Conception of 3 Stages in Risk Management in Road Transport Systems

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In the paper is presented a conception of „three stages" of risk management in transport. So risk management can be considered at three levels (planes) of each transport system: 1. level of system structure elements; 2. level of processes which realize system purposes; 3. level of system "attitude". Risk is a "multidimensional product" and relates all negative transport effects (NETs). It is, among the others, about risks: life loss (safety aspect), natural environment degradation, transport congestion arising.
Keywords: transport, risk management, structural risk, functional risk, negative transport effects.

1. INTRODUCTION

The main purpose of transport system management is safe, efficient and economics justified realization of transport processes, by existing technology, organization and economics conditions. Transport safety is just one of the basic feature of each transport system. The essential issue in transport safety management is estimation of all possible risks in analyzed transport system.

The main goal of risk analysis in transport is working out sensible basis to make decisions related loss avoiding, which can happen at any level of transport management and in any place of concrete transport system, [1]. The first stage of that process is risk analysis where risk size is estimated. Risk analysis in transport systems is a structural process of identification both possibilities and range of losses caused in system and/or its surrounding.

Risk analysis comes to choice of "the best" method, which allow to: 1. danger identification (undesirable events); 2. frequency estimation of undesirable events; 3. consequences estimation of undesirable events; 4. reconstruction of possible emergency scenarios.

Risk analysis depends on „dangers map" in analyzed transport system. The map shows potential losses in: 1. system structure; 2. system work processes; 3. negative effects of system behavior. This is a main idea of that conception. This is a simple implication of triple interpretation of complex system which is each transport system.

Problems of risk analysis has a rich bibliography and it is not a place for exact review. Representative literature related to analysis methods, valuation and risk control in technology, also in transport is in author's monograph, [2]. From extensive monograph foreign publications of risk analysis are [3], [4], [5], [6].

Risk management problem from years is in articles published in famous magazines of safety ad reliability. From earliest publications are [7], [8].

From 2000 year there are tries of harmonizing risk management methods in technology, but up to now there is not general European standard in this subject, [9]. It relates also risk management in transport. Recommendations for further works on risk estimation in transport are among others in report, [10]. On the other hand risk estimation criteria in transport safety programs are a subject of among others of a report [11].

New research approaches in the range of transport risk management can be searched in supply chain risk management. Research perspectives in that range are in one of the newest publication [12]. The example conception of new approach to those problems is shown in the lecture [13].

2. THREE "STAGES" OF RISK MANAGEMENT IN TRANSPORT

„Three stages" conception of transport risks (3S-TR) are signalized in non published work [14]. This conception comes out from three different definitions of general system [15]:

1. structural definitions – which relate to internal system construction;
2. functional definitions – which relate to system functioning by processes identification as a changes carrier of system (features change follows by process);
3. model-simulation definitions – which allow for observation and prediction system behavior in determined conditions of activity.

Structural system interpretation relate to classic definition of L. von Bertalanffy, where the system is "a collection of elements which stay in relations", [16]. Structural definitions describe the system by: a. elements collection; b. relation collection between elements; c. goal – that is system-creating relation. Functional interpretation of system relate to short definition of M. Mesarović, [17]: "system is a collection of relations between its features". Relations between features describe system functioning. Researched those relations we can state if system functioning is normal. Systems functioning in cybernetics represents as transformation of entries to surroundings. Each system has some features and change one value or few features is an event. Series of events determine system functioning. The process goal is achieving by system preferred (in determined time period) effects (products, results) which determine new system phases. In that sense system phase is a collection of its essential features. Functional definitions put an accent on processes identification which are in system. In transport system there are four interesting process groups: 1. traffic processes; 2. steering processes; 3. loading processes (initial-final); 4. disturbing processes.

Model-simulation interpretations put the accent on observation and prediction of system behavior in determined conditions of activity. Simulations give possibility of prediction the hypothesis consequences of system activity and verification and choose of analyzed variants of system activity.

So according to 3S-TR conception risk analysis should be provided on each three planes (levels):

4. plane of transport system structure;
5. plane of work processes in transport system;
6. plane of transport system "behaviors" that is de facto – level of "negative effects of transport" (NETs).

It is all about: 1. structural risks – generated by elements and relations which create system structure; 2. functional risks – generated by working system processes; 3. system risks – generated by system in long term and related with danger of falling system into undesirable situations, that is such, which generate losses; for example transport accidents

2.1. STRUCTURAL RISK (SR) STAGE/PLANE I

If the structural definition would be used in "transport system" then at level of "elements" and "relations", that is at level "structure of system" can be analyzed different risks; they can be called as "structural risks". Structural risks should be relate to undesirable changes of transport system structure. Precisely "structural risks" come out from dangers "which are effect of such changes of number and elements features and changes of system structure that in system and in surrounding can be generated losses", [18, p. 68].

Structural risks are dependent on effects of all undesirable interactions between elements of transport system structure, it means such which generate losses in that system. Helpful is here classification proposed in non published lecture [18]. After some modification it is presented below (table 1). Marks: RF– risk factor; HF – human factor in transport; MT – means of transport; TI – transport infrastructure; N – norms, rules, procedures; TA – transport accident; → - implication operator; ∧ - conjunction operator.

There should be also analyzed relations: TA → AE, (AE – accident effect).

Formally structural risk factors are relations and intuitively relation means in system a relation between system elements. For example about relation CL ∧ N → we say: if there is simultaneity (implication) CL and N, then there is an accident

Table 1. Classification structural risk factors of accident with propositions of analysis that risk

Risk	RF→ TA	Structural risk factor
	relations 1-argument	*Individual risk factors*
SR1	HF → TA	Human factor
SR2	MT → TA	Damage means of transport
SR3	TI → TA	Defect/damage of transport infrastructure
SR4	N → TA	Wrong norms, bad rules
	relations 2-arguments	
SR5	HF ∧ MT → TA	„wrong fit of means of transport to human-operator"
SR6	HF ∧ IT → TA	„wrong reading a transport infrastructure elements"
SR7	HF ∧ N → TA	„norm breaking and road regulations"
SR8	MT ∧ IT → TA	Effects at: means of transport – transport infrastructure
SR9	MT ∧ N → TA	„norms for means of transport"
RS10	TI ∧ N → TA	„norms of designing and IT exploitation"
SR11	HF ∧ HF → TA	Such relations (interactions) are possible to become in road transport systems, but it is difficult to give them unequivocal definition.
SR12	MT ∧ MT → TA	
SR13	TI ∧ TI → TA	
SR14	N ∧ N → TA	
	relations 3-arguments	
SR15	HF ∧ MT ∧ TI → TA	
SR16	HF ∧ MT ∧ N → TA	
SR17	N ∧ MT ∧ TI → TA	
SR18	HF ∧ N ∧ TI → TA	
	relations 4-arguments	
RS19	HF ∧ MT ∧ N ∧ TI → TA	

2.2. FUNCTIONAL RISKS (FR) – STAGE/PLANE II

Structural dangers can change into dangers of second level, more difficult – as I think – to identify and estimation. Dangers of 2nd plane are effects of such changes of system properties, that in system and surrounding can be generated losses. And risks related with properties changes are "functional risks" – that is risks (non controlled) of undesirable changes for safety of work processes in system (e.g. traffic is a such process in road transport system). Theoretically for general system can be mentioned five changes then five types of functional system dangers, [18]:

1. shaking dynamic balance of system;
2. disturbing information processes in system;
3. disturbing steering processes;
4. disturbing self-regulation of system;
5. shaking integration of system.

With each danger is associated risk of not fulfilling by system desirable functions 1 – 5. It would be for sure difficult to interpreted dangers 1 – 5 for transport system. Less general level of reflections is need. That is why the interpretation of "process approach to transport system" was used, [15]. According to it for transport activity consist three basic processes:

1. process of shaping transport infrastructure: a. infrastructure planning; b. infrastructure realization; c. infrastructure exploitation.
2. process of transport realization, which can be defined as follows: transport process include group of organization activities, administra-

tive realized by experts in exact order by using means of transport for moving concrete loadings in exactly determined relations, [19]. Only moving that is traffic is a component of such defined process, and its importance for transport safety follows from that during this process more losses are generated.

Process risks in other words functional risks are connected with three process groups existing in any transport system:

- risks of losses in traffic processes – it is about losses risks related with decreasing traffic efficiency or transports efficiency;
- risks of losses in initial-final processes: it relates generally losses risks important for load chain realization, that is "logistics losses"; they can be described by logistics indicators;
- risks of losses in transport steering processes: the example is here losses caused by wrong determined signalization cycles in traffic, or losses which come out of steering the landing and taking-off cycles of passenger planes, steering subway trains, etc.

3. process of transport Policy creating; this is a process of manage character which assure integration and coordination of all transport system elements. This process relies on conscious reaction to cause concrete behaviors of institutions, companies or transport users, driven for goal realization, [15, p.9].

Cooperation of those three processes is composed on transport system functioning.

Functional risks in transport system are associated risks with three above processes; they can be defined as:

FR1. risk of wrong infrastructure shaping-

FR2: risk of wrong transport services

FRF3. risk of wrong transport policy; there are here particular.

2.3. RISKS OF NEGATIVE EFFECTS OF TRANSPORT (NET's-risks) – STAGE/PLANE III

It seems that dangers of II level that is functional dangers can "release" undesirable behaviors of transport system observed in long term perspective. Those behaviors – system dangers called negative effects of transport (NET-s). They generate losses both in structure and in system surrounding. It is like 3rd plane of dangers and connected with them risks, which we call as "NET risks". Theoretically for general system can be mentioned also five types of system dangers [18, p. 69]: 1. lack of adaptive; 2. loss of accommodation abilities; 3. homeostasis disturbances; 4. increase stoppage (if the increase was desirable); 5. step changes of system parameters.

With each danger is connected risk. But there are questions arise: 1. what is "lack of adaptive" of transport system?; 2. what is accommodation "ability loss " of transport system? etc. These are difficult questions and it is necessary to find simplifications; NET are them (negative effects of transport). Here can be described at least three groups:

A. undesirable transport events – as states of working processes in transport system – which determine risk levels in transport system:

- transport incidents;
- transport conflicts;
- transport collision;
- transport accidents;
- transport crashes;

B. undesirable phases of natural environment (surrounding of transport system):

- losses in natural environment,
- lowering the quality of life;

C. undesirable phases of traffic schedule in area, that is phases of transport congestion.

The most obvious and the most researched are risks of undesirable transport event, which defined transport safety problems by analysis transport accident risk, death risk in transport accident, risk of injury in transport accident, risk of transport catastrophes and others. Risks of appearing such events can be analyzed by:

- different transport events models; e.g. models of road accidents;
- marking out risk indicators in relation on empiric data;
- simulation methods of traffic situations.

3. METHODS OF TRANSPORT RISKS ANALYSIS

Risk analysis methods allow to account (estimate) risk in systems "HF - TI – MT" and according PrPN-IEC 603000-3-9 norm risk estimation is a process used to create measure of analyzed risk level. From that norm and known multiplicative formula of risk estimation comes out that choice of risk analysis method comes to the choice of "the best" method which allow to:

1. danger identification (undesirable events);
2. frequent estimation (possibilities) of undesirable events;
3. consequences estimation (effects) of undesirable events;
4. reconstruction of possible emergency scenarios (accidental).

Above phases of risk analysis determine choice of risk analysis methods and are a criteria of such choice. There are not any directives for choice the risk analysis method; it relates also transport. Works on methodology of integrated risk management in transport still lasting.

Taking "3S-TR conception" we can propose idea of next criteria of selection risk analysis method:

1. for structural risks proper would be methods of "subject dangers" analysis, that is come from structure elements;
2. for functional risks proper would be methods of "process dangers" analysis e.g. Process Safety Analysis (PSA);
3. for system risks proper would be methods based on models and indicators of undesirable transport events; example are here methods from "Probabilistic Risk Analysis" (PRA).

The choice of proper risk analysis method is more "an art" than "science". Below in table 2 there is presented first version of choose of common risk analysis methods for transport. In another version it would be published in [1, s. 294-295].

There is not placed helpful risk analysis methods such as: RM - result models; DM - delphic method; DI - danger indicators; ST - simulations techniques – e.g. Monte-Carlo simulation, others. The are also passed over the following norms: ISO 28000: managing safety in load chains, ISO 31000: Risk Management Guidance Standard; new ISO standard, currently at the phase of project including directives in the range of general risk management implementation. ISO 17799: "practical rules of safety management information" was published in January 2007 as a PN-ISO/IEC 17799:2007. By practices is noticed as the best edition relates system approach to safety management information. And assume the following shorts of basic methods and other methods.

Basic methods

SR - Safety Review; RR - Relative Ranking; PHA - Preliminary Hazard Analysis; WI - "What - if" Analysis; HAZOP - Hazard and Operability Analysis; FMEA - Failure Modes and Effect Analysis; ETA - Event Tree Analysis; FTA - Fault Tree Analysis; CCA - Cause Consequence Analysis; HRA - Human Reliability Analysis; QRA - Quantitative Risk Assessment.

Other methods

Barrier Analysis (BA) – method introduced by energetic sector; identify barriers counteracted accidents, damages and injuries arise. Barrier analysis is a quality method for accidents analysis. It is connected with MORT.

Black Spot Analysis (BSA)– method of black point analysis; the philosophy relies on giving the sources there where are the lowest.

Bow-Tie Analysis (B-TA) – Bow-Tie: left side wing shows danger for that factors which allow to avoid entering in accidents chain; right side wing shows consequences. Bow-tie is constructed in that way - "risk approach" should be minimal or impossible.

Change Analysis (ChA) – technology of designing danger identification, which arise as a result of planned or non planned changes; used among others in post-accidental investigation.

Swiss Cheese Model (SChM) -

Following shortcuts mark:

HF – human factor; MT – means of transport; TI – transport infrastructure; STS – surrounding of transport system; EF – external factors (floods, terrorist actions); AR – accident research; CA – central authorities; LG – local governments; TB – transport boards; T – transporters; PCT – production companies for transport.

4. SUMMARY

Risk management conception at "three stages" of any transport system is natural – it comes out of three possible transport system interpretation. From presented here 3S-RT conception follows reasonableness of analysis structural risks, functional (process) and system risks (NET's risks). Such research approach indicates that there is not one transport risk but at least three forms of that.

Presented here conception is an example of wider look on interpretation problems of modeling and risk analysis. A need of looking for analogies and integration conceptions in researches of safety of different technology systems is a necessity today. It comes out of 20year Geysen's thesis: *„(...) safety problems in different domains are often of the same nature and can be formalized in the same way"*, [20].

Creating new methodology of transport risk management requires wider use and building safety models and risks in systems of "organization" type.

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