Temporal Characteristics of Distribution of Traffic Accidents in Yakutsk

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Abstract. A purpose of this article is research of temporal characteristics of traffic accident in climatic conditions of the North on an example of Yakutsk. The extreme natural and climatic conditions of the North significantly affect mental and physiological functions of road traffic users. Analysis of accident distributions by hours has been carried out separately for cold and warm seasons. The hours of an increased accident rate have been identified, which are compared with circadian rhythms of a human body. It has been established that influence of the circadian rhythms on statistics of road traffic crashes in Yakutsk is observed only for a cold period. In the warm period, dynamics of the crashes corresponding to the circadian rhythms of the human body were not detected. During development of measures aimed at a reduction of the accident rate, it is necessary to take into account the characteristics of the particular locality traffic, the natural and climatic conditions and temporal characteristics of the accident distributions. Since road users errors, leading to the road traffic crashes, are largely related to limited reliability of a psychophysiological human state, the natural and climatic conditions of the North can be considered as a factor of a negative impact on road safety.

1. Introduction

An increase of motorization, which has been observed in these recent times, has caused many problems, but the main ones are deaths and injuries from the road traffic crashes. A level of these indicators in Russia is noticeably higher than in some European countries. About 20 thousand people die on the roads of Russia every year and almost 220 thousand citizens suffer the injuries of varying degrees of severity [1]. According to data of the World Health Organization, economic damage from the traffic accidents in most countries makes up 3% of their gross domestic product [2]. During the development of the measures aimed to improve the road safety, it is necessary to take into account the road traffic characteristics that have been formed in each inhabited locality with allowance for the natural and climatic factors. Yakutsk (a capital city of the Republic of Sakha (Yakutia)) is located in a northern climatic zone of Russia in a permafrost territory. A sharply continental climate of the city is characterized by a short hot summer and a long cold winter. The maximum summer air temperature was 38.4°C. The period of white nights is in June and July. The cold season is characterized by the short daylight hours, frost fogs and extremely low air temperatures (the lowest temperature in the city was fixed at –64.4 °C). The extreme climatic impacts and permafrost in bases of the automobile roads lead to their rapid degradation with formation of numerous cracks, holes, subsidences and potholes.
which significantly complicate the traffic conditions. Sharp temperature changes of a road surface contribute to the formation of cracks. A temperature range of the asphalt concrete road surface can reach 100 °C and more during its operation [3]. In the cold season snow and ice deposits are formed on the road surface, leading to a decrease of wheel adhesion and respectively the increase of a stopping distance of vehicles. All of these factors worsen quality of the roads and road safety. Due to a lack of warm garages and parking lots in Yakutsk, on cold days cars are left to run at idle, also one uses a remote starter and various engine heaters. Because of insufficient natural ventilation of Yakutsk, exhaust gases of motor vehicles form smog, which together with the frost fog reduces visibility to several meters sometimes [4]. In addition, due to the changes of the fuel combustion conditions in engines at the low temperatures, a content of harmful substances in the exhaust gases rises [5]. The main toxic components of the exhaust gases are hydrocarbons, oxides of carbon and nitrogen [6]. Emission of carbon oxides and hydrocarbons into an atmosphere increases, when the engine is operated at the minus air temperatures. It should be noted that most of the harmful emissions take place during operation of the cold engine [7]. A particularly high concentration of carbon monoxide in the exhaust gases is observed when the engine runs at idle [8]. All these worsen the air quality in winter that can adversely affect the physiological state of road users. An ecological situation is aggravated because Yakutia is in top ten regions of Russia with the oldest cars – an average age of the cars is 17.6 years. The old vehicles no longer meet ecological requirements [9]. The study purpose is to determine the characteristics of the road accident distributions in Yakutsk by the hours depending on the year season.

2. Material and research methods
For the study, statistical information of the traffic police about the road crashes in Yakutsk was entered into a database “Road Accidents”. The information on each accident is in 28 fields of the base – date, time, type of accident, type of road surface, state of the road, visibility, weather conditions, make and color of the car, etc. The analysis of a great deal of the information allows one to make reasonable conclusions about the main causes and temporal characteristics of the accidents and the influence of the external factors. This statistical information is distributed over time intervals to assess the influence of the climatic conditions and human circadian rhythms.

The analysis of the information showed that the largest number of the crashes in Yakutsk is due to the poor road conditions (29.9%), and there has been a tendency of the increase in this number. In Russia, according to the information of the traffic police, an amount of the crashes for this cause is less (21%) [10]. Despite the harsh climatic conditions, the number of the accidents in Yakutsk due to technical failures of the vehicles is negligible. The remaining causes of the crashes are non-observance of traffic rules by drivers (16%) and pedestrians (14.5%), movement speed does not match the specific conditions (13.3%), etc. These causes can be combined into one main cause – the human factor. Many researchers of the road safety have reached this conclusion [11, 12]. Reduction issues of error of the drivers and pedestrians are largely related to driver schools, upbringing, education, culture, etc. But since the accident is a result of an adverse combination of the systematic and random factors, the certain amount of the road crashes always happens due to the external impact influences on the road users [13].

Often the errors of the drivers and pedestrians are caused by their adverse mental and physiological states. The human states are influenced by the climatic factors that change the speeds of mental processes, including those controlling decision-making in the dangerous road situations. The Far North is characterized by a variety of the extreme climatic impacts on the human states. These are the low air temperatures in winter and high ones in summer, the sharp changes in the daily temperatures in spring and autumn, variability of atmospheric pressure, the short daylight hours in winter and long ones in summer. In addition, due to peculiarities of the Earth’s magnetic field at high latitudes, strong geomagnetic disturbances arise from solar wind action [14]. Because of all these external factors of the North, human reflexes and signal reactions are slowed down and emotional instability increases. The
lack of sunlight and oxygen also weaken the human body in the cold regions. In winter and autumn, many people experience a decline in body functioning [15].

One of the main psychophysiological characteristics affecting the road safety is the driver reaction time to the dangerous road situation [16]. This parameter changes depending on the time of day (24 hours). The optimal reaction time is in the period from 7 a.m. to 1 p.m. At night it increases by 20-25%. This is due to cyclical oscillations of the various biological processes in the human body during the day. The circadian biorhythms of the human body are mainly associated with duration of the daylight hours. Human visual receptors react to luminance of the light from sunshine, initiating hormone production in the body: the hormone melatonin regulating sleep-wake cycles is produced more in the dark and the hormone cortisol in the daylight [17]. The circadian rhythms of the human body have two main periods of mental and physiological activity – from 10 a.m. until 12 noon and from 4 p.m. until 6 p.m. The decline in the activity occurs at 2 p.m., it coincides with weakness and sleepiness after lunch. The slowest speed of the human response reactions is observed at night from 10 p.m. until 4 a.m.

3. Research results and discussion of them
To assess the impact of the natural and climatic factors, the information of the “Road Accidents” database was divided into the periods: cold (October, November, December, January, February and March) and warm (April, May, June, July, August and September). In Yakutsk 2492 accidents with the injuries were registered in 2009-2014, of which 1477 occurred in the warm season and 1015 in the cold one. To identify an effect of the human circadian biorhythms on the accident rate, the road crashes were distributed over the hourly intervals separately for the cold and warm periods. The accident distribution by the hours in the cold period is shown in figure 1.

Figure 1. Distribution of number of traffic accidents in Yakutsk by hours in cold season.

In the cold season, most of the accidents happened between 8 a.m. and 8 p.m. The greatest number of the crashes (70 cases) occurred in the time interval from 8 a.m. until 9 a.m., when traffic density increased. Moreover, in winter during this time in Yakutsk it was still quite dark, accordingly the road users did not fully wake up and their attentiveness and reactions decreased. The frost fogs take place also in the mornings, significantly reducing the road visibility. The next growth in the road accident rate happened in the period between 12 noon and 2 p.m. that is associated with the increase in traffic at lunchtime. The local maximum of the crashes (66 cases) is observed from 2 p.m. until 3 p.m., i.e. during the weakness and sleepiness after lunch. Then the increase in the road accident number (69 cases) occurred from 7 p.m. until 8 p.m., when the production of melatonin was already beginning in the human body. It may be concluded that in the cold period the accident rate increase in Yakutsk
during the determined hours is associated not only with the heavy traffic, but also with the decrease in the attentiveness and reaction time of the drivers and pedestrians in accord with the circadian rhythms of the human body.

The accident distribution by the hours in the warm period is shown in figure 2. It can be seen that the road crashes occurred more often from 12 noon until 12 midnight and in the afternoon the accident rate changed insignificantly. The greatest number of the crashes occurred at end of the working day from 5 p.m. until 7 p.m. (180 cases), then from 8 p.m. until 9 p.m. (84 cases) and from 10 p.m. until 12 midnight (166 cases). The warm period is characterized by the long daylight hours; the Sun rises quite early and sets late. The production of cortisol in the human body begins at about 6 a.m., and the road users are already alert and attentive in the morning despite the heavy traffic. At lunchtime, the number of the vehicles on streets of Yakutsk increases that affects the accident rate. In addition, the hot summer weather can influence the rise in the amount of the crashes in the afternoon. The high traffic density is noted in the evening hours – there are more trips to the country after work. Also, at this time the amount of drunk driver detention rose. This explains the increase in the crash number in the evening and at night. The accident rate peak between 10 p.m. and 12 midnight can be explained by the natural decline in the mental and physiological activity of the road users. Moreover, at this time, the traffic density is reduced and some of traffic lights are switched to a night mode, when they do not control the traffic, and some drivers accelerated the cars to the very high speeds. It can be concluded that the accident rate caused by the drivers during these evening hours is greater than during the daytime.

![Figure 2](image.jpg)

**Figure 2.** Distribution of number of traffic accidents in Yakutsk by hours in warm season.

4. Conclusion
Improving a road safety system as a multifunctional hierarchical one requires a system approach [18, 19]. The most vulnerable subsystem of the road traffic system is the “person”, especially due to the increase in the motorization and mental stress. The extreme climatic factors negatively affect the psychophysiological states of the road users; that slows their reactions necessary to prevent the dangerous traffic situations and to make a way out from them. This effect may not be so noticeable in the temperate zones, but in the Far North it is more clearly seen.

The considered changes in the dynamics of the crashes in Yakutsk indicate the impact of the seasonal variations in a daily routine of citizens, which are caused by climatic features of the North. In the cold season, the population activity and usage of the personal vehicles diminish, therefore, the traffic declines, but the accident rate does not decrease. The analysis of the accident distributions by the hours in the cold season showed the most pronounced oscillations of the accident rate during the day, correlating with the human circadian biorhythms. The maximum number of the crashes occurred
from 8 a.m. until 9 a.m., from 2 p.m. until 3 p.m. and from 7 p.m. until 8 p.m. In the warm season, the largest number of the crashes was observed between 12 noon and midnight, and in the daytime the accident rate changed insignificantly. Thus, in the summer, the hourly dynamics of the traffic crashes do not match the human circadian biorhythms.

During the development of the organizational measures aimed at reducing the amount of the crashes and their consequences, the determined temporal characteristics of the accident distributions by the hours may be useful. For example in Yakutsk, traffic police control should be strengthened in the hours with the largest number of the crashes: in the cold period – from 8 a.m. until 9 a.m., from 2 p.m. until 3 p.m. and from 7 p.m. until 8 p.m., and in the warm season – from 5 p.m. until 7 p.m., from 8 p.m. until 9 p.m. and in the period between 10 p.m. and 12 midnight. Optimization of the traffic light modes should be carried out taking into account the time of year and the traffic density. In the warm period, the work time of all traffic lights should be continued until 12 midnight. At the low climatic temperatures, to account for the poor visibility and slippery road surface, it is necessary to increase the time intervals allocated for each colour signal of the traffic light. One can conclude that during the development of the measures to improve the road safety, it should be taken into account the road traffic features of the particular locality, the climatic conditions and other factors that influence the psychophysiological states of the road users with consideration for their temporal variability.

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