Safety and Risk Management

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Abstract: The article is devoted to the problem of creating a system of security and risk management. Formulated in relation to the process of movement of trains:

- factor of safety of the train
- the probability of traversing the trains on a particular route without transfer of its movement in a dangerous condition;
- a measure of risk of the transfer movement of the train in a dangerous state
- transition probability of motion in a dangerous state when the movement of trains on a given route.

The objectives of security and risk management are: to provide values of their indicators are not worse than normative, namely, the values of the performance security shall be not less than the normative, and the values of indicators of risk - not more than normative. Proposed functional framework and organizational structure for the management of safety and risks.

Keywords: safety index, a measure of risk, a dangerous condition, standard indicators of safety and risk.

Safety and Risk Index

Safety and risk management gain particular significance when managing responsible technological processes (RTP), which lack of security leads to great financial losses and loss of life.

RTP is distinguished by two groups of states – dangerous (DS) and non-hazardous (NS). Transitions of RTP states from NS to DS are accompanied by the emergence of damaging factors whose impact on the external environment objects and RTP objects causes loss and damage.

With this consideration in mind we can formulate the following definition of security RTP - this characteristic of RTP not to move from NS to DS during some estimated time. Transitions of RTP into DS are random events, so the measure of safety, that would numerically estimate the security, must be a probabilistic observation. Thus, safety indicator – is the probability that the RTP won't turn from of NS to DS for the estimated time. Obviously, the larger the indicator, the higher is safety.

Practically, it is important to know what the minimum level of safety should be, for losses and damages not to exceed to an estimated level. This minimum level of safety normalizes and the actual levels of safety should not be smaller.

The word risk, according to the norms of the Russian language [1, 2], means the possibility of occurrence of an unwanted event. In this case, when considering RTP, the undesirable event is the transition of RTP into a dangerous sate. With this consideration in mind, linguistically correct is the following definition of risk transition of RTP from DS: risk transition of RTP into DS - is the ability to turn into RTP from NS into DS.

Taking into account that the transition of RTP into DS is random, risk index as well as safety index, should be of probabilistic nature, that is: risk rate transition of RTP from NS into DS – is the probability of transition of RTP from NS into DS.

Obviously, the larger the risk transitions of RTP into DS, the lower is safety. Therefore, in this case the maximum value of risk index is limited. Such index value is called normative.

Transitions of RTP into DS occur under the influence of dangerous destabilizing factors (DDF) in the form of dangerous hardware failures, dangerous errors in software and dangerous mistakes of the personnel. DDF events are random and undesirable. Therefore, on the analogy of the above indexes for RTP, it is possible to formulate a number of additional indexes to assess the safety and risks of the individual components of RTP – technical equipment of specific functionality, software and personnel:

- safety index of technical equipment is the probability that the technical equipment won't have any dangerous failures during estimated time;
- risk index of dangerous failure is the probability of occurrence of a dangerous failure during the estimated time.

In the study [3] there are other types of indexes, including other types of RTP, for example, train movement.

With regard to the train movement:

- safety index of the train movement is the probability of a train going on a certain route without transition of its movement into a dangerous state;
- risk index of the train transition into a dangerous state is the probability of transition of train movement into DS when going on a scheduled route.

Since the transition of trains in the DS ends with loss and damage, it is possible to use the following indexes:

- risk index of losing M_i during train movement is the probability of losing M_i due to the transition of movement into the DS on a scheduled route;
- risk index of damaging N_i during train movement is the probability of damaging N_i due to the transition of train movement into the DS on a scheduled route.

The study shows all possible safety indexes and calculations in respect to the transportation process and trains movement.

In the future, in order to reduce the text instead of "probability of transition RTP and NS into DS" there will be used - the transition probability of RTP into DS.

OBJECTIVES AND MANAGEMENT PROCESSES.

The objectives of the safety and risk management of RTP are: to provide the index values just as well as the standard, that is the index values of safety should not be less than the standard, and the values of risk indexes should not be more than the standard. At that there should be observed resource limits.

With regard to this RTP as the train movement on a scheduled route, the purpose of safety management is to ensure the safety index movement is not lower than the standard value. As for the risk management purposes, they provide safety index movement does not exceeding the standard values.

Process safety and risk management consists of changing their indexes until you reach the purpose of management. Thus special techniques are used: endurance, structural, parry CRF.

To implement the safety and risk management process of RTP there must be the complex of functionally related hardware, software and personnel, which are capable of implementing the above methods.

Safety and risk management is possible only for certain standard values of safety and risk of RTP as a whole and its individual functional components. At the stage of design and production of technical equipment, these standard values should be provided and confirmed by a safety certificate. In the process of operation of RTP there should be monitored the actual values and risks. If the actual values are worse than the standard, there should be developed and implemented measures for the elimination of this situation.

In order to do this efficiently, it must be based on well-developed:

- regulatory framework;
- functional baseline;
- organizational structure;
- legal and regulatory framework;
- technological base;
- scientific methodological basis;
- personnel framework;
- conceptual framework.

The more perfect the listed frameworks are, the smaller amount of resources will be required to achieve safety and risk management.

Features of construction of these frameworks are discussed below.

The legal framework of safety and risk management.

Legislative framework consists of three Federal Laws of the Russian Federation

- «Consumer rights protection»
- «Technical Regulation»
- «Railway transport in the Russian Federation».

The first two laws form the legal framework of safety management systems and risk of RTP for any functional purpose, the third forms the legal framework of safety and risk management only on the railways.

In the «Consumer rights protection» it is claimed: «This law regulates relations between consumers and employers , sets out the rights of consumers to purchase goods (work, services) of good quality, the safety of their life and health ... ».

Thus, according to this law, the services for passengers and cargo must be safe especially to the consumers of these services, i.e. concerning passengers and not those who provide these services, i.e. railways.

According to the Federal Law about "Technical Regulation": "regulates relations arising in: development, accepting, application and enforcement of mandatory requirements for products or related processes of design (including research), manufacturing, construction, installation, commissioning ". According to Article 7 of the Law, mandatory requirements include requirements of mechanical, thermal, radiation security, etc.

According to this law, "the harm risk degree" should be taken into account in determining the characteristics and parameters of technical means.

In addition, and in accordance with the Federal Law about "Consumer Rights Protection", the mandatory requirement is the requirement of products and services safety."

According to the Federal Law about "Railway Transport in the Russian Federation" the mandatory requirement is the requirement to ensure the absence of "unacceptable risk" accidents occurrence and health injury of citizens, environmental damage, and property of individuals or legal entities.

Thus, according to the Federal Law about "Consumer Rights Protection", "Railway Transport in the Russian Federation", "Technical Regulation", which form the legal framework of safety and risk management, the mandatory are:

- security requirement of products and services in regard to passengers, the environment, the goods transported, the transport system;
- quantitative (probabilistic) requirement of "risk level" of harm to consumers of transport services and the environment and to ensure that this "level" is not more than the "acceptable" value, i.e. not more than the standard value.

Functional baseline management

The functional baseline below refers to a set of functions that must be performed in the management process to achieve the most effective security and risk management. These features include:

- specification and justification of a complete range of safety and risk performance; in solving certain problems there can only be used a part of the indexes;

- task of harmonized between each other normative values of the indexes of transport safety in general, traffic safety, safety of hardware operation and software, operators, as well as the standard values of all types of risks. Depending on the solvable problem operation it may be required knowledge of the standard values of the indexes;
- specification of the parameters and characteristics of hardware and software, as well as the professional characteristics of operators, which provide normative values of their safety and risk performance;
- development of classifiers of dangerous destabilizing factors on the basis of analyzing the causes of the transition into dangerous states and on the basis of special methods of identification of dangerous hardware failures;
- frequency response analysis of CRF;
- specification of safety indexes and risks of complex devices via the CRF probability, for example, by the method of event tree analysis;
- efficiency analysis of ensuring methods of standard values of safety and risks;
- provision of given safety parameters and characteristics indexes at all stages of their life cycles;
- certification of technical means in terms of the safety of operation;
- licensing of the company performance in view of its ability to produce hardware with planned safety indexes of functioning (presence of the required technological base, personnel, methodological support, etc.);
- control of the use of certified equipment;
- a statistical analysis of operational safety indexes of trains movement, operation of technical equipment and operators, the identification of the CRF and their occurrence;
- forecasting possible changes in safety and risks indexes due to changes in operating conditions of technical equipment, production technology, etc .;
- programs development of preventive operational measures aimed at preventing the CRF and the transition into dangerous states;
- development of long-term programs of providing normative safety and risks values.

If at least one of these functions won't be accomplished during the performance, the process of safety and risk management won't be as effective as possible. But there may be cases where the accomplishment of all these functions is not necessary.

Organizational structure of control facilities.

For performance of all listed above functions it is necessary to have a set of the organizations, enterprises of the technical means and the personnel, which are in a functional interrelation, which it is possible to call a control system of safety and risks. The system has to possess a certain organizational structure. The modern System has the three-level hierarchical structure including:

- federal,
- branch and
- corporate (separate corporations, organizations, enterprises, companies, etc.) levels.

The Federal Assembly, the President and the Government of the Russian Federation refer to the Federal hierarchical level. According to the Federal law "On technical regulation" they have to:

- adopt the laws of the Russian Federation relating to area of safety of production and services, including safety of rail transportation;
- accept the technical regulations in the form of Federal laws of the Russian Federation, decrees of the Russian President and resolutions of the Government of the Russian Federation defining the relations between all participants of transportation process arising at safety of transportations and freights.

To the branch hierarchical level of System refer the following:

- the ministries, the state committees, agencies the main function of which is assistance to execution of the main functions of bodies of federal level at management of safety;
- the state control (supervision) authorities for observance of requirements of technical regulations;
- national authority of the Russian Federation on standardization, technical committees on standardization;

- body for certification, test laboratories (centers);
- body for accreditation of participants of transportation process.

Governing bodies of branch level have no right to publish normative documents of Federal level in the field of management of safety, obligatory for execution.

The main function of structural components of System of corporate level (corporations, the companies, the enterprises, etc.) is ensuring standard values of indicators of safety and risks at various stages of life cycles of technical means and the personnel by selection of the corresponding characteristics and parameters of technical means and the personnel.

The functional and organizational structure of System of each organization is defined by its concrete functions at safety of transportations.

Thus, the control system of safety and risks is the centralized state control system for traffic safety of trains as the state establishes standard indicators of safety and risks and exercises the supervision of application only of the technical means certified on indicators of safety.

Regulatory legal base of System

Part of process of management of safety and risks is technical regulation, i.e. legal regulation of the relations in the field of establishment, applications and executions of obligatory requirements to production or to related design processes (including researches, productions, constructions, installation, adjustment, operation of storage, transportation, realization and utilization, and also in the field of establishment and application on a voluntary basis of requirements to production, design processes, including researches, productions, constructions, installation, adjustment, operation, storage, transportation, to realization and utilization, performance of work or rendering services and legal regulation of the relations in the field of an assessment of compliance of production to obligatory requirements).

The regulatory legal base of technical regulation is formed by:
- technical regulations;
- national standards;
- sets of rules.

The technical regulations – the document which is accepted by the international treaty of the Russian Federation ratified in the order established by the legislation of the Russian Federation, or the intergovernmental agreement concluded in the order established by the legislation of the Russian Federation, either the Federal law, or the decree of the President of the Russian Federation, or the resolution of the government of the Russian Federation. It establishes requirements to objects of technical regulation (to production, including buildings, structures and constructions or to the design processes connected with requirements to production (including researches), productions, constructions, installation, adjustment, operation, storage, transportation, realization and utilization obligatory for application and execution.

Technical regulations are accepted for:
- protection of life and health of citizens, property of natural or legal entities, state or municipal property;
- environmental protections, life and health of animals and plants;
- preventions of the actions misleading consumers.

Adoption of technical regulations in other purposes isn't allowed.

Technical regulations taking into account the degree of risk of harm establish minimum necessary requirements ensuring mechanical safety electric, thermal, biological, safety of radiations and other types of safety.

The technical regulations have to contain requirements to characteristics of production, production processes, etc., but shouldn't contain the requirements to designs and execution, except for the cases if due to the lack of requirements to a design and execution taking into account degree of risk of harm the achievement of the purpose of adoption of technical regulations formulated above isn't provided.

The words "taking into account degree of risk of harm" assume knowledge of value of an indicator of risk at which admissible losses and damages at transportation process aren't provided.

Technical regulations are subdivided on:
- all-technical technical regulations and
- special technical regulations

They differ in that the requirements of the general technical regulations are obligatory for application and observance concerning any kinds of production, production processes, etc., and the requirements of special technical regulations consider technological and other features of separate types of production, production processes, etc.

The general technical regulations, for example concerning safe operation and utilization of cars and the equipment, fire safety, electromagnetic compatibility, etc.

Technical the regulations have to contain a list and (or) the description of objects of technical regulation, the requirement to these objects and rules of their identification for application of technical regulations.

The documentary certificate of compliance of production and (or) other objects of technical regulation to the requirements of technical regulations, provisions of standards and sets of rules is called as compliance confirmation.

Forms of confirmation of compliance are subdivided into voluntary and obligatory confirmation of compliance.

Voluntary confirmation of compliance is carried out in the form of voluntary certification.

Obligatory confirmation of compliance is carried out in the forms of: adoption of the declaration on compliance (compliance declaring); obligatory certification.

Voluntary confirmation of compliance is carried out at the initiative of the applicant on terms of the contract between the applicant and certification body. It can be carried out for establishment of compliance to the national standards, standards of the organizations, to the sets of rules, systems of voluntary certification, to the conditions of contracts.

The certificate of conformity on the objects, which passed voluntary certification, gives out body for certification.

Obligatory confirmation of compliance is carried out only in the cases established by the corresponding technical regulations and is exclusive on compliance to requirements of technical regulations.

Production released in the territory of the Russian Federation can only be object of obligatory confirmation of compliance.

Forms and schemes of obligatory confirmation of compliance can be established only by technical regulations taking into account degree of risk of impossibility of achievement of the objectives of technical regulations.

Declaring of compliance is carried out on one of the following schemes:
- adoption of the declaration on compliance on the basis of own proofs;
- adoption of the declaration on compliance on the basis of own proofs, the evidence obtained with participation of body for certification and (or) the accredited test laboratory (center).

Obligatory certification is carried out by the body for certification accredited in the order established by the Government of the Russian Federation.

The body for certification attracts the test laboratories accredited in the order established by the Government of the Russian Federation on a contractual basis for carrying out researches (tests) and measurements; exercises control of objects of certification if such control is provided by the corresponding scheme of obligatory certification and the contract.

The state control (supervision) for observance of requirements of technical regulations is exercised concerning production and other objects of technical regulation.

Concerning production the state control (supervision) of observance of requirements of technical regulations is exercised only at a stage of the address of production.

The national standard – the document in which for voluntary repeated use the characteristics of production, rules of their implementation and the characteristic of processes of design are established (including researches, productions, constructions, installation, adjustment, operation, storage, realization and utilization, performance of work and services).

The purposes of standardization are:

- the increase of level of life safety and health of citizens, property of natural and legal entities, the state or municipal property, objects taking into account the risk of emergency situations of natural and technogenic character, increase of the level of ecological safety, safety of life and health of animals and plants;
- ensuring competitiveness and quality of production (works, services), unities of measurements, rational use of resources, interchangeability of technical means (cars and equipment, their components, components and materials), technical and information compatibility, comparability of results of researches (tests) and measurements, technical and economic data, carrying out analysis of characteristics of production (works, services), executions of the state orders, voluntary confirmation of compliance of production (works, services);
- assistance to observance of requirements of technical regulations;
- creation of systems of classification and coding of technical and economic and social information, systems of cataloguing of production (works, services) systems of ensuring quality of production (works, services), systems of search and data transmission, assistance to work on unification.

Develops and approves national standards national authority on standardization.

Provisions of the national standard have advisory nature, except for those a case when on it links in technical regulations take place.

The set of rules documents of standardization which contains technical rules and (or) the description of processes of design (including researches, productions, constructions, installation, adjustment, operation, storage, transportation, realization, utilization of production and which is applied on a voluntary basis).

Development and the approval of sets of rules are carried out by federal executive authorities within their powers.

Technical base of System

The technical base of a control system of safety is formed by the technical means of two main groups differing in a functional purpose:

- technical means of safety of train service and
- the technical means intended for the analysis of the actual and predicted traffic safety and functioning of the technical means influencing traffic safety.

Special systems of safety of train service, for example, of system of automatic lock-out, the automatic locomotive alarm system, etc. treat the first group.

The automated systems treat the second group:

- collection of information about dangerous failures of hardware and the reasons of their emergence; about dangerous errors of software and the personnel, about the reasons of their emergence; about transitions of the movement to dangerous states, about losses and damages;
- transfers of this information in the device of calculation of the actual values of indicators;
- calculation of the actual (operational) values of indicators of safety of functioning of technical means and personnel, and also traffic safety indicators in general;
- estimates of residual safe resources of technical means;
- calculation of expected values of indicators of traffic safety of trains and functioning of technical means;

- formations of operational recommendations about prevention of decrease in the actual indicators of safety are lower than standard level.

Without the developed technical base of System its effective functioning, i.e. effective management of safety and risks isn't possible.

NORMALIZING PRINCIPLES OF SAFETY INDEXES

Normalizing of safety indexes is the process of setting their normalized values (standards). Normalized value of safety indicator – limited value, for instance, min allowed value of traffic safety indicator $P(S_0)$, max allowed value of loss risk indicator $Q(M_i)$ and damage risk indicator $Q(N_i)$.

It is possible to use two principles in setting normalized values of safety indexes. First principle is based on economic and second one – on social approach to normalizing task solution. According to the first principle normalized values of safety indexes are set on the basis of economic expediency evaluation while the second principle is based on estimation of public opinion about necessary level of safe transportation.

According to the 1st principle the resource level for normalizing of indexes can be limited or not.

As a rule, traffic safety improving is concerned with investment and that is why economic expediency of traffic safety improving projects is determined according various evaluation methods of investment projects [4].

Investment project's efficiency is characterized by a rating system:

- commercial efficiency, which considers financial implications of project implementation for its direct participants;
- budget efficiency, which considers financial implications of project implementation for federal, regional or sectorial budgets;
- economical efficiency, considering costs and effects which are concerned with project implementation and which come out of project participants' direct financial interests and allow cost measurement.

Future costs and effects' estimation for efficiency determination of investment project is carried out within calculated period which duration is called "time horizon". Time horizon is measured by a number of calculated intervals each of which can be equal to a month, a quarter or a year.

It is recommended to compare different variations of traffic safety improving by using such indexes as net present value (integral effect), profitability index, internal rate of return, pay-off period, etc.

During transportation process implementation it is convenient to use a formula of net present value for safety indexes' optimization task solution in economic context:

$$Э_{инт} = \sum_{t=0}^{T} (R - З_{t}) \cdot \frac{1}{(1+E)^{t}} , \quad (1)$$

where T - time horizon equal to calculated period number on which writing-off of technical resource occurred;

t - calculated interval;

R_t - results, taken out on t-calculated interval;

$З_t$ - costs, born on the same interval;

E - discount rate, equal to acceptable for investor rate of return on equity.

Discounting is understood as reduction of timely asynchronical costs, results, effects to their values for any one time moment, for instance primary moment (t=0).

Following from formula (1), for increasing value of $Э_{инм}$ it is necessary, in particular, to decrease costs $З_t$. In general costs are determined as investment costs K and current costs C, that is

$$З = \mathrm{K} + \mathrm{C} ; \quad (2)$$

discounted investment costs' amount

$$K = \sum_{t=0}^{T} K_{t} \cdot \frac{1}{(1+E)^{t}} \quad (3)$$

for K_t - investment costs for t - interval;

discounted current costs' amount

$$C = \sum_{t=0}^{T} C_{t} \cdot \frac{1}{(1+E)^{t}} \quad (4)$$

where C_t - current costs for t - interval.

For normalizing safety indexes' task it is useful to consider only costs $З_Б$, necessity of those is determined by target safety level:

$$З_Б = К_Б + С_Б, \tag{5}$$

where

$$K_Б = \sum_{t=0}^{T} K_{Бt} \cdot \frac{1}{(1+E)^t} \quad , \tag{6}$$

$$C_Б = \sum_{t=0}^{T} C_{Бt} \cdot \frac{1}{(1+E)^t} \ . \tag{7}$$

Current costs $C_Б$ are divided into two parts – 1st one $C_{Б1}$ is determined by costs, which are necessary for controlling of target safety level, and the 2nd one $C_{Б2}$ - is determined by damage suffered from traffic movement to dangerous condition:

$$C_Б = С_{Б1} + С_{Б2}. \tag{19.8}$$

This is the key difference between normalizing reliability and normalizing safety.

As a rule, increasing of traffic safety level is only possible as a result of increasing indexes $K_Б$ and $C_{Б1}$. However, economic damage index $C_{Б2}$ decreases as a result of traffic safety level increase. Picture no.1 contains a diagram of idealized relationship between cost $K_Б + C_{Б1}$, damage $C_{Б2}$ and traffic safety level. Follow from total costs' diagram there is some optimal value of traffic safety index $P_{opt}(S_0)$, wherein total costs have minimum value and net present value $Э_{инм}$ from transportation, as safety function, reaches its maximum value.

Therein lies a determination principle of economically proved traffic safety index.

In case of volume limitation in consequence of decreasing $K_Б$ and $C_{Б1}$ line ($K_Б + C_{Б1}$) may not cross line $C_{Б2}$ so $P_{opt}(S_0)$ cannot be achieved.

As for socially proved traffic safety standards they represent standards which are only sufficient against morality norms and ethics of certain society. Such approach takes into account the fact that absolute traffic safety cannot be principally reached. Moreover, traffic safety level depends not only on resources volume supplied but on extent of development of science, technique and technological base of the society. It follows here from that social requirements to traffic safety can be really met only in the framework of scientific knowledge, mature technology as well as state and industry sector's economic health.

Normalizing traffic safety indexes' results according to these two approaches scarcely ever match each other. In such case two situations are possible: economically proved traffic safety index value $P_{opt}(S_0)$ is higher than the social one, then it is excepted as a standard; socially proved safety index value is higher than economically proved one – then the first one becomes a standard.

When social requirements to traffic safety is much more strict than economically proved one the government is to make the following decisions:

- to oblige railroaders to increase traffic safety level by decreasing economical efficiency for transportation;
- to devote additional funds from the state budget to railroads for the development of traffic safety to a socially proved level;
- not to take public opinion into account.

Thus, socially proved determination principle consists of matching safety standards and morality norms and ethics of certain society.

Determination methods of economically optimal safety standards

For practical task solutions of economical safety standards' optimization continuous dependence of volumes ($K_Б + C_{Б1}$) and $C_{Б2}$ from safety index value $P(S_0)$, cannot be determined, as set on the picture no. 1. In fact these diagrams are plotted point by point which belong to different system variations which supply different values of safety indexes and are characterized by certain volume of investment and current costs needed to insure such indexes. Different system variations are characterized by different methods of traffic safety improving. These methods can be alternative, when it is only possible to use on of them, and nonalternative, when it is possible to use them together.

Determination of standards for federal level considers nonrecurrent and current costs of all traffic safety improving project's participants as well as transport services consumers' costs. However, multiple counting of same costs is to be excluded as well as costs of one participants in results of other participants.

Hereinbefore, in general costs are divided into various types – freight loss, loss of railroad technical facilities, loss of ecological character, loss of business entity, social character loss, loss of health and passenger lives, loss of technical staff, and loss of population. Loss value term of M_i type is regarded as economic damage N_i suffered from this type of loss.

Each method of supplying of one and the same safety index value is characterized by its own volume of economic damage

$$C_{Б2} = \sum_i N_i Q(N_i), \tag{9}$$

It is possible to change parameters which influence economical efficiency of transportation process in case of changing of safety indexes for technical facilities. For example, increasing of underlying strength of technical facilities' elements leads to both safety and reliability increase. In addition there are safety improving methods according which reliability of technical facility decreases and economical damage suffered from non-dangerous failure increases as a result.

Safety standards' optimization task solution is possible under certain limits for types of losses. For instance, in case of safety normalizing of passenger-train traffic only passenger health and lives are regarded as possible losses. In such case it is said about safety indexes optimization in one or another narrow sense.

For building dependences shown on picture no. 1 there is a method which is based on Pareto diagrams' initial building shown on pictures no. 2 and 3. Alternative variations of traffic safety indexes' increase $P(S_0)$ are situated on horizontal axis of such diagrams. It is essential that there should be an optimal value variation $P_{opt}(S_0)$ among these N_B variations. The points corresponding to the same options of improving safety are shown in a system of coordinates $((K_Б + C_{Б1}); P(S_0))$ in picture 4. With the help of these points we plot a graph of dependency $((K_Б + C_{Б1}); P(S_0))$, which must be plotted in such a way, that the minimal value of $(K_Б + C_{Б1})$ should be the case, no matter what the value of $P(S_0)$ is. The options that don't match the requirements should be considered economically unfavorable and shouldn't be used while plotting a graph.

Graphic coordinates of the unknown dependency are found using the following way. With the help of additional axes we limit the space of the right lower quadrant for each of the points. The point is considered to be pertaining to the required graph if there are no points pertaining to other options within this quadrant. The dependency graph should go through a sequence of such points $((K_Б + C_{Б1}); P(S_0))$.

In cases where the option to improve traffic safety are not an alternative, the plotting of dominant sequence comes to the choice of such sequence of options in which the lowest value $P(S_0)$ corresponds to the lowest extent of expenses. Firstly a Pareto graph should be built $(K_Б + C_{Б1})$ (pic.5), it stands for cost-efficiency in case of different options of improving safety. As the indicator of the use of safety improving cost we use the relation of safety improving index $\Delta P(S_0)$ to the safety expenses index $\Delta(K_Б + C_{Б1})$.

$$Э_в = \frac{\Delta P(S_o)}{\Delta(K_Б + C_{Б1})}. \tag{10}$$

Here $\Delta P(S_0)$ means the index of traffic safety and related costs, and $\Delta(K_Б + C_{Б1})$ means the basic option. It can be an option with a minimum safety level or an option used in the running of a subsystem responsible for train (shunting) operation. This graph gives us a visual representation of the relative efficiency of the options. So it is possible to determine the sequence of their application in order to increase traffic safety index. It is obvious that the first option to be used is the option 6, then the options 8 and7, etc.

№1 – 6,
№2 - 6+8,
№3 – 6+8+7,
№4 – 6+8+7+3,
№5 - 6+8+7+3+9,
№6 - 6+8+7+3+9+4, (11)

№7 - 6+8+7+3+9+4+5,
№8 - 6+8+7+3+9+4+5+1,
№9 - 6+8+7+3+9+4+5+1+2,
№10 - 6+8+7+3+9+4+5+1+2+10.

Using this sequence of options 6, 8, 7, 3, 9, 4, 1,2,10 we plot a graph of dependency $((K_Б + C_{Б1}); P(S_0))$ (pic. 6). The results of safety index improvement, in case of a simultaneous use of several options, are added (integrated), i.e. they possess the property of additivity.

In other cases we can have alternative as well as non alternative options. As a result, to plot the graph $((K_Б + C_{Б1}); P(S_0))$ they are all divided into alternate groups, each of which combines non alternative groups. For example let's suppose that the following groups are alternative.

№1 – 2,4,9;
№2 – 1,3,7;
№3 – 5,6,8,10.

For each group we determine the sequence of options according to the rule, used to plot the graph of non alternative options $((K_Б + C_{Б1}); P(S_0))$.

№1 – 9, (9+4), (9+4+2);
№2 – 7, (7+3), (7+3+1);
№3 – 6, (6+8), (6+8+5), (6+8+5+10).

Then each option subsequently is depicted with a point in the system of coordinates $((K_Б + C_{Б1}); P(S_0))$ according to its efficiency.

For the dominant sequence we choose only those points that comply with the rule, which was laid down while we were considering alternative options.

To determine the economically optimal value of the traffic safety standards we need to plot and additional dependency graph $((K_Б + C_{Б1}); P(S_0))$. That is why we need to determine the extent of economic damage $C_{Б2}$ for each of the options of traffic safety improvement, which were examined above in the graph $((K_Б + C_{Б1}); P(S_0))$.

The damage is the result of the impact on the train and the environment in which it moves made by damaging factors H_j, which emerge when a train transits into a dangerous condition S_{ok}. Therefore, to reduce the losses and the damage it is necessary to reduce the likelihood of dangerous conditions of motion $Q(S_{ok})$. Also we have to reduce conditional probabilities of damaging factors H_j in these conditions $Q(H_j / S_{ok})$.

It is important to note that when the value of $Q(S_{ok})$ is the same, the probability rate $Q(H_j / S_{ok})$ may be different. For example, to reduce the likelihood of corrosive liquids spills the tanks must be equipped with special protective devices. It reduces the likelihood of a damaging factor in the form of corrosive liquids such as sulfuric acid. Another example is the high-speed train with special zone which can absorb impact energy. It reduces the likelihood of forming such an inertial force that the impact of this force would have led to the passenger's death.

Therefore, the level of economic damage depends not only on traffic safety, but on rolling stock properties to reduce the levels of losses in the accidents by eliminating the damaging factors.

In addition the extent of damage depends on the protective measures efficiency; these measures are devised in case of emergency.

Thus in determining an economically viable factor of traffic safety it is necessary to take the constraints imposed on all other factors into account, because the affect the damage from the crash.

In general while we determine the dependency $(З_Б; P(S_0)$ it is necessary to evaluate the economic feasibility of measures aimed to reduce the amount of losses carried out by all the stakeholders. To do this we apply a combined Pareto chart (picture 7). The horizontal axis is responsible for the options N_B of reducing the damage, the positive vertical axis is responsible for additional costs $\Delta(K_Б + C_{Б1})$ and the negative vertical axis is responsible for reducing the damage. $C_{Б2}$

Economically viable are those activities for which the following condition is true $\Delta C_{Б2} > \Delta(K_Б + C_{Б1})$.

The graph shows that economically viable are options 1,2,4,6,7,8,9. If these options are not an alternative, their application is determined by the order of their succession 7,2,8,4,6,1,9. The efficiency of options 1, 9 and 4, 6 is the same, so the order of their use does not matter.

Let's have a look at picture 1. Solid lines show the most rational option of improving $P(S_0)$ and all economically viable options of reducing the damage. Then, if one or more of cost-effective measures are not used, the graph of dependency $((K_Б + C_{Б1}); P(S_0))$ will lie a little bit lower than the corresponding chart. But the graph of dependency $((C_Б; P(S_0))$ will lie higher. It will increase $P_{opt}(S_0)$ and the minimal value of $З_Б$.

Optimal economic value of safety indicator was determined with the help of the dependency graph $((C_Б; P(S_0))$. The saddle point of this graph corresponds to the minimum $З_Б$ and is determined by the condition:

$$K_Б + C_{Б1} = C_{Б2}\,. \qquad (12)$$

Then the minimal value of the costs $З_Б$ can be found from the condition (12) and without the use of graphs, which have been used only for purposes of clarity of the optimization method of traffic safety.

It is possible that none of the real options corresponds to the saddle point $((C_Б; P(S_0))$, and then we accept the one, that closely complies with our condition, as optimal (19.12).

After determining the optimal value of the safety indicator $P_{opt}(S_0)$ and outlining the system of measures for its maintenance, we can determine the safety performance standards for all the structural components of the subsystem of the train (shunting) operation. Safety performance standards are accepted values of the structural components of security subsystem, which provides economically optimal value of the traffic safety indicator.

SOCIAL SAFETY STANDARD.

Social safety standard is established only with respect to one type of loss, namely, loss of life and relative health of the passenger. Immediately we have to standardize the value of the indicator of risk of death when the train transits into a dangerous state. It is not possible to use rigorous scientific methods or at least the methods used in determining cost-optimal safety standards.

The establishment of social norms of a passenger's death, which was a result of train derailment largely depends on the social, political and economic systems of the country. The more progressive the society is, the more developed and focused on solving of social problems is the economy of the state. And the higher the country values an individual and their safety.

However, the severity of the public requirements for traffic safety, as well as for other important technological processes, depends on the psyche of an individual.

Thus, the results of the studies suggest that if the probability of death is 10^{-6} a year and it is the result of technogenic emergencies, the public usually does not express undue concern. Based on this, many experts take the value of 10^{-6} as a normative value of the technogenic risk indicator.

We can assume that it is a psychologically reasonable standard which measures the risk of death.

In addition, people's attitude towards the value of this type of risk depends on how free they are to decide — to expose themselves to the risk or not. For example, the athlete himself takes the decision to participate in a car race on mountain roads with the aim of establishing a sports record. Another thing is when a person from force of circumstances is forced to use the services of railway transportation. In these cases, the difference in the assessment of acceptable loss of life reaches 3 orders of magnitude, namely, in the latter case the safety requirements are stricter.

Another feature of the human psyche is that people consider single emergencies with severe consequences less acceptable than a large number of accidents with less severe consequences. For example, the public reacts more sharply to relatively rare derailments with severe consequences than to the daily deaths in car accidents. This being said, train wreck is considered to be a truly extraordinary event, and car accidents are considered to be everyday phenomena, an inevitable attribute of modern city life. At the same time we know that the automobile safety is substantially lower than the train safety.

Thus, the establishment of social norms of risk of death indicator as the passenger travel by train, we should take into account the real state of the society as well as the state of overall security of the individual in society. We should also take into account the current state of train safety.

If the social norm of the risk of death of the passenger is more strict than economically feasible, then it should underlie the safety standards of structural components, which are parts of train and shunting operation. To do this we use the methods discussed above to determine the most economically rational option of implementing of a subsystem, which can provide the risk of death standard. The safety values of structural components of such a system are accepted as normative.

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