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Evaluation of Effect on Traffic Flow Due to Transverse Rumble Strip on Section of National Highway

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ABSTRACT
Road accidents is a major issue in the developing countries like in Nepal. Major safety precautions are presented at the national highways. The traffic control device with improper geometric design further leads to the more crashes. So proper traffic control device could aid in mitigation the crash occurrence by driver attentive to up coming decision, transverse rumble strip act to provide driver with an audible and tactile warning that the vehicle is approaching a decision point of critical section with importance of safety.
The objective of this this is to provide a rational and precise regression relation of reduced speed of vehicle with different geometrical physical parameters of rumble strip such as length, width, area, and adjacent rumble strip distance. To evaluate the speed at rumble strip zone, vehicular speeds were measured at five locations along the approach of bridge on both direction of traffic flow. All the analysis were made using IMB SPSS Statistics and Microsoft Excel 2010. The statistically significant relationship could be established between different geometrical physical parameters of the rumble strips. There were some negative driver behaviors impact (i.e erratic behavior). The vehicle type bus and hiace were found out to be following the speed limit noted in sign board.
Key words: Rumble Strip, Width, Area, Reduced Speed, Regression

I. INTRODUCTION

MuglingNarayanghat road is recently upgraded four lane road of 36 km. This section of road is the much trafficflow to connect the northern and southern part of country along with hilly and terai region more over this area is the hub point for mobility of trafficflow. At one side below the road is the large Trishuli river while in the other side is steep hills prone to landslides, especially during rainy season. Yet, this is one of the busiest road sections with estimated annual average daily traffic of 5,968 vehicles, connecting eastern and western part of Nepal to the two major cities: Kathmandu and Pokhara.[1] Traffic safety data revealed that most of the all crash and fatal injury occurs at this section.

This study will focus on impact of transverse rumble strips on traffic such as velocity and its reduction due to rumble strips physical parameters. In the context of Nepal, it has been newly adopted in few tolls plaza Nagdhunga (Previously but currently it is removed) and highways in order to control the speed of traffic in aspect of safety. The major finding is that the vehicles' speeds are affected by the transverse rumble strips and spacing in between strips due to attention getting characteristics of driver and breaking behavior.

Road crash is a major issue in present context in Nepal. Crashes occur mainly due to haphazard increased speed of vehicles. Transverse rumble strips are used as one of the mechanisms of controlling speeds and crashes at Mugling-Narayan section, mainly on narrow bridges and sharp curves. The installation of rumble strips these sections are of varying geometry. The study intends torelationship between speed and geometry of rumble strips.

II. LITERATURE REVIEW

Transverse rumble are strips slightly raised or depressed road surface into the pavement that act as a warning device. When driven over, the strips create noticeable sound and vibrations to warn drivers of an attention to such features as unexpected changes in alignment and to conditions requiring velocity down or stop

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2.1 Safety Effects of Rumble Strips

the installation of rumble strips is effective in reducing accidents on intersection approaches. Several highway agencies have indicated their concern that the effectiveness of rumble strips deteriorates over time. A 1962 study by Kermit and Hem [2] evaluated rumble strip pads installed on the approaches to four STOP-controlled intersections in Contra, Costa County, California. . These rumble strip installations reduced accidents per year by 59, 76, 84, and 100 percent, respectively, at the four intersections.

The British Transport and Road Research Laboratory (TRRL) [3] evaluated the effect on accidents of rumble strips at 10 sites on main rural highways in the United Kingdom. The study design used was a before/after analysis with control sections. The length of the before and after study periods ranged from 10 to 23 months. The study found that total accident frequency at the 10 sites decreased from 56 accidents in the before period to 34 accidents in a comparable after period. This decrease in accident frequency was not statistically significant. However, the frequency of accidents related to high speed or lack of driver awareness decreased from 44 in the period before rumble strip installation to 22 in the period after rumble strip installation.

2.2 **Effect of Rumble Strips on Vehicle Speeds**

In a study of rumble strips on the approaches to rural intersections in Minnesota, Owens [4]measured speeds of free-flowing vehicles at distances of 1,500; 1,000; 500; and 300 ft from the intersections on STOP-controlled intersection approaches, both before and after rumble strips were installed. The presence of rumble strips was found to reduce average speeds by 2 to 3 mph at each of these observation points, which indicates that rumble strips are effective in reducing vehicle speeds.

A recent study performed at the University of Toledo[5] evaluated the effectiveness of rumble strips in reducing vehicle speeds during the initial portion of the deceleration maneuver on approaches to STOP controlled intersections. It compares the mean speeds of vehicles at a location 300 ft downstream of the first rumble strip pattern on the intersection approach before and after rumble strip installation on seven intersection approaches in Ohio. On five of the seven approaches, there was a reduction in the mean vehicle speed that was statistically significant at the 95 percent confidence level; there was no statistically significant change in mean vehicle speed at the other two locations. These results are similar to the Israeli study discussed above in that there appears to be greater slowing early in the braking maneuver and, consequently, lesser slowing later in the maneuvers.

2.3 **Effect of Transverse Rumble Strip in Vehicle Movement**

Transverse rumble is designed to promote orderly movement and improved safety. However, at certain locations such as approaches, sharp curves, accident prone locations, control of speed is necessary. Road humps, where permitted to be installed, provide visual, audible and traffic stimuli which alert drivers and cause them to slow down. The humps have got both the positive and negative properties.

- The positive property is that it reduces the vehicle speed. The design profiles of rumble strip have an impact on the speed of vehicles; the design profiles of the road humps especially in terms of number of strips and width of strips. Therefore, the higher width, the lesser will be the velocity. When the velocity becomes less, then there is automatic reduction of speed. When there is reduction in speed, there is reduction in number of crashes.
- The negative property is that noise may affect nearby residents. The noise impact of their implementation near residential areas should be evaluated before installation. Also, rumble strips gradually lose their effectiveness due to wear and should be monitored and maintained in order to provide original levels of noise and vibration. (NDD9T, North Dakota department of Transportation). The velocity is reduced by the strip, due to which the journey time is obviously increased.

The objective of this study is categorized as general objective and specific objective. The general objective includes:To compare speeds of bus, car and hiace/scorpio at normal stretch transverse rumble strips; To determine the operational and safety effectiveness of the transverse rumble strips. The specific objective includes:To analyze the parameters that affect speed; that is to find the relation between reduced speed and geometry of the rumble strips.

III. METHODOLOGY

3.1 Site Selection

Minimum five sites were selected for field testing along Mugling- Narayanghat, which have hazardous conditions, such as poor sight distance, long uninterrupted approaches, and high speed. These conditions could potentially be remedied through the use of TRS. Since TRS is prominent for reducing the free velocity. During the selection of site, road stretches is so selected that vehicle

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travels under free flow traffic and access controlled so that there is no obstruction to speeding. Road geometry is fairly straight to have constant effect of geometry and entire road surface is smooth to ensure constant effect of rolling resistance. Five locations were chosen because they had higher average daily traffic than the other available study sites, different shoulder conditions, and good locations to place a video trailer for data collection. Both approaches had a posted 40 kmph speed limit. Three sets of TRSs were installed at each site. The sets were spaced 31.5 meter apart, with the downstream set being 31.5 meter downstream of the warning sign and the upstream set being 31.5 meter upstream of the warning sign

3.2 traffic operation data collection

Speeds of free-flowing (> 15-second headway) [7]passenger vehicles were measured for every field evaluation and were the basis for a majority of the measure of effectiveness.A 15 second headway was chosen because it was sufficiently large to ensure that drivers were uninfluenced by the brake lights of downstream vehicles.

3.3 **sample size and sampling procedure**

the minimum number of individual speed observation required deepens on the variation in speeds and the accuracy of the speed measurement. Following equation [8]was used to determine the number of observations needed to 85th percentile speed at each site

$$n=\{\frac{ts}{\varepsilon}\}^2$$

n=required sample size,s = standard deviation, ε = user-specified allowable error,t = coefficient of the standard error of the mean that represents user-specified probability level. For 95 percent confidence interval (t = 1.96), and an ε value of 1 mph were chosen.We get n= 245 adopt 250 minimum. Total number of 624 traffic count was taken among them 221, 206, and 227 was bus, car and haice respectively.

IV. DATA ANALYSIS

4.1 Analysis of Physical Parameters of Rumble Strips

Most rumble strips placed in the traveled way consist of a pattern of raised or grooved bars spaced relatively close to one another and oriented in a transverse direction across the roadway. Rumble strip dimensions and features include the length, width of the pattern of rumble bars, measured longitudinally along the highway; the number of rumble bars per pattern ; the width of each rumble bar; adjacent distance between successive bars, the height of the raised bar(thickness); the cross-sectional shape is rounded.

4.2 85th percentile Speed Reduction Chart at Different Sites

Speed measurements were made using radar at two locations. The first, location was at minimum 25 m away from the start of first rumble strip this location was just to identify the free flow velocity. Moreover, about more than 50maways from the start of rumble there was no any disturbance for free flow of traffic. The second location where speeds were measured was at a point between the last rumble strip and the start of the crossover to return to the normal lanes. Out of five different location, Chinsenji bridge has the low 85^{th} percentile speed velocity as compared to the other four different location at rumble strip zone for all type of vehicle. It indicates the vehicle are obeying to follow the traffic speed limit in Chinsenji bridge than other due to appropriate instillation and good efficiency of rumble strip.

Table 4. 1 85th percentile speed on normal and on rumble strip with vehicle type

		Location				
Vehicle type		Chinsenji bridge	Dumre bridge	Simaltal bridge	Khahare bridge	Lamo Baluwa bridge
Bus	Normal	45	60	62.55	59	55.85
	Rumble	38	49.6	50	46.3	44
Car	Normal	50	61	64	67	65.5
	Rumble	42	50	50	52.85	51.2
Scorpio/ Hiace	Normal	51	63.8	64.45	68.45	59.7
	Rumble	41	51	51.45	52.45	49.35

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4.3 Approach of Modelling

The reduction velocity is mainly influenced by the physical parameters of rumble strips, moreover, it is observed that the zone through which the vehicle is approaching towards transverse zone also influence the velocity.A multiple linear regression was carried out to predict the reduction velocity at the zone. The independent variables used for the analysis are length, width, area, corresponding adjacent strip distances, ie s1, s2, s3. , category of the approaching through vehicle. Prior to the regression modeling modeling, all the independent variables we checked for multiple multicollinearity, and no significant correlation among these variables at 5% significance level was observed.Similarly, the p-value obtained from ANOVA is also less 0.05 which shows that there is a significance difference between all the independent variables. Therefore, each independent variables have a significance effect on the outcome of dependent variable (reduction velocity).

Here we have six independent variables and a dependent variable; independent variables are Length (L), Width (W), Area(L_W), Inter distance of corresponding rumble strips S1, S2, S3. Obviously, dependent variable is reduced velocity in strip zone Vz. We develop the zone reduced velocity equation. We checked for the nature of relationship between the dependent and each of the independent variables at this particular case and all are found to be linear. Here, checking for collinearity between variables by developing inter correlation matrix, and this is the result of the calculation of correlation coefficient between a set of independent as well as dependent variables and the result is shown in table 4.3.

Table 4. 2 Correlation Matrix of Regression Model With Vehicle Type Bus

Correlations								
		Vz	L_W	L	W	s1	s2	s3
Vz	Pearson Correlation	1	-.372**	-.363**	-.196**	-.390**	-0.129	0.027
	Sig. (2-tailed)		0	0	0.004	0	0.057	0.693
L_W	Pearson Correlation	-.372**	1	.814**	.745**	.534**	-0.067	0.003
	Sig. (2-tailed)	0		0	0	0	0.324	0.964
L	Pearson Correlation	-.363**	.814**	1	.287**	.594**	0.024	.246**
	Sig. (2-tailed)	0	0		0	0	0.728	0
W	Pearson Correlation	-.196**	.745**	.287**	1	.301**	-0.121	-.208**
	Sig. (2-tailed)	0.004	0	0		0	0.075	0.002
s1	Pearson Correlation	-.390**	.534**	.594**	.301**	1	.358**	.203**
	Sig. (2-tailed)	0	0	0	0		0	0.003
s2	Pearson Correlation	-0.129	-0.067	0.024	-0.121	.358**	1	.606**
	Sig. (2-tailed)	0.057	0.324	0.728	0.075	0		0
s3	Pearson Correlation	0.027	0.003	.246**	-.208**	.203**	.606**	1
	Sig. (2-tailed)	0.693	0.964	0	0.002	0.003	0	
Sample Size (N):		217	217	217	217	217	217	217
	*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).							

Inter correlation matrix and significance is very important analytical in regression analysis, their effect of all the most independent variable on the dependent variables as well as inter correlation between each of the among the independent variables. Here inters correlation matrix demonstrate that strong significance with the level of 95 percent confidence level though the degree of relation is not much satisfaction.

For bus, the results were statistically significant, negative correlation between reduced velocity (vz) and area (L_W). r= -.372 n= 218, p< .000 with reduced velocity explaining 14% of the variation in area, negative correlation between reduced velocity (Vz) and Length (L). r= -.363 n= 218, p< .000 with reduced velocity explaining 13% of the variation in length, negative correlation between reduced velocity (vz) and width (W). r= -.196, n= 218, p< .000 with reduced velocity explaining 3% of the variation in width. Similar, we can get the results for another parameter from the above table.

4.4 Method of Regression:

4.4.1step wise method of regression

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In stepwise regressions[10] decisions about the order in which predictors are entered into the model are based on a purely mathematical criterion. In the forward method, an initial model is defined that contains only the constant (b0). The computer then searches for the predictor (out of the ones available) that best predicts the outcome variable- it does this by selecting the predictor that has the highest simple correlation with the outcome. If this predictor significantly improves the ability of the model to predict the outcome, then this predictor is retained in the model and the computer searches for a second predictor. The criterion used for selecting this second predictor is that it is the variable that has the largest semi-partial correlation with the outcome. The predictor that accounts for the most new variance is added to the model and, if it makes a significant contribution to the predictive power of the model, it is retained and another predictor is considered. The stepwise method in SPSS is the same as the forward method, except that each time a predictor is added to the equation, a removal test is made of the least useful predictor. As such the regression equation is constantly being reassessed to see whether any redundant predictors can be removed. This significance value is compared against a removal criterion (which can be either an absolute value of the test statistic or a probability value for that test statistic). If a predictor meets the removal criterion (i.e., if it is not making a statistically significant contribution to how well the model predicts the outcome variable) it is removed from the model and the model is re-estimated for the remaining predictors. The contribution of the remaining predictors is then reassessed.

Model Parameters: the output of the model is concerned with the parameters of of independent variables. Below out of SPSS model shows the parameters for both steps in the hierarchy. We will be concerned only with the parameters for the final model (in which all predictors were included). The format of the table of coefficients will depend on the options selected. The confidence interval for the b-values, collinearly diagnostics and the part and partial correlations will be present only if selected in the dialog box.

Table 4. 4 Coefficients of Regression Model

Coefficients[a]

Vehicle Type			Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
Bus	1	(constant)	68.751	5.394		12.747	0.000
		s1	-1.455	0.231	-0.395	-6.306	0.000
	2	(constant)	77.353	5.907		13.096	0.000
		s1	-0.997	0.266	-0.271	-3.744	0.000
		L_W	-0.733	0.226	-0.235	-3.244	0.001
Car	1	(constant)	101.331	9.696		10.451	0.000
		L	-7.381	1.224	-0.389	-6.029	0.000
	2	(constant)	129.551	13.111		9.881	0.000
		L	-7.152	1.201	-0.377	-5.955	0.000
		s2	-1.816	0.582	-0.198	-3.121	0.002
Hiace	1	(constant)	59.266	7.898		7.504	0.000
		s1	-0.820	0.337	-0.160	-2.435	0.016

a. Dependent Variable: Vz

In the final model, independent variables(S_1, L_W) were staticiallly significant with S1 ($t=-3.744$,$p<0.000$, $\beta= -.271$),multiple regression the model takes the form of equation $Y_i = b0 + b_1X_{i1} + b_2X_{i2} + ... + b_nX_n + \varepsilon_i$, Y is the outcome variable, b1 is the coefficient of the first predictor (X1), b2 is the coefficient of the second predictor (X_2), b_n is the coefficient of the nth predictor (X_n), and εi is the difference between the predicted and the observed value of Y for the i^{th} participant. In that equation there are several unknown quantities (the b-values). The first part of the table gives us estimates for these b-values and these values indicate the individual contribution of each predictor to the model. If we replace the b-values in equation we find that we can define the model as follows:

$$V_{z\,Bus} = 77.353 + (-0.997)*S_1 + (-0.733)*L\_W$$
$$V_{z\,Car} = 129.55 + (-7.152)*L + (-1.816)*S_2$$
$$V_{zHiace} = 59.266 + (-0.820)*S_1$$

The b-values tell us about the relationship between reduced velocity and each predictor. If the value is positive, we can tell that there is a positive relationship between the predictor and the outcome, whereas a negative coefficient represents a negative relationship. For these data all three predictors have negative b-values indicating negative relationship relationships.

Bus:

In the final model, independentvariables (S1, L_W) werestaticiallly significant with S1 (t=-3.744, p<0.000, β= -.271), L_W (t=-3.244, P<0.000, β= -0.235) in reduced velocity. The final prediction equation was Reduced velocity = 77.353 + (-.997) *S1 +(-.733) * L_W. The negative slope for the s1 (-0.997) as predictor of reducing velocity indicate there was about a 0.997 decrease in reduction velocity for each 1 unit increase in s1 when L_wremains Constraint. Similarly, the negative slope for the L_W (-.733) as predictor of reducing velocity indicate there was about .733 decrease in reduction velocity for each 1 unit increase in L_W. when s1 remain constraintL_Win reduced velocity.

Car:

In the final model, independent variables (L, S_2) were staticiallly significant with L (t=-5.955, p<0.000, β= -.377), S2 (t=-3.121, P<0.000, β= -.198) in reduced velocity. The final prediction equation was Reduced velocity = 129.551 + (-7.152) *L +(-1.816) *S_2The negative slope for the L (-7.152) as predictor of reducing velocity indicate there was about a 7.152 decrease in reduction velocity for each 1 unit increase in L when s2 remains constant. Similarly, the negative slope for the S_2 (-1.816) as predictor of reducingvelocity indicate there was about 1.816 decrease in reduction velocity for each 1 unit increase in S_2 remaining constraint.

Hiace:

In the final model, only one independent variablesS1,) was statically significant with S1 (t=-2.435, p<0.016, β= -.160), in reduced velocity. The final prediction equation was Reduced velocity = 59.266 + (-.820) *S_1. The negative slope for the s1 (-0.820) as predictor of reducing velocity indicate there was about a 0.820 decrease in reduction velocity for each 1 unit increase in S_1

4.5 Validation of Approach Model

Root mean square error (RMSE) is one of the most popular measures to estimate the accuracy of forecasting model's predicted values vs. the actual or observed values while training the regression models.Itmeasures the error in our predicted values when the variable is a continuous. In vehicle type, bus we have got the root mean square as 6.20, indicates as 6.20 Kmph errors in model for in reduced in velocity of bus for particular collected data. Similarly, we obtain the model is validate up to 15.18 percent. Similar for vehicle types Car and Hiace we have got the root mean square as 18.36 and 11.64Kmp errors in model for reduced in velocity of car and hiace and obtained the model is validate up to 36.79% and 27.11% respectively. It concludes that the vehicle type bus has the good model because it follows the traffic rules and concern about the importance of rumble strips to minimize the crash.

V. CONCLUSION

One of the major things known from this study is that the physical parameters of rumble strips at every place is different. Hence, the conclusion is that proper geometry must be designed to reduce the free velocity and hence to prevent crashes. For the proper design and effectiveness, the equation obtain by modeling can be used. For different type of vehicle, from linear regression we obtain the following equation For bus, the standard equation is: Vz Bus = 77.353 + (-0.997) *S1 + (-0.733) *Area For car, the standard equation is: Vz Car = 129.55 + (-7.152) *L + (-1.816)*S2 For hiace , the standard equation is: VzHiace = 59.266 + (-0.820)*S1 . The model determines the if the presence of rumble strips result in more uniform deacceleration of velocity. Deacceleration patter indicates that drivers had been more aware of upcoming decision point and make better decision with significant reduction in speed. More over data analyzed to determine that for buses were more effective in reduction of speed than that car and hiace. Previous reports from accidents indicates the reduction of accidents.

This paper presents the derivation and application of a series of equation of reduced velocity at rumble strip zone. It has emphasized the physical characteristics of rumble strip be used. The application of derived equation for different vehicle type indicates the reduced velocity, length, width, area and adjacent spacing strip indicates the major contribution to the reduced velocity. It should be noted that for the vehicle type bus, area and adjacent first spacing strip was receiving strong parameters.

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