Method for determining integral damage from road accident

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Abstract. In practice, the inspection of the scene of an accident, the conclusions, the collection of materials and execution are carried out, as a rule, by measuring electronic roulette, filming and visual methods without instrumentation, which does not allow to obtain the true (direct and indirect) causes that caused the accident, dimensions failures in the organization and management of traffic, both on the streets of its occurrence, and on the streets parallel to it, and the consequences of an accident, both on the transport involved in the incident and on other vehicles transport vehicles and their passengers affected by this incident. This article presents a method for determining the integral damage from a road accident taking into account the participating vehicles, drivers and passengers, as well as thousands of traffic participants (vehicles and passengers) who suffered damage due to a failure in the organization and management of traffic (factors, mileage), as well as road conditions that do not meet the requirements of traffic safety.

Each traffic accident (traffic accident) is associated with the restriction of traffic flows not only in the traffic lanes of the carriageway at the place of its occurrence, but also with an increase in the density of traffic flows, reducing their speed, and correspondingly increasing the travel time associated with speed and mileage, as well as higher cost of the final transport product [1, 2, 5]. On the street where the accident occurred, as a rule, a traffic jam (oncoming traffic) condition occurs. The oncoming streams of this street, leaving (right and left) through intersected (transverse) streets to parallel streets, where there is an opportunity for their passage. With the distance from the street of the accident, the flux density – resorption decreases, reaches up to 2–3 km in the transverse and longitudinal directions (figure 1).

The causal relationship of an accident, as a rule, is based on material with reliability. The unsatisfactory technical condition of the transport (according to the traffic police of the Ministry of Internal Affairs of the Russian Federation) [4] accounts for 0.7...1.5 % of all accidents committed in the Russian Federation. For this reason, 17...27 % – in Germany, 13...21 % – France, 22 % of all accidents committed in these states were committed in the USA. The reason is lack of technical competence or lack thereof.

Road conditions, professionalism and law-abiding drivers of vehicles, the human factor (the driver’s ethical condition, attentiveness in the process of driving) are the basic guarantors of ensuring traffic safety.
These parameters should be set during the inspection of the scene of the accident and the preparation of a conclusion on the true causes. The duty units of the traffic police of the territorial bodies are not always equipped with traffic control engineers, automotive engineers, and therefore these parameters are not available in the materials of road accidents.

The services of duty units of the traffic police traffic police inspection of places of road traffic accidents (DTP) and their execution is carried out, as a rule, by visual [3] method, video shooting, without proper instrumentation, which does not allow to collect and present reliable materials, characterizing their material involvement, preliminary and emergency situations of accident processes not only in the contours of the places of their implementation, but beyond them, as a failure of the traffic management system, the redistribution of traffic flows, which resulted in reprogram, congestion, and sometimes traffic accidents associated with the loss of time of passengers in vehicles due to traffic accidents and malfunctions. At the same time, often the establishment of the true cause of the accident, as well as related factors and the extent of the consequences, is not ensured. As a rule, a charge is brought against a driver or a pedestrian, while neither one nor the other is responsible for the organization of traffic, for the creation of road conditions that meet the requirements of road safety (road lighting, a visibility triangle at intersections, overloading the information field on lanes of carriageways, the degree of serviceability of the surface layer of the carriageway, coefficient of adhesion, provision with bends on curved roads, respectively, their radii, etc.). The consequences of an accident are usually limited to the loss of working capacity of the passengers participating in it and damage to vehicles. All this negatively affects the conduct of preventive measures and, accordingly, the reduction of casualties on the roads of cities and towns and beyond. Each accident causes damage to tens of thousands of vehicles due to failures in the organization and management of traffic and passengers of these funds, which is the focus of this scientific study.

Despite the significance and mass character of the size and consequences of road traffic accidents, damage to road traffic from a significant part of the Russian population is not established and is not reflected in the statistics. On the inspection schedule, the list of materials and instrumentation that ensure their reliability, registration of incidents on the basis of software and methodological principles aimed at preventing emergencies in the aspect of emergency safety, allowing to establish direct and
indirect causes of the accident, as well as the amount of integral damage, allowing at the same time to
determine and develop targeted (priority and promising) – long-term comprehensive measures,
standards are not developed us. There is no standard for the competence (qualification) of an executor
who has the right to draw up accidents, produce opinions, and conclusions.

Since traffic is a multifunctional, multi-factorial, multi-parameter and multi-level process that
inspects the traffic police, the device must be equipped with competent engineers who know the theory
of movement of transport and pedestrian flows and the functioning of the road transport complex [5].

The formula for determining the damage (integral) caused by a traffic accident to a society, a city
(district), road facilities, traffic, ecology can be presented as follows:

- for one i-th accident

\[
Y = \sum_{1}^{365} \sum_{1}^{L} \sum_{1}^{K} \sum_{1}^{Z} \sum_{1}^{L} \sum_{1}^{M} \sum_{1}^{T} \sum_{1}^{J} \sum_{1}^{H} [((\lambda_{1}) [(q_{1}^{\lambda_{1}}) \delta_{1}^{\lambda_{1}}] + [(t_{1}^{\lambda_{1}}) \delta_{1}^{\lambda_{1}}]) + \]

\[+ \left( (\mu_{1}^{\lambda_{1}}(b_{1}^{\lambda_{1}}) \delta_{1}^{\lambda_{1}}) \right) + \left( (\mu_{2}^{\lambda_{1}}(b_{2}^{\lambda_{1}}) \delta_{2}^{\lambda_{1}}) \right) + \left( (\mu_{n}^{\lambda_{1}}(b_{n}^{\lambda_{1}}) \delta_{n}^{\lambda_{1}}) \right) + \]

\[+ \left( (\mu_{1}^{\lambda_{2}}(p_{1}^{\lambda_{2}}) \delta_{1}^{\lambda_{2}}) \right) + \left( (\mu_{2}^{\lambda_{2}}(p_{2}^{\lambda_{2}}) \delta_{2}^{\lambda_{2}}) \right) + \left( (\mu_{n}^{\lambda_{2}}(p_{n}^{\lambda_{2}}) \delta_{n}^{\lambda_{2}}) \right) + \]

\[+ \left( (\mu_{1}^{\lambda_{3}}(p_{1}^{\lambda_{3}}) \delta_{1}^{\lambda_{3}}) \right) + \left( (\mu_{2}^{\lambda_{3}}(p_{2}^{\lambda_{3}}) \delta_{2}^{\lambda_{3}}) \right) + \left( (\mu_{n}^{\lambda_{3}}(p_{n}^{\lambda_{3}}) \delta_{n}^{\lambda_{3}}) \right) + \]

\[+ \left( (y_{k}^{1,2,3} + y_{l}^{1} + y_{m}^{1} + y_{n}^{1}) \right)
\]

where 1, 2, 3 – number of the knee (gender, genealogy);
\(y_{k}^{1,2,3}\) – damage caused to the k-th relative 1, 2 and 3 the knee (clan), thousand rubles;
\(y_{l}^{1}\) – damage caused to the \(\lambda\)-th vehicle associated with damage to its technical condition and
delays \(Z\) due to the i-th accident, as well as congestion situations, thousand rubles;
\(z\) = 1, 2, …, \(Z\) – the duration of the delay, h;
\(\lambda\) = 0.1, 0.2, …, 0.7 \((\lambda_{\text{max}}) = 360, 720, 2520 (\lambda_{\text{max}})\) – traffic flow, TE/s, TE/h;
\(k\) = 1, 2, …, \(K\) – the number of the relative, of the 1, 2, 3-th knee;
\(q_{1}^{\lambda}\) – a list of malfunctions (consequences) in the first vehicle that arose as a result of the i-th
accident;
\(\delta_{1}^{\lambda}\) – the cost of the cost of eliminating technical malfunctions (consequences) that arose in the
first vehicle related to the i-th accident, thousand rubles;
\(i = 1, 2, \ldots, I\) – accident number;
\(t_{1}^{\lambda}\) – the duration of the preservation of the place of the first accident, h;
\(\delta_{1}^{\lambda}\) – the cost of one hour to save the accident scene, thousand rubles;
\(\mu_{1}^{\lambda}\) – the number of drivers in the first vehicle participating in the accident;
\(b_{1}^{\lambda}\) – a list of injuries, damage caused by the drivers of the first vehicle of the i-th accident;
\(\delta_{1}^{\lambda}\) – the cost of loss of health (injuries) and damage, thousand rubles;
\(\mu_{2}^{\lambda}\) – the number of drivers in the second vehicle participating in the i-th accident;
\(b_{2}^{\lambda}\) – a list of injuries and damage caused by the driver of the second vehicle in the i-th accident;
\(\mu_{n}^{\lambda}\) – the number of drivers in the n-th vehicle participating in the i-th accident;
\(b_{n}^{\lambda}\) – a list of injuries and damage caused to drivers of the n-th vehicle in the i-th accident;
\(\delta_{1}^{\lambda}, \delta_{2}^{\lambda}, \delta_{n}^{\lambda}\) – the cost of treating injuries and damage caused by drivers of the second and n-th vehicle
in the i-th accident, thousand rubles;
\(\mu_{1}^{p_{1}}, \mu_{2}^{p_{2}}, \mu_{n}^{p_{n}}\) – the number of passengers in the first, second and n-th vehicle participating in the
i-th accident, people;
\(b_{1}^{p_{1}}, b_{2}^{p_{2}}, b_{n}^{p_{n}}\) – a list of injuries and damage caused to passengers of the first, second and n-th vehicle
involved in the i-th accident;
\(\delta_{1}^{p_{1}}, \delta_{2}^{p_{2}}, \delta_{n}^{p_{n}}\) – the cost of treating injuries and damage caused to passengers of the first, second and n-th vehicle
involved in the i-th accident, thousand rubles;
\(p_{1}^{t}, p_{2}^{t}, p_{n}^{t}\) – the duration of the delays of passengers in the first, second and n-th vehicles participating in the
i-th accident, h;
\(\delta_{1}^{p_{1}}, \delta_{2}^{p_{2}}, \delta_{n}^{p_{n}}\) – the cost of an hour of passenger delays in the first, second and n-th vehicles
participating in the i-th accident, thousand rubles;
\(y_{l}^{1}\) – damage to the n-th vehicles related to their mileage within the l-extent, thousand rubles;
l=1, 2, ..., L – the length of the mileage of the n-th vehicles associated with the i-th accident, km/TE;

\( \lambda = 1, 2, \ldots, \lambda_{\text{max}} \) – the intensity of the movement of vehicles on each lane of the carriageway in the j-th direction associated with rerun at the i-th accident, TE/h, TE/s;

\( y^\mu_z \) – the delay value of the \( \mu \)-th passenger in vehicles participating in the i-th accident, as well as those related to the rerun of other vehicles in this accident, where \( \mu \) means the delay value of the \( \mu \)-th, i.e. passenger number, hour/pass., (\( z = 1, 2, \ldots, Z \));

\( y^\prime_m \) – damage caused to the t-legal and m-th individuals (owners of vehicles), thousand rubles;

\( y_j \) – damage caused by the failure of traffic organization on the lanes of the carriageway of the j-th direction to the city (district) road traffic, utilities, including the carriageway of the roads and the environment, thousand rubles;

\( j = 1, 2, 3 \) – number of the object that suffered damage, respectively, traffic, urban (district) economy, ecology;

\( y_h \) – damage caused to productivity (of the final transport product) and associated with the loss of working time of \( h \)-persons involved in road accidents, registration, visiting emergency rooms, hospitals, etc. – disability, thousand rubles;

\( h= 1, 2, \ldots, H \) – number of the person involved in the commission, execution of an accident that has lost its working capacity, and sometimes death;

\( y_c \) – costs of investigative, investigative and judicial proceedings (actions) on the i-th accident, thousand rubles;

\( c = 1, 2, 3 \) – number of the event, respectively: inquest, investigative and judicial.

On the roads of municipalities of cities and rural settlements and between them in the Russian Federation, about (on average) 200 thousand accidents occur each year with serious consequences, about 30 thousand with a fatal outcome and more than 200 thousand people received various degree of injury. At the same time, unjustified material and moral damage is caused to road users, road and public utilities, the environment and society as a whole (table 1).

Not all employees of the duty department of the traffic police traffic police have comprehensive knowledge in organizing and managing the processes of traffic and pedestrian flows, ensuring road conditions within the requirements of regulatory installations, the functioning of aggregates and systems, trouble-free driving, and the assessment of movement as vehicles (any models), pedestrian flows, and the safe movement of passengers on all types of urban passenger transport.

| Years | Number of accidents | Consequences of accidents | Dead people | Wounded people |
|-------|---------------------|---------------------------|-------------|---------------|
| 2008  | 210000              | 29936                     | 270883      |
|       | 218322 [3]          |                           |             |
| 2009  | 210500              | 26084                     | 257062      |
|       | 203603 [3]          |                           |             |
| 2010  | 211000              | 26567                     | 250635      |
|       | 199431 [3]          |                           |             |
| 2011  | 199868              | 27957                     | 251848      |
|       | 224035 [3]          |                           |             |
| Change in 2011 to 2010, % | 5,3 | 5,2 | 0,5 |

It is necessary to acquire knowledge not only of the content of standards and normative settings in the field of traffic safety, but also to solve the problems of their implementation in production in vertical and horizontal planes.

The lack of in-depth knowledge among traffic police officers does not allow, not only to evaluate, but also to ensure the collection of reliable information at all stages of the accident. In parallel, other
employees study and confirm the facts of the consequences of an accident (the extent of damage to the vehicles of their passengers and pedestrians and other vehicles of their passengers who lost time in traffic jams, reruns) due to the redistribution of flows due to the accident.

It is advisable to develop a program-methodical complex of regulated solutions to problems associated with establishing the true causes of the accident and the size of the injuries to road users, and material damage to road traffic and utilities.

In the last century, there was a standard for determining braking distance:

\[ L = K \cdot V^2 / (254 - (\varphi \pm i)) \]

where

- \( K = 1 \pm 2.5 \) – the coefficient of wear of the brake system;
- \( V^2 \) – square of the speed of movement, km²/h²;
- \( 254 = 2 \cdot 3.6^2 \cdot 9.81 \) (3.6² – km/h to m/s conversion, 9.81 m/s² – body gravity acceleration);
- \( \varphi = 0.1 \ldots 0.3 \) – coefficient of adhesion of the roadway;
- \( i \) – descent or ascent.

At the end of the last century, the standard was adjusted:

\[ L = V^2 / (26 \cdot j_{\text{est}}) \]

where

- \( V \) – the speed of movement, km/h,
- \( V^2 \) – square of the speed of movement, km²/h²;
- \( j_{\text{est}} \) – steady-state acceleration 5 or 5.8 m/s².

These formulas are empirical. The kinematic energy formula is used:

\[ E = \frac{1}{2} \cdot m \cdot V^2 \]

where

- \( m \) – the mass;
- \( V^2 \) – square of the speed of movement, km²/h².

According to two standards, these formulas did not provide the required reliability, one of the key parameters characterizing the serviceability of the vehicle’s brake system under loading conditions and without it, the state of tires and the value of adhesion coefficients, which directly affect the length of the braking distance. Despite the importance of this system, there are no monitoring systems for estimating the length of the braking, from both the state of the brake system, the degree of its loading, the speed of movement, from the nose of tires and the coefficient of adhesion.

**Conclusion**

In our opinion, it would be justified by the Ministry of Transport of the Russian Federation to find the opportunity to allocate allocations in the order of fulfilling the priority tasks for the development of:

- systems for monitoring the state of the brake system, such as the braking length, depending on the degree of loading of vehicles (cargo, passenger, passenger), tire tread wear, speed, both on horizontal sections of roads and on slopes;
- a software and methodological complex that optimizes the solution of tasks related to the design of accidents (establishing a pre-emergency, emergency and post-emergency situation), determining the severity of the injured and the extent of damage both to the participants in the accident and to other traffic flows and their passengers due to mileage and delays in congestion associated with this accident;
- registration of an accident, inspection of vehicles, establishment of direct and indirect causes of the accident should be carried out by specialists (engineers) in road transport or traffic management.

It would be right for the Ministry of Transport of the Russian Federation to take on the mission to streamline the training of transport drivers at the level of standards, in particular: to take into account the drivers of buses, trams, trolleybuses and minibuses, to transport a large (18–200 people) number of passengers. This work is carried out on intense routes with high traffic intensity, training should be carried out according to specially developed programs for at least 1.5 years, which, during the movement, will exclude not only conflict situations, but also prevent traffic accidents.
Given there is mass profession (the driver of the subway, tram, trolley-bus, driver-master of the bus, minibus taxi and taxi driver), (driver-master of the truck (carrying capacity is 5–12 tons), the driver of a car), we develop and publish the state standard for these professions and their training in schools of passenger transport on the basis of universities, institutes, in schools of freight and passenger transport on the basis of universities, institutes and technical schools (colleges).

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