Evaluation of traffic safety conditions where accidents are frequently occurred (road section between Ulaanbaatar-Baganuur)

Erdenetuya AMGALAN[a], Myagmarjav JIGJJAV[b], Tsevegjav TSEVEGMID[c], Bazarragchaa ICHINNOROV[d], Choisuren PUREVDORJ[e]

[a,b,c,d,e] *School of Mechanical Engineering at Mongolian University of Science and Technology, Ulaanbaatar, 976, Mongolia;*
[a]*E-mail: erdenetuya@must.edu.mn*
[b]*E-mail: tsevegjav@must.edu.mn*

Abstract: In Mongolia, 350 people died per year due to traffic accidents, and 193 people died in road of rural area. According to statistic, focusing on the accidents' reason, about 94.9 percent of accidents are caused by faulty operation of driver and 0.4 percent is caused by road condition. The purpose of this study was to analyse the influence of road condition on the route Ulaanbaatar-Baganuur, where traffic accident have frequently occurred and through that find solutions to relieve the traffic accidents. Traffic safety was evaluated with a coefficient of traffic safety that defined as divide the safe speed of vehicles on the road with invisible areas such as crest and sag vertical curve and horizontal curve to the speed of vehicles from the opposite direction. The coefficients of traffic safety are had between 0.30-0.81 on the sections that required limiting the traffic speed.

Key words: Road, the coefficient of traffic safety, sight distance, crest and sag vertical curve, road maintenance

1. INTRODUCTION

In Mongolia, 320-350 people died per year because of traffic accidents. About 193 people died in road of rural area. About 70 percent of died people and 50 percent of injured people referred to road accidents that are outside of Ulaanbaatar such as Ulaanbaatar-Darkhan-Erdenet, Ulaanbaatar-Baganuur, Ulaanbaatar-Erdenesant and Ulaanbaatar-Choir route with asphalt surface (Bumnanjid 2010). The causes of traffic accidents are divided into two categories, subjective and objective causes. Subjective causes are mainly personal factors, while objective causes include vehicles, road, traffic and climate factors (Yulong 2003). There are no research results available to determine the reasons of traffic accidents on those roads with better technical condition comparing to other roads.

The purpose of this research work is to determine the stretches where accidents s frequently occurred, the possible reasons of traffic accidents influenced by road condition and finding the solutions to relieve the traffic accident situation and risk.

2. STATISTIC RESULT OF TRAFFIC ACCIDENTS

The route Ulaanbaatar-Baganuur locates districts Bayanzurkh, Nalaikh and Baganuur of Ulaanbaatar city and Tuv aimag and is a 130 km long road with asphalt surface (Bumnanjid 2010). Basic documents to determine the reason of traffic accident is information of road traffic accidents that are registered by the traffic police. The analyzed data has been gathered

from chancery information of traffic accidents for last three years and criminal case file of traffic accidents, the sample survey had made to determine the points which are people injured and died of accidents.

During the last three years about 93 traffic accidents occurred on the route Ulaanbaatar-Baganuur. Of these about overturned 49 and collided 44 accidents were registered by the traffic police. Hereupon, 24 people died and 88 people were injured. In this study 37 points have been determined as stretches where accidents have occurred frequently. After the integrating individual stretches by location and similarity of road technical and geometrical parameters, exactly 14 stretches for further analysis were defined. Totally 22 traffic accidents occurred at the point 144th km from Ulaanbaatar (east of 5th bag of Erdene soum, Tuv aimag); 15 traffic accidents occurred on the road between 103 and 105 km from Ulaanbaatar (Togosiin hooloi front of the Bayandelger soum, Tuv aimag); 11 traffic accidents occurred on the road between 62 and 68 km (Bayan davaa, Erdene soum); 7 traffic accidents occurred on the road between 72 and 75 km (Dotluuriin davaa, Erdene soum); 5 traffic accidents occured on the road between 39 and 41 km (5th bag, Nalaikh district, Ulaanbaatar); 5 traffic accidents occured on the road between 56 and 58 km (Statue of Chingis khaan).

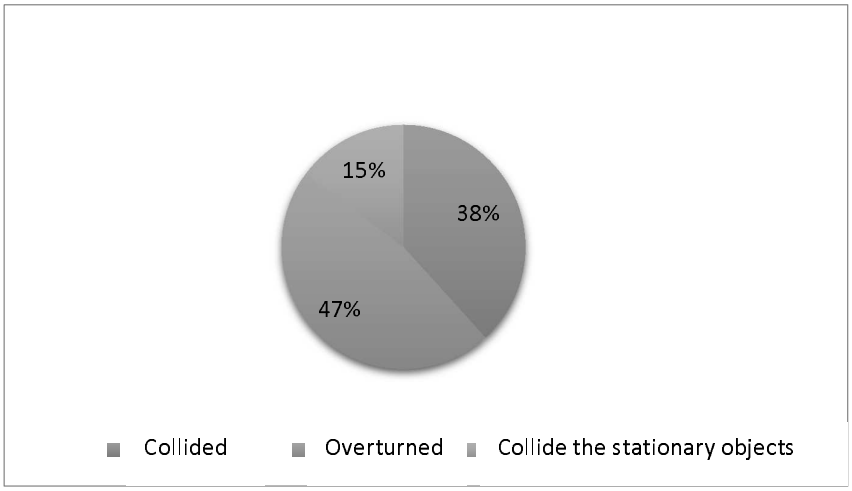

Figure 1. Types of accidents on route Ulaanbaatar-Baganuur, in last three years.

Classifying the traffic accidents by types, collided and overturned accidents are those ones occurred commonly as shown in Figure 1. Most overturned accidents are occurred on the Togosiin hooloi of Bayandelger soum, Derst honhor, Aguit, Gun Galuutai, Dotluuriin davaa of Erdene soum, Bayandavaa, front of the NIK, 2th horoo of Baganuur district and intersection of Terelj.

The main reasons affecting collided and overturned accidents were speeding and harsh weather conditions. Colliding fixed objects occur commonly at night time as a colliding rear end of a big truck that has been broken and stopped on the road. This accident occurred mainly because of faulty operation of the driver leaving the truck on the road lane with inadequate visibility. But because of the narrow road shoulders the driver had really no possibilities to clear the road.

According to the study, on the route Ulaanbaatar-Baganuur, within last three years, about 37 stretches were occurred traffic accident. Analyzing traffic accident statistic by repetition, road condition, location and similarity of neighbor points, so on the 14 stretches, the accidents were occurring frequently. Classifying the accidents with 14 stretches, about 14

percent of accidents were occurring at the end of road ascent; 28 percent on straight section; 35 percent on a curve; 16 percent of broken surface section of road; 7 percent on the place that road asphalt surface was missed partly.

3. EVALUATION OF TRAFFIC SAFETY ON THE STRETCHES

Traffic safety is estimated with a coefficient of traffic safety defined by the maximum safe speed pass section with dangerous case and speed of the vehicle goes on the next lane. Section with a dangerous case refers sections with inadequate visibility.

Figure 2. Location of 14 stretches with total accident

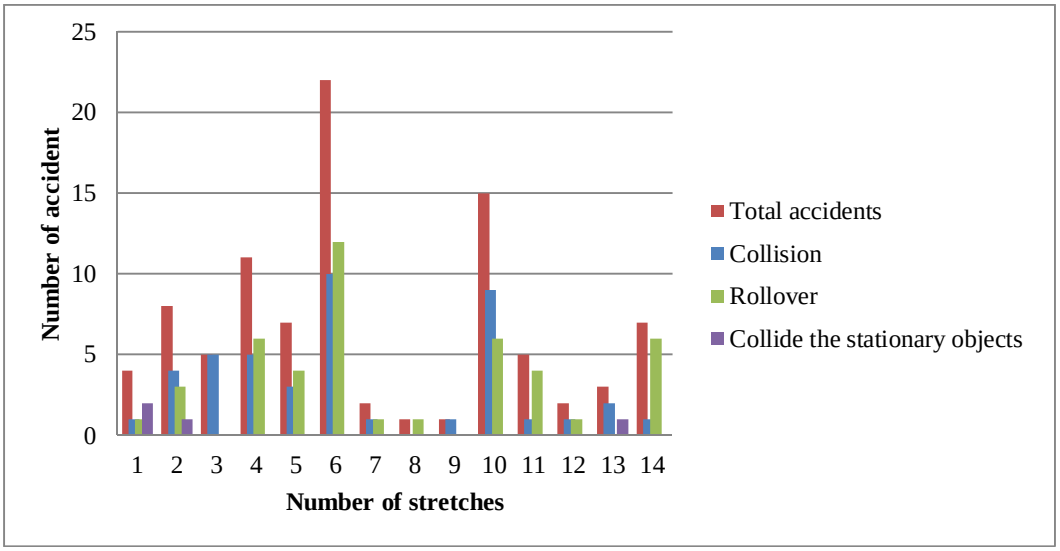

Figure 3. Types of accident in the 14 stretches

The values of the geometry of surface are determined at 37 stretches of the route "Ulaanbaatar-Baganuur". These are: road lateral slope; width of shoulder; a slope. The road lateral slope is measured by using device "Level stick" in two directions. Additional measurement was made by theodolite at the sections such as crest and sag vertical curve and ascent of the 14 points that occurred traffic accident frequently (Figure 2-3).

3.1. Evaluation results from points with inadequate visibility

In order to drive safely, a driver is required to see freely in distance able to stop without running into the obstacle on the road. In route Ulaanbaatar-Baganuur has sections with inadequate visibility such as the end of the road ascent and the road curve that turning the mountain. Within traffic safety, sight distance is determined by one of the two methods, catching to stop before collide the object and passing the object without collision. The braking distance is the distance required to stop the vehicle from the instant brake application begins. Required stopping sight distance is determined as the sum of perception-reaction distance and braking distance (Ioannis *et al.*, 2001). The method catching to stop before collide the object is appropriate because of additional danger as the car may fall from the shoulder slope of the road. In road with two lanes, the calculating sight distance S_T is determined by following formula while vehicles going the opposite direction. The minimum distance of the visibility along the road can be calculated with the following formula (1) depending on the measurement.

$$S_T = \frac{v}{1.8}(t_p + t_c) + \frac{2v^2}{254_\varphi} K_э + l_0 \qquad (1)$$

where:

v : traffic speed,
t_p : reaction of driver,
t_c : lag time; in the calculation $t_p + t_c = (1 \div 2)$ sec.
φ : coefficient of friction,
$K_э = 1.5$: characteristic value of the disc brake, and
$l_0 = 1.5$ m : spare distance to stop that is not colliding the object.

The route Ulaanbaatar-Baganuur is hill area road with third category. The third category road has 80 km/h calculating traffic speed and its sight distance is 133.7 m. In case of inside of road curve has invisible by hill, the minimum sight distance is determined by the distance (AB) between two drivers of the vehicle that's going with opposite direction and along the tangent line to the bisectors of slip angle α (Figure 4).

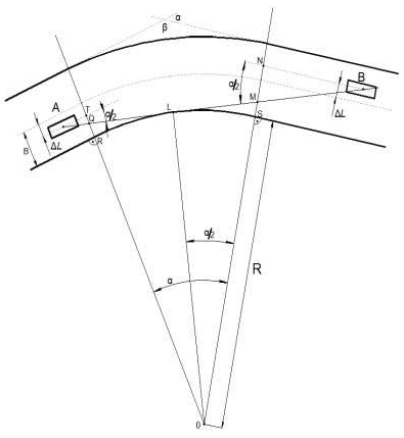

Figure 4. Diagram to determine the sight distance when inside of the road curve invisible to drivers

To determine the actual sight distance, the slip angle α measured by theodolite and turning arch length RLS is measured by a ruler. The formula to determine minimum sight distance had defined with the measured values (2).

$$S_{\text{yv}} = \frac{2R(1-\cos\frac{\alpha}{2})^2+4B\cos^2\frac{\alpha}{2}}{\sin\alpha\cdot\sin\frac{\alpha}{2}} \quad (2)$$

Where:

R : cornering radius, m
α : slip angle grad, and
B : width of lane, m.

Measuring sight distance, traffic safe speed had determined by formulas (1), (2) and coefficient of traffic safety is shown in table 1.

Table 1. Sight distance, safe speed and coefficient of traffic safety on the road curves

№	Points, km	Sight distance, S_v, m	Safe speed, V_s, km/h	Coefficient of traffic safety
1	58.5	50	41.0	0.5
2	83.5	92.7	63.04	0.78
3	84	119	74.16	0.9
4	8 6	124	76.14	0.9
5	87	48.7	40.44	0.5
6	88	93	63.17	0.7
7	89	33.8	30.82	0.3

Sight distance has been inadequate to the end of road ascent. The driver's sight level is 1.2 m high from the road surface and the distance to see without move eyes must be longer than calculating sight distance (Hassan, 2002; Hawkins, 2007). If assume that the crest vertical curve is a curve with constant radius R_c, the sight distance S_1 can be found by following formula and the relative height and arch length have to measure at least three points of a crest the road curve section of road to find the radius R_c.

$$S_1 = \sqrt{2hR_c} \quad (3)$$

Where:

R_c : radius of crest and sag vertical curve, m,
h : sight level of driver, m.

By distance between measuring points become same, the calculation will be easier. There are two categories of vertical curve, crest curve and sag curve. Relative height is measured by theodolite using with a ruler. Based on the measuring results the crest (sag) vertical curve radius is determined by following formula.

$$R_c = \frac{2\cdot(\Delta h_1+\Delta h_2)\cdot\Delta h_1}{2\Delta h_1+\Delta h_2-\Delta h_3} \quad (4)$$

Where:

$\Delta h_1 = h_O - h_A$: relative height points OA, m,
$\Delta h_2 = h_A - h_Б$: relative height between "А – Б", m, and
$\Delta h_3 = h_Б - h_В$: relative height between "Б – В", m. (Figure 5.)

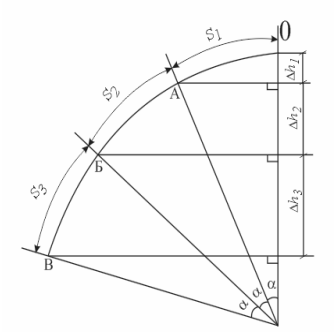

Figure 5. Diagram to determine the radius of road crest vertical curve

In the table 2 and 3 shown measured values of crest and sag vertical curve, its calculated radius and coefficient of traffic safety (CTS, $K_б$) that determined by calculating sight distance and sight distance S_1on the crest vertical curve section of the road.

Table 2. Measurement value and calculation result to determine the radius of road crest vertical curves

Points, km	Measured height of the points, cm				Relative height, cm			Radius R_c, m	Sight distance, S_1, m	Safe speed, V_s km/h	CTS $K_б$
	h_O	h_A	$h_Б$	$h_В$	Δh_1	Δh_2	Δh_3				
17	76	157	265	518	81	108	253	18.01	6.57	42.22	0.527
18	65	126	204	391	61	78	191	18.84	6.72	43.23	0.540
24	245	293	337	472	44	48	135	80.96	13.93	84.29	1.05
29	126	157	202	308	31	45	106	47.62	10.69	67.35	0.84
83	26	157	317	772	131	160	405	44.84	10.38	65.62	0.82

On the sag vertical curve, the sight distance has not inadequate, but additional load is applied by centrifugal force (Barbosa, 2011). According to road construction act and norm in Mongolia, that centrifugal force load must be less than 5 percent of the vehicle permissible maximum mass. So, the permissible speed of the vehicle to pass sag vertical curve is determined by following formula 5.

$$V_p = \sqrt{0.05gR_s} \quad (5)$$

Where:

R_s : radius of sag vertical curve, m,
g = 9.81 m/sec^2

Table 3. Measurement value and calculation result to determine the radius of road sag vertical curves

Points, km	Measured heights of the points, cm				Relative height, cm			Radius R_s, m	Sight distance, S_1, m	Safe speed, V_s km/h
	h_O	h_A	$h_Б$	h_B	Δh_1	Δh_2	Δh_3			
19	57	89	119	204	32	30	85	4.40	5.29	0.06
19.5	3	49	114	220	46	55	106	2.26	3.79	0.04
46	137	139.6	141.4	149.2	2.6	2.8	7.8	140.4	30.87	0.38
47	15	18	22	31.85	3	4	9.85	280	42.40	0.53
57	21	24.5	28.4	39.2	3.5	3.9	10.8	518	57.83	0.72
63	20	24.4	29.3	42.9	4.4	4.9	13.6	818.4	72.12	0.90
87	11	15.5	20.4	34.2	4.5	4.9	13.8	846	73.33	0.91

3.3. Evaluation of traffic safety

The points at 83.5 and 88 km from Ulaanbaatar are defined as unsafe, at 58.5 km and 87 km are defined as dangerous and at 89 km is as critical because the invisibility of the road curve inside on hilly area. Earn points at 58.5 km from Ulaanbaatar or the front of the status of Chingis Khaan, the main reasons of accidents influenced by road condition are related to inadequate visibility in the inside road curve when drivers have lost their attention and driving control. Although, by calculation, level of danger of the point at 89 km from Ulaanbaatar seemed to be critical but there are no accidents occurred during the analysis period.

To decrease the level of danger at the point, lowering the hillside would be needed to guarantee better visibility. The required arrangements to improve the traffic safety on the dangerous stretches for example:

- Speed limit signs
- auto-radar control of speed
- In the road curve with small radius the “safety gap” or “island”
- Direction sign with light-emitting diodes (LEDs)
- Put the red reflector outside of the road curve with small radius and placing the white reflector dividing strip of two directions.

Conclusion

1. In some points of route Ulaanbaatar-Baganuur road vertical curves at the crest and sag introduce inadequate visibility that influences negatively to traffic safety. Although small radius of sag vertical curve seemed not to have direct influence on accidents, the additional load broke the asphalt surface and was then indirectly influencing traffic safety.
2. Road condition problems could be also affected using proper signing e.g. with warnings and speed limits.
3. As rollover accidents happened in great numbers on the straight and good visibility steppe or valley roads, it is required to study the mutual influences of side wind and vehicle speed on the local roads as well as the influence of the Mongolian road condition to the driver distraction.

ACKNOWLEDGEMENTS

This research is supported by a Competitive Small Grant from the Health Project of the Millennium Challenge Account Mongolia.

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