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Development of mathematical model of cross-docking technology at railway warehouses

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ABSTRACT: In recent years, a stable trend of a constant increase in the number and volume of transportation of various types of packaged goods can be observed. The main factor that forms this trend is the dynamics of small and medium business development. Correspondingly, the issue of introducing modern transport and warehouse technologies is of particular relevance.

Here, the main problem is the frequent downtime of transport due to the mismatch between arrival and departure transport or its irrational use.

The purpose of this work is to demonstrate both the technical and economic feasibility of developing cross-docking technologies for railway transport. For the traditional railway warehousing system of direct transshipment transport, this is a real innovation.

The research is based on the theory of optimization of economic relations and complete deliveries. Accordingly, the necessary methods have been chosen. The result was the proposal of a mathematical model of cross-docking technology, which calculates the best variant of cargo delivery to railway warehouse and further to the end-user.

On the basis of the specified mathematical model, the simulation model in the environment of Microsoft Excel, demonstrating improvement of cargo flow through the warehouse system due to the application of cross-docking technology is built.

KEYWORDS: railway transport, railway warehouse, tare and piece cargo, cross-docking, transshipment.

I. INTRODUCTION

A stable trend of a constant increase in the number and volume of transportation of various types of packaging cargoes, formed in recent years due to the dynamics of development of small and medium businesses requires special attention from the railway transport to the development of warehousing, functioning and equipment of warehouse complexes. It is evident that these complexes are capable of handling not only domestic but also transit cargoes. Modern railway warehouse not only provides transshipment from one type of transport to another, but also provides a wide range of additional services for picking and sorting of goods.

The high competition encourages manufacturers and wholesalers to strive to reduce transport costs, looking for new, more efficient and inexpensive ways to deliver goods to the end customer.

This is precisely what cross-docking technologies are used for.

According to the principles of technology development, there are two main types of cross-docking: one-stage and two-stage (sometimes also called pick-by-line).

In the first case, the cargo is addressed to a specific recipient and goes through the warehouse as a separate unchangeable order. Otherwise, it is called "direct overload."

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In the second case, the original consignment - the cargo unit that the shipper shipped to the warehouse - will be transformed to meet the requirements of the consignee. This usually happens in the sorting and packing area.

However, in both the first and the second case, the goods are not stored in the warehouse.

When goods arrive in batches (orders) and need only be distributed among vehicles (one-stage cross-docking), we can talk about the types of cross-docking presented in Table 1.

Table 1
Cross-docking types in railway warehouses

№	Type	Characteristics
1	Handling through a railway warehouse	Vehicle is being replaced without disbanding the cargo unit
2	Deconsolidation	One supplier - several consignees. Multiple machines are supplied in which the cargo is shipped to the final consignees
3	Small shipments	Several shippers - one consignee.
4	Sorting from the warehouse	The freight which is stored in a warehouse is added to the wagon during transshipment.

II. DESIGN OF CROSS-DOCKING MODEL AT RAILWAY WAREHOUSES

The optimal way is to consider the task of transshipment of goods at railway warehouse and further delivery to the consumer as a classic transport task.

Let us have *m* ($i = \overline{1, m}$) - the number of consignors, *n* ($j = \overline{1, n}$) - the number of consignees and *p* ($k = \overline{1, p}$) - the number of transshipment warehouse complexes. For a_i and b_j we can take, respectively, the volume of supply and consumption.

Let's take as d_k the capacity of some kind of k-th warehouse complex. Then c_{ik} и c_k j- respectively, the cost of transporting the unit of freight from the supplier to the transshipment warehouse and from there to the consumer. Our task model takes on the following form

$$Z = \sum_{i=1}^{m}\sum_{k=1}^{p} C_{ik} \cdot x_{ik} + \sum_{k=1}^{p}\sum_{j=1}^{n} C_{kj} \cdot x_{kj} \to \min \quad (1)$$

with limitations:

$$\sum_{k=1}^{p} x_{ik} \le a_i, \ \sum_{i=1}^{m} x_{kj} \le b_j, \ \sum_{i=1}^{m} x_{ik} \le d_k, x_{kj} \ge 0, \ x_{ik} \ge 0 \quad (2)$$

where d_k - transshipment capacity; $i = \overline{1, m}$ -consignor; $j = \overline{1, n}$ -consignee; -consignee; x_{ik},x_{kj} - delivery volume by route; a_i - amount of resources from *i*-supplier; b_j - size of j-th consumer order. Accordingly, the matrix of the extended task takes the form described in Table 2.

Let's describe the content of matrix blocks.

The first upper left block is the essence of the connection between transshipment warehouses and shippers.

The second upper right block is the connections of consignors and consignees. The initial condition - a ban on direct transportation from the consignor to the consignee - allows us to consider all tariffs in this block equal to *M* (where *M* is a large number).

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The third lower left block is formed by rows and columns of transshipment warehouses. Since direct transportation between them is prohibited, these indicators are also considered to be equal to *M*. Tariffs in the third block, which reflects the relationship of the transshipment warehouse with itself, zero. Accordingly, the diagonal formed by zero tariffs is called fictitious.

The fourth block is the connection of transshipment warehouses and consignees.

Table. 2.

<table>
<tr><th colspan="8">Consumers and their volumes</th></tr>
<tr><td rowspan="2">Supplier</td><td rowspan="2">Capacities</td><td>D_1</td><td>....</td><td>D_p</td><td>B_1</td><td>....</td><td>B_n</td></tr>
<tr><td>d_1</td><td>....</td><td>d_p</td><td>b_1</td><td>....</td><td>b_n</td></tr>
<tr><td>A_1</td><td>a_1</td><td rowspan="3" colspan="3">I</td><td rowspan="3" colspan="3">II</td></tr>
<tr><td>⋮</td><td>⋮</td></tr>
<tr><td>A_m</td><td>a_m</td></tr>
<tr><td>D_1</td><td>d_1</td><td rowspan="3" colspan="3">III</td><td rowspan="3" colspan="3">IV</td></tr>
<tr><td>⋮</td><td>⋮</td></tr>
<tr><td>D_p</td><td>d_p</td></tr>
</table>

Appendix 1 shows the simulation model built in Microsoft Excel area.

III. ANALYSIS OF RESULTS

Pictures 1 and 2 demonstrate the impact of cross-docking technology on transshipment at railway. The diagrams show that, thanks to this technology, it is possible to load cargo for other purposes, with all restrictions.

The following designations are used in these Pictures:

A_1, A_2, A_3, A_4, A_5 - volumes of shippers' deliveries;

$Д_1, Д_2, Д_3, Д_4, Д_5$ - transshipment capacities;

B_1, B_2, B_3, B_4, B_5 - volume of consignees' consumption.

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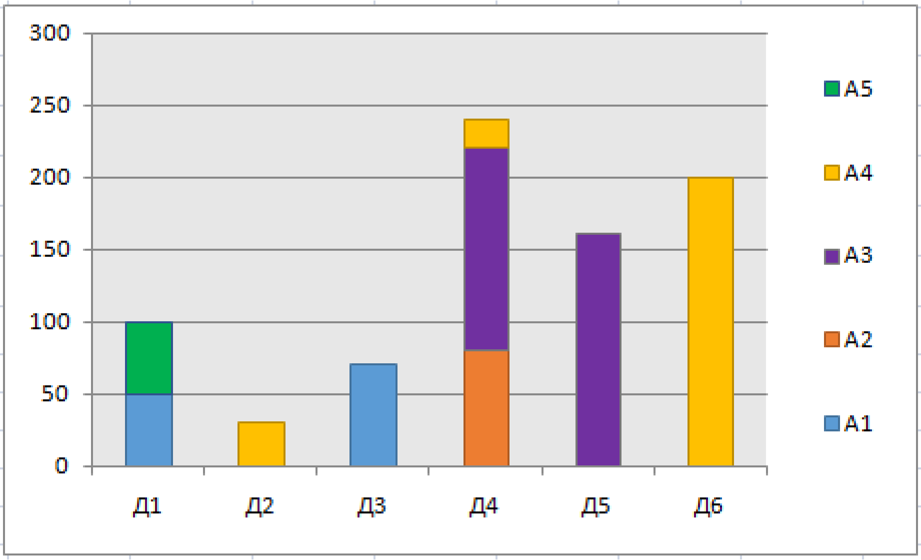
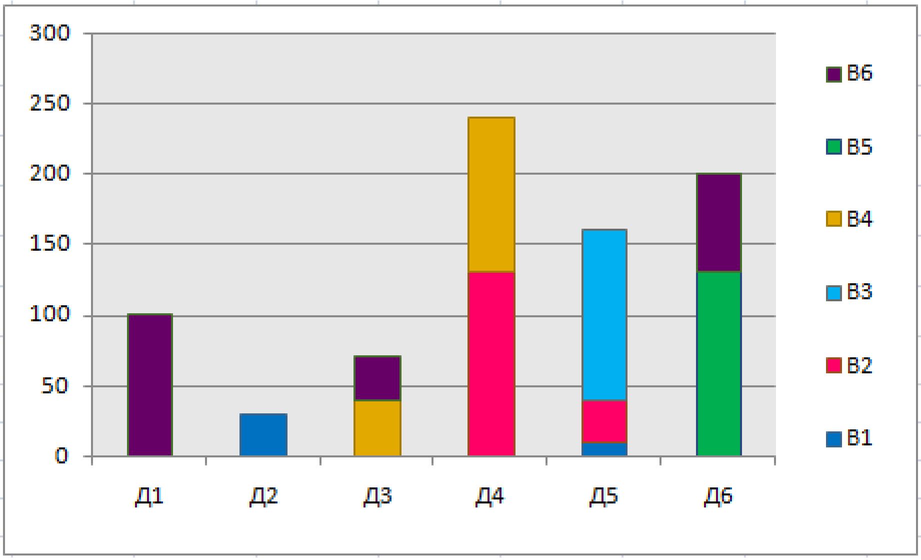


Picture 1: Diagram of dependence of supply volumes on transshipment facilities



Picture 2: Diagram of the dependence of consumption on the capacity of transshipment warehouses

IV. CONCLUSION

Thanks to the presented model, it is possible to realize the most optimal variants of cargo transshipment to railway warehouse and their further delivery to the end user. The model takes into account such necessary factors as warehouse capacity, supply and consumption volumes. Considering the expanded tasks of warehouses in the general economy of the railway transport, we can see that cross-docking technology forms the basis for the dynamic development of the Uzbek market, while increasing the income of the railway industry.

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