The development of models of risk assessment complex transport systems

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Abstract. The article deals with the actual problem of risk optimization for complex transport systems. Optimization models for risk aspects are proposed and developed: "probability-damage"; "quality-price"; "variation-damage"; acceptability of the measurement system; degradation monitoring.

The urgent task of our time is to increase effectiveness and efficiency of creation and functioning in time of complex social engineering and natural engineering systems. This fully applies to complex defense and civil transport wheeled vehicles that are used in extreme conditions (figure 1). This problem can be resolved through analysis, management optimization and risk optimization, the effects of uncertainty [1, 2]. A more detailed risk analysis in the correlation between \( P(\tau) \) probability of a hazardous event and \( U(\tau) \) damage because of this event, between variation and damage with optimization of the product/process according to the price-quality criteria [3] made it possible to develop an appropriate fundamental model (figure 2).

Figure 1. Mobile machines and elements that determine their safety.

\( P(\tau) \) parameters are determined with hazardous process and operational influences, and \( U(\tau) \) values depend on the liability and cost of the machines, as well as the degree of damage caused by impacts.

It should be noted that the probability-damage risk analysis and risk management start from a point single-criterion assessment and develops step by step to implementation of the prioritization strategy in the form of hyperbolic dependence. For easy practical use, the nonlinear function is converted into a stepped point scale with the inverse approximation (figure 2). The proposed model makes it possible to harmonize the criteria for achieving compliance with the established requirements for complex engineering systems, including transport, based on the risk-based approach. This allows you to optimize costs when creating a type of engineering object, its replication and operation based on
prioritization for the type of the engineering system, to set goals in the scope of compliance variation control during replication, depending on priorities, based on identification of the optimal quality-price ratio function (figure 2).

![Figure 2](image-url)

**Figure 2.** Fundamental five-component model of optimization of dependencies “probability-damage” – “quality-price” – “variation-damage”.

Depending on the potential damage, the criteria are proposed for optimizing costs for adequate interrelated accuracy of risk assessment, depending on the priorities, fundamental models for the choice of measuring systems used both for creating a type of engineering object and for its replication at: selection of types of measuring systems; tolerance for the acceptability of variation of arrays of measuring systems for the selected type (figure 3).

![Figure 3](image-url)

**Figure 3.** Fundamental model of optimization of the choice of the type of measuring system and its variations depending on the damage.
To reduce the cost of creating engineering objects by using means of the V process order, a risk optimization model has been developed by introducing and applying a subsystem of diagnostics/monitoring of degradation in the social-engineering system (figure 4).

This allows you to reduce unnecessary safety factors and the failure probability without detriment to the consumer. If there is evidence that the degradation process of an engineering system is approaching a critical value, the excessive risk, the engineering system prevents occurrence of this event and allows you to move to the acceptable risk zone (figure 4).

Thus, it is possible to reduce the material consumption of an engineering object and operating costs with acceptable failure risks when it is functioning [3, 4]. It should be noted that the risks of measuring systems for identification of degradation processes, depending on the risks of the engineering systems they serve, are also taken into account, both when choosing acceptability of the type, and when assessing acceptability of variation of the measuring systems (figure 4).

The proposed models were gradually applied in the development of technical regulatory legal acts of state and interstate standards to scale the economic effect based on widespread using of risk-based thinking [1-4] when creating equipment and technologies by optimizing costs to reduce the cost of products and processes to competitive values while meeting consumer requirements and legal restrictions.

For legislative, systematic application in organizations that design and produce complex engineering systems, the proposed models were used for development of standards for design and production management systems for the following: mobile machines of various types (road, quarry, automotive and other equipment) [5]; special dual-purpose equipment [6].

Numerous methods of risk analysis for both products and processes have different degrees of reliability and resource requirements, including databases and knowledge bases [1-4], while FMEA method is the most widely used in the automotive industry. To prevent its inappropriate practical use, it is proposed [7] to use risk management plans, cause-and-effect trees (deduction/induction), etc. as input data, which allows, based on the model of effective knowledge management developed in [3], to carry out decomposition and managing the likelihood of damage from a configurator (a top-level system, failure of which determines the damage, e.g., a hazardous chemical transportation system) to

Figure 4. Model for risk optimization by introducing a system for diagnostics/monitoring of degradation.
the root cause of a nonconformity (e.g., chemical composition of the material of the part) based on the present level of knowledge.

At present, numerous methods have been developed and are used for assessing the variation of product replication processes, statistical process control, statistical acceptance (streaming, batch), as well as continuous control [8]. Their systematization and methodological support are required for their adequate application in the risk-oriented approach according to the variation-damage criterion (see figure 2). To select an acceptable variation that is based on the quality-price methodology (see figure 2), the methodological support for selection of appropriate statistical methods was proposed for the first time, both depending on potential damage and taking into account the stages of verification and validation processes in preparation of manufacturing of products and at daily adjustment of the manufacturing process [8].

It was proposed [9] to improve the methods of analysing the variation of measuring systems both in methodological terms (taking into account numerous factors, e.g., personnel, environment, type of measuring system), and in combination with the risk-oriented approach of their application, depending on the potential damage [9].

Methodology of risk management within implementation of projects in the supply chain is proposed [10] to ensure the probability of non-conformances that appear both at designing and development of a type of product and manufacturing processes, and at its replicating, through the whole supply chain (starting from creating of materials, parts, units, finished products, maintenance/recovery to disposal).

Methodological support for risk analysis, management and optimization has been created, including one based on developed risk-oriented models, for wide practical application when creating engineering systems for adequate risk analyzes [7], statistical methods [8], measurement processes [9], verification and validation in the supply chain from primary suppliers of materials to suppliers of maintenance processes in operation and disposal of engineering products [10].

Interstate standards have been developed to implement the optimal requirements in designing and manufacturing of components of the transport systems that primarily ensure their active and passive safety using the proposed models, which, among other things, are used in development of the EAEU technical regulations (TR TS 018 EAEU) for steering, brakes, suspension and supporting structures of vehicles [11-14].

References
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