METHODOLOGY OF FORMATION OF DIAGNOSTIC CRITERIA
FOR EVALUATION OF SAFETY OF MOTOR TRANSPORT
PUBLIC SERVICE

M. Z. Erknapeshyan, V. A. Zelikov, K. A. Yakovlev and V. A. Ivannikov
G. F. Morozov Voronezh State Forestry University, Russia
E-Mail: sciencescience108@yahoo.com

ABSTRACT
Methodology of formation of diagnostic criteria for evaluation of safety of motor transport public service is offered. The main diagnostic indicators are determined. An integral criterion for evaluation of realization of activities as to prevention of accident by subjects of motor transport activity on the basis of 5-point system is offered.

Keywords: traffic safety, road passenger transport, accident indicators, diagnostic indicators, safety evaluation, questionnaire survey, motor transport public service.

INTRODUCTION
At present, collection of information about accident in the sphere of motor transport public service is conducted on the basis of current legal acts, passed by the Government of the Russian Federation, the Ministry of Internal Affairs, the Ministry of Transport, and the Federal State Statistics Service. At that, it was found that existing methods of informational provision of traffic safety in the sphere of motor transport public service are ineffective for prevention of accident and, primarily, due to absence of the system of true and effective indicators of evaluation of accident on passenger transport of general use.

Main part
Evaluation of traffic safety for road passenger transport of general use is conducted according to the following types of indicators: accident indicators - for evaluation of actual accident (absolute, relative, specific); diagnostic - for evaluation of activities for prevention of accident and risks, related to nonfulfillment of these activities; additional indicators - technical and operating indicators, used for comparative evaluation of indicators of accident and diagnostic indicators [1].

Diagnostic indicators of safety evaluation cannot be based on the RTI (road traffic incident) statistics, unlike accident indicators. The objects of their evaluation should be, first of all, motor transport companies and individual businessmen, so the differentiation of these indicators as to the types of connection is not advisable [2].

Diagnostic indicators of safety evaluation of motor transport public service are used for assessment of motor transport activity subjects’ performance of measures for prevention of accident with motor transport of general use. At present, these indicators are used by Federal Agency for Transport Supervision during control of transport operators as to their observation of license requirements [3]. These include: provision of permit for operation of motor transport units (passing of state technical inspection); availability of specialists, responsible for traffic safety control, which passed the review for the right to occupy the corresponding office; correspondence of specialists to qualification requirements; driver’s compliance with the regimen of labor and rest; passenger transportation permit for drivers who possess the corresponding qualification and work experience; provision of organizational and technical conditions for keeping all motor transport vehicles, which operate, in proper technical state; organization of pre-trip medical inspection of drivers; organization of control of medical examination of drivers; organization of pre-trip technical inspections of vehicles; prevention of road traffic incidents (RTI) [4].

The indicators that are not included in this list are not diagnostic.

In the safety control system of motor transport public service which includes the complex of measures of “driver-vehicle-road-environment” system, the subjects of motor transport activity have the authority and possibility to regulate just two main components of this system: “driver” and “vehicle”. Moreover, the “environment” element includes the necessity to provide three out of four above mentioned requirements: availability of specialists, responsible for traffic safety control, which passed the review for the right to occupy the corresponding office; correspondence of specialists to qualification requirements [5].

These requirements may influence the risk of RTI only through the system “driver”. That is, if a driver is not prepared by a qualified specialist, is not controlled by him as to the provision of traffic safety and passenger transportation and is not provided with the necessary materials (route scheme with dangerous spots, schedule, etc.), the risk of RTI will grow. However, the evaluation of these requirements for risk of RTI can be conducted only through the evaluation of specific measures which include professional selection of drivers, briefing them, training and professional development, control of drivers
before start of work on line and during the work, etc. This evaluation relates to the system “driver”, not “environment” [6].

Analysis of requirements set in normative legal documents, and of the requirements, set by Federal Authority for Transport Oversight, allowed forming the list of 12 main diagnostic indicators which most fully meet the requirements of accident prevention in motor transport company (Table-1).

Table-1. List of the main diagnostic indicators.

<table>
<thead>
<tr>
<th>№</th>
<th>Indicators of the sub-system “driver-vehicle”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Vehicle”</td>
</tr>
<tr>
<td>1</td>
<td>Control of technical state of vehicles before start of work on the line</td>
</tr>
<tr>
<td>2</td>
<td>Control of technical state of vehicles on the line</td>
</tr>
<tr>
<td></td>
<td>“Driver”</td>
</tr>
<tr>
<td>3</td>
<td>Professional selection (shortlisting) of drivers for hiring</td>
</tr>
<tr>
<td>4</td>
<td>Providing the drivers with information as to driving conditions on the route (briefing on traffic safety)</td>
</tr>
<tr>
<td>5</td>
<td>Training of drivers on the routes</td>
</tr>
<tr>
<td>6</td>
<td>Annual training of drivers as to traffic safety, according to 20-hour program</td>
</tr>
<tr>
<td>7</td>
<td>Professional development of drivers (at least once in 3 years)</td>
</tr>
<tr>
<td>8</td>
<td>Drivers’ medical examination for the driving license of “D” category</td>
</tr>
<tr>
<td>9</td>
<td>Conducting the pre-trip medical inspection of drivers</td>
</tr>
<tr>
<td>10</td>
<td>Conducting the medical inspection of drivers between trips</td>
</tr>
<tr>
<td>11</td>
<td>Conducting the medical inspection of drivers after trips</td>
</tr>
<tr>
<td>12</td>
<td>Controlling the work of drivers on the line</td>
</tr>
</tbody>
</table>

The list of indicators in the Table shows the measures which are conducted by the subjects of motor transport activity for control of safety of passenger transportation – that’s why these parameters may be applied for determining the diagnostic criterion of safety evaluation of motor transport public service.

The evaluation of safety of motor transport public service requires the development of the model which allows determining the influence of the complex of measures for prevention of accident by subjects of motor transport activity in the risk of RTI [6, 7]. The object of evaluation should be the motor transport company or individual businessman. Their sphere of responsibility for provision of passenger transportation safety within the system “driver-vehicle-road-environment”, as was mentioned above, includes only the sub-system “driver-vehicle” which is a basis of logical node of the model (Figure-1).
In the Figure-1, the conditions for \( x_n \) are the characteristics of the object. In this case, these are diagnostic indicators of safety. The consequences are values of the model state, depending on the values of the initial parameters (conditions). The target function of the model is the integral diagnostic criterion of safety evaluation of motor transport public service, including, according to the logic of the offered system, the diagnostic criteria which were defined earlier.

Thus, on the basis of the determined criterial diagnostic indicators of safety evaluation (Table 1) and using the methods of mathematical logic, combinatorial and probability theory, there form a multifactorial model for assessment of safety risks of motor transport public service. It can be expressed in graphic form, used in the theory of mathematical logic, shown in Figure-1; in graphic form, used in combinatorial theory (Figure-2); in the form of formula (1) [8]:

\[
p(Y) = p(Y_1 | Y_2) = p(Y_1) \cdot p(Y_2)
\]

where: \( P(Y) \) – integral risk of passenger of getting into RTI; \( p(Y_1) \) – probability of RTI because of technical malfunction of a vehicle; \( p(Y_2) \) – probability of RTI because of insufficient level of driver and of control of his work.

Probability of RTI because of technical malfunction of a vehicle \( p(Y_1) \), taking into account that this system includes only two main parameters, may be presented in the following form:

\[
p(Y_1) = p(x_1) \cdot p(x_2)
\]

where \( p(x_i) \) – probability of a passenger being hurt in RTI as to conditions \( x_1 \) und \( x_2 \); indices 1 and 2 correspond to the number of indicator entry in Table 1.

Probability of RTI because of insufficient level of driver and of control of his work \( p(Y_2) \) is determined by the formula:

\[
p(Y_2) = p(f_1) \cdot p(f_2) \cdot p(f_3) \cdot p(f_4),
\]

where \( p(f_i) \) – probability of RTI because of non-performance of professional selection of drivers; \( p(f_2) \) – probability of RTI because of non-performance of briefing of drivers as to the traffic safety; \( p(f_3) \) – probability of RTI because of non-performance of measures as to training and professional development of drivers; \( p(f_4) \) – probability of RTI because of non-performance of necessary medical inspection of drivers.

Whereas:

\[
p(f_1) = p(x_3),
\]
\[
p(f_2) = p(x_4),
\]
\[
p(f_3) = p(x_5) \cdot p(x_6) \cdot p(x_7),
\]

\[
p(f_4) = p(x_8)\]
\[ p(f_4) = p(f_5) \cdot p(x_{12}), \]
\[ p(f_5) = p(x_8) \cdot p(x_9) \cdot p(x_{10}) \cdot p(x_{11}). \]

The essence of the model consists in the fact that during inspections of Federal Transport Oversight Agency of the motor transport companies and individual businessmen, it allows determining their compliance with regulatory requirements according to the set list of indicators, taking into account the influence of each of the indicator on the risk of RTI.

As the formula (2) allows determining the risk of RTI, in order to determine the risk for passenger to be injured in RTI, it’s necessary to find the average share \( \delta \) of the injured in RTI in the number of RTI for 5 years - then the sought risk will equal:

\[ p(Y) = p(Y') \cdot \delta. \]  \hspace{1cm} (4)

In order to provide clarity of the final value of the transport operator activity as to observation of requirements of safety of motor transport public service, we offer to use the well-known 5-point system of evaluation. In order to use this evaluation, it is necessary to find define the correspondence of its points to the estimated values of RTI risk. The procedure of determining the correspondence should be the following.

Total possible results of risk assessment comply with exponential dependence, so it is very difficult to clearly determine the limits of points as to the RTI risks. In order to simplify the solution of the task, it is necessary to logarithm the final possible values of risk and use the absolute value, i.e.

\[ p(Y_m)' = |\log(Y_m)|. \]  \hspace{1cm} (5)

The received dependence will be close to linear one (correlation coefficient not lower than \( r^2 = 0.97 \)) and it can be and it can be used for determining the limits of the intervals of RTI as to corresponding estimating points.

Maximal value \( p(Y_{max}) \) receives the highest point - 5. To find the other points, it is necessary to open the limit, within which all possible results \( p(Y_m)' \) are located, i.e., the difference between the maximal and minimal value \( \Delta = (p(Y_{max}) - p(Y_{min})) \), which then is divided into 5 parts (5 points). Correspondingly, the value of the limit \( p(Y_{min}) \) will correspond to 0 points, then \( (p(Y_{min}) + \Delta) - 1 \) point, \( (p(Y_{min}) + 2\Delta) - 2 \) points, \( (p(Y_{min}) + 3\Delta) - 3 \) points; \( (p(Y_{min}) + 4\Delta) - 4 \) points.

In general form, the offered mechanism for determining the upper limits \( p(Y_m)_{max} \) of evaluating points \( A \) may be presented in the form of the formula:

\[ p(Y_m)'_{max} = p(Y_{min}) + A \cdot (p(Y_{max}) - p(Y_{min})), \]  \hspace{1cm} (6)

where \( A \) - points from 0 to 5.

In order to compare the received values of points with estimated values of risk, it is necessary to modify the received upper values of limits \( p(Y_m)_{max} \) in reverse to the formula (5):

\[ p(Y_m) = 10^{\pm p(Y_m)'}, \]  \hspace{1cm} (7)

if during the calculation according to the formula (5) the value beneath the modulus sign took the positive value, the value of the degree is determined by the “plus” sign, if it took the negative value – the “minus” sign.

In practice, the use of evaluation of RTI below 3 points is not advisable, as these evaluations are unsatisfactory.

In order to determine the values of integral diagnostic criterion of safety evaluation of motor transport public service, it is necessary to have the values of RTI risks for each criterial diagnostic indicator, shown in Table 1. No scientific research on this issue was conducted in our country, and the data of foreign sources are selective and do not reflect the Russian peculiarities of organization and provision of passenger transportation safety [1]. In this regard, there arose a necessity for development and conduct of questionnaire polls as to the expert evaluation by specialists in traffic safety of the influence of main measures in safety of on the risk of RTI [9].

Similar to the methods of previous research, a questionnaire was created. 35 experts took part on the research, which is statistically true and sufficient; the sought evaluations of RTI risks were received. As the evaluation was conducted based on the 10 point system, the received values were transformed into the fractions, with the one corresponding to 10 points. The generalized average values of results of expert poll are shown in Table-2.
Table-2. Average expert evaluations of risk values as to the main diagnostic indicators.

<table>
<thead>
<tr>
<th>№</th>
<th>Indicators of sub-system “driver-vehicle”</th>
<th>Risk of RTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control of technical state of vehicles before start of work</td>
<td>0.029</td>
</tr>
<tr>
<td>2</td>
<td>Control of technical state of vehicles on the line</td>
<td>0.387</td>
</tr>
<tr>
<td>3</td>
<td>Professional selection (shortlisting) of drivers at hiring</td>
<td>0.209</td>
</tr>
<tr>
<td>4</td>
<td>Providing the drivers with information as to driving conditions on the route (briefing on traffic safety)</td>
<td>0.169</td>
</tr>
<tr>
<td>5</td>
<td>Training of drivers on the routes</td>
<td>0.088</td>
</tr>
<tr>
<td>6</td>
<td>Annual training of drivers as to traffic safety, according to 20-hour program</td>
<td>0.165</td>
</tr>
<tr>
<td>7</td>
<td>Professional development of drivers (at least once in 3 years)</td>
<td>0.312</td>
</tr>
<tr>
<td>8</td>
<td>Drivers’ medical examination for the driving license of “D” category</td>
<td>0.308</td>
</tr>
<tr>
<td>9</td>
<td>Conducting the pre-trip medical inspection of drivers</td>
<td>0.054</td>
</tr>
<tr>
<td>10</td>
<td>Conducting the selective medical inspection of drivers between trips</td>
<td>0.037</td>
</tr>
<tr>
<td>11</td>
<td>Conducting the medical inspection of drivers after trips</td>
<td>0.348</td>
</tr>
<tr>
<td>12</td>
<td>Control of drivers’ work on the line</td>
<td>0.229</td>
</tr>
</tbody>
</table>

Based on the methodology of evaluation of safety control of motor transport public service by the subjects of motor transport activity, based on the diagnostic criteria and on the formula (3), there was conducted a calculation of the minimal possible level of influence of transport company activity on the RTI risk during him providing the transportation services to the population:

\[ p(Y_{\text{min}}) = 8.8 \cdot 10^{-30} \text{ RTIs per year}. \]

The received value should be transformed into the number of injured passengers in RTI. For this, a documentary research of values of accidence indicators at passenger transport of general use in the Russian Federation for the 5 recent years (2009-2014) was conducted. The research showed that the number of injured passengers in RTIs at motor transport of general use was stable during all 5 years and constituted in average 60% of all registered RTIs.

Thus, the sought value, according to the formula (4), is equal:

\[ p(Y) = 8.8 \cdot 10^{-10} \cdot 0.6 \approx 5.3 \cdot 10^{-10} \text{ of passengers injured in RTIs}. \]

This value is assigned with 5 points.

Then, according to the methodology and the formulas (5-7), the calculation of values of evaluations of transport companies is conducted, and the maximum allowable limits of intervals of RTI risks are determined. The results of the calculations are shown in Table-3.

Table-3. Estimated values of diagnostic criterion of evaluation of transport companies’ activity.

<table>
<thead>
<tr>
<th>Points</th>
<th>Interval of values of the risk of passenger getting injured in RTI</th>
<th>Acceptable values for evaluation of the risk of passenger getting injured in RTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>no more than 5.3 ( \cdot 10^{-10} )</td>
<td>no more than 5.3 ( \cdot 10^{-10} )</td>
</tr>
<tr>
<td>4</td>
<td>1.8 ( \cdot 10^{8} )…5.29 ( \cdot 10^{-10} )</td>
<td>1.8 ( \cdot 10^{8} )…5.29 ( \cdot 10^{-10} )</td>
</tr>
<tr>
<td>3</td>
<td>6.3 ( \cdot 10^{-7} )…1.8 ( \cdot 10^{-8} )</td>
<td>less than 6.3 ( \cdot 10^{-7} )</td>
</tr>
<tr>
<td>2</td>
<td>2.2 ( \cdot 10^{-5} )...6.3 ( \cdot 10^{-7} )</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>7.4 ( \cdot 10^{-4} )...2.2 ( \cdot 10^{-5} )</td>
<td>-</td>
</tr>
<tr>
<td>0</td>
<td>more than 7.4 ( \cdot 10^{-3} )</td>
<td>-</td>
</tr>
</tbody>
</table>

In order to simplify the procedures of calculation and possibility of practical application of developed diagnostic criterion in MS Excel based on the formula (1), a program “Risk evaluation” was created.
The developed program allows the regulatory authorities to perform the express-evaluation of risk of the transport company providing the motor transport services, based on the received results. For that, the inspector needs to enter into the program’s entry field for initial data the information about performance or non-performance by the transport company of the corresponding regulatory indicator: to put 1 or 0. After that, the program gives the result in points and in risk values. The point 2 and lower should be a strong reason for making a decision as to transport company’s compliance with the licensing requirements.

Together with bodies of federal control in the transport sphere, this program may be used by the transport companies for evaluation of their correspondence to the requirements of the current regulatory acts and for making further decisions and taking measures as to improving the passenger transportation safety [10, 11].

CONCLUSIONS

The offered methodology of formation of diagnostic criteria for evaluation of safety of motor transport public safety allows determining 12 main diagnostic indicators and set an integral criterion of evaluation of realization of measures for prevention of accident by subjects of motor transport activity, evaluated according to 5-point system. The minimal value of the indicator is \( p(Y_{\text{min}}) = 5.3 \times 10^{-10} \) of possible injured passengers in RTI (corresponds to 5 points), the maximum allowable value of the indicator is set at the level \( p(Y_{\text{min}}) = 0.6 \times 10^{-6} \) of possible injured passengers in RTI (corresponds to 3 points).

REFERENCES


