About the development of multimodal transportation based on modeling of cargo placement

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Abstract. The organization of logistics transportation management systems with the interaction of various modes of transport is an important present problem of the development of the transport system, as well as the development of transport infrastructure with the construction of terminal complexes and ports providing multimodal transport and intermodal technologies. This problem includes the task of integrated transport development within the framework of multimodal transport hubs (transport and logistics centers). Multimodal transport hubs are capable to solve tasks in participants work coordinating in the transport process within the framework of the existing transport system, and tasks in modernizing of the transport system and creating a modern support transport grid. A great contribution to the development of the transport system is also made by modeling. Modeling of the rational cargo placement in a vehicle will make it possible to achieve the most rational using of space in a vehicle, which will also bring economic benefits.

1. Introduction
For the efficient transportation of passengers, one of the main tasks is to improve the technical and technological structure of planning decisions of transport and transfer hubs and to optimize the interaction of transport in the transport and transfer hub. This solution will reduce the total travelling time.

Integration of international transport systems allows to increase the level of technical development of transport infrastructure, to reduce the number of transshipment operations, to simplify customs duties and to reduce the time for transportation of goods and the transportation cost.

Multimodal transport is one of the most common transport options at current.

Multimodal transportation is transportation carried out based on the single contract, which is performed by at least two types of transport. According to the interaction of several types of transport, it is necessary to organize such transportation in a quality manner and to provide for the safety of cargo along the entire trip to the final destination.

The term "multimodal transport hub" (MTH) is the geographical point of the interaction of several types of transport. Such hub connects railways, sea and river ports, airports, railway stations, highways, trunk pipelines, and municipal transport networks. The infrastructure of multimodal transport hubs includes warehouse complexes and cargo terminals with centers for the management and distribution of cargo flows, objects of customs clearance, transport insurance, organizations representing freight forwarding and banking services. An important factor is the presence of a single multimodal transport operator.
2. Formation of a system of coordination and logistics centers and its main characteristics
The formation of an extensive support system of coordination and logistics centers is designed to provide increased efficiency and flexible response to changing market conditions. Coordination and logistics centers should work on the principles of an integrated logistics operator of different modes of transport, which allows rationally organizing the transportation process in the interests of customers and carriers.

The functions of the coordination and logistics centers are:

- Providing the opportunity to solve complex, interconnected strategic and tactical tasks aimed at the coordinated development of the logistics infrastructure, in particular, terminal and management-information automated system;
- Elimination of functionally narrow supply chains;
- Supply chains modeling, optimizing the processes of interaction of different types of transport and reducing the number of intermediaries with the delivery of goods from the consignor to the consignee;
- Optimization of the cooperation functioning to reduce costs and increase profits;
- Formation of a single work plan for the transport hub based on the observance of the financial interests of all participants in the supply chain and the functioning of a single information space;
- Implementation of public-private partnerships based on the achievement of the goals of two parties (regulation of the market for logistics services from the state and the stable functioning of their companies by businesses).

3. Development of automated intelligent systems.
Intelligent Transport System (ITS) is a system that uses innovative developments in the field of modeling transport systems and traffic control, providing end users with information capacity and security, and increases the level of interaction between traffic participants in comparison with conventional transport systems.

The use of automated systems in practice brings a specific economic result related to the acceleration of the processes of information exchange, processing of document flows and the promotion of cars and goods. For each level of process control, certain information which supplied by relevant information systems is required/

In order to develop automated information support for independent participants of container transportation in the transport hub, the possibilities of modern automated systems that are operated at the landfills of the Russian railway network, as well as during the carriage of goods by water, were studied.

In the course of the study, a scheme of information exchange between the main existing and introduced automated systems was developed during the organization of the movement of container block trains between the rear logistics terminals and the commercial sea port. Information transmitted during the organization of block trains for delivery shipments of containers to the port, according to the figure:

1 - about the availability and receipt of containers at the logistics terminal by road; carrying out technological operations with containers on the territory of the terminal;
2 - about the approach, expected flow on the terminal platform;
3 - about the approach of vessels for loading; readiness for cleaning wagons from the sea trade port;
4 - on the expected supply of wagons to the port; information about containers in the volume of transportation documents;
5 - data received from the client ACS (automatic controlled systems) and from the port ACS for display in the information and reference system of the ACS PS (automatic controlled systems of parcel station), AWP (automated working station);
6 - complete information in the volume of shipping documents on goods, wagons, containers loaded into the port address; location of wagons and containers loaded at the port address on the railway network;

Figure 1. Scheme of information exchange between automated systems in the organization of container block trains.

- 7 - information about the basic technological operations at the terminal adjoining station and port station, made with containers, wagons and trains;
- 8 - information on loading a batch of containers received from ETRAN (electronic waybill); train advancement received from the ACS GID;
- 9 - information about the loaded batch of containers;
- 10 - information about the locomotive and the staff for transmitting to the departure of the train;
- 11 - information about the wagons filed for loading at the terminal;
- 12 - data on the location of the train along the section from the adjoining station to the port station and vice versa;
- 13 – information about the temporary storage of containers for customs clearance; placement under the customs procedure of customs transit; information on compliance with the customs transit period;
- 14 - information on cargo operations, container promotion;
- 15 - preliminary transfer sheet; information on cargo operations, container promotion;
- 16 – information about carriage documents;
- 17 - data of the customs declaration for registration of carriage documents.

Organization of information exchange during the movement of block trains according to the developed scheme will allow:

- to carry out the supply of a batch of containers directly to the moment of loading onto the vessel for reloading according to the direct option “wagon - vessel”;
- reduce the time of customs clearance at the terminal.

The implementation of the information interaction scheme of the main automated systems will increase the level of automation of information support for independent participants in the organization of container block train traffic and accelerate their progress between the terminal and port in transport hubs.
4. Modeling of cargo placement on various modes of transport

To solve the problem of placing of goods in the compartment of a single transport unit (with the exception of water transport), we introduce the following notation and assumptions.

We assume that the Ox axis is horizontal and the positive direction is defined on it from left to right. The Oy axis is vertical, and the positive direction on it is from top to bottom; the Oz axis is orthogonal to the Ox and Oy axes and the positive direction on it is towards the observer.

\[ G = \{a_i; b_i; c_i\} \] - the set of parallelepiped-shaped objects (weights) with linear dimensions - \(a_i; b_i; c_i\). The number of goods placed is \(I\).

\(A_i; B_i; C_i\) - length, width, height (respectively) of the \(i\)-th transport compartment along the axis Ox, Oy and Oz, respectively.

\(<x_i; y_i; z_i>\) are the coordinates of the center of the \(i\)-th cargo object, having the shape of a parallelepiped.

We introduce the variable \(\tau_i\), which takes the value 1 if the corresponding load has a given orientation, that is, the linear dimension \(a_i\) is parallel to the Ox axis, otherwise \(\tau_i\) is 0. The variable \(\gamma_i\) takes the value 1 if the corresponding load has a given orientation, that is, the linear size \(b_i\) is parallel to the axis Oy, otherwise \(\gamma_i\) is 0. For the Oz axis, the parallelism property is ensured from the orthogonality properties of the edges of a rectangular parallelepiped.

For the rational placement of goods \(G\) in the cargo compartment \(S\), it is necessary to find such values of the variables \(<x_i; y_i; z_i>\) which provide the most dense filling along the axis Ox and Oy. The near boundary \(B\), the right boundary of section \(A\) filled with goods and the lower boundary \(Y\) are considered as the desired variables, the values of which should be minimized: \(F(A, B, Y) \rightarrow \min\)

To place cargo inside the hold for each \(i\)-th cargo, its center must be no closer than half of its linear size from the corresponding boundary loading area. For the left boundary: \(x_i - 0.5f_i \geq 0\).

For the upper boundary, \(y_i - 0.5f_i \geq 0\) Therefore, restrictions must be met:

- for the right border \(A\):
  \[x_i + 0.5(\gamma_i * \tau_i * a_i - \tau_i * b_i - \gamma_i * c_i) < A - 0.5(b_i + c_i)\] (1)

- for the near boundary of \(B\):
  \[z_i + 0.5(\gamma_i * \tau_i * c_i - \tau_i * a_i - \gamma_i * b_i) < B - 0.5(b_i + c_i)\] (2)

- for the lower boundary of \(Y\):
  \[y_i + 0.5(\gamma_i * \tau_i * b_i - \tau_i * a_i - \gamma_i * c_i) < Y - 0.5(b_i + c_i)\] (3)

The above mathematical model is a description of the general requirements for placing cargo on various modes of transport.

5. Conclusion

The effectiveness of multimodal transportation is determined by two main factors: firstly, minimizing the cost of transshipment of goods (a reasonable role is played by a reasonable concentration of cargo flows); secondly, the participation in multimodal transportation of an economically highly efficient mode of transport, which on its segment of the track provides cost savings that significantly exceed the additional costs caused by the need for transshipment of cargo. In cases where the carrier is interested in participating in multimodal transportation, he can assume the obligation of timely and safe delivery of goods to the consumer, providing all necessary operations on the way, including transshipment, without the participation of the cargo owner.
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