Intermodal supply chains methodology and economic efficiency study of its implementation (using the example of an Iron and Steel Company)

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Abstract. Currently the global market for intermodal transport (containers in particular) is evolving at a significant pace. The Russian market development of intermodal transport occurs with low speed. It should be noted that low competitiveness of container transport prevents the development of intermodal delivery method within Russia. In addition, this factor stops implementing national transit potential of transport corridors passing through the territory of the country. To date the delivery chains formation is perceived as a secondary process, which provides the scope for production sector and delivers the finished product to the consumer. However, it is the intensive development of intermodal technologies that remains an economic security guarantee and a reserve for increasing the product competitiveness opposed to the rate of finished products production. As a result, the method development of intermodal supply chains formation at large industrial enterprises appears very important. The paper deals with a model and algorithm of forming a system of intermodal cargo delivery chains of the metallurgical enterprises. We performed calculation of the potential economic benefits from their introduction.

1 Introduction

The main trend in the development of Russian and world transport appears an active growth of container traffic volumes, as the basis of intermodal technologies [6, 9, 23]. Experts estimated the ratio of cargo containerization in international transportation that reaches 63%. It is important to note that the coefficient annual growth rate over the last 5 years amounted to 1-2%, and the limit value, according to experts' opinion, is 70%. However, despite the proven high efficiency of container traffic, at present this type of transportation is not attractive to domestic shippers.

Many scientific works of Russian and foreign scientists are dedicated to the improvement of the container transport efficiency. The authors pay great attention to solving the tasks of managing the cargo movement in containers, of organizing various transport modes interaction, of optimization and container infrastructure development. However, the developed methodological tools, as a rule, are designed either to solve specialized tasks, or they contain significant restrictions and simplification.

Objectives and contributions of the study

In order to increase the attractiveness of intermodal delivery technologies, to form highly efficient logistics supply chains it is of great importance to study methodically the issues of forming a container system for the delivery of the products, taking into account economic, infrastructure, technical and technological conditions of the transport market. The formation mechanism should be adaptive to changes in the quantitative and qualitative characteristics of participants in the delivery process and should allow justifying the decisions, both of operational and of strategic levels.

2 Theoretical background

A. Russian Authors' Works Review

Numerous works of Russian scientists are devoted to the issues of improving the efficiency of construction and operation of intermodal supply chains and transport systems. The significant contribution to the solution of these problems has been made in the works of A. T. Deribas, L. A. Kogan, P. A. Kozlov, Y. T. Kozlov, K. M. Lazarev, L. B. Mirotin, S. M. Rezer, A. A. Smekhov, M. F. Trikhunkov, B. A. Lyovin, V. M. Say, V. M. Samuylov et al. An integrated description of the results of the above-mentioned authors was performed in the following works [4, 16].

The works of Russian scientists deal with the following aspects of the intermodal system organization of goods delivery [13, 17]: the formation and development of logistics systems (federal and regional), the principles of rail container traffic are

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formulated. The authors reflect methodological foundations of rational distribution of transport infrastructure elements on the territory of Russia, give proposals to increase the transport competitiveness, design streaming concept of material flow promotion, develop proposals of Russia's integration with the international transport space and of the development of regional transport and logistics systems.

B. Foreign Authors' Works Review

The analysis of foreign information sources allowed having summarized the main results obtained by foreign scientists:

• some studies consider the development process of an outline classification of relevant dimensions where the concepts of supply chain and supply network are compared and their distinctive features are highlighted [7].

• the study provides implications for large system change and action steps for change agents in organizations, arguing that by understanding change initiatives through the lenses of complexity and wicked problems, change agents are likely to be more effective [25].

• the following work considers economic behaviour under different economic-political regimes demonstrating continuities and changes during a fundamental social-economic reorientation of an important regional economy, through close observation at the micro and meso-level of, respectively, the workplace, organizations and industry, outlining theoretical, practical and social implications [27].

• the famous author classifies research on distribution network design according to the methodologies adopted and themes tackled. Second, it discusses the main implications for practitioners. Finally, it proposes a few promising directions for future research [20].

• some of the authors investigate the microfoundations of customer knowledge acquisition during logistics innovation development. Specifically, the authors explore the activities and behaviors of employees with customer contact (i.e. boundary-spanning employees) to deepen and broaden their knowledge about customers for the development of innovations [1].

• other scientists facilitate interaction between the domains by increasing the level of joint understanding of the principles used in each domain, and to look at the potential frictions and challenges [5].

• the researchers emphasize that the sorting rules applied in the product recovery process are crucial for the performance in the activity chain from disposer to end-user [10].

• some of the studies give descriptions of benefits from information sharing in supply chains [11].

• the following study analyses behaviour patterns and determined that the segmentation of customers on the basis of both sales and return patterns can facilitate a differentiated service delivery approach [12].

• key findings are that both innovative and non-innovative supply chain operators attribute supply chain synchronization as only a minor indicator of strategic supply chain capability, contrary to the literature; and they also indicate strategic supply chain capability has a minor influence in achieving beneficial outcomes from utilizing industry-led innovation [14].

• it is commonly recognized that the development of a framework for route selection in multimodal transportation that includes a six-phase framework to select an optimal multimodal transportation route. The first phase is to collect the data of each route and select the origin and destination [2].

• formalizing these processes and related activities becomes the differentiating factor in reverse logistic program development and implementation. In addition, providing structure to the reverse logistic effort helps companies to strategically control the related value-added [22].

• weak points of the suppliers as well as dimensions that drive satisfaction were identified [28].

• statement that it is simply not enough to have flexible manufacturing, distribution and procurement systems to achieve supply chain agility. Flexibility in managing demand is also needed. Furthermore, it is the premise of this paper that demand and supply integration inside the firm is critical to achieving supply chain agility [8].

• identifying and explaining the challenges with joint operational decision-making in this context and investigate the precise role of information technology therein [18].

• upgrading from supply chain process modelling towards supply chain business model management; from information to knowledge transfer and from the maturity of supply chain to dynamic capabilities [19].

• research describes the behaviors and processes that impede successful supply chain alliances [21].

• strategic supplier partnership fully mediates the relationship between a lean supply chain strategy and supply chain responsiveness, and that postponement partially mediates the relationship between an agile supply chain strategy and supply chain responsiveness [24].

C. Definitions (conceptual and terminological base)

In order to solve the work tasks we formed terminological apparatus that would unify the basic terms and definitions. The following concepts were used in the study.

Logistics approach means the integration of individual links of material production into a single system, ordered along material flows and it is able to respond to the external environment perturbation adequately.

Logistics supply chains denote many of the elements of the logistics system, linearly ordered by the material (or another one) thread with the purpose

of the analysis or design of a certain logistical functions set and (or) costs.

Material flow is the product (goods) considered in the process of using various logistics operations and attributed to a specific time interval.

The flow of services is a complex of specialized tasks performed by each element of logistic system to improve the logistic system effectiveness and achieve its objectives.

Information flow is a term of a message flow in the speech, bond (paper and electronic) and other forms, associated to the material and service flows in the considered logistics system and this flow is intended mainly for the implementation of the control actions.

Financial flow is the directional movement of funds circulating in the logistics system, and between the logistics system and the environment that are necessary for the efficient movement of a particular commodity stream.

Intermodal transport means a goods delivery system under a single transport document and the transfer of cargo from one mode to another in a single loading unit. The basis of modern intermodal transportation is the international standard ISO containers.

3 Methodology

A. Container Transport Market Review

Container Transport Market Review The global market for container transport is developing at a significant rate. In 2015, total worldwide shipments exceeded 190 million. TEU (Fig.1), the total volume of container handling in ports closes to 700 million. TEU. The share of Russian container traffic is 3.02 million. TEU (Fig.2).

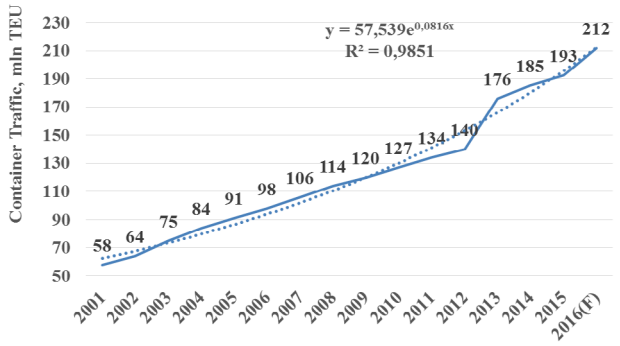

Fig.1. The World's Container Traffic Dynamics.

It should be noted that the main reasons hampering the development of container traffic in Russia are considered to be low speed trailers, considerable time of rolling stock turn-around, lack of integration with railway transport, significant infrastructure constraints, changing the payment system for the use of the owners of the private tracks private cars and containers, lack of studied methodological unit the interaction control of the transport market participants in Russia [15, 26].

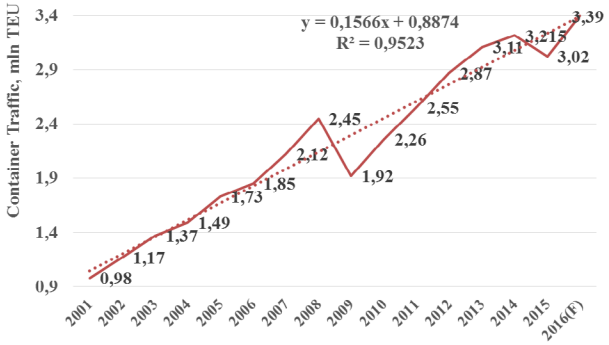

Fig. 2. Russian Container Traffic Dynamics.

B. Methodological tools development

The system of container flow processing for metallurgical enterprise conditions has been examined as the object of the study.

Currently, from 30% to 70% of commercial production of metallurgical enterprises remains suitable for transportation in universal 20 (TEU) and 40-foot containers (FEU), however, in practice, freight containers carried cargoes in the test mode only [3]. Nevertheless, satisfactory results of trial shipments of finished goods in containers have failed to lead to intensive development of containerization.

For the intermodal supply chain formation, it is proposed to consider the containerization process as a system of interrelated flows: the material (the flow of services is combined with the material flow promotion), information, and financial (Fig.3). Allocated flows circulate between the system elements – input, storage, processing, transport, and weekends' ones. For the conditions of metallurgical enterprise functioning, the authors considered three main schemes of product delivery in containers to consumers: direct delivery to a vessel at the port, through regional distribution centers, using port distribution terminals. Promotion and recycling of container flow between participants must be accompanied by financial and informational interaction between participants of the system.

Below there is an algorithm for the formation of the transport and logistics container system on the basis of the developed model (Fig.4).

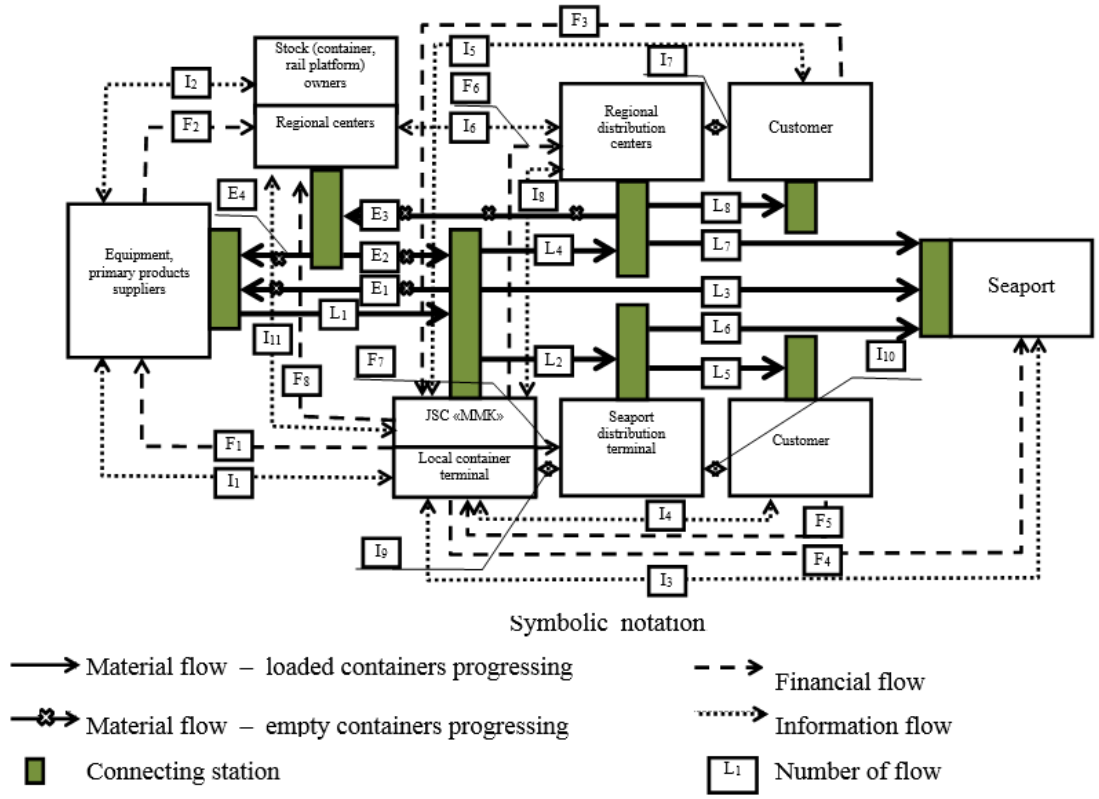

Fig. 3. Product Intermodal Transport Model of a Metallurgical Enterprise.

In order to solve the problem of profit maximization in the intermodal supply chains organization the authors have developed economic and mathematical optimization model, the objective function of which is as follows (1)

$$F(P) = \sum_{i=1}^{n} P_i = \sum_{i=1}^{I} P_1 + \sum_{j=1}^{J} P_2 \rightarrow max, \quad (1)$$

where P_i - profits from products sales, rub;
P_1 - profits from products sales, delivered to the consignee on traditional (existing) delivery schemes, rub, as in

$$\sum P_1 = \sum n_i \cdot \frac{365}{T_i} \quad (2)$$

P_2 - profits from products sales, delivered to the consignee in containers, rub, as in

$$\sum P_2 = \sum n_j \cdot \frac{365}{T_j} \quad (3)$$

n_i – profits from sales of i-mix, delivered to the consignee on traditional (existing) delivery schemes, rub;
n_j – profits from container products sale of j-mix, delivered to the consignee in containers rub;
T_i – the operating cycle time of i-mix products processed, delivered to the consignee on traditional (existing) delivery schemes, days;
T_j – the operating cycle time of container products processing of j-mix, delivered to the consignee in containers, days;
365 – number of days a year.

The following restrictions (4) are imposed on the objective function of economic-mathematical model of the container stream acceleration

$$\begin{cases} Q_1 + Q_2 = Q; \\ W < \Delta P \end{cases} \quad (4)$$

where W – container flow acceleration costs, rub;
ΔP – profit change as a result of the container stream acceleration according to the delivery scheme, rub;
Q_1– flow of cargo, processed on existing delivery schemes, tons;
Q_2 – flow of cargo, processed by the proposed container schemes of delivery, tons;
Q – annual plan for the finished products shipment, tons.
The calculation results are shown in Table 1.

Table 1. An economic effect estimate.

Delivery time, days	Total acceleration costs, mln rub	Current assets turnover time, days	Number of capital turnover, times	Extra profit, mln. rub	Economic effect, mln. rub
6	-	9	36.6		
5	11.92	8	40.6	45.78	33.86
4	23.84	7	45.7	57.99	34.15

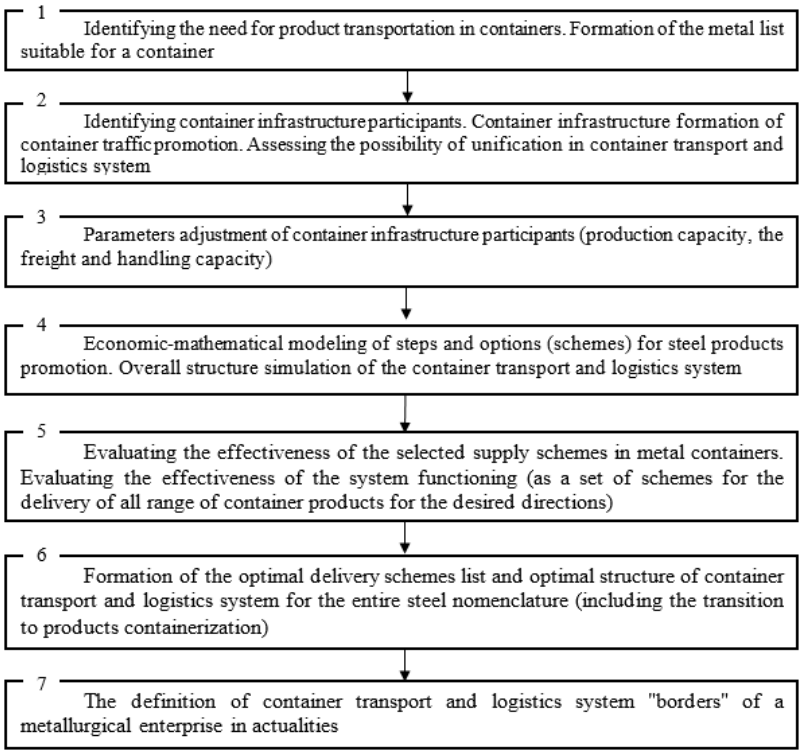

Fig. 4. Container Infrastructure Formation Algorithm.

The following results were obtained in the result of the experiment on the economic and mathematical optimization model (Fig.5).

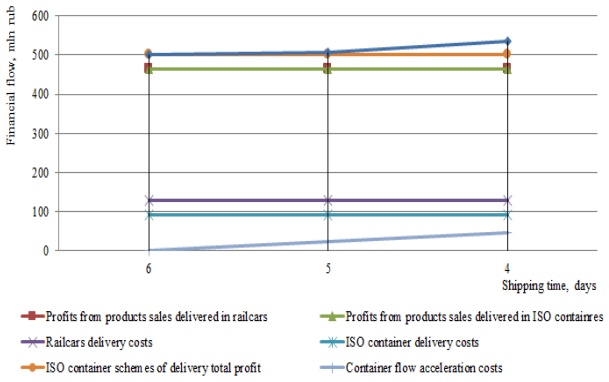

Fig. 5. Payment Iteration of Container Traffic Acceleration Model.

The calculations have shown that using intermodal products supply chains (container delivery scheme) due to a lower rate (price list №10-01) are economically viable for steel transportation in this direction. In addition. accelerating the container stream for 2 days is possible to obtain an additional annual economic impact of 34.1 mln. rub.

4 Conclusions and implications

Currently. despite the high efficiency of container transport. Russian steel companies prefer to deliver products in a traditional way in railway rolling stocks. The formation of the delivery schemes is situational. usually without considering the potential additional costs for products delivery, which are compensated by profit.

The authors developed model and method of forming the transport and logistics products container delivery system of metallurgical enterprises, which allow proving the feasibility of intermodal schemes of delivery of cargoes in containers, to determine the optimal structure of delivery patterns, to assess the potential costs for finished products delivery to the consumer.

The economic-mathematical optimization model has been performed and it enables to maximize profit of participants on the basis of the generated logistic container delivery system of products. The model is based on delivery term reduction to the consumer. The expected economic effect from implementation of the proposed activities is 34.1 mln. rub.

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