METHODOLOGICAL ISSUES OF ENSURING OPERATIONAL SUSTAINABILITY OF TRANSPORT AND LOGISTICS SYSTEMS

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Abstract: *Sustainability of integrated transport and logistics systems is ensured based on the interaction of processes in different phases of the systems life cycle using risk management methods.*

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Recently, the concept of "sustainability" has been increasingly mentioned in relation to transport and logistics systems (TLS). Initially, “the sustainability of transport system referred to its ability to provide high level of satisfaction of public needs in transport while minimizing the negative impacts on health, economy and environment," i.e., on a qualitative level. Currently, however, researchers recognize the need to introduce integrated criteria and quantitative assessments of TLS sustainability levels [1, 2].

Based on the analysis of literature sources, the following criteria (indicators) of sustainable operation of transport and logistics systems can be formulated:

1. ACCESSIBILITY (physical) - to markets and employment; access to basic social services; access to international trade.

2. AFFORDABILITY (economic) - low-cost access to employment and education, to basic transport and logistics services; long-term investment in transport infrastructure;

3. SAFETY – safe transport of cargo, passengers and luggage, safety of people and property throughout the life cycle of transport facilities, transport and logistics technologies; prevention and/or mitigation of transport-related accidents and man-made disasters.

4. SECURITY - protection of individuals, human and cultural capital against the adverse effects of transport; protection of transport facilities, transport and logistics technologies from contingencies (and losses) of social and man-made nature.

5. ENVIRONMENTAL SUSTAINABILITY - TLS is sustainable in relation to energy use, safe environmental pollution levels, land use; transport infrastructure is resistant to natural disasters and calamities.

Risk management methods appear suitable for integrated assessment of TLS sustainability criteria that are so diverse in their nature and physical characteristics. The methods entail assessment of risks for each of the above criteria, i.e. the likelihood of dangerous (unwanted) events or trends, multiplied by the consequences of their occurrence [3, 4, 5], that are additive and can be aggregated. The resulting estimate of integrated risk is then compared to the acceptable value, and risk control algorithm is employed if necessary to reduce risks to an acceptable/admissible level [6, 7]. To perform such comprehensive evaluation reliably in relation to TLS of a city, region or country does not currently appear feasible.

Therefore, further we will address the methodological issues of sustainability (reliability and safety) of TLS over their life cycle, using the risk management methods for the case of risk assessment in the integrated supply chains. Supply chains are complex multi-structural systems with active elements operating in a fast-growing market environment. Their operation is associated with considerable uncertainty that creates systemic risks. Uncertainty is one of the key issues analysed in the supply chain security management systems. Despite considerable technological and industrial capabilities available, it becomes increasingly difficult to manage supply chain systems due to occurrence of failures that affect the TLS sustainability level.

It appears practical to address supply chain security and sustainability issues from the perspective of system management and system life cycle management theories, through evaluation of the quality of resources and processes utilized at different stages of the life cycle (LC) [8]. Global trends for integration of stakeholders in transport of goods and services on the basis of supply chain management model form new principles and mechanisms of integrated support for efficient operation of transport companies.

Application of the methods of system life cycle management is based on the concept of integrated supply chain security, which is supported by integrated management models, latest information technology and risk management system. [9] Supply chains, designed according to the above requirements, can adapt to ever changing environment and have a significant impact on the TLS sustainability level.

Performance evaluation of the organizations within the supply chain depends on various attributes and on their current strategic and operational objectives. Regular compliance evaluations are carried out to identify vulnerabilities of processes and outcomes in the supply chain, which results in the reduction of overall costs and losses. This enables acceleration of the transport and logistics processes, including vehicle operation.

The process analysis provides detailed description of all current activities related to the delivery of products (goods) in order to collect and analyze relevant information on existing methods and indicators. Reliability indicators for logistics processes are expressed by probabilistic data values in the range $0 \leq p \leq 1$ where "0" indicates a complete cessation of operation (failure), and "1" – a complete interaction (success). Reliability of the processes in the supply chain refers to the probability of reaching the target ("ideal") parameter values in a defined time interval and within specified tolerances. An order for product delivery is considered completed if it is implemented within the admissible deviation domain, or within the positive domain. Areas within the limits of "acceptable" risk level indicate reliable process activity.

TLS development shows trends towards becoming more integrated, holistic systems that operate based on integration of infrastructure, links, resources of the supply chain and *integrated logistics support* for the processes throughout their life cycle. The operation of TLS should be addressed at the three stages of its life cycle: planning (development), operation (activity), recycling. The life cycle model forms the framework of the new generation TLS, that operates within supply chain and interacts on the principles of self-regulating transport links (elements) with shared resources, providing highly efficient operation through utilization of IT and uniform process management standards. At each stage of the life cycle the three activities are considered: determining what to do (activity W); determining how to do (activity H); delivering (activity D)

Table 1 shows the activities and interrelations between the stages of TLS life cycle.

Table 1. *Relationship between LC stages and activities of TLS*

Stage	Activity W	Activity H	Activity D
Planning and Development	Setting goals Defining strategy Defining needs for TLS processes	Requirements engineering Concept definition Designing TLS services Process planning Service provision planning	Determining parts (components) Provision of services Testing Delivering services
Operation	Defining support needs Definition of use	Determining operational requirements for TLS Determining requirements for logistic support	System operation Logistic support for processes
Recycling	Identifying needs for recycling	Determining requirements for recycling	Recycling of services Decommissioning

Different life cycle stages may fall under different models, that should be able to interact. Obtaining information at different stages of the life cycle provides a seamless integration of processes, which improves operation quality. Process integration will represent TLS dynamics towards the optimum, i.e. sustainable condition.

The following organizational and technical model consisting of five interconnected modules is proposed as a comprehensive scheme [8]:

The module of standard processes related to quality management system, structurally supported by ISO 9000 series standards;

The module of integrated logistical product support, comprising the processes of analysis of logistic support, maintenance and repair, material and technical support, e-manuals for the product;

The module of the operational logistics cycle management, integrating the resources within the logistic cycle of supply, material and technical support, physical distribution;

The entire system life cycle process management module, providing adaptation based on the systems engineering methods and product open coding;

Strategic life cycle management module (planning, sourcing, production, service and reverse flows).

Fig 2 Shows the hierarchy of the supply chain life cycle management:

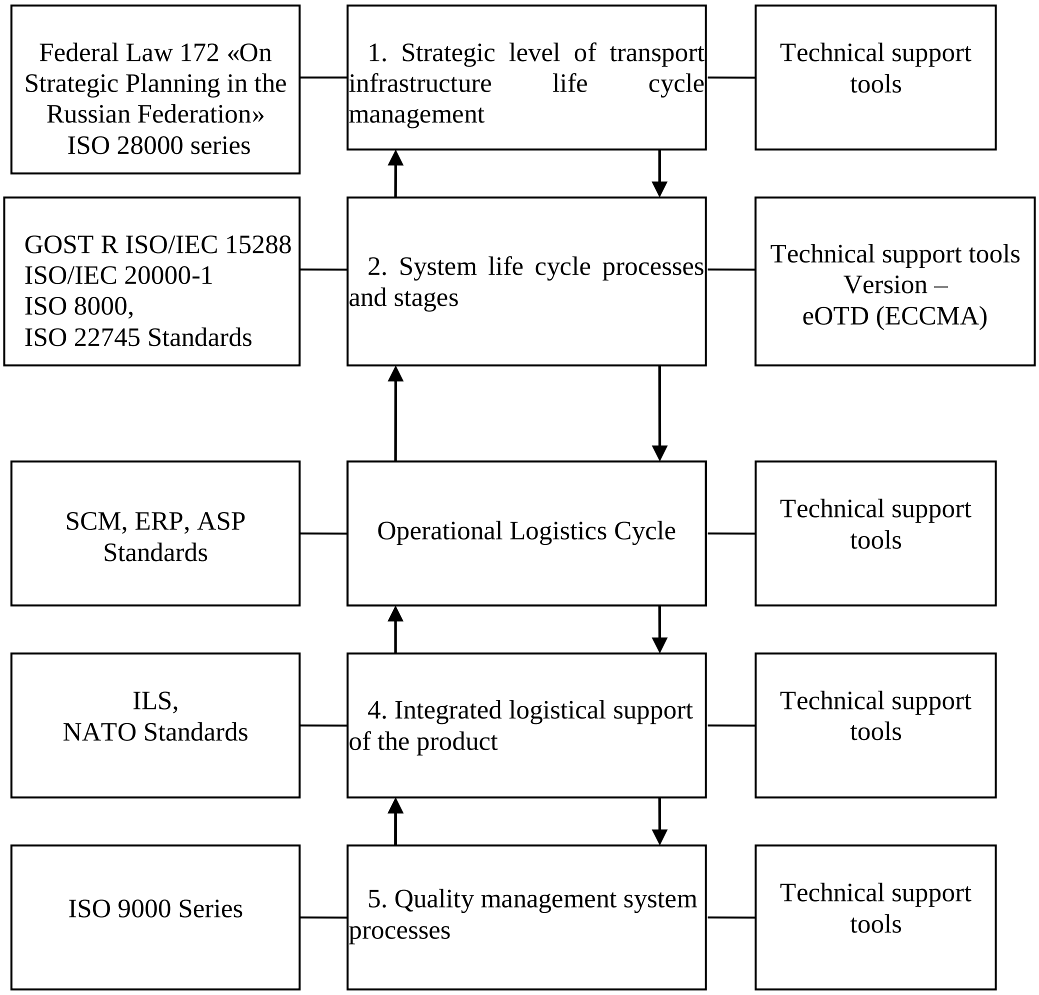

Fig 2. *Organizational and workflow diagram of the supply chain life cycle management*

The bottleneck of the TLS supply chain life cycle is the integration of production and operation (application) material support with transporting based on compatible logistical technologies, electronic document workflow within common information space. At the same time, the issues of operational and technological hazards and related failures (malfunctions) in manufacturing, transport and logistics processes receive little attention. Risk management in the real sector is evolving somewhat independently in several areas: industrial and environmental safety, reliability theory, other disciplines. The logic of management process analysis involves the assessment of the model sustainability and efficiency within the system "design – manufacturing – maintenance – transportation/warehousing – operations – additional services". To understand the technological effects of risk mitigation and ensuring TLS sustainability we will look at the main trends of their development.

The main trends in the development of vehicles and transport infrastructure are expected to be determined primarily by:

- Autonomous (automated) vehicles - driver assistance systems (ADAS);
- Information technologies (broadband 4G, 5G) and connected cars (V2V, V2I, V2P);

- Digital road infrastructure (the BIM technology), web-based services for adaptation of users (transport companies) in the transport and communications environment;

- Electric personal and commercial vehicles.

The above technological trends may bring far-reaching social and economic consequences, including the following:

- Automakers will integrate with IT companies and freight carriers (offering the service of delivering goods or passengers, not the vehicle itself);

- The information and communication services will evolve for citizens, drivers, service and dealer centers, freight consignors and consignees;

- ADAS will develop further, increasing the time in automatic mode up to fully automatic driving. This will allow to slash the number of road accidents resulting in deaths and injuries;

- The use of self-driving trucks and ADAS-equipped vehicles will help to lower the economic risks of carriers by shortening the delivery time, reduction of pilferage and loss, cutting down stock volumes.

With the implementation of the above trends the transport and logistics system is likely to become adapted to info-communications environment to the extent that it will form a new culture of human interaction with the environment (human – vehicle, human – urban environment, human – human, human – natural environment, human – means of production and consumption), which may lead in the near future to the transition from «homo sapiens» stage to «homo in nexu» (man connected) stage. The signs of such transition can already be found in the development of urban transport and logistics systems (implementation of the principle of multimodality, development of info-communication environment, etc.). It is important to understand and adequately respond to them, striving to achieve a seamless fit of the transport and logistics technologies into the natural, social and economic environment.

The implementation of the above trends will require identification and addressing new fundamental and practical problems in the transport and related areas of research, including the following:

1. Setting up new environmental and social standards of human life, economic development, including the mobility of goods, services and people with respect to the use of pervasive global info-communications networks;

2. Development and implementation of intelligent traffic management systems and access of individual vehicles and road users equipped with robotic, mechatronic and bio-adaptive systems to public road network;

3. Elaboration and implementation of supercomputing technology and data storage systems for real time traffic management, assessment and forecasting of integrated TLS development, environmental and social conditions, emergency situations of natural and man-made nature, effects of climate change on transport activity and infrastructure facilities;

4. Stepping up measures to reduce the impact of transport on the environment, decrease the carbon footprint of transport activities [10] by equipping the vehicle fleet with electric vehicles, vehicles with integrated power plants (plug-in hybrids), vehicles running on fuel cells, hydrogen;

5. Development of an integrated approach to management of logistics processes of delivery

and transportation of goods and passengers based on adaptive risk management systems.

Based on the above, it is clear that we are witnessing explosive growth in information technologies creating the info-communications environment of a new type, where the supply chain safety and reliability are the "golden spike" of the transportation process (of both passengers and cargo), and TLS sustainability. Consequently, the owners of the transport and communications infrastructure may offer their customers not just a vehicle but a transport service of appropriate quality. And this may happen in the foreseeable future.

The practical significance of the suggested methodological approach using the risk management methods lies in setting up requirements for the development of organizational and technical mechanisms and for safety management processes in integrated TLS, which will allow organizations to improve process efficiency in terms of failure prevention and cost reduction, and to achieve sustainable operation of TLS.

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