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Traffic intensity on roads with big longitudinal slope in mountain conditions

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Abstract. The instantaneous, average, and critical speeds of vehicles passing through the Kamchik pass were determined in this article. The law of critical speeds of safe movement of the traffic flow has been developed. The research results on determining the speed of movement of vehicles of different categories in mountain conditions are presented. To ensure safety, depending on the speed of the vehicles and the condition of the road surface on the dangerous areas of the mountain road, recommendations are given on the speed limits and road signs to be installed.

1 Introduction

Mountain regions occupy about 22% of the territory of Uzbekistan [1-6]. Difficult terrain in mountainous regions greatly impacts the mode and safety of vehicles. The large length of sections with maximum longitudinal slopes, and curves of small radii in the plan, often with unsecured visibility, force drivers to dramatically change the modes of movement of vehicles, which often leads to emergencies. The greatest influence on the speed and safety of motor vehicles on mountain roads is exerted by curves in terms of a small radius with large turning angles, the number of which is 2-3 per 1 km. Mountain highways in Uzbekistan make up about 3% of the total road network.

A mountain road hurts the operation of the vehicle. As the altitude rises above sea level, the engine power decreases due to air thinning. In mountain conditions, the weather changes dramatically. Sunny weather may change to rain or sleet to snow as you climb higher. The intensity of engine heating increases. All this worsens the car's traction and leads to decreased traffic safety [7-9].

The cargo is transported non-stop day and night through Kamchik Pass. In this pass, depending on the season, the intensity of the traffic is from 10,000 vehicles/day to 30,000 vehicles/day. Therefore, ensuring the safety of vehicles on these roads is an urgent issue.

The rapid development of the economy of Uzbekistan creates wide opportunities for transporting goods and passengers by road transport, as well as the complexity of the traffic flow on the country's roads, as a result of which the number of road traffic accidents increases. Most of the traffic accidents occurring on the Kamchik Pass are caused by the increase in the speed of vehicles [10-16].

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The analysis of the available data indicates that the number of cases related to the death of citizens resulted from accidents that occurred in the Kamchik Pass section of the A-373 "M-39 highway-Guliston-Boka-Angren-Kokan and Andijan-Osh" highway in recent years is increasing.

The scientific researches show that the cause of the accidents observed on A-373 "M-39 highway-Guliston-Boka-Angren-Kokan and Andijan-Osh" is the drivers' overspeeding.

2 Methods

Mathematical modeling, experimental studies, distribution curve, cumulative speed curve, and average speed methods were used in the research process. Relations between critical speed and turning radius of the road for different conditions are calculated using the software MatLab.

The average speeds of vehicles on the dangerous part of the mountain road were determined using camera recordings. Cameras are mounted at points A and B of the dangerous area of the mountain road (Figure 1). The passage of exactly one car from points A and B is recorded using a camera. The distance between points A and B is known, and the time taken to cover this distance is available in the camera recording. The average speed of vehicles in this dangerous section was determined using time and distance. In this study, test research works with M1 (passenger car with 8 seats), N1 (truck with gross weight up to 3.5 tons), N2 (truck with a gross weight of more than 3.5 tons, and up to 12 tons), N3 (truck with gross weight more than 12 tons) category vehicles were carried out.

3 Results and Discussion

The movement speed of vehicles on longitudinal slopes with 7%, 10%, 12% of A-373 "M-39 highway-Guliston-Boka-Angren-Kokan and Andijan-Osh" has been searched. The areas of A-373 "M-39 highway-Guliston-Boka-Angren-Kokan and Andijan-Osh" between 256-258 km with a distance of 2 km and longitudinal slope of 7 %, between 238-242 km with a distance of 4 km and longitudinal slope 10 %, between 248-251 km with distance 3 km and longitudinal slope 12 % have been chosen as a difficult condition and scientific researched. The width of the road is 18-20 m, and cornering radiuses are 200-1800 m in these areas of the road.

Cameras were installed at the beginning and end of the road kilometer to determine the speed of vehicles in these dangerous sections (Figure 1). The accuracy of the mileage was determined by installing a fifth wheel (device for counting the distance and speed) on the Nexia car. The start and end of the speed detection path are marked. To increase the study's accuracy, the speed of at least 500 cars of the M1, N1, N2, N3 classes was measured [1-3].

Fig. 1. Mounting the camera on the road side

Using the record from the camera, the speed of vehicles of M1, N1, N2, N3 classes on the road with longitudinal slopes of 8%, 7%, 10%, and 12% is determined.

$$V_{avr}=\frac{\sum_{i=1}^{n} vt+\sum_{i=1}^{m} vt+\sum_{i=1}^{k} vt+\sum_{i=1}^{l} vt}{\sum_{i=1}^{n} t+\sum_{i=1}^{m} t+\sum_{i=1}^{k} t+\sum_{i=1}^{l} t} \quad (1)$$

where n, m, k, l are quantity of vehicles of M1, N1, N2, and N3 categories, respectively; v is vehicle speed km/hour; V_{avr} is average speed of the vehicle, km/hour.

With the help of formula (1), each category's vehicle's speed is determined for road conditions with longitudinal slopes of 7%, 10%, and 12% (Figure 2).

	average speed M1	average speed N1	average speed N2	average speed N3	average speed for all, km/h
7% slope	67,16	52,4	49,7	44,9	65,1
10% slope	68,75	52,88	46,31	34,72	61,29
12% slope	62,43	42,38	34,3	30,7	55,04

Fig. 2. Speeds of the vehicle depend on longitudinal slope of the road

Speeds of vehicles M1, N1, N2, and N3 on the road with a slope of 7% are 67.16, 52.4, 49.7, and 44.9 km/hour, respectively. The average speed of vehicles of all categories between 256-258 km is 65,1 km/hour.

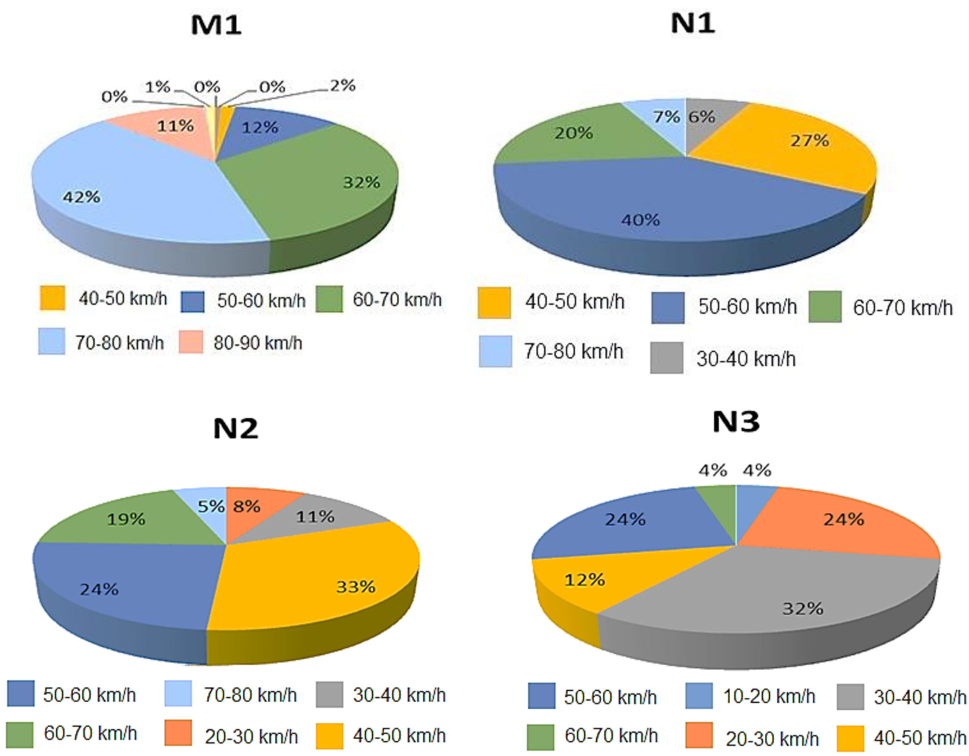

Fig. 3. Speeds of vehicles of categories M1, N1, N2 and N3 in the traffic

It can be seen from Figure 3 that 42% of M1 category cars were driven in the speed range of 70-80 km/h. 32% of N3 category cars moved in the speed range of 30-40 km/h. The speed difference between cars and trucks is 40 km/h. A sharp difference in speeds leads to an increase in road accidents.

Determination of modal and cumulative speed of transport flow. The amount of movement given to passenger cars is determined using the following formula:

$$N_{given} = \sum_{1}^{n} n_i \cdot K_{given} \tag{2}$$

where N_{given} is amount of movement given to passenger cars; n_i is amount of movement of the vehicle of n_i type; K_{given} is coefficient of the vehicle of i type given to the passenger car [5, 8].

Speeds of the traffic determined on the road with a distance of 3 km and longitudinal slope of 12 % between 248-251 km of the Kamchik pass are shown in table 1:

Table 1. Speeds of the traffic determined on the road with a distance of 3 km and longitudinal slope of 12 % between 248-251 km of the Kamchik pass.

Traffic speed	Cumulative density of passenger cars, %	Cumulative density of trucks, %	Cumulative density of all vehicles, %
20	0	1.3	0.25
30	0.31	12.96	2.75
40	0.62	29.84	7.25
50	2.17	54.5	13.26
60	13.66	81.8	27.8
70	45.96	96.1	55.6
80	87.57	100	90
90	98.75		99
100	99.07		99.25
110	100		100

Based on the obtained results, a graph of the modal speed of the traffic flow was constructed (Figure 4).

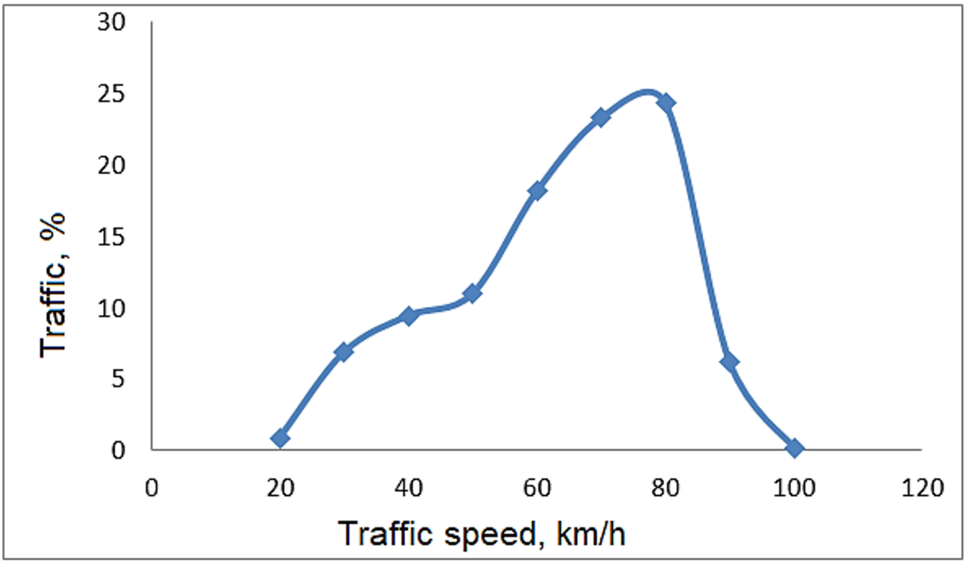

Fig. 4. Modal speed of the traffic

With the help of a cumulative curve, speeds are determined, provided with 15, 50, 85, and 95 % (Figure 5). Here 15 % must be taken into account as a minimum in the organization of the traffic, minimal speed will be limited with that help, and mandatory sign 4.7 must be installed. The traffic provided with a 50 % speed value showed the average speed of all vehicles. In case of speed provided with 85 %, the road signs and road markings can be installed. In the case of speed provided with 95 %, the safety speed is assumed to be the design speed, and this value is used in the calculation of road elements.

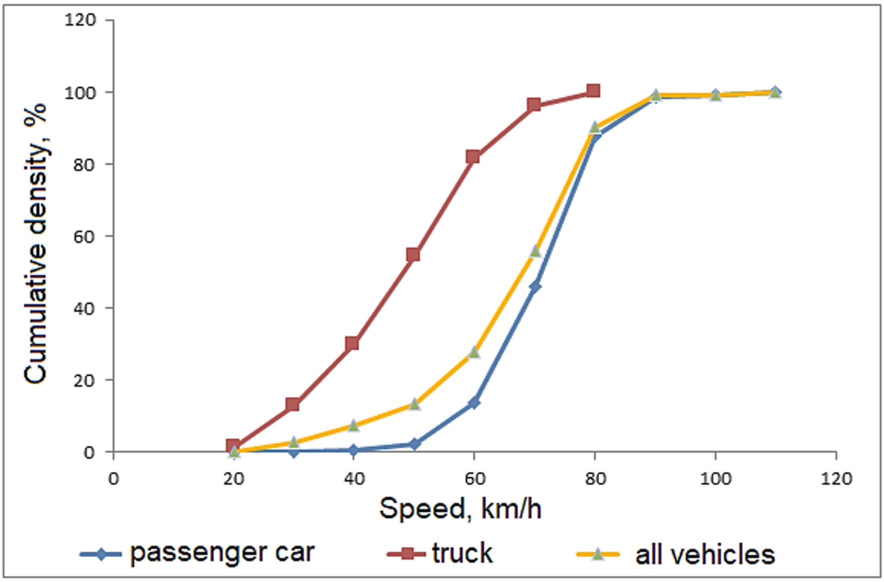

Fig. 5. Speeds by cumulative curve provided with 15, 50, 85, and 95 %.

Determination of the speed in dangerous districts. It should be mentioned that the climate of the mountainous regions is changeable, and precipitation is often observed. Driving vehicles in bad weather conditions creates difficulties for drivers. This causes a significant increase in the number of road traffic accidents. The main task of ensuring the safe movement of a turning vehicle on road turns is to maintain its stability. Loss of stability can be observed in the form of overturning, side sliding, and skidding of the leading wheels. The overturning and sideslip situations are represented by the overturning critical speed and the sideslip critical speed [5-7].

The critical speed for the sideslip, in turn, is determined using the following formula:

$$V_{a\varphi} = \sqrt{gR\varphi}\text{, m/s or } V_{a\varphi} = \sqrt{\frac{gR\varphi}{tg\theta}}\text{, m/s}$$

The critical speed for rollover, in turn, is calculated by the following formula:

$$V_{over} = \sqrt{\frac{gRB}{2h_g}}\text{, m/s or } V_{over} = \sqrt{\frac{gLB}{2tg\theta \cdot h_g}}\text{, m/s.}$$

Where R is turning radius, m; φ is adhesion coefficient; B is vehicle track, m; L is car base, m; h_g is center of gravity of the vehicle, m; Θ is turning angle of the steering wheel, g is acceleration of gravity, m/s^2.

Table 2. Adhesion coefficients depending on the road condition

Adhesion coefficient, φ			
Dry road	Wet road	Snowy road	Icy road
0.75	0.4	0.25	0.12

Graphs of relations between critical speeds and turning radiuses for each road condition are shown in Figures 6, 7.

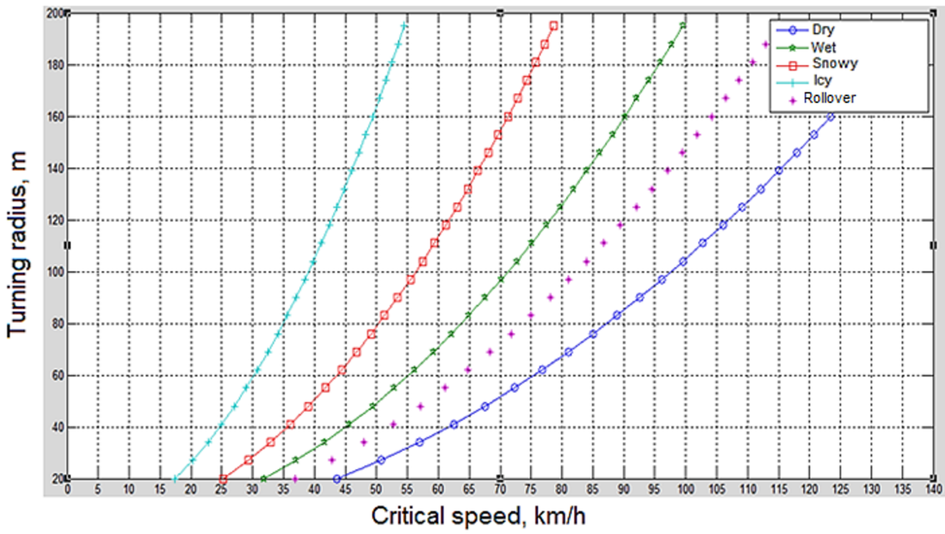

Fig. 6. Graph of relations between critical speed and turning radius of the road for different conditions

Using the graph below, critical speeds of rollover are determined for a road turning radius of 40 m.

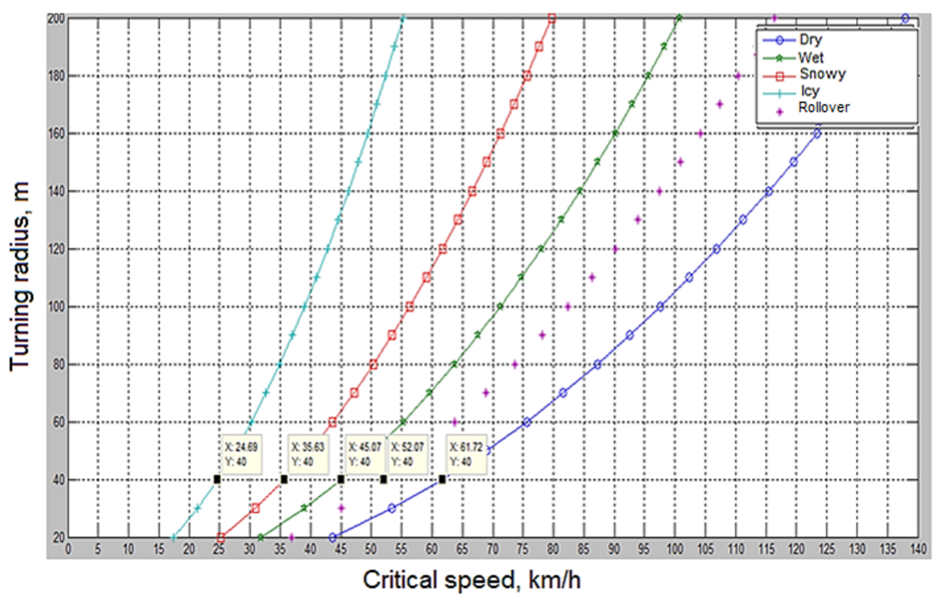

Fig. 7. Determination of critical speed for rollover in turning radius of $R = 40$ m

It can be seen that when the road surface is dry, when the vehicle moves at a speed of $V = 62.48\ km/h$, the skidding starts, but from the graph (Figure 7), it can be seen that the speed of V = 52.07 km/h is the critical rollover speed, and at a higher speed, the vehicle loses stability. When the road surface is wet, the speed of V = 45.07 km/h and above, the vehicle loses stability due to sliding. When the road surface is covered with snow, the speed V = 35.63 km/h and above, the vehicle loses stability due to sliding. It was found that when the road surface freezes, the speed of V = 24.69 km/h and above, the vehicle loses its skid stability.

As a result of the research, it can be said that the main reasons for the occurrence of accidents observed in the Kamchik pass are as follows:

- over speeding;
- inability of drivers to correctly choose the speed of the vehicle in the radius of curvature;
- variation of the road longitudinal slope in the range of 7-12 %;
- low road visibility;
- frequent changing of the weather.

4 Conclusion

In conclusion, it can be mentioned that the change of weather greatly influences the safe movement of the vehicle; there is a difference of V = 30 km/h between the difficult weather conditions and the average weather conditions. In the Republic of Uzbekistan, the only highway connecting the valley regions with the capital and other regions passed through the Kamchik pass.

This aspect means that this road is highly intensive and important; therefore, the limited speed creates various problems in installing the road sign. If the speed is set for normal weather conditions, cases of speeding in such conditions by inexperienced drivers will be observed, and as a result, road traffic accidents will occur. Considering the latter, installing road signs, controlled from a distance corresponding to the weather and road surface conditions, is recommended.

To reduce the occurrence of accidents on mountain roads: the analysis of vehicle speeds shows that the average speed of N3 class trucks is 44.9 km/h on a 7% slope where drivers do not slow down despite the high road gradients. The fact that the speed of some cars on a 7% slope is 120 km/h leads to increased traffic accidents. We recommend limiting the traffic speed to 60 km/h in these areas.

Knowledge of these laws and dangerous sections of mountain roads plays an important role in successfully solving road safety in mountain conditions by adapting the technical parameters of highways to modern requirements and, as a result, in preventing accidents on mountain roads.

References

1. Evlonov R.G. Development of measures to improve road safety (on the example of the Republic of Dagestan). p. 185, (2007).
2. Andryanov Y.V. Study of the influence of road and transport conditions on the efficiency of the technical operation of vehicles. p. 176, (1979).
3. Moldaliev E.D. Research and development of organizational and technical measures to reduce road accidents on mountain roads. p. 214 Bishkek, (2005).
4. Fayzullaev E., Rakhmonov A., Mukhtorjonov U., Nosirjonov Sh. Improving road safety using intelligent transportation systems on mountain roads. Journal of Engineering and Technology (JET). Vol. 12(2). pp.59-66, (2016).

5. Fayzullaev E., Tursunbaev B., Xakimov Sh., Rakhmonov A. Problems of Vehicle Safety in Mountainous Areas and Their Scientific Analysis. AIP Conference Proceedings. Vol. 2432, p. 030099, (2022).
6. Sh.Khakimov, E. Fayzullaev, A. Rakhmonov, and R. Samatov. Variation of reaction forces on the axles of the road train depending on road longitudinal slope. E3S Web of Conferences Vol. 264, 05030 (2021).
7. Fayzullaev E.Z., Rakhmonov A.S., Mukhtorjonov U.M. Implementation of intellectual transportation systems to ensure traffic safety on mountain roads. Railway transport: topical issues and innovations. Vol. 2. pp.81-88. (2022).
8. Sh. Khakimov, E. Fayzullaev, A. Rakhmonov. Evaluation of the complexity of the road in the mountains. Silk Road transport. Vol. 3-4. pp.48-60. (2019)
9. Magomedov M. Mountain roads (Features of design, construction and exploitation of the example of Dagestan). Moscow. (2006).
10. Ross H. L., and Ross H. L. Why Functional Safety in Road Vehicles? Springer International Publishing. pp. 7-39. (2016).
11. ISO 26262 (2011): Road vehicles - Functional safety. International Organization for Standardization, Geneva, Switzerland. (2011).
12. Mauro, R. (2015). Traffic and random processes. Trento: Springer International Publishing Switzerland. DOI: https://doi. org/10.1007/978-3-319-09324-6.
13. Elefteriadou L., An Introduction to Traffic Flow Theory, Springer, New York, (2014).
14. Mauro, R., Calculation of Roundabouts: Capacity, Waiting Phenomena and Reliability, Springer-Verlag, Berlin-Heidelberg, (2010).
15. Wegman F., Brouwer M., Cauzard J. P. and Elvik R. Transport safety performance indicators. European Transport Safety Council. (2001).
16. A. A. Tursunov Vehicle performance management in mountainous operating conditions. p. 441. (2002).