University of North Carolina Highway Safety Research Center. This data base contains accident and roadway information collected over the period 1985 to 1989 from five states (Illinois, Maine, Michigan, Minnesota, and Utah). Although the data collected by each state are different, each state has three basic files: accident, roadway, and traffic. For location-based safety analysis, various files are combined using route-milepost as common reference variables.

Because different states in HSIS collect different variables, depending on the nature of the analysis, one or more states could be selected for use. For the present study, a preliminary analysis of the data base was done to determine the type and quality of the variables available in each state. The states were compared on the basis of the important variables identified in the literature review. The preliminary analysis indicated that Illinois and Utah have all the major variables required for the study, but Utah has more complete curvature and gradient variables. Hence, the state of Utah was selected for use in this study.

DATA ANALYSIS

Utah Accident File

The accident file for Utah contains approximately 37,000 accidents/year involving approximately 65,000 vehicles. There were 185,341 total reported accidents in Utah for the 5-year period (1985–1989), out of which 124,161 (70 percent) were property damage accidents, 44,178 (31 percent) were minor injury accidents, and 17,002 (9 percent) were serious accidents (combined fatal and incapacitating injury accidents). The overall accident rate was 1.72 accidents/km/year (2.87 accidents/mi/year) for the 5-year study period.

The important accident characteristics of the Utah data are shown in Table 1. The total number of trucks and nontrucks present in Utah accidents, along with their overall percentage with respect to total vehicles, is indicated in this table. The last two columns show the relative percentage of truck and nontruck involvements. These columns show that trucks are more involved in property damage accidents, serious accidents, daylight accidents, dry roadway condition accidents, run-off-road accidents, overturning accidents, sideswipe and single-vehicle accidents compared with nontrucks.

TABLE 1 Summary of Accident Statistics for Utah (Vehicle Based)

Variable Name	Total Number of		Total % of		Relative % of	
	Trucks	Non Trucks	Trucks	Non Trucks	Trucks	Non Trucks
Total Accs.	11060	327794	3.26	96.7	100	100
PDO Accs.	7762	218055	2.29	64.35	70.18	66.52
Injury Accs.	2074	81685	0.61	24.11	18.75	24.92
Serious Accs.	1224	28054	0.36	8.28	11.07	8.56
Daylight Accs.	8389	231998	2.48	68.47	75.85	70.78
Dark No luminaries.	1605	31555	0.47	9.31	14.51	9.63
Dark with luminaries.	5415	44244	0.16	13.06	4.89	13.50
Dawn or Dusk Accs.	454	16714	0.13	4.93	4.10	5.10
Dry Accs.	8336	244009	2.46	72.01	75.37	74.44
Wet Accs.	1189	46829	0.35	13.82	10.75	14.29
Snow Accs.	848	18816	0.25	5.55	7.67	5.74
Icy Accs.	626	16372	0.18	4.83	5.66	4.99
Muddy/Oily Accs.	23	476	0.01	0.14	0.21	0.15
Motor Vehicle	7519	269760	2.22	79.76	67.98	82.30
ROR	942	16952	0.28	5.00	8.52	5.17
Fixed & Other Obj	732	9223	0.22	2.73	6.62	2.81
ROR-Median	421	5815	0.12	1.72	3.81	1.77
Animals	386	11143	0.11	3.29	3.49	3.40
Overturn	362	1954	0.11	0.58	3.27	0.60
Ped/Bic	89	6411	0.03	1.90	0.80	1.96
Train	16	199	0.00	0.06	0.14	0.06
Single Vehicle	3063	49088	0.90	14.49	27.69	14.98
Rearend	2248	96658	0.66	28.53	20.33	29.49
Turning	1729	23253	0.51	6.86	15.63	7.09
Approach Angle	860	54994	0.25	16.23	7.78	16.78
Sideswipe-Pass	792	11532	0.23	3.40	7.16	3.52
Parked Vehicle	560	15055	0.17	4.44	5.06	4.59
Intersection	478	40560	0.14	11.97	4.32	12.37
Backing	384	6149	0.11	1.81	3.47	1.88
Passing	282	13740	0.08	4.06	2.55	4.19
Sideswipe-Opp	245	4908	0.07	1.45	2.22	1.50
Head-On	177	4787	0.05	1.41	1.60	1.46
Rearend-Pass	155	5705	0.05	1.68	1.40	1.74

Utah Roadlog and Traffic File

The roadlog file covers 21,710 km (13,000 mi) of roadway. Seventy percent of these are primary and the rest are secondary roads. Eighty-four percent of the mileage is for two-lane roads and 60 percent of the mileage has an annual average daily traffic (AADT) of less than 500. The traffic file has data on the curvature and gradient of roadway segments. The horizontal curvature file covers 9,719.4 km (5,820 mi) with variables indicating degree and direction of curvature, whereas the vertical grade file has 9,769.5 km (5,850 mi) of data with variables such as percent and direction of grade. The data used for the final model development were filtered out by eliminating the sections having a length of less than 1.67 km (1 mi). A section in the file was defined by the beginning and ending mile post and had various geometric variables attached to it. Sections with AADT less than 10; routes with zero truck percentage, indicating that there was no truck travel on them; and sections without curve or grade variables were eliminated to obtain the final file. The final file contained 2,073 sections covering 12,174 km (7,290 mi) of roadway.

The final file showed that most of the sections are in rural areas (97 percent) and very little roadway mileage is classified as local roads. Urban freeways and local roads have little for data 68.5 km (41.01 mi) out of 12,174 km (7,290 mi) because the majority of the roads in Utah are classified as either rural Interstates, or rural arterial collectors. Hence these categories were not considered for model development. Also 99 percent of approximately 10,688 km (6,400 mi) of roadway classified as primary arterials and arterial collectors is made up of two-lane roads. On the basis of these observations, two models were selected for development: Interstates and two-lane rural roads. The models developed for Interstates do not have shoulder width as an independent variable because the data for the Interstate highways indicated constant 3.05-m (10-ft) wide shoulders. The data used for the Interstate truck accident model included 264 road sections [1,200.24 km (718.71 mi)] and 1,787 total trucks involved in accidents. The two-lane rural road model included 1,614 road sections [10,458.8 km (6,259.17 mi)], with 1,313 total trucks involved in accidents.

MODEL DEVELOPMENT

Variables Used In Model

After the analysis of the Utah files and based on the conclusions of the literature review, the variables considered for model development were nontruck average annual daily traffic/lane (AADT), truck ADT/lane (TRUCKADT), shoulder width (SHLDWID), horizontal curvature and vertical gradient as the independent variables, and truck involvement rate/km/year (TINVOL/KM/Y) as dependent variables. Truck ADT is obtained by multiplying the truck percentage by AADT, whereas nontruck AADT per lane is determined by subtracting the truck ADT from the total AADT for each section. The truck percentage varied from 1 to 59 percent for roadway sections under consideration. In order to take the effect of the number of lanes in the model, both ADTs were divided by the number of lanes to obtain the AADT/lane. Other variables such as median width, median type, shoulder type, pavement width, and pavement type, which may be related to truck accident occurrence, were found to be incomplete in the Utah files and these were not considered in the model development.

The curvature and gradient file could not be directly linked to the roadway file because the beginning and ending mile post in the curve and grade file do not directly match with those of the roadway file. To take this fact into consideration, aggregate curve and grade variables were created, indicating the percentage of the road section having a particular percentage of grade or degree of curvature. Three categories for Interstates and four categories for rural two-lane roads were created on the basis of typical design guidelines (*13*). The variables for Interstates are HCUV1, HCUV2, and HCUV3 for degree of curvature between 1 and 2.5, 2.5 and 4, and ≥4, respectively, and GGRD1, GGRD2, and GGRD3 for the percentage of gradients between 1 and 3 percent, 3 and 5 percent and ≥5 percent.

One km of Interstate section is shown in Figure 1 to demonstrate the developed curvature and gradient variables. Assuming that the 1-km section has four 0.25-km subsections, each with curvature and gradients as shown, then the value for each variable will be HCUV1 = 25 percent, HCUV2 = 25 percent, HCUV3 = 0 percent, GGRD1 = 25 percent, GGRD2 = 0 percent and GGRD3 = 25 percent. A similar example for a two-lane rural road is shown in the lower half of Figure 1.

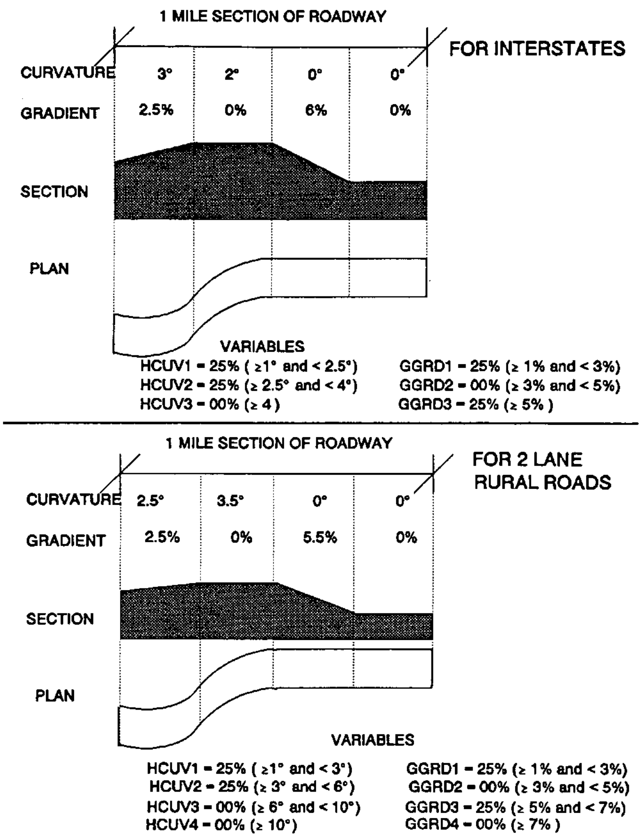

FIGURE 1 Curve and grade variables for Interstates and two-lane rural roads.

Selection of Models

Several general models identified in the literature were examined to determine their suitability for modeling truck involvement rates:

$$Y = \beta_0 (A_1)^{\beta_1} (A_2)^{\beta_2} (A_3)^{\beta_3} (A_4)^{\beta_4} \dots \varepsilon \qquad (1)$$

$$Y = \beta_0 + A_1\beta_1 + A_2\beta_2 + A_3\beta_3 + A_4\beta_4 \dots + \varepsilon \qquad (2)$$

$$Y = \beta_0 (\beta_1)^{A_1}(\beta_2)^{A_2}(\beta_3)^{A_3}(\beta_4)^{A_4} \dots \varepsilon \qquad (3)$$

where

β_0 = intercept,
$\beta_1, \beta_2, \beta_3, \beta_4$ = regression coefficients,
A_1, A_2, A_3, A_4 = geometric variables, and
Y = truck involvement rate/km/year.

A two-step process was used to determine the values of regression coefficients in these three models and to determine which model was best fitted using the available data. In the first step the stepwise SAS® [SAS is a registered trademark of SAS Institute, Inc., Cary, North Carolina.] procedure was used to determine which variables were significant at α = 0.05. The variables used in running the stepwise procedure for the Interstate model and the two-lane rural road model are shown in Table 2.

In the second step, the values of beta obtained from the stepwise procedure were used as initial values for the SAS® procedure NLIN, which is a nonlinear equation fitting procedure. This procedure produces the least-square estimates of the parameters through the Marquardt iterative method, where the residuals are regressed onto the partial derivatives of the model with respect to the parameters until the iteration converges. Using this procedure, it was found that there was no significant improvement in the parameter estimates obtained from the stepwise procedure, and the linear model had a higher R^2 compared with other models. Also, some of the coefficients for nonlinear models showed opposite signs than expected.

The best models, based on their R^2 values, are

Truck Accident Model for Interstates

$$\begin{aligned} \mathrm{TINVOL}_i/\mathrm{KM}/Y = {} & -0.1777 + 0.0002\mathrm{AADT} \\ & + 0.0006\mathrm{TRUCKADT} + 0.0053\mathrm{HCUV2} \\ & + 0.0098\mathrm{HCUV3} + 0.0022\mathrm{GGRD2} \\ & + 0.0048\mathrm{GGRD3} \end{aligned} \qquad (4)$$

where $\mathrm{TINVOL}_i/\mathrm{KM}/Y$ is the truck involvement rate/km/year and R^2 equals 0.713.

TABLE 2 Variable Definition for Interstate and Two-Lane Rural Models

Variable Name	Definition
INTERSTATE MODEL	
$TINVOL_1$/KM/Y	Truck involvement rate per mile per year for Interstate
AADT	Average daily non-truck traffic per lane
TRUCKADT	Average daily truck traffic per lane
HCUV1	Percentage of roadway section with curve between 1° and 2.5°
HCUV2	Percentage of roadway section with curve between 2.5° and 4°
HCUV3	Percentage of roadway section with curve ≥ 4°
GGRD1	Percentage of roadway section with grade between 1% and 3%
GGRD2	Percentage of roadway section with grade between 3% and 5%
GGRD3	Percentage of roadway section with grade ≥ 5%
TWO LANE RURAL MODEL	
$TINVOL_2$/KM/Y	Truck involvement rate per mile per year for 2-lane rural road
AADT	Average daily non-truck traffic per lane
TRUCKADT	Average daily truck traffic per lane
SHLDWID	Shoulder width
HCUV1	Percentage of roadway section with curve between 1° and 3°
HCUV2	Percentage of roadway section with curve between 3° and 6°
HCUV3	Percentage of roadway section with curve between 6° and 10°
HCUV4	Percentage of roadway section with curve ≥ 10°
GGRD1	Percentage of roadway section with grade between 1% and 3%
GGRD2	Percentage of roadway section with grade between 3% and 5%
GGRD3	Percentage of roadway section with grade between 5% and 7%
GGRD4	Percentage of roadway section with grade ≥ 7%

Truck Accident Model for Two-Lane Rural Roads

$$\begin{aligned} TINVOL_2/KM/Y = {} & 0.0027 + 0.00009AADT \\ & + 0.0004TRUCKADT - 0.0025SHLDWID \\ & + 0.0011HCUV3 + 0.0007HCUV4 \end{aligned} \quad (5)$$

where $TINVOL_2/KM/Y$ is the truck involvement rate/mi/year and R^2 equals 0.415.

All the variables in the models are significant at $\alpha = 0.05$. The variables AADT, TRUCKADT, CURVATURE and GRADIENT have positive signs, indicating that as the values of these variables increase, the truck involvement rate would increase. In Equation 4, the coefficients for HCUV3 and GGRD3 are larger than HCUV2 and GGRD2, respectively, showing that a road section with a degree of curvature ≥ 4 will lead to more accidents compared with degree of curvature between 2.5 and 4, and a section of a roadway with a gradient ≥ 5 percent will have higher truck accidents compared with a section with gradient between 3 and 5 percent. However, this is not true for the two-lane rural model according to Equation 5, and also it does not have any variables for gradient that may be caused by the inadequacy of the data. The shoulder width coefficient in the two-lane model has a negative sign indicating that with increased shoulder width, the truck involvement rate would decrease. The parameter estimates, along with the standard error values and t statistic for both the models, are shown in Table 3.

TABLE 3 Results of Interstate and Two-Lane Rural Highway Models

Variable	Parameter Estimate	Standard Error	t
MODEL FOR INTERSTATE HIGHWAY			
INTERCEPT	-0.1777	0.0577	-3.082
AADT	0.0002	0.0000	13.068
TRUCKADT	0.0006	0.0002	3.883
HCUV2	0.0053	0.0033	1.616
HCUV3	0.0098	0.0028	3.532
GGRD3	0.0022	0.0014	1.577
GGRD4	0.0048	0.0015	3.196
MODEL FOR TWO LANE RURAL HIGHWAY			
INTERCEPT	0.0027	0.0033	0.819
AADT	0.00008	0.0000	17.665
TRUCKADT	0.0004	0.0000	12.500
SHLDWID	-0.0025	0.0011	-2.286
HCUV2	0.0007	0.0003	2.324
HCUV3	0.0011	0.0005	2.485

For Interstate highway model:

$df = 6$; p-value = 0.000; Observations = 264, $R^2 = 0.731$

For Two lane rural road model:

$df = 5$; p-value = 0.000; Observations = 1,614, $R^2 = 0.415$

Model Validation

To validate the Interstate model, the data were divided in half using even- and odd-numbered observations. Even-numbered observations were used to develop the model for truck accident involvement for Interstates, and the following model resulted:

$$TINVOL_I/KM/Y = -0.3014 + 0.0002AADT + 0.0009TRUCKADT + 0.0067HCUV2 + 0.0139HCUV3 + 0.0042GGRD2 + 0.004GGRD3 \quad (6)$$

with $R^2 = 0.756$. The coefficients in this equation are close to Equation 4. This model was then used to determine the predicted value of truck involvement rates from the other half of the data. The predicted values and observed values matched closely with a correlation coefficient of 0.844 and the result of a t test on the values of predicted and observed values of truck involvement rate at $\alpha = 0.05$ also indicated that the validation was successful.

Employing a similar procedure for the two-lane rural roads model the following model resulted:

$$TINVOL_2/KM/Y = -0.0025 + 0.00009AADT + 0.0004TRUCKADT - 0.0023SHLDWID + 0.0008HCUV3 + 0.001HCUV4 \quad (7)$$

with $R^2 = 0.431$. The coefficient of correlation for predicted and observed truck involvement rate was 0.631 and in this case also t test at $\alpha = 0.05$ was successful in validating the model.

IMPLICATIONS OF THE MODELS

The two models developed could be used for comparing various sections of roadway and estimating the expected percentage decrease in accidents caused by geometric improvements. The following example illustrates the use of the models.

Consider a hypothetical 1-km section of Interstate roadway having an AADT of 4000, 5 percent trucks, 4 lanes, 3.05-m (10-ft) shoulders and 3.66-m (12-ft)-wide lanes. Let 40 percent of the section have 3 curvature, 60 percent have 6 curvature, 50 percent have 4 percent gradient, and the other 50 percent 6 percent gradient. Using Equation 5, the truck involvement rate can be calculated for this section. The truck involvement rates for the base section previously discussed and for the section obtained after certain modifications are shown in Table 4. Example 1 indicates that if the length of the 6 curve section is increased from 60 to 80 percent, the truck involvement rate increases. Similarly in Example 2, if the length of the 6 percent gradient section is increased from 50 to 70 percent, the truck involvement rate increases. Comparison of Examples 3 and 4 indicates that truck accidents are affected more by presence of curvature than gradient. Example 5 demonstrates the potential reduction in truck involvements if all curves and grades are eliminated.

CONCLUSION

In this paper the first step in modeling of the relationship between the roadway design variables and truck accident involvement rates is provided. Also pointed out is the difficulty in developing these models from the existing data sources. The lack of existing truck models in the literature can be directly traced to the lack of good data. This paper uses a newly developed data source in a location-based analysis to develop truck accident models. It provides an effective demonstration of both the potential of HSIS and the need to supplement this data with more accurate truck exposure and more detailed roadway design data.

The models developed illustrate the effect curvature and gradient have on truck accidents. For truck accidents on Interstates, the significant degree of curvature was found to be ≥2.5, whereas on two-lane rural roads it was ≥6. In the case of gradients for Interstates, the significant percentage was found to be ≥3 percent, whereas the two-lane rural model did not include a gradient variable. The appearance of the grade variable in the Interstate model with a high R^2 strongly suggests a lack of adequate data for the two-lane rural road model.

TABLE 4 Predicted Number of All Truck Involvement Rates Using Interstate Model

Examples	Non-Truck AADT/Lane	TRUCK AADT/Lane	HCUV2	HCUV3	GGRD2	GGRD3	$TINVOL_I/M/Y$
Base section	950	50	40	60	50	50	0.714
1	950	50	20	80	50	50	0.768
2	950	50	40	60	30	70	0.745
3	950	50	0	0	50	50	0.235
4	950	50	40	60	0	0	0.504
5	950	50	0	0	0	0	0.025

Conversion factor: 1 km = 0.6 mi.

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