PAPER • **OPEN ACCESS**

Efficient and secure logistics transportation system

IOP Conf. Series: Materials Science and Engineering **918** (2020) 012031 doi:10.1088/1757-899X/918/1/012031

Efficient and secure logistics transportation system

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Abstract. The presented comparative characteristic of the values of the indicators of the Logistics Efficiency Index illustrates the problems of the transport and logistics complex of Russia. Consideration of the effectiveness of the transport and logistics complex from various perspectives (financial, production) made it possible to justify the need to formalize the relations (coordination of conflicting interests) of the participants in the logistics process, to ensure the internal integrity and security of the functioning of the transport and logistics complex. The solution to these issues was proposed by creating a special cyberphysical system using multi-agent systems, Internet of things, blockchain, and Big Data, Data Mining intelligent technologies. The presentation of the transport and logistics complex as a cyber-physical system made it possible to consider it in the following aspects: - as an interaction of agents based on multi-agent systems (information interaction is organized on the principles of blockchain and the Internet of things); - as a continuous process of transport services, the improvement of the technology of which is proposed to be carried out using the process and design approaches, a mathematical description - through models based on the theory of mass service and coordination of economic interests of economic entities; - as an artificial intelligence system based on Big Data, Data Mining technologies, including the theory of pattern recognition, game theory, methods of self-organization of models (for example, the method of group accounting of arguments), cognitive analysis and others.

1. Introduction

The role and place of transport and logistics complexes (TLC) in the national economy is difficult to overestimate. They connect the economies of spatially dispersed regions of Russia, provide the work of international transport corridors. TLCs containing ports are especially important. They concentrate operation of almost all types of transport: sea, rail, pipeline, automobile, river.

Cargo turnover of Russian ports in recent years is constantly growing. So, in 2017, the largest ports of Russia handled 787 million tons of cargo. The largest share of transshipment is occupied by the Azov-Black Sea basin (ABSb) - 34.2%. The cargo turnover of the ports of ABSb in 2017 amounted to 269.5 million tons, which doubles the figure for 2010 [1].

In TLC, the following interacts: the owner of the cargo, the sender of the cargo, various subsystems of its processing (stations, storage systems, road sections, ports, etc.), the receiver of the cargo, higher-order management systems (ministries, various departments, analytical centers). So, TLC is:

1. A lot of participants and, as a result, a lot of interests of economic structures (the task of coordinating these interests arises).

2. The complexity of the technological processes of cargo handling (it is necessary to assess the effectiveness and safety, both at the local levels of individual participants, and at the level of the entire TLC).

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3. The complexity of the information interaction of the TLC participants. Two issues should be highlighted here:

- the need to process large amounts of information;
- to ensure regulated openness / closeness of information. On the one hand, the quality of TLC work depends on the availability of this information (it should be complete, objective and accessible to all participants in the transportation process). On the other hand, this availability reduces its security.

Every two years, the World Bank carries out a study of the logistics capabilities of 167 countries, which also includes the section "Logistics Performance Index" (LPI) [2]. LPI analyzes countries according to six indicators and reflects its convenience and safety. These indicators are: the effectiveness and accessibility of customs and border controls, the quality of transport and trade infrastructure, the quality and competence of logistics services, the ability to track goods, the frequency with which the goods are delivered to the recipient on the planned delivery dates, the possibility of organizing competitively priced supplies.

These indicators are selected on the basis of theoretical and empirical studies, practical experience of logistics operators associated with international freight forwarding. Figure 1 gives a comparative description of these indicators for Russia and Germany, which reflects the problems of the Russian TLC.

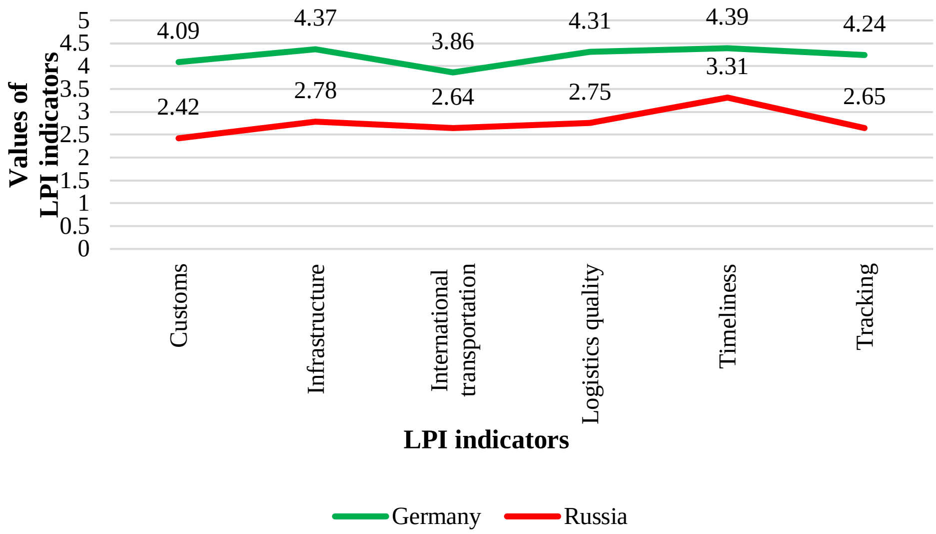

Figure 1. The values of LPI indicators of Germany and Russia**.** Built on data [2].

The effectiveness of TLCs should be considered in various aspects: financial (this is a requirement of a market economy), production (loading / unloading volumes, cargo traffic volumes should correspond to the interests of all economic entities - EE). At the same time, private indicators (of individual EE) and general indicators (of the whole TLC, regional and national economy as a whole) are distinguished.

All these problems and tasks are related to the regulation of human interaction (H) and decision support systems (DSS), which in turn are divided into two types: internal (the decision maker (DM) interacts and his DSS) and external (interact person and DSS of a competing company and / or co-executor of the transportation process).

For internal communications, it is necessary to reduce the role of the decision-maker's subjectivity and the level of errors due to his emotionality, fatigue, low qualification, but the person is an expert, and therefore it is necessary to include the mechanism of teaching the machine how to make a decision and derive an agreed decision from the decision-maker and the machine. It is also necessary to protect their communication from external disturbances (cyberattacks, in particular).

For external communication and chatting procedures, efficiency, completeness, and again, protection are important (it is more difficult, since communication goes beyond the scope of a closed system, uses weakly protected channels).

The solution to the problems formulated is seen in the creation of a specialized cyber-physical system (CPS) based on technologies: multi-agent systems (MAS) [3], the Internet of things (IW), and blockchain [4]. The coordination and regulation of the relations of the TLC participants is supposed to be carried out using approaches and methods of the theory of active systems [5], intelligent technologies (Data Mining, Big Data) [6].

1.1. TLK is a cyberphysical system

The analysis allows us to present TLC in several aspects:

1. *As the interaction of agents* (which are various EE of transport process). In this setting, the basis for interaction should be the MAS. In this case, it is necessary to distinguish the MAS of two types:

- market type MAS. Each agent is looking for the most profitable partner, based on their own interests. For example, the owner of the wagons does not supply them for the transportation of disadvantageous goods. Relevant digital platforms ignore common interests. The transport process slows down and crumbles.
- MAS, providing the work of various transport and economic associations. For example: Unified network technological process, transportation ground, regional economy, transport corridor, etc.

Information interaction in these MASs is implemented on the principles of the Internet of things and blockchain. The “things” in the MAS of the TLC are individuals and the general population, as well as individual actuators and systems included in the TLC (sorting and cargo stations, sections of the track, repair and storage points, ports, etc.).

Blockchain is a software scheme for information re-recording that provides: user-friendly access to it, secure storage, efficient (in speed and minimizing data errors) information transfer and use.

1.2. As a continuous transport service process

The implementation of this property of TLC is achieved by a number of technological procedures and mathematical models.

It is proposed to improve the transport process of the TLC through the implementation of the process and design approaches [7]. In the first case, the traditional functional (structural) organization of production (relations hierarchy) is subject to the requirements of the process organization (principles of “one window”, “delivery of goods to doors”). The project approach distinguishes individual projects from the whole process, on which the attention of consumers and performers is concentrated.

In this case, there is a double subordination of performers (to the head of the functional unit and the project manager). This managerial shortcoming is compensated by increased reliability of work (double control) and focus on the final result. The situation, when everyone has fulfilled their functions, and the transport problem is not solved, is excluded.

For the mathematical description of the transport and logistics process, it is proposed to use two formalized models based on the queueing theory (QT) [8] and the use of the procedure for reconciling the economic interests of EE [9].

QT represents the entire transport and logistics process in the form of series and parallel connections of individual links. An example of a serial connection: receiving trains at a station, sorting, moving along a section, accumulation, transshipment at a port. Parallel connection can be realized by simultaneous servicing at the station by different teams, parallel dissolution, movement along different routes with matching starting and ending points, etc.

QT is well developed for the simplest (Poisson) cargo flows with stationary properties (flow characteristics: average value, dispersion, and other process indicators are independent of time), lack of aftereffect (system performance at time *t* does not depend on its performance up to this point), ordinary (two service requests cannot enter the system at the same time).

These properties are difficult to put into practice. Indeed, the traffic flows are affected by the time of year, days of the week, weather conditions, that is, they cannot be stationary. The same can be said for the lack of aftereffect (the harder the system works, the less resource it has in the future), and for ordinary (several ships come to the port for loading and unloading).

In this regard, to evaluate the performance of the TLC, it is recommended to use the QT:

- in limited areas of time (the flow properties do not have time to significantly change and the adequacy of the model is not lost);
- as a model of the first (linear) approximation.

The procedure for reconciling the economic interests of individuals due to their particular importance is discussed in detail below in the clause “Refinement and development of mathematical models to ensure the “economic interest” of CPS participants.”

2. As a system of artificial intelligence

Consideration of TLC as MAS, the use of IoT technology is already creating the so-called “ant” intelligence in the system. This is the intelligence of a community of interacting agents. It manifests itself as a result of synergy: each agent does not possess this intellect, but the system functions reasonably.

In addition, it is appropriate to introduce special intelligent technologies into the work of the TLC. These, for example, include the so-called Big Data, technologies for extracting knowledge from data (Data Mining).

Currently, all TLC subsystems operate quite independently of each other. For example, when releasing on a hump yard, the cut of cars did not show the running properties expected from it, but this information is not available for other TLC subsystems. Technical means that make it possible to identify any carriage, generally any vehicle (car, sea or river vessel), wherever it is, are already exist. We need a digital platform that combines this information, sorts and gives out to an interested person. These platforms are developed within Big Data technologies.

Classical statistics (for example, regression analysis) allows you to find unknown relationships between the studied variables. But this process is completely dependent on the person (it indicates the task, assigns the structure of the model, and the machine calculates its parameters only).

Data mining technologies automate this process. The basic technologies of Data Mining are the theory of pattern recognition, game theory, methods of self-organization of models (for example, the method of group accounting of arguments), cognitive analysis, etc.

3. Results of the research

3.1. Refinement and development of mathematical models to ensure the "economic interest" of CPS participants

We consider the solution of the problem by the example of reconciling the conflicting interests of the EE of different levels of management. In the theory of active systems [5], a priori given models of their behavior are used for this purpose:

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$$y(x,k)=\begin{cases} \&cx-\frac{1}{2e}x^2,\ \text{at}\ x\geq x_g \\ \&kcx-\frac{1}{2e}x^2,\ \text{at}\ x<x_g \end{cases} \quad (1)$$

As a rule, it is not possible to satisfy the requirements of this formalization in practice, therefore, in [9], an improved model for reconciling the interests of EE is proposed.

We identify the dependence of the company's revenue (EE interest) in the vicinity of the extremum point using a quadratic dependence of the general form:

$$y = a_0 + a_1x + a_2x^2 \quad (2)$$

We transform (2), to complete the square, we get:

$$y = -\ m(x - a)^2 + b \quad (3)$$

If the EE fulfills the plan established by the upper level of management, then the reward is carried out according to the identified dependence (3), curve 1 in Figure 2 (without penalties).

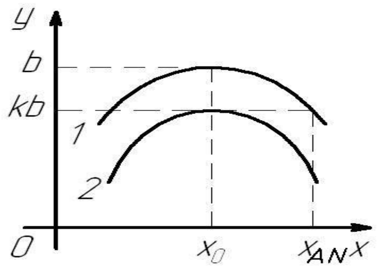

Figure 2. A geometric illustration of the imposition of sanctions on the company for not fulfilling the plan. Borrowed from [9].

For the area [0; x_0] it is profitable for the company to fulfill the plan, and for the loading area from a and further, the company tends to underestimate the volume of work performed. If the EE does not fulfill the plan, sanctions are imposed on it by proportionally reducing the value b with coefficient $0 < k < 1$. That is, if the plan is not fulfilled, the enterprise works according to the model (4) curve 2 in figure 2:

$$y = -\ m(x - a)^2 + kb \quad (4)$$

Obviously, the curvature of curve 1 should also be preserved for curve 2, for reasons that the production process in both cases develops similarly, that is, either without sanctions (formula 3) or with sanctions (formula 4).

Obviously, while the value of the plan is between [x_0; x_{AN}], the company is also profitable to implement the plan. If the upper level of management assigns a plan that exceeds the value x_{AN}, then it will be more profitable for the company to sell products (transport services) in the amount of x_0 and get revenue for this in the amount of kb (when overfulfilling the plan, it is less). That is, the segment [x_0;x_{AN}] – area of coordinated decisions of the considered EE. We find this area in terms of the known parameters a, k, b, m. To do this, we solve the equation (we find the abscissa of the intersection of curve 1 with a horizontal line y = kb):

$$kb = -\ m(x - a)^2 + b \quad (5)$$

From (5) it follows easily that:

$$X_{AN} = a + (b(1 - k)/m)^{0.5} \quad (6)$$

Example. The interest of the transport company is described by the ratio:

$$y = -1055.51(x - 120.44)^2 + 753946 \quad (7)$$

Suppose that, in accordance with plans agreed upon with the highest level of TLC management, a load on a transport company of 130 million tons is expected. Obviously, this value exceeds the desired (optimal) value equal to 120.44 million tons. The penalty parameter that ensures the fulfillment of the task is to be determined.

We use the formula (6). From where it easily follows:

$$k = 1 - m(x_{AN} - a)^2/b \tag{8}$$

By the terms of our task c = 130, parameters m, a and b are known from (3), respectively m = 1055.51, a = 120.44 million tons and b = 753946 ths. dollars. USA. And x_{AN} we take equal to 130. From (8) we have: k =0.88.

That is, when the plan is fulfilled, the enterprise receives revenue in accordance with model (7), and if it is not fulfilled according to the model:

$$y = -1055.51(x - 120.44)^2 + 753946 \cdot 0.88 = -1055.51(x - 120.44)^2 + 663472.5 \tag{9}$$

4. Discussion of the results (debates)

4.1. Conclusions

1. The task of researching the TLC on the basis of new digital and intelligent technologies that ensure the transition of the Russian transport system to the technologies of the sixth technological structure has been actualized.

2. The essence of the author's vision of the modern transport and logistics complex, corresponding to the goals and objectives of the development of the Russian economy, is revealed.

The author's mechanism for ensuring the economic interests of CPS participants is described.

4.2. Prospects for further research on the topic

Study of legislative documents governing the work of the TLC. The introduction of new technologies and models should not conflict with established management practices. The development of a single management mechanism that takes into account the private and common interests of TLC participants.

Development of special digital platforms that by means of the software implement the innovations proposed above in the operation of TLC.

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