ON THE POSSIBILITIES TO IMPROVE THE RELIABILITY AND EFFICIENCY OF TRANSPORT PROCESS BY THE USAGE OF ANALYTICAL METHODS AND MODELS

Nikolay Georgiev [1]

ABSTRACT
Each mode of transport (transport system) is built of multiple interconnected and Interacting subsystems: transport infrastructure, information network, signaling systems, rolling stock, dispatching devices and operating personnel. In terms of the requirement to achieve a reliable (and efficient) transport process, these subsystems are linked in series. Of course, this is a conditional definition and means that the failure of just one of these subsystems (the subsystem does not function at all or functions without compliance with respective predefined requirements) leads to a failure of the whole system. Achieving a reliable and efficient transport process requires an integrated approach to the essence, peculiarities and interrelationship between the various reliability problems of the separate technical and technological transport subsystems, which can be realized only by applying appropriate and adapted to every specific problem analytical methods.

Key words:
Transport technical exploitation, operational reliability, efficiency of transport service

1 INTRODUCTION

Undoubtedly, the transport as a whole is a very complex system consisting of many and different in nature, internal structure and operating use subsystems, functioning to carry out a reliable transport process. Any inadequate and non-compliant to public demand behavior of this complex system would give rise to a very serious public interest.

In the past, when transport incidents were considered to be unavoidable and logically related to the operational activities, the reliability of transport service (and also its efficiency) was not considered to be a particularly important issue and an issue

[1] Nikolay Dimitrov Georgiev, Professor, PhD, Higher School of Transport-Sofia, “Geo Milev” Str., No 158, email:safetyniky@mail.com

of major public interest. Contemporary concepts and requirements regarding reliability of the transport process arose in the middle of the last century as a normal result of the industrial revolution, associated with that revolution rapid growth of transport, increasing public expectations and increasingly frequent accidents (many of them with a large number of human casualties and material damage) that caused *humanitarian concern* to society for their prevention.

Today, achieving a high level of operational reliability in transport is an extremely important national and international issue, the successful solution of which requires the overcoming of a number of scientific, technological and organizational problems.

In this sense, the acquisition of knowledge and experience only on the basis of information regarding the occurrence of incidents and accidents remains a possible but generally very outdated approach to solving the problems of operational reliability (and transport process efficiency) - mainly due to the lack of prevention. This is why, a new integrated approach to operational reliability is needed to address this shortcoming.

The concept of system reliability offers a solution to this problem and this is the main reason for it to become more and more widespread approach in the field of the technical exploitation of transport. Essentially related to the application of risk management principles (and a set of analytical methods within this area), this concept offers a good opportunity to develop theoretical fundamentals, methods and algorithms for solving a number of technical and technological problems. In this regard, the present paper discusses the possibilities, peculiarities and methodological issues for applying system reliability approach and some of used in this area analytical methods (and models) [1], [3] to improve the reliability and efficiency of transport process.

2 EVOLUTION OF ATTITUDE TOWARDS ISSUES OF TRANSPORT PROCESS RELIABILITY AND EFFICIENCY

Addressing the problems of operational reliability in transport and the understanding of its key role in providing a qualitative and efficient transport process as a whole are undergoing a rapid development throughout the entire period of progress of the transport industry. The evolution process begins at a stage where operating reliability and safety (and also efficiency of measures connected with them) are only identified by the number of accidents occurring over a certain period of time. This evolutionary phase begins at the dawn of the transport industry and continues until the end of the first decade of the last century, and the transport experts usually call it a stage of a traditional approach to understanding operating reliability. This initial attitude towards operating reliability is characterized by trivial activities, such as: incident reporting, spontaneous (unplanned) audits, development and enrichment of exploitation rules without targeted and in-depth analysis, low level of awareness on the part of the executive and management staff, separate consideration of the influence of various factors on the reliability and efficiency status, etc.

The second stage of understanding operational reliability issues is characterized by the further development of elements (singly or in combination) of the first stage, for example: improving the requirements for performance analysis of the interaction between operational staff and equipment, enriched rules and procedures on the basis of purposeful analysis in the scope of technical exploitation, increased awareness of the staff, enhancing the role of personal responsibility, planned monitoring, increasing the role of control staff and so on.

The third stage of evolution is called reliability (and safety) management. The latter is based on the concept of system reliability (safety) and considers the interactivity and interdependence of external and internal operational factors within the transport undertaking concerned (e.g., transport carrier, infrastructure manager, etc.).

The main issue today is not whether the operational reliability (safety) management is needed to ensure a high level of transport process reliability (efficiency of the transport service), but how it could be improved. The answer is yes, and this improvement can only be realized on the basis of known and adapted to the operational reliability issues scientific analytical approaches and methods. The possibilities for applying some scientific approaches and methods in the operational reliability management within the transport are considered in the following chapters of this paper.

3 METHODS FOR ANALYZING TRANSPORT OPERATIONAL RELIABILITY

In this part of the article, the peculiarities and practical applicability in the field of the technical exploitation of transport of the most famous and simple to use methods for analysis and assessment of the operational reliability and efficiency are considered. The choice of approach and method depends on the type of analysis that is determined by the following main characteristics: purpose of study, level of detail of the analysis, type of data available and type (and structure) of the results obtained.

3.1 WHAT-IF ANALYSIS

What-if analysis is a system approach to the identification, analysis and assessment of hazards. It is based on Brainstorming method - an intuitive approach utilizing the creativity of a group of experts. The analysis is implemented by the answers to certain questions that form the basis for identifying potential hazards (operational problems) and taking decisions regarding the tolerability of their concomitant risks, including the identification of respective action scenarios to mitigate those risks that are assessed as unacceptable.

Table 1.Exemplary form of What-if analysis

Description of the system

No	What - if	Answer (description)	Probability of occurrence	Consequences	Comments and recommendations
1	-/-	-/-	-/-	-/-	-/-
2	-/-	-/-	-/-	-/-	-/-
i	-/-	-/-	-/-	-/-	-/-
n	-/-	-/-	-/-	-/-	-/-

Based on the available information regarding the system that is on process of analysis, the research team formulates *What-if issues* that relate to factors affecting the system reliable functioning (technical failures, human errors, deficiencies of technology, organization and management, influence of other systems, etc.). This analysis ends with compilation of a specific worksheet (form) – Fig. 1.

What-if analysis is an easy-to-implement method for qualitative analysis, effective and practical in a number of industries and the typical processes connected with them.

Even people with less knowledge regarding system reliability (for example, operating staff at executive level) after some training can participate in a meaningful way in this type of analysis. It is an universal method and can be performed within all aspects of the technical exploitation regarding every transport undertaking (use and maintenance of technical means, management of human resources and organization of transport process).

3.2 EVENTS AND CAUSAL FACTORS ANALYSIS

The purpose of *Events and Causal Factors Analysis* is to provide a methodological basis to support the collection, processing and analysis of information for an incident (accident). It makes it possible to identify the chronology of events in the structure of accident scenario, thus facilitating revealing the root and direct cause of its occurrence.

Events and Causal Factors Analysis is an extremely useful method to achieve a qualitative investigation of transport incidents (accidents). It provides:

-causal explanation for the occurrence of a investigated incident;

-basis for useful changes to the failed technical or technological system to prevent future (similar to the investigated) accidents;

-illustration of the accident scenario chronology by showing the sequence of occurrence of events in time;

-flexibility in interpreting and compiling collected data, reveals *White spots* (lack of sufficient data) in the available information;

-factual basis for assessing possible mitigation measure.

3.3 FAULT TREE ANALYSIS

Fault Tree Analysis (FTA) is a deductive methodology. That is it involves reasoning from the general to the specific, working backwards through time to examine preceding events leading to a given unwanted event (system failure that is under study, e.g.: equipment failures, human errors and management system failures). The latter is called *Top event*.

FTA is based on the construction of the so called *Fault tree* (Fig. 2) which is a graphic model displaying the various logical combinations of events that can result in the Top event. This *Top event* is then broken down into a series of transitional events that are structured according to certain logical rules. This process of breaking down the events continues until the *Base events* (*Top event* causes) are identified (Events 1, 2, 3 and 4 in figure 2).

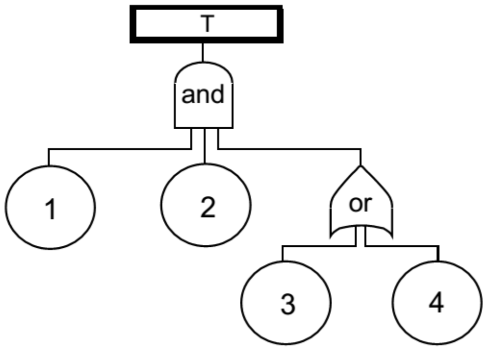

Figure 2. Fault tree

FTA allows both qualitative and quantitative analysis. The qualitative analysis is made up of getting only sufficient knowledge about logical connections between events. Quantitative analysis complements the qualitative one, providing the capability to obtain the probability of occurrence of the *Top even*. To do that it is necessary to know the probability of *Base events* with the usage of respective logical rules in probability theory.

Fault tree has two basic types of nodes called *Logical gates*. The basic symbols and rules for quantitative analysis in *FTA* are shown in figure 3.

Symbol	Description
	Text box: contains text for fault tree nodes and events
	Base event: a basic equipment failure that requires no further development of failure causes
	Secondary event: an externally induced failure or a failure mode that could be developed in more detail if desired
	Normal event: an event that is expected to occur as part of normal system operation
In Out	**Transfer symbols:** transfer in-out continuation symbols (eg. see same symbol on another page)
G A B	**AND-gate**: indicates that the output event G occurs when all the input events (A and B) occur simultaneously $P_G = P_A . P_B \rightarrow (2\,inputgate)$ $P_G = P_A . P_B . P_C \rightarrow (3\,inputgate)$
G A B	**OR-gate**: indicates that the output event G occurs if any of the input events (A or B) occur $P_G = P_A + P_B - P_A . P_B \rightarrow (2\,inputgate)$ $P_G = (P_A + P_B + P_C) - (P_{AB} + P_{BC} + P_{AC}) + P_{ABC} \rightarrow (3\,inputgate)$

Figure 3. Fault tree symbols and logical rules

3.4 EVENT TREE ANALYSIS

Event Tree Analysis (ETA) is an analytical tool for identifying and evaluating the structure of a potential scenario following the occurrence of a given event that is under study, called *Initiating event* (e.g. transport incident or accident). Similarly to *FTA*, *ETA* is also based on the construction of a tree, known as *Event tree*.

Event Tree Analysis includes four main steps:

-Defining the Initiating event.

-Identification of the events that may arise after the initial event, as well as the logical interconnections between them.

-Construction of the *Event tree*.

-Quantification of the consequences (resulting events, also called outcomes).

Figure 4 shows an exemplary *Event tree* (modeling transport accident) and the way of obtaining the probabilities of outcomes.

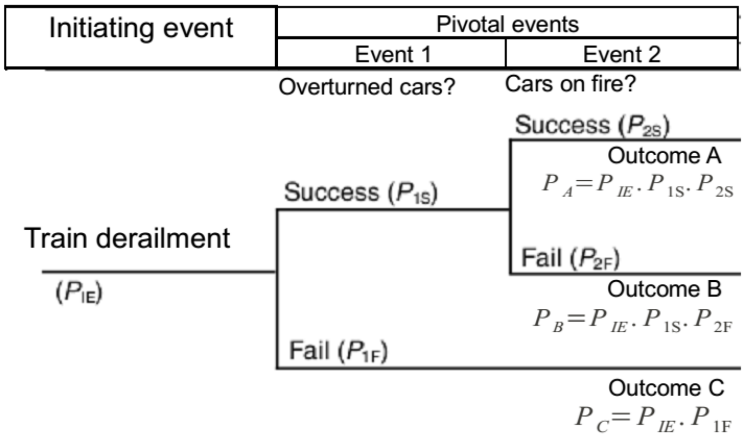

Figure 4. Exemplary Event tree

3.5 X-TREE ANALYSIS

This method is also known as *Bow-Tie Analysis* because it uses the model *Hazard-Barrier-Target (Bow-Tie Diagram)*. It combines the opportunities for analysis that *FTA* and *ETA* provide to obtain the assessment of a set of potentially possible results that follow the occurrence of an unwanted event (investigated event or hazard). The analysis begins with identification of the unwanted (initiating) event and influencing factors by performing *FTA*. Subsequently, an *ETA* is performed and *Barrier behavior* (pivotal events) is judged to prevent the negative consequences after the occurrence of initiating event. Figure 5 describes the stages for performing *X-Tree Analysis*.

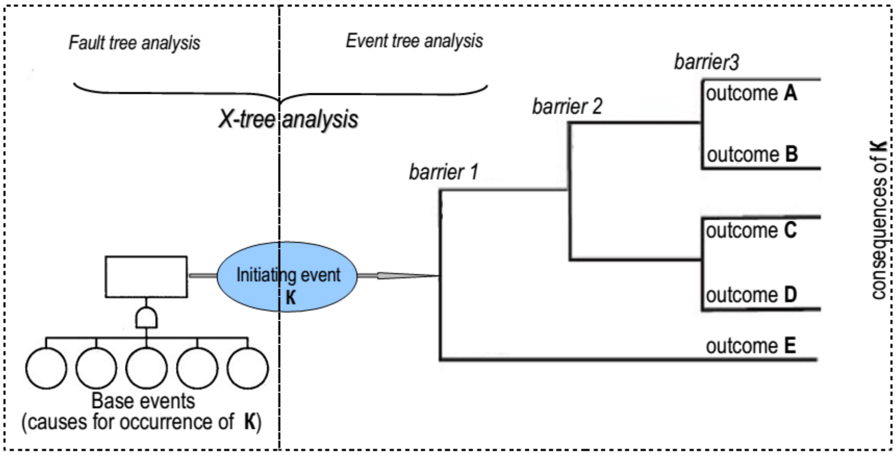

Figure 5. X-tree analysis

X-Tree Analysis is characterized by simplicity and universality of practical application and is very powerful analytical instrument for analysis and investigation of transport incidents (accidents). It is also very appropriate tool for assessment of the operational reliability of transport technical and technological systems.

3.6 METHOD COSTS -VOLUME-PROFIT

This method is also known as *Break-Even Point (BEP)* and provides the capability to select the optimal solution in short term period regarding the relationship between costs, business activity volume, revenues from sales of products or services, financial result and efficiency. The method uses the theory of marginal economics and the basic equation when performing that type of analysis is as follows:

$$NP = TR - TC = p.q - (a + b.q) \quad (1)$$

where:
NP – net profit;
p – selling price per unit production;
q – marketed production volume;
a – fixed costs
b – variable costs per unit production.

BEP method has different applications and some of them and especially its adaptation to the analysis of transport service efficiency is discussed in [4].

3.7 SIX SIGMA ANALYSIS

Six Sigma is a contemporary methodology for analysis helping the decision-making regarding the improvement of a given technological or manufacturing process. Using the normal distribution and some indices, *Six Sigma* methodology provides an appropriate way to assess process capability. The so called *Capability index* C_p is the simplest index (way) to measure the process capability. It is calculated by the usage of the next equation:

$$C_p = \frac{SL_{upper} - SL_{lower}}{6\sigma} \quad (2)$$

where:
SL_{upper} - upper specification limit;
SL_{lower} - lower specificaion limit;
σ - standard deviation of the parameter that is under analysis.
SL_{upper} and SL_{lower} are determined on the grounds of the technical specifications and express the customer`s requirements whereas σ represents the real process.

Depending on the computed value of C_p, the studied process could be:

-*Highly capable process* ($C_p = 2$). It is unlikely that the process will generate an unacceptable performance;

-*Marginally capable process* ($C_p = 1$). There is a great probability of unacceptable performance (process or technology failure).

-*Incapable process* ($C_p < 1$).The process is incapable to meet the predefined requirements (technical specification).

It is broadly recomended and accepted that a process with $C_p > 1.33$ is capable. But a too high level of capability index $C_p \gg 1.33$ means that the studied process is characterized by great and unjustified material and financial expenses.

Six Sigma concept has many practical applications and its adaptation for solving problems within the area of transport service efficiency is analyzed in [2].

4 CONCLUSION

The new time and characteristic of it new peculiarities of the technical, technological and infrastructure solutions are a very serious challenge to the reliability and efficiency of transport process. Worldwide, the last decades have been marking a whole new approach to the problems of operational reliability. Following the two previous approaches, focused only on technical means or only on the human-operator, today the transport process organization and management are the main concern. The question now is the following: What should be done to ensure that the human-operator and technical devices work in such a manner that all hazards and concomittant risks are controlled. The answer lies in the concept of reliability management (including the usage of appropriate analytical methods and models for system analysis of reliability of the diferent transport technical and technological subsystems). The present paper discusses some of the most appropriate and simple to implement methods for analysing the operating reliability and efficiency of transportation process realized in the different transport undertakings.

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