Development Genesis of Functional Safety on the Example of an Element of the Railways Infrastructure Subsystem

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Abstract. The degree of protection against the danger arises as a result of incorrect (unforeseen by the developers) operation of a technical object is determined by the issues of functional safety, which have acquired the greatest relevance in this period of human development and have become the object of research. Authors consider the problems of functional safety of dynamic systems on the example of an element of the railway infrastructure subsystem – a railway track. It is shown that an attempt to create a single universal system for classifying tracks, considering the satisfaction of heterogeneous requirements to ensure the conditions for interoperability of various railway systems, is unrealistic in the current circumstances. The missing components for the classification system of the railway track structure operability are considered. An analysis of the historical understanding of various processes in relation to real-time is given. The main direction for improving the quality of the functional safety of a railway track is formulated – the need to combine the theory of elasticity with new theories that change the approaches to studying time-varying processes from quasi-dynamic to dynamic.

Keywords: Genesis · Functional safety · Railway infrastructure · Infrastructure subsystem · Railway track

1 Introduction

To ensure their own life, men have created many technical objects and systems, the totality of which is the Technosphere. All objects and systems of the Technosphere undergo significant changes in the process of operation. The degree of protection against the danger that may arise as a result of incorrect (unforeseen by the developers) operation of a technical object is determined by the issues of functional safety, which have acquired the greatest relevance in this period of human development and have become the object of study. In this paper, the authors consider the problems of functional safety of dynamic systems on the example of an element of the railway transport infrastructure subsystem – a railway track. Historically, there is a railway track with a track gauge of

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1,435 mm and 1,520 mm, for which design, operation, and control systems have been developed in parallel in various countries. Modern integration processes provide for the interoperability of these structures and require compliance with the same technical standards. With all the apparent variety of regulatory documents developed for two railway track structures, they do not cover the uniqueness of each individual situation associated with changing national standards to common ones established by technical standards for interoperability.

Therefore, the objective of the study is to show the incapacity of the approach to manage the process of ensuring functional safety, which responds to changes occurring throughout the functionality during all stages of the life cycle, by imposing regulated dependencies obtained on the basis of a deterministic approach to solving local problems for each functionality.

2 Research Method

Since the genesis of development is the origin and subsequent development process, which led to a certain state that exists at the time in question, the paper considers the formation of concepts and the approaches developed on their basis that are used today to address issues of ensuring functional safety.

A functional attribute determines the purpose of the system, as well as its main goals, objectives and functions. Comprehensive and sustainable management of rail infrastructure requires a structured and methodical approach. Therefore, the requirements for ensuring the functional safety of the railway as an element of the transport infrastructure subsystem are considered bearing in mind the various areas of requirement given in Table 1 at all stages of the life cycle.

Solving problems related to ensuring the functional safety of any system can be compared with the creation of various objects using the Lego constructor, where each module is an accumulator of modern theoretical and practical knowledge in various fields. When considering issues of functional safety, in addition to the usual coordination of classical knowledge, methods and approaches, such areas as project management (organization of efficient use of resources), system diagnostics (the process of identifying problems in the system and solving them), reliability of systems (setting the boundaries of the values of all parameters characterizing the ability to perform the required functions in specified modes and operating conditions), system safety (taking measures against unwanted intrusions into the operation of the systems themselves, and from undesirable effects of the operation of systems on the surrounding systems (in the broad sense, both technology and people and ecology), combined possibilities are created. As an example, it is possible to cite the option of describing algorithms by mathematical methods built on a combination of principles for constructing algorithms in programming (describing a sequence of actions) and principles for the construction of structural diagrams in reliability (describing structural diagrams of the operation of objects in various loading systems and duplication of functions performed) with the binding of the technical states in the operation of elements and their systems, adopted in diagnostics, to the states classifying the ability to perform work, adopted in reliability. Thus, consideration of the safety issues in the functioning of systems makes it possible to combine knowledge of

3. Processes, where the change is fixed in conjunction with the information of the measuring equipment in real time, and they are considered as dynamic.

With the first type of processes, the parameters characterizing it are easily calculated and there are no problems in predicting its behavior. In this case, the researcher understands the physical nature (reasons that caused it, and regularities as reactions to incoming impacts) of the course of this process in the full volume for the research. Accounting for real-time does not affect the flow of the process under investigation within the framework of the study.

The second type of processes, as a rule, has clear patterns of change over a fixed time interval, so it is not difficult to set a function that describes the changes in the best way and find its parameters using differential or integral calculus. However, when forecasting its behavior, problems arise that can be solved using a measure of the probability of the system being in a given state. In this case, the researcher partially understands the physical nature of the process and adjusts the behavior of the process to that obtained in the experiment. The velocity of the process under investigation within the research partly depends on the velocity of the physical process in real time.

The third type of processes is interesting in itself since it is really created only with a continuous flow of information from the registered devices in a particular experiment. In this case, the experiment should give real values, but how can one assert that they are real if there is no understanding of the true value? Consequently, there are difficulties in forecasting its behavior on the basis of any data whatsoever, since there is no way to understand the pattern of change and accept a function for research over the entire time interval of the research. In this case, the researcher does not understand the physical nature of the process, makes assumptions, and plans experimental confirmation of his/her assumptions using the second type of processes. The course of the physical process under study within the framework of the study completely depends on real time accounting.

The above gaps, by determining the missing dependencies to improve the quality of the functional safety of the railway track, show the need to change the theoretical provisions adopted on the basis of the use of the theory of elasticity. One should take an example in the field of visualization, where raster graphics are replaced by vector ones. And on the basis of using such a method, to describe the propagation of impacts (impulses) using the propagation of waves (the theory of elastic waves and electromagnetic waves), as energy carriers for performing processes [15, 16, 18], and create new software systems. That will allow us not to assign which function will change, but to create these functions in time, taking into consideration the impact characteristics and the propagation time of this impact in the structure.

4 Conclusion

The essence of modern managing the functional safety of the railway track is not to process all the results with the help of artificial intelligence, but to formulate comprehensive criteria for evaluating the achievement of the main goal, and to define this goal in such a way that it would be achieved with available technical means. Given that modern technical means exceed the capabilities necessary to verify the results (determined on the basis of the provisions of the theory of elasticity, which is embedded in all methods and approaches, both theoretical and experimental research), it is necessary to change the system concept. The general aspiration of the new concept is the use of various fields of science with a focus not on ways to solve the problem, but on ways to describe the nature of the change in physical processes that take place both in the structural elements and in the structure of the railway track in real time for the processes under investigation.

The complexity of the situation lies in the fact that it is impossible to achieve effective management of functional safety by considering and solving only local problems, for example, such as the organization of the transportation process, the organization of the diagnostic process, the organization of repair work, etc. Although the whole range of actions necessary to ensure the functional safety of the railway track is carried out by various structures and organizations that do not contact each other in real life, only the formation of a common understanding of the process will allow developing the criteria for local tasks. Therefore, there is a need to create an information center, on the basis of the data of which experts from various fields in cooperation will create a new classification of track design performance. It will be based on criteria common to all types of railway tracks, for example, on the deformability work performed by the track under the rolling stock impact, and further, depending on the type of track, both geometric and mechanical requirements for these structures will be recalculated. AQ1

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