Transport and logistics service of foreign trade cargo flows in integrated production systems

Oleksandr Gryshchuk1, Anatoliy Petryk2*, Nelіa Kopiak3, and Tetiana Litus4

1 National Transport University, Department of Tourism, Mykhail Omelianovycha-Pavlenka Str., 1, Kyiv, Ukraine, 01010
2 National Transport University, Department of International Transportation and Customs Control, Mykhail Omelianovycha-Pavlenka Str., 1, Kyiv, Ukraine, 01010
3 National Transport University, Department of Transport Technologies, Mykhail Omelianovycha-Pavlenka Str., 1, Kyiv, Ukraine, 01010
4 National Transport University, Department of Transport and Information Technologies, Mykhail Omelianovycha-Pavlenka Str., 1, Kyiv, Ukraine, 01010

Abstract. The work describes the conditions of functioning of integrated service and logistics formations, taking into account the performance of consolidating operations in transport hubs. A methodology for optimizing structural indicators in transport and service systems is proposed based on the condition of the creation of combined consignments of international cargo. There is a well-founded possibility of applying the principles of comprehensive evaluation of the results of service of foreign trade cargo flows to increase the competitiveness of the transport and logistics service. Using the basic principles of probability theory and mathematical statistics, the random nature of cargo flow service is modeled, and a methodology for substantiating the numerical values of the main indicators of the production activity of integrated formations is proposed under the condition of the random nature of the demand for transport and logistics services. According to the results of the calculations, the main indicators of service and logistics maintenance of foreign trade cargo flows in consolidating nodes were determined under the condition of the stochastic nature of transport and technological processes. The interpretation of the performed calculations provides grounds to propose a set of measures to improve the infrastructure support of integrated production formations. And the structural optimization of transport and service systems of international direction allows ensuring a competitive level of reliability of transport and logistics service of foreign trade cargo flows.

1 Formulation of the problem

The sustainable development of international trade relations between individual countries is based on the principles of global economic integration. With the specified conditions, improving the economic indicators of individual economic structures requires the introduction into everyday practice of their systemic interaction within the agreed transport and technological processes [1]. Comprehensive studies of the efficiency of international transport and service systems testify to the need to improve infrastructure support for integrated processes. In the mentioned production formations, the optimization of infrastructure characteristics is the basis of the development of organizational and structural foundations for improving the operation of transport and logistics systems [2]. Therefore, increasing the competitiveness of the transport and logistics service in servicing foreign trade cargo flows should be based on taking into account a large set of influencing factors in the system. [3].

In these circumstances, an important and necessary condition for increasing the competitiveness of integrated production processes in production entities of an international orientation should be the justification and creation of an optimal structure of transport and service systems [4]. Service-logistics connections in the specified production formations, including load-generating, load-consolidating and load-absorbing arrays, are considered as influencing factors in a single transport-technological process formed from individual components of the system [5]. Effective production activity of transport nodes is ensured by achieving a certain level of reliability of cargo flow maintenance, provided that the existing level of infrastructure support is used [6]. Therefore, the organizational structure of such a system must simultaneously meet both the competitive level of technical and operational indicators, and the reliability of service and logistics of foreign trade cargo flows in transport-consolidating nodes [7].

The use of criteria for the optimization of transport and logistics costs when servicing a consolidated batch of import-export and transit cargo flows involves mathematical modeling of transport and service processes under the condition of the random nature of...
technological and technical-operational indicators [8]. In the specified production structures, the theoretical basis for conducting complex calculations should be the substantiation of the numerical values of the influencing factors of the transport and service system in the stochastic process [9]. Modeling of service and logistics maintenance of the production process should take into account the functional features of infrastructure components in production structures [10]. And the application of the proposed methodology of integrated assessment of freight flow service allows forming a complex of measures for structural optimization of transport and service systems of international direction [11].

2 Methodology for optimization of structural indicators in transport and service systems

A thorough analysis of the production interaction of individual components in the integrated system testifies to the random nature of independent transport and technological processes [12]. The structure of such a transport and service system should take into account the stochastic nature of technological indicators.

A necessary condition for ensuring the reliability of the provision of service and logistics services in competitive international production systems is the integration process of creating a consolidated batch of foreign trade goods in transport hubs. The pre-accumulation of a combined batch of export or transit goods followed by the use of high-performance loading mechanisms has a significant impact on the reduction of ship service times in sea trade ports. The implementation of the specified cargo consolidation operations has a significant impact on both the increase in the balance sheet value of the main production assets and the amount of working capital, as well as on the improvement of technical, operational and economic indicators of transport and logistics systems.

In the practical activity of production structures, the achievement of a certain level of reliability of service and in everyday production conditions, it is often necessary to provide a wide range of commercial services and to change the volume and structure of cargo flows throughout the entire service cycle [13]. Therefore, the results of the impact of the specified features of the transport and technological process are characterized by the random value of the resulting indicators of the system's functioning [14].

At the same time, the need for timely fulfillment of contractual obligations to customers of transport and logistics services requires integrated production structures to comply with the specified deadlines for the performance of contracted service and logistics operations. In addition, the need to ensure certain reliability of the provision of such services should not affect the competitiveness of the production entity itself. That is, the organizational structure of such an integrated formation must be adapted to the stochastic nature of influencing factors.

From such circumstances, in order to maintain the necessary competitiveness of transport and logistics service of foreign trade cargo flows, there is a need to create transport and service systems of international direction with an optimal organizational structure. On the example of functioning in the transport hub of production structures for service and logistics of export cargoes, the methodology for the formation of such systems is presented in fig. 1.

**Fig. 1.** Methodology for optimization of technological indicators in the structure of international transport and service systems

_Source: compiled by the authors based on [3]_

The operational response of the integrated system to the influence of random factors consists in the modernization of the organizational structure of the production formation and the creation of new internal connections of the improved integration process. In addition, the unification of the transport and logistics infrastructure in a wide range of service technologies is of great importance in the process of prompt response of the system to the influence of external factors.
3 Service and logistics maintenance of foreign trade cargo flows in conditions of stochastic nature of transport and technological processes

Methodology for improving the competitiveness of integrated production structures involves increasing the reliability of transport and terminal service, provided that the production indicators meet the specified criteria. The set goal requires system interaction and coordinated cooperation from service entities in the conditions of both the stable operation of service and logistics formations and the stochastic nature of transport and technological processes. Under such circumstances, the solution to the practical problems of the specified direction consists in optimizing the structure of transport and service systems in the conditions of the stochastic nature of service processes.

In production structures of an international orientation, when creating a consolidated batch of foreign trade cargoes, economic indicators are usually used as a criterion of competitiveness. To evaluate the results of system activity of integrated production formations, the total transport and service costs in the system can be accepted as optimization indicators using the number of n vehicles as a control variable

\[
B(n) = f(P_k^{(p)}, S_k^{(p)}, C_k^{(p)}, q, C_k^{(r)}, C_d^{(r)})
\]

(1)

Numerical values of random values of hourly productivity \(P_k^{(p)}\) and hourly costs \(S_k^{(p)}\) of a separate station in a transport hub are determined by the reliability of terminal service in the system. The cost of transporting a ton \(S_k^{(p)}\) of a consolidated batch of export-import cargo by cars with a carrying capacity \(q\) is characterized by the reliability of transport service. And the costs associated with downtimes of service stations \(C_k^{(r)}\) and road vehicles \(C_d^{(r)}\), respectively, are interpreted as interrelated values in the system.

Each component of the logistics cycle in the transport and service process has its own probabilistic characteristics, and their sum is characterized by a normal distribution. In the case of the stochastic nature of such a transport and service process, the probability of timely execution of individual \(X\) operations is determined as

\[
p[X] = \Phi \left( \frac{x - m_X}{\sigma_x} \right)
\]

(2)

where \(\Phi(\ldots)\) is a tabular function of the standard normal distribution.

In this case, the reliability of transport and terminal service of foreign trade cargo flows, as a probability value in the interval \((\beta_1 \ldots \beta_2)\), is determined by the dependence

\[
p[\beta_1 \leq X \leq \beta_2] = \Phi \left( \frac{\beta_2 - m_X}{\sigma_x} \right) - \Phi \left( \frac{\beta_1 - m_X}{\sigma_x} \right)
\]

(3)

Using the theoretical prerequisites outlined, it became possible to determine the main transport and technological parameters and the resulting indicators of integrated production systems. For this purpose, on the example of the creation of a consolidated export batch of grain cargoes in the transport terminal, the total transport and service costs for servicing one ton of the specified cargoes \(B(n)\) and the optimal number of rolling stock in the system were calculated. As a random variable, the performance of the unloading mechanism in the system with two \(m = 2\) service posts is characterized by the coefficient of variation \(\upsilon_{pq} = 30\%\). Transport support of the system was carried out by heavy-duty road trains with a carrying capacity of \(q = 22\) tons (table 1).

<table>
<thead>
<tr>
<th>(P_k)</th>
<th>Reliability of transport service</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_k = 0,50)</td>
<td>(n_{opt} = 20) (B(n)), (\varepsilon/)ton</td>
</tr>
<tr>
<td>(P_k = 0,65)</td>
<td>(n_{opt} = 20) (B(n)), (\varepsilon/)ton</td>
</tr>
<tr>
<td>(P_k = 0,80)</td>
<td>(n_{opt} = 20) (B(n)), (\varepsilon/)ton</td>
</tr>
<tr>
<td>(P_k = 0,95)</td>
<td>(n_{opt} = 20) (B(n)), (\varepsilon/)ton</td>
</tr>
</tbody>
</table>

Table 1. Changes in costs in integrated production structures due to changes in the level of reliability of transport services in transport hub [compiled by the authors].

The performed calculations confirm the well-known facts that the increase in productivity \(P_k\) of service mechanisms contributes to the reduction of total costs \(\Delta B(n)\) for different values of \(P_k\) of service reliability. So, under the condition of the average distance of delivery of consolidating goods \(lm = 50\) km occurs within \(\Delta B(n) = 5,0\%\) (from \(B(n) = 11,50\) \(\varepsilon/\)ton for \(P_k = 20\) ton/hour to \(B(n) = 11,08\) \(\varepsilon/\)ton for \(P_k = 180\) ton/hour) for \(P_k = 0,50\) to \(\Delta B(n) = 7,9\%\) (with \(B(n) = 12,03\) \(\varepsilon/\)ton for \(P_k = 20\) ton/hour to \(B(n) = 11,08\) \(\varepsilon/\)ton for \(P_k = 180\) ton/hour) for \(P_k = 0,95\).

The specified situation is explained by the reduction of non-productive stoppages of road trains at service points, and accordingly, the reduction of the turnover time of the rolling stock on the route, the increase in productivity and the reduction in the total costs of the transport component.

At the same time, the increase in reliability indicators \(P_k\) of terminal service leads to both an increase in service and logistics costs \(B(n)\) in the system and a decrease in the optimal number of road trains \(n\) in the transport and service system. For example, an increase in the reliability index of terminal service within the range of \(P_k = 0,50...0,95\) in the case of the productivity of
service mechanisms \( P_s = 20 \text{ tons/hour} \) leads to an increase in service and logistics costs by 4.6% (from \( B(n) = 11,50 \text{ €/ton} \) for \( p(P_s) = 0.50 \) to \( B(n) = 12,03 \text{ €/ton} \) for \( p(P_s) = 0.95 \)). And the optimal number of \( n_{opt} \) road vehicles for the numerical value of productivity \( P_s = 180 \text{ tons/hour} \) under the same production conditions decreases by 43.6% (from \( n_{opt} = 55 \) units for \( p(P_s) = 0.50 \) to \( n_{opt} = 31 \) units for \( p(P_s) = 0.95 \)).

The mentioned tendency of the change of the resulting indicators is explained by the fact that with increasing indicators of the reliability of terminal service \( p(P_s) \) using the mathematical dependence (3), numerical values \( \beta_i \) of the hourly productivity of a separate post are used in the calculations. In this case, when \( p(P_s) \geq 0.50 \), the numerical value of productivity is less than the mathematical expectation of \( m_P \) of the specified parameter. And the value of the variable components of the mathematical dependence (1) has a significant influence on the reduction of the optimal value of \( n_{opt} \) in the system.

The second important factor in the stochastic service-logistics process is the duration of terminal service of foreign trade cargo flows. The specified operation includes the entire range of technological and logistic services in transport hubs: weighing of road vehicles, documentation of goods, non-production downtime while waiting for service, etc.

Under these circumstances, in the transport and service system with two service posts \( m = 2 \) of the design productivity \( P_h = 120 \text{ ton/hour} \) each, the hourly productivity of \( P_{hour} \) and the hourly profit of \( G_{hour} \) were calculated on the condition that motor vehicles of different load capacities are involved in the system. The results of the influence of the average duration of terminal service \( t_{term} \) 1.5 hour as a random variable with a coefficient of variation \( \sigma_{term} = 35\% \) are presented in table 2.

<table>
<thead>
<tr>
<th>( q ) ( \text{ton} )</th>
<th>( p(t_{term}) = 0.50 )</th>
<th>( p(t_{term}) = 0.65 )</th>
<th>( p(t_{term}) = 0.80 )</th>
<th>( p(t_{term}) = 0.95 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_{hour}, P_{hour}, P_{hour}, P_{hour}, G_{hour}, G_{hour}, G_{hour}, G_{hour} )</td>
<td>( P_{hour}, P_{hour}, P_{hour}, P_{hour}, G_{hour}, G_{hour}, G_{hour}, G_{hour} )</td>
<td>( P_{hour}, P_{hour}, P_{hour}, P_{hour}, G_{hour}, G_{hour}, G_{hour}, G_{hour} )</td>
<td>( P_{hour}, P_{hour}, P_{hour}, P_{hour}, G_{hour}, G_{hour}, G_{hour}, G_{hour} )</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2.63, 6.54</td>
<td>2.49, 6.19</td>
<td>2.35, 5.84</td>
<td>2.14, 5.31</td>
</tr>
<tr>
<td>12</td>
<td>3.14, 9.19</td>
<td>2.98, 8.75</td>
<td>2.81, 8.22</td>
<td>2.56, 7.49</td>
</tr>
<tr>
<td>14</td>
<td>3.64, 12.20</td>
<td>3.46, 11.59</td>
<td>3.26, 10.92</td>
<td>2.97, 9.95</td>
</tr>
<tr>
<td>16</td>
<td>4.15, 15.53</td>
<td>3.94, 14.76</td>
<td>3.71, 13.91</td>
<td>3.38, 12.67</td>
</tr>
<tr>
<td>18</td>
<td>4.65, 19.22</td>
<td>4.41, 18.21</td>
<td>4.17, 17.20</td>
<td>3.80, 15.68</td>
</tr>
<tr>
<td>20</td>
<td>5.14, 23.09</td>
<td>4.89, 21.97</td>
<td>4.61, 20.70</td>
<td>4.20, 18.87</td>
</tr>
<tr>
<td>22</td>
<td>5.62, 27.18</td>
<td>5.35, 25.86</td>
<td>5.05, 24.38</td>
<td>4.59, 22.24</td>
</tr>
</tbody>
</table>

The performed calculations confirm the previous thesis about the expediency of equipping transport and service systems with heavy-duty vehicles and road trains. For example, an increase in the carrying capacity of road vehicles in the range of \( q = 10...22 \) tons leads to an increase in the hourly productivity indicator by 2.13 times (from \( P_{hour} = 2.63 \text{ ton/hour} \) for \( q = 10 \) ton to \( P_{hour} = 5.62 \text{ ton/hour} \) for \( q = 22 \) ton) provided \( p(t_{term}) = 0.50 \) and 2.15 times (from \( P_{hour} = 2.14 \text{ ton/hour} \) for \( q = 10 \) ton to \( P_{hour} = 4.59 \text{ ton/hour} \) for \( q = 22 \) ton) under the condition of reliability of terminal service \( p(t_{term}) = 0.95 \).

The indicator of the hourly profit of \( G_{hour} \) in the specified conditions increases by 4.15 times, respectively (from \( G_{hour} = 6.54 \text{ €/hour} \) for \( q = 10 \) ton to \( G_{hour} = 27.18 \text{ €/hour} \) for \( q = 22 \) ton) under the condition of \( p(t_{term}) = 0.50 \) and 4.19 times (from \( G_{hour} = 5.31 \text{ €/hour} \) for \( q = 10 \) ton to \( G_{hour} = 22.24 \text{ €/hour} \) for \( q = 22 \) ton) for the reliability indicator of terminal service \( p(t_{term}) = 0.95 \).

At the same time, as the previous comment shows, the increase in the reliability of service and logistics service in the transport and service terminal slightly worsens the resulting indicators of \( P_{hour} \) and \( G_{hour} \) in the system. For cars with a carrying capacity of \( q = 10 \) tons, an increase in the reliability indicator \( p(t_{term}) \) of terminal service within the range of \( p(t_{term}) = 0.50...0.95 \) leads to a decrease in the \( P_{hour} \) indicator from 18.6% (with \( P_{hour} = 5.62 \text{ ton/hour} \) for \( q = 10 \) ton to \( P_{hour} = 4.59 \text{ ton/hour} \) for road trains \( q = 22 \) ton). In similar conditions, the decrease in the hourly profit of \( G_{hour} \) is 18.8% for the carrying capacity indicator \( q = 10 \) tons and 18.2% for the value \( q = 22 \) tons, respectively.

By analogy with the previous influencing factor, the increase in the numerical value of the reliability of terminal service \( p(t_{term}) \) requires taking into account the increased range of values of the \( t_{term} \) indicator in the system. As a result, the well-known thesis that increasing the reliability of system functioning requires either additional financial costs or the use of system material and financial resources is confirmed.

### 4 Ensuring a competitive level of transport and terminal service of export cargo flows

The conducted analysis of the peculiarities of service and logistics activities of integrated production formations allows determining trends and the nature of changes in the resulting indicators. And with the help of the obtained results, it becomes possible to substantiate the directions of structural optimization of transport and service systems of an international direction.

The peculiarity of the transport and terminal service of foreign trade cargo flows in sea trade ports is the great demand of participants in the transportation process for the performance of consolidating and service operations and the limitation of the number and capacity of warehouses in places of direct transshipment. In most cases, proven production practice in such processes is the preliminary accumulation of products purchased from manufacturers ready for export in specialized warehouses at a relatively short distance from the consolidating node.

For this purpose, the work of transport hubs for the consolidation of export grain cargo flows and the
justification of the choice of technology for the maintenance of sea merchant ships were modeled in the work. Typical transport and technological processes of servicing foreign trade cargo flows in sea trade ports are presented in the table 3.

Table 3. Typical transport and technological processes in sea trade ports with export and transit grain cargoes.

<table>
<thead>
<tr>
<th>№ technol. scheme</th>
<th>Transport and service maintenance of foreign trade cargo flows in transport hubs</th>
<th>Volume of supply, tons</th>
<th>Delivery time, day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Consolidation of the export batch of grain cargoes at the elevator and warehouse enterprise</td>
<td>5000</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Formation of a consolidated batch of foreign trade goods for export loading using additional storage vehicles</td>
<td>10000</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Comprehensive service of export and tranship cargo flows by motor vehicles for loading grain onto a ship</td>
<td>12000</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Participation in the combined delivery of grain cargoes using port infrastructure</td>
<td>15000</td>
<td>5</td>
</tr>
</tbody>
</table>

That is why one of the important components of the transport and terminal service of foreign trade cargo flows in integrated formations should be the structural optimization of motor vehicle support.

Table 4. Dependence of the resulting indicators of the transport and service system on the reliability of transport and terminal service [compiled by the authors].

<table>
<thead>
<tr>
<th>№ technol. scheme</th>
<th>Levels of transport and terminal service</th>
<th>initial</th>
<th>average</th>
<th>high</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r_{opt}, unit</td>
<td>ΔP_{day}, ton/day</td>
<td>ΔB(n), €/cons</td>
<td>ΔG_{cons}, €/day</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>53,5</td>
<td>2150,0</td>
<td>171,6</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>53,5</td>
<td>4300,0</td>
<td>303,6</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>5160,0</td>
<td>488,4</td>
<td>2930,4</td>
</tr>
<tr>
<td>4</td>
<td>56</td>
<td>6450,0</td>
<td>739,2</td>
<td>3696,0</td>
</tr>
</tbody>
</table>

The numerical value of the daily productivity \( P_{day} \) of the transport enterprise for the defined levels of reliability of transport and terminal service is highly correlated with the indicators of the optimal number of \( n_{opt} \) road vehicles and the hourly productivity \( P_{hour} \) of an individual vehicle. In the situation of infrastructural support of the transport and service system with road trains with a carrying capacity of \( q = 22 \) tons for the transportation of grain cargoes over an average distance of \( l_w = 50 \) km, the change in daily productivity \( \Delta P_{day} \) for technological scheme №1 occurs within the range of \( \% P_{day} = 8,3\% \) under the condition of the initial level indicator \( p(t_{warn}) = 0,65 \) to \( \% P_{day} = 25,0\% \) with a high level of reliability \( p(t_{warn}) = 0,95 \) of transport and terminal service. For technological scheme №4 under the specified conditions, \( \Delta P_{day} \) indicators change from \( \% P_{day} = 5,6\% \) under the condition \( p(t_{warn}) = 0,65 \) to \( \% P_{day} = 12,2\% \) under the condition of reliability of transport and terminal service \( p(t_{warn}) = 0,95 \). The decrease in the rate of growth of \( \Delta P_{day} \) of the daily productivity of the enterprise with an increase in the ship consignment of cargo is explained by a greater number of \( n_{opt} \) vehicles involved, a more stable operation of the transport and service system, and therefore a much smaller impact of non-production stoppages of road vehicles on the numerical values of \( P_{day} \) productivity indicators.
At the same time, increasing the level of service reliability $p(t_{tcmp})$ in production structures by increasing the number of road trains leads to an increase in costs $\Delta B(n)$ in the system. Considering the specificity of the theoretical distribution of the random variable $B(n)$, the increase in costs $\Delta B(n)$ between the basic ($p(t_{tcmp}) = 0.50$) and the initial ($p(t_{tcmp}) = 0.65$) and the basic ($p(t_{tcmp}) = 0.50$) and average ($p(t_{tcmp}) = 0.80$) reliability levels differ by 2.16 times. Under the same conditions, the growth rate of $\Delta B(n)$ for the following levels: «average – high» compared to the previous «initial – average» is 3.62 times. The noted uneveness is explained by the acceleration of the number of requests in the queue for service, which indicates the «saturation» of the production formation with road vehicles.

As a result, the increase in the level of service reliability of consolidating cargo flows is the reason for the reduction of the total $\Delta G_{cons}$ profit in the system. The numerical value of the decrease in the $\Delta G_{cons}$ indicator is, on the example of technological scheme №1, within the range of 55.9% for the initial level ($p(t_{tcmp}) = 0.65$) to 57.3% for the high level ($p(t_{tcmp}) = 0.95$) service reliability from the growth of $\Delta B(n)$ costs. The obtained results indicate the presence of additional income for the services provided in the system in the event of an increase in service reliability.

5 Conclusions

The methodology of the optimization process for production structures in integrated formations is given in the completed work. The conducted studies of the functioning of service and logistics systems in consolidation nodes take into account the stochastic nature of transport and technological processes of an international direction.

The generalization of multivariate calculations of the resulting indicators indicates the expediency of equipping production structures with large-tonnage cars and road trains. The specified direction allows minimizing the total transport and logistics costs, thereby increasing the competitiveness of such integrated formations.

Increasing the level of reliability of transport and terminal service in consolidation nodes increases the stability of service and logistics systems, as well as significantly improves the reputational attractiveness of the specified production structures. At the same time, achieving the specified results requires additional involvement in the system of material and financial resources, which is reflected in the final results of production formations.

One of the directions of optimization of the structure of transport and service systems should be the inclusion of additional infrastructure elements for the preliminary consolidation of cargo or changes in the throughput of such a system. And future research in such a scientific direction should provide an answer to the question of establishing an economically justified balance between the level of reliability of transport and terminal service and the competitiveness of production structures.

References

5. V. Danchuk, O. Bakulich, V. Svatko, Identifying optimal location and necessary quantity of warehouses in logistic system using a radiation therapy method: Transport, 34(2), 175-186 (2019)
7. O. Gryschuk, A. Petryk, A. Kozlov, O. Bura, M. Tyshevych, Organization of transport provision of export of grain cargo under the conditions of stochastic nature of receipt of service requirements, Transportation science and technology, 621-631 (2021)
10. R. Lovelace, J. Parkin, T. Cohen, Open access transport models: a leverage point in sustainable transport planning: Transport policy, 97, 47-54 (2020)