Improving Road Safety by Affecting Negative Factors

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Abstract: The current increase in automobilization leads to a decrease in road safety. Therefore, the purpose of this research is to analyze and identify the causes that significantly affect the size and severity of accidents. Most often, only the time factor is analyzed, which includes the month, day of the week and directly the time of day when the accident occurred. However, among the influencing factors it is necessary to consider such as weather and climatic conditions, the parameters of the road and the surrounding infrastructure, the condition of the driver, the type of incident and the type of violation. The main problem in constructing a model explaining the dependence of target factors is the sparsity of the initial data and a large number of independent variables. In this regard, the construction of a unambiguous predictive model is difficult. However, general patterns and factors potentially influencing the result were identified. For this purpose, both the classical methods of descriptive statistics and the methods of intelligence and prognostic analysis were used. The adoption of measures affecting the selected factors will reduce human losses. At the same time, the evaluation of made decisions effectiveness should be based on feedback.

1 INTRODUCTION

The currently observed increase in motorization leads to a decrease in road safety (RS). A traffic accident (TA) is the result of a complex interaction between drivers, vehicles, roads, road infrastructure and environmental elements. Not all factors that can potentially influence its occurrence can be recorded and measured during the observation process. For this reason, searching for new methods that make it possible to analyze and identify the causes significantly influencing the number and severity of TA remains relevant.

According to statistics, in the Russian Federation for 11 months, 2018, there were 151291 accidents (-1.78% compared to the same period last year), in which 16412 people died (-5.4%) and 192959 people were injured (-1.49%)(Road Safety Indicators, 2019).

Despite the general improvement in the situation on the roads of Russian Federation, the state inspectorate for road safety is currently faced with an ambitious task - to achieve zero road mortality and take the leading positions among European countries on this indicator. To achieve this goal, a road safety strategy in Russia until 2024 was approved at the beginning of the year (On approval of the Road Safety Strategy, 2019). According to its key indicator, the death rate on the country's roads by the end of the program should be reduced to 20 thousand people per year. In fact, this figure was reached in 2017: according to the Ministry of Internal Affairs, more than 168 thousand accidents occurred in Russia, in which almost 19 thousand people died (this is 6.5% less than in 2016). However, the strategy proclaims the desire for zero road mortality by 2030. As a target for 2024, the social risk index was also set, which is not more than four killed per 100 thousand people.

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2 THE SELECTION OF PATTERNS THAT AFFECT THE ACCIDENT

Improving RS requires precise methods of analyzing the road network (RN) to identify the most dangerous areas that are prioritized for the implementation of countermeasures in order to maximize the measures' effectiveness. When analyzing, critical points are usually identified using statistical (regression) models and criteria obtained on the basis of accident data for the period (Park et al., 2013; Hu et al., 2013; Yannis et al., 2016; Yannis et al., 2017; Srinivasan et al., 2013).

Then, to quantify the risk of TA for each identified critical point, a Bayesian aposteriori analysis is used (Stipancic et al., 2018; Jiang et al., 2014; Huang et al., 2009; Serhiyenko et al., 2016). However, it should be noted that since collisions' databases have inherent errors, omissions of values and distortions of actual values, a significant drawback of this approach is the low reliability of the results (Park et al., 2013).

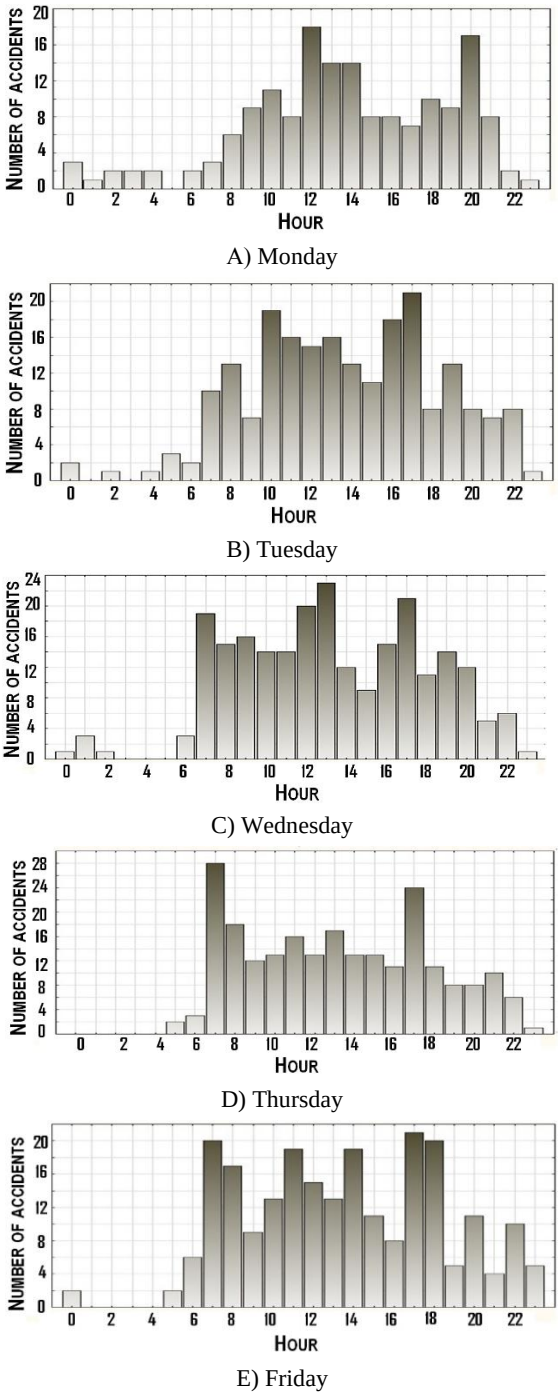
In order to identify patterns and build prognostic models in this work, classical methods of descriptive statistics, as well as methods of data mining and prognostic analysis, were chosen.

3 DESCRIPTIVE ANALYSIS

The data collected by the State Traffic Safety Inspectorate for the city of Elabuga for 2017 were used as the initial information.

86 factors were available in the original sample. However, such a large number of independent variables is a problem in constructing a model explaining the dependence of target factors. Considering also the source data spacing, upon further analysis, we were forced to reduce the number of factors to 18. These included the type of TA, traffic violations, street, the type of road infrastructure object in place, lighting, number of lanes, weather conditions, month, day of the week, hour, social characteristics of the driver, driving experience (years), gender, degree of intoxication (mg/l), number of vehicles involved in the accident, type of vehicle, mark and model of vehicle.

On the constructed histograms of the distribution of the accidents' number by the hour and by the week's day (Figure 1) it can be seen that on weekdays (except Monday) and on Saturday, the greatest number of accidents occur during the morning and evening peak hours, as well as during the lunch break (Figure 1B-E). On Monday and Sunday (Figure 1A, F) the morning surge of accidents is not observed.



A) Monday

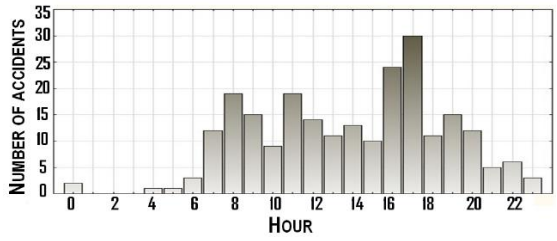
B) Tuesday

C) Wednesday

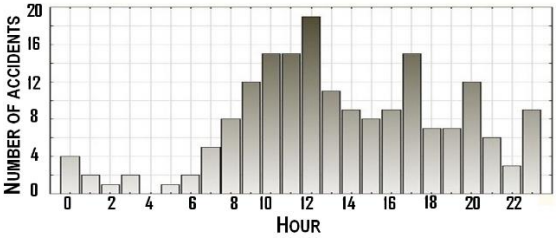
D) Thursday

E) Friday

Figure 1: Histograms of the distribution of the accidents' number by the hour and the week's day.

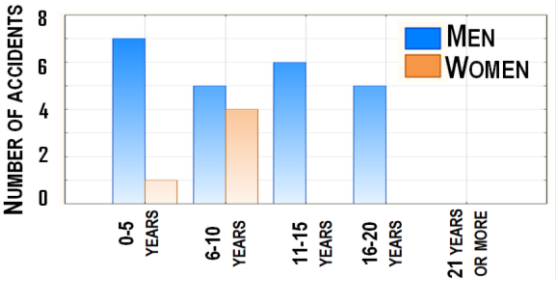


F) Saturday

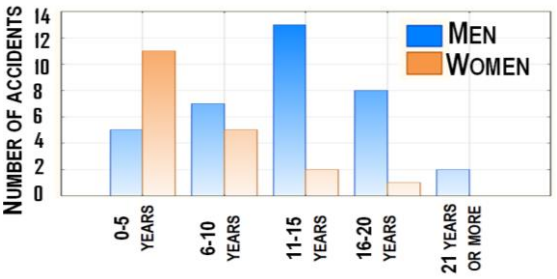


G) Sunday

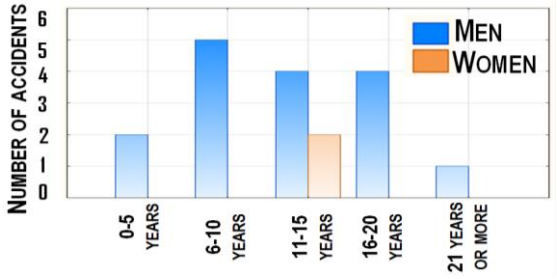
Figure 1: Histograms of the distribution of the accidents' number by the hour and the week's day (cont.).



A) Thursday



B) Saturday



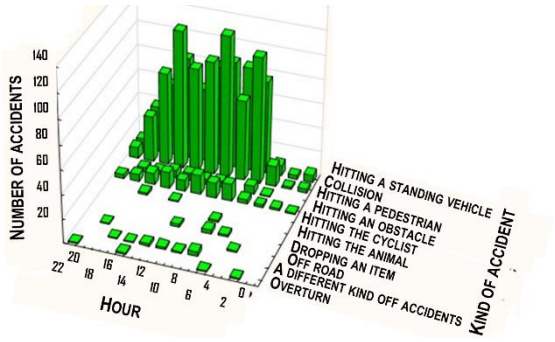
C) Sunday

Figure 2: Histograms of the distribution of the accidents' number committed by male drivers during rush hours.

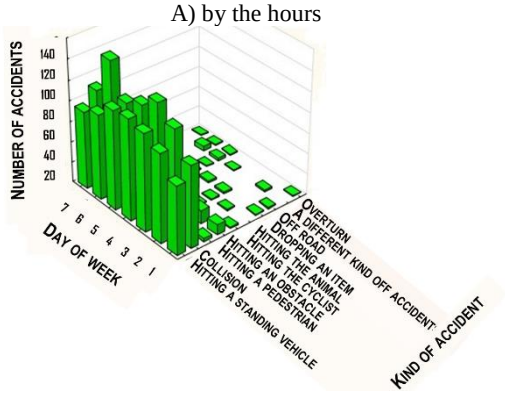
For further analysis, records of accidents that occurred in the morning rush hour on Thursday, on the evening on Saturday and on lunch on Sunday were selected. According to the histograms of the distribution of accidents at these intervals (Figure 2), it is clear that men are the causers of a greater number of accidents. Namely, in the morning rush hour on Thursday, the maximum number of accidents is done by male drivers with average driving experience (Figure 2A). This circumstance can be explained by the fact that they are in a hurry to work. Hour-peak weekends (Figure 2 B, C) are characterized by a large number of accidents involving male drivers with long driving experience, perhaps - these are people in age who go out of town on a Saturday, to a country house, to nature, and on Sunday come back home.

As for female drivers, on Sunday there were significantly fewer TA involving them than on Thursday and Saturday (Figure 2A-C). This may be due to the fact that on weekends women are busy with household chores and do not get behind the wheel.

As can be seen from the Figure 3, the most common types of accidents are collisions, hitting a standing vehicle, hitting an obstacle, hitting a pedestrian.

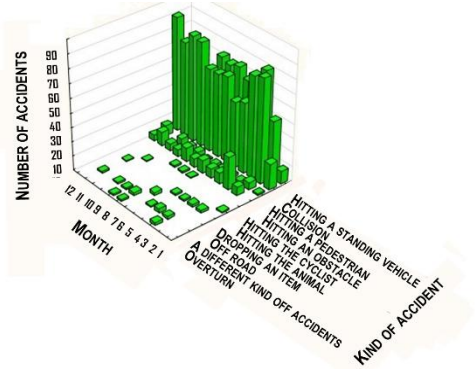


A) by the hours



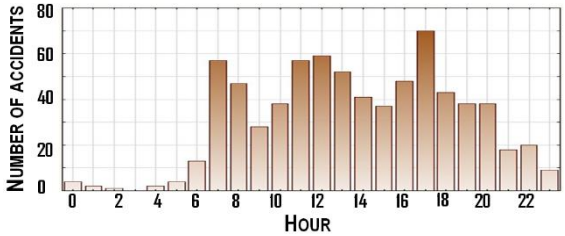
B) by the week's days

Figure 3: Histograms of the distribution of the accidents' number by accident types.

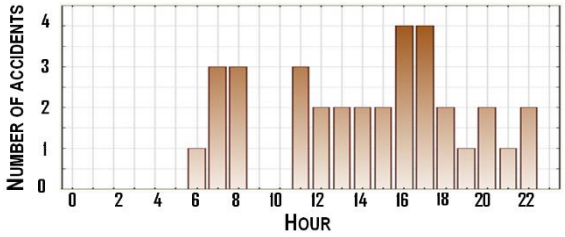


C) by the months

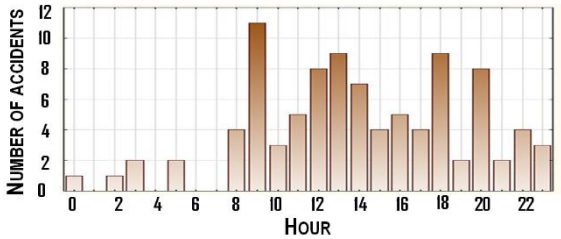
Figure 3: Histograms of the distribution of the accidents' number by accident types(cont.).



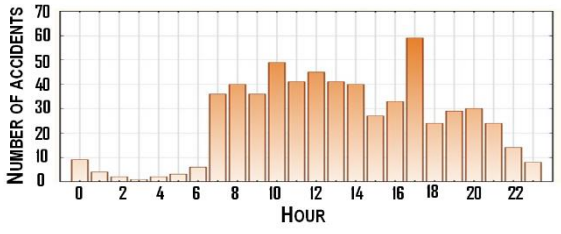
A) collisions



B) hitting a pedestrian



C) hitting an obstacle

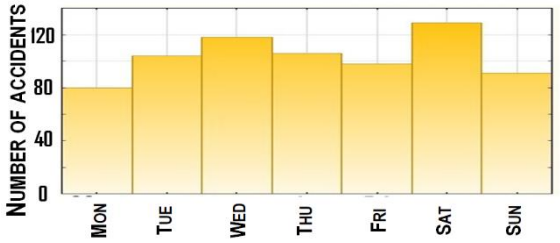


D) hitting a standing vehicle

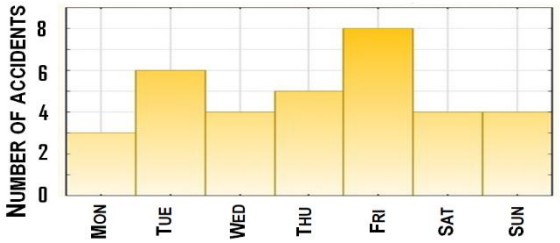
Figure 4: Histograms of the distribution of the accidents' number by hours and by type of accidents.

Daily analysis of accidents' types shows that their distribution is generally similar and also has three bursts - in the morning, in the afternoon and in the evening (Figure 4). It should be noted the lack of facts of hitting a pedestrian at night (Figure 4B).

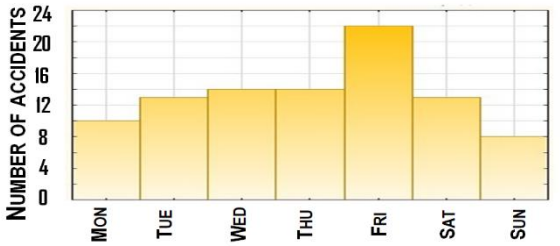
When analyzing the type of accident on week's days, it can be seen that the distribution of the number of accidents during a collision and hitting a standing vehicle is constant (Figure 5A, D). For hittings on pedestrians and obstacles the number of accidents increase on Friday (Figure 5B, C).



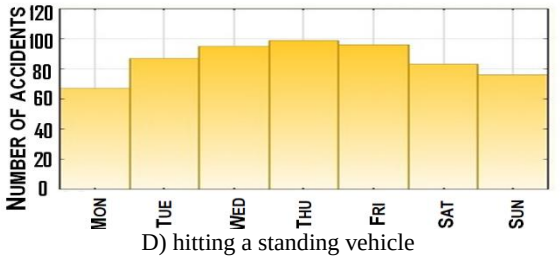
A) collisions



B) hitting a pedestrian



C) hitting an obstacle



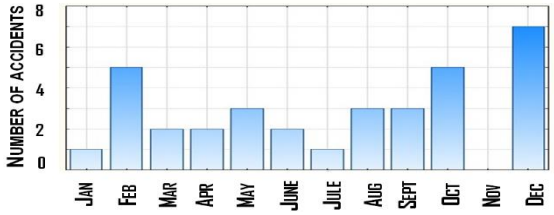
D) hitting a standing vehicle

Figure 5: Histograms of the distribution of the accidents' number by week's day and by type of accidents.

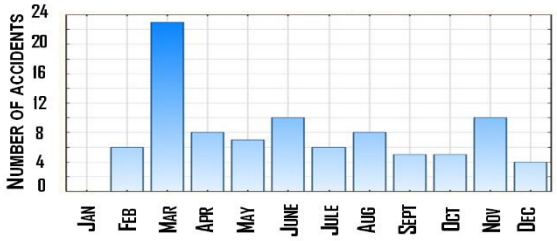
Analyzing the distribution of the accidents' number by months (Figure 6), you can see that the most alarming months are December, February and

March. For the winter months, the increase in the accidents' number is associated with a short light day and difficult weather and road conditions (blizzards, drifts, reduction of the roadside's width). For March, average daily temperature drops, morning and evening frosts, and as a result - deterioration of road conditions (ice on the road) are characteristic. Also, after the snow melted, a large number of road surface defects appear, which are not always visible to the driver, especially at night. In summer, the number of accidents decreases significantly. This is the main vacation time, so the number of official and personal transport is reduced. Road and weather conditions at this time of year are also quite favorable. In January, there is the least amount of accidents, which is obviously due to the long New Year holidays.

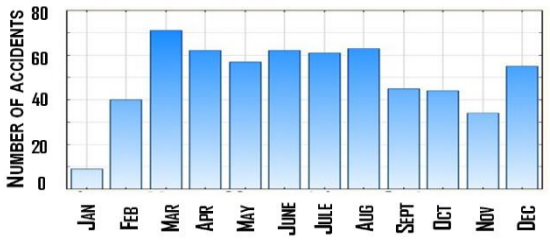
A) collisions



B) hitting a pedestrian



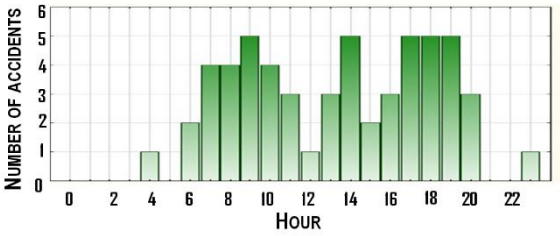
C) hitting an obstacle



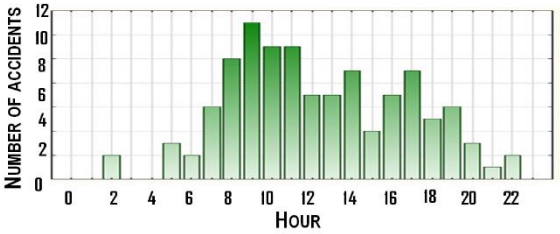
D) hitting a standing vehicle

Figure 6: Histograms of the distribution of the accidents' number by months and by type of accidents.

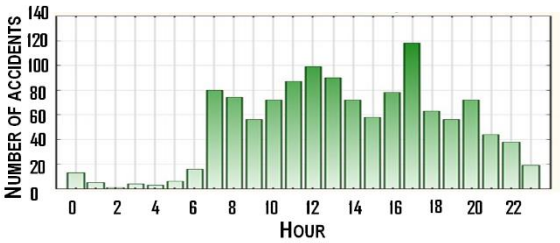
Considering, in particular, the histograms of the distribution of the accidents' number by hours and types of participant (Figure 6A-B), we can see that the greatest number of accidents are committed by drivers of passenger vehicles. This pattern can be associated with a large flow of passenger vehicles on the roads, as well as gross violations of the driver himself, such as speeding, violation of the rules of overtaking, maneuvering, driving under the influence of alcohol. Among busses, the peak of accidents occurs in the morning and evening rush hours, for vehicles- lunchtime is added to them (Figure 7 A, B). For trucks, the largest number of accidents falls on the interval between 8 and 11 am (Figure 7 B), which is obviously related to the morning delivery and unloading of goods to the distribution networks of medium-tonnage trucks within the city territory.



A) busses



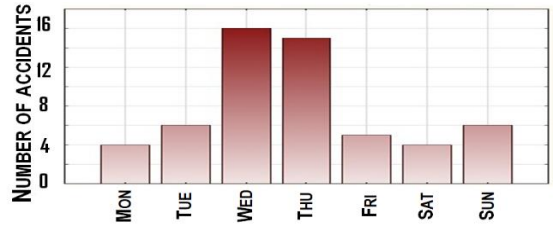
B) trucks



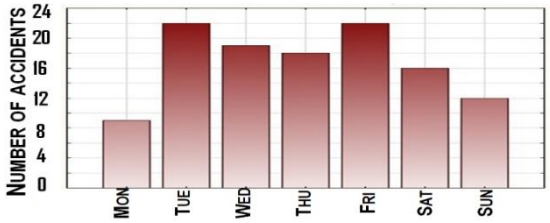
C) passenger vehicles

Figure 7: Histograms of the accidents number by the hours and types of participants.

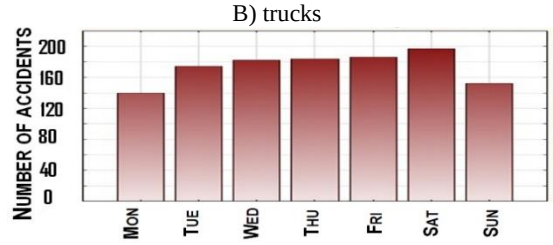
Most often, buses become participants in an accident on Wednesday and Thursday (Figure 8 A), trucks - on Tuesday and Friday (Figure 8 B). For passenger vehicles, the distribution of accidents by week's days is fairly uniform (Figure 8C).



A) busses

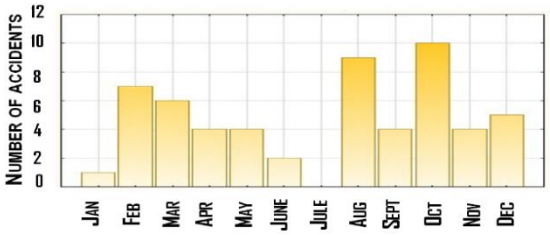


B) trucks



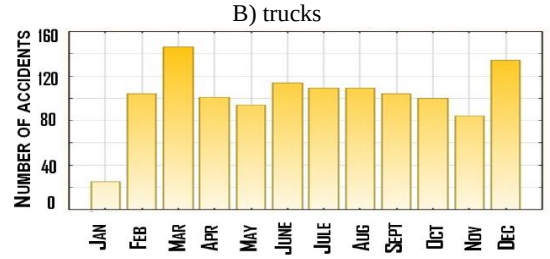
C) passenger vehicles

Figure 8: Histograms of the distribution of the accidents' number by days of the week and by types of participants.



A) busses

B) trucks



C) passenger vehicles

Figure 9: Histograms of the distribution of the accidents' number by month and by types of participants.

The most dangerous months for buses are February, March, August, October (Figure 9 A), for trucks - February, March, November (Figure 9 B), for passenger vehicles - March, December (Figure 9 C).

An analysis of the accident by gender showed that the most frequent types of accidents for both men and women were collisions and hitting a real vehicle (Figure 10).

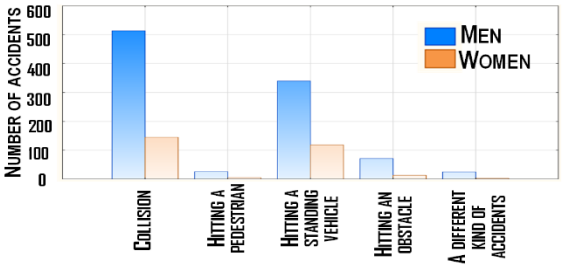


Figure 10: Histograms of the distribution of the accidents' number by gender and by type of accidents.

It should be noted that for women there is a gradual decrease in the number of accidents with increasing driving experience, which indicates the positive role of the accumulated driving practice. The same can't be said about male drivers. They are characterized by the same high number of accidents up to 20 years of experience (Figure 11), which may indicate a lack of driving culture and neglect of traffic rules.

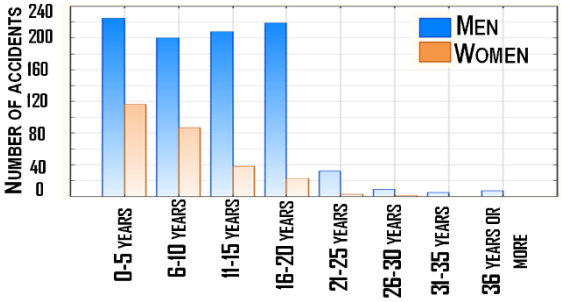


Figure 11: Histograms of the distribution of the accidents' number by gender and by driving experience.

Taking into account this fact and the relatively large number of male drivers, it can be explained why the number of accidents by types does not decrease with increasing driving experience (Figure 12).

It was found that the greatest number of accidents with the injured fall on clear weather (Figure 13), they occur on the roadway 60 m wide (Figure 14). In collisions there are accidents with a large number of injured (Figure 15).

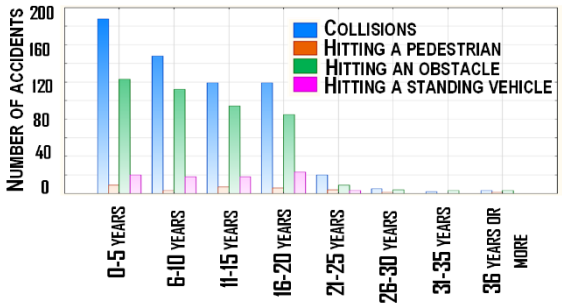


Figure 12: Histograms of the distribution of the accidents' number by driving experience and by type of accidents.

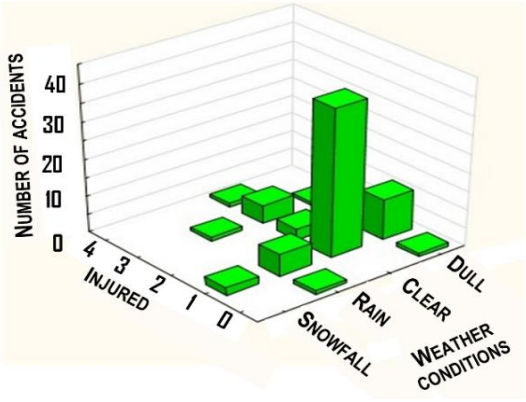


Figure 13: Histogram of the distribution of the accidents' number by the number of injured and weather conditions.

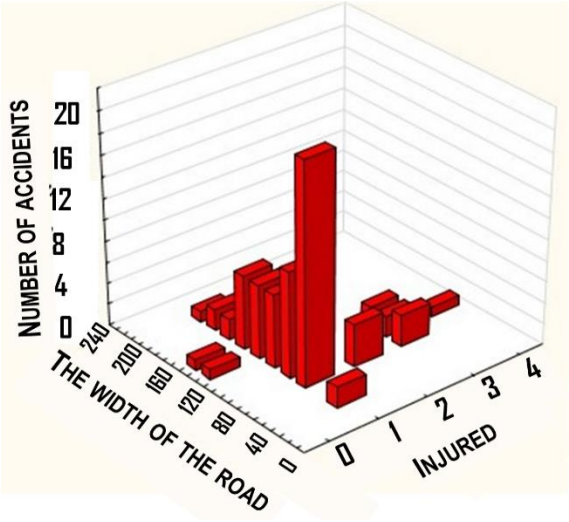


Figure 14: Histogram of the distribution of the accidents' number by the number of injured and the roadway's width.

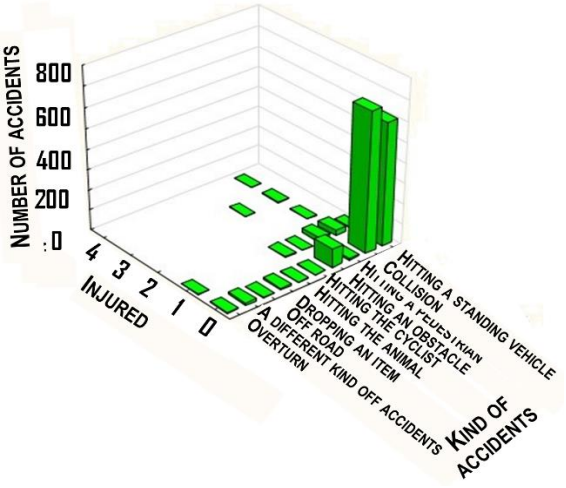


Figure 15: Histogram of the distribution of the accidents' number by the number of injured and by type of accidents.

4 BUILDING A PROGNOSTIC MODEL

At the following stage the analysis of severity of road accident according to the algorithm presented in Figure 16 was carried out.

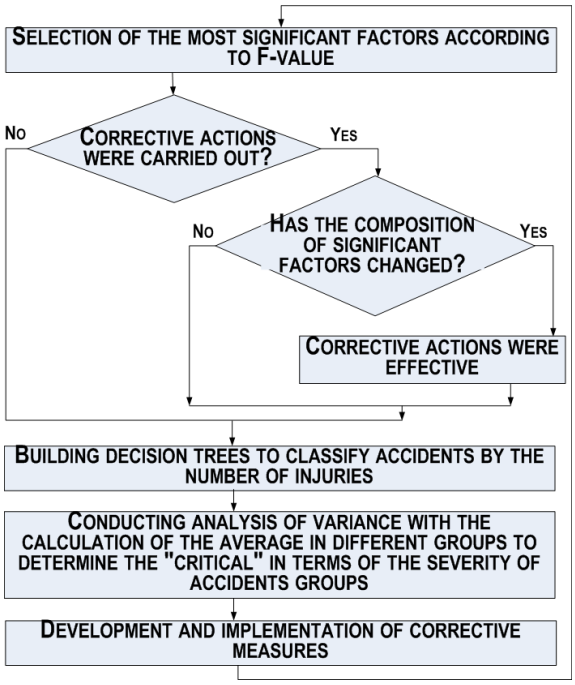


Figure 16: Algorithm for building a prognostic model.

When building a prognostic model for the predicted variable – Number of injured– in the first step, the most significant factors were identified.

The graph shows that the most important factor for describing the number of injured is the degree of intoxication. Day of the week and Time of day, Type of vehicle (bus, truck or vehicle) are the least affecting the result variables (Figure 17).

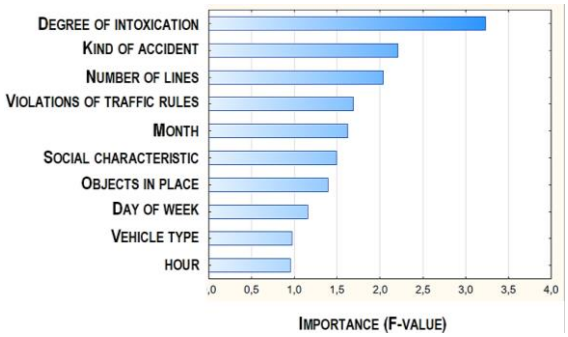


Figure 17: Predictor Importance Graph.

The next step was to find the optimal model, which allows to classify accidents by the number of injured. To solve the problem, so-called growing trees were used, as part of the algorithm, a whole system of trees is being built, more and more reducing the classification error. We describe the results of the construction of some of these trees.

The type of accident occupies a consistently high place in the list of important predictors, and the number of injured is 1 for hitting a pedestrian, and two or more for a collision.

According to the types of traffic violations, the division is as follows: for accidents resulting from violations of rules of the vehicle's location on the carriageway and non-observance of the travel order, the number of injured is 2, in accidents with violation of the pedestrian crossing driving rules, non-observance of conditions allowing traffic to go in reverse, violation of requirements of traffic light signal, wrong choice of distance, departure to the oncoming traffic, violation of the rebuilding rules - equal to 1.

For March, April, October, the number of injured is 2, for the remaining months - 1.

Among the objects of the RN, attention must be paid to unregulated intersections of unequal streets (roads), where the number of injured is 2. On the stretches, departures from the adjacent territory, regulated pedestrian crossings, the average number of injured is 1.25, on regulated crossings , unregulated pedestrian crossings, public transport stops, unregulated intersection with a roundabout, inner yard territory - 1.

Also, to study the factors affecting the accident rate, the method of single-factor dispersive analysis was used. Variables from the number of attributes selected during screening were taken as predictors. Result variable - Number of injured. Among the factors that have the greatest impact on the resulting variable, according to Fisher's criterion at a significance level of $p = 0.05$, such factors as the Type of traffic accident, the degree of intoxication (μg / l), the type of traffic violations, Month, Hour, Number of lanes were highlighted.

Table 1: The distribution of the average number of injured by time of day.

Times of Day	The average number of injured in the accident with injuries
0, 8, 9, 10, 15, 16, 18	1,000000
7, 13	1,142857
14	1,166667
12	1,250000
17, 20	1,333333
11, 22	1,500000
6	1,666667
1, 5, 21	3,000000

The algorithm gives the Social category, the type of vehicle involved in the accident, as the least affecting the result variables.

Also, the most critical in terms of the number of injured hours (Table 1), as well as the concentration of accidents with the largest number of injured were identified (Table 2).

Table 2: The distribution of the average number of injured by location.

Street	The average number of injured in the accident with injuries
Molodezhnaya st., Okruzhnoye sh., Neftyanikov per., Chapaeva st., Sh-2 st., Mardzhani ul, Kazanskaya st., Proletarskaya st., Zemlyanukhina st., Gabdully Tukaya st., Bolgar st., Malaya Pokrovskaya st.	1,000000
Oilmen pr-kt	1,133333
Mira pr-kt	1,125000
Moscow st.	1,250000
Builders st.	1,375000
Naberezhno-Chelninskoe sh.	2,000000
Tugarova st.	2,333333
Gassar st.	3,000000

5 CONCLUSIONS

As a result of the analysis, the following recommendations were formulated for reducing the number of TA on the roads of Yelabuga:

1. Organization of events to reduce traffic load and curb traffic violations at the entrances to the city on Saturday from 17.00 to 18.00 and Sunday from 12.00 to 13.00 by summer drivers and tourist drivers

2. Development and implementation of propaganda and educational activities to improve the driving culture of men with driving experience up to 20 years.

3. Development and implementation of activities for training and consolidating driving skills among women with driving experience up to 5 years.

4. Organization of events to reduce the number of drivers who are driving in a state of alcohol and drug intoxication.

According to the prognostic model built on the basis of growing trees, an accident class with the number of injured 2 or more people has been allocated. The following decision rules were obtained for him: Type of accident - collisions resulting from violations of the rules of the vehicle's location on the carriageway and non-observance of the travel order; place of the accident - unregulated intersections of unequal streets (roads); Month - March, April, October; The time of the accident - 1.00, 5.00, 21.00.

It is necessary to analyze the impact of the measures taken for the reconstruction of road infrastructure, preventive or regulatory measures, and the modernization of vehicle design on road safety. At the same time, the evaluation of the effectiveness of decisions should be made on the basis of feedback. For this, it is necessary to select among the whole set of factors those that most strongly influence the severity of accidents, and then re-calculate quantitative criteria for assessing the severity of accidents in the next period. In this case, the adoption and evaluation of the effectiveness of measures affecting the selected factors will reduce human losses.

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