OPERATIONAL EFFICIENCY OF RAILWAY TERMINALS: CORRELATION ANALYSIS OF FREIGHT FLOWS IN UZBEKISTAN

Akhmatov N.B.[1]

[1] *– Tashkent State transport University (Tashkent, Uzbekistan).*

Keywords: *railway, terminal, resource efficiency, operational indicators, optimization.*

Annotation: *An analysis of the cargo handling capacities of logistics centers in Uzbekistan shows that the existing infrastructure allows for effective cargo flow management in some regions, but overall capacities are not fully utilized. The article examines methods for optimizing resource efficiency and operational performance of railway terminals in Uzbekistan and provides necessary proposals.*

Introduction. Especially in the context of the growth of container traffic, existing centers require a sustainable distribution of logistics loads and a strengthening of the processing system based on modern technologies. Therefore, by digitizing logistics centers and increasing their technical capabilities, it is possible to organize container transportation by rail more efficiently. Container operators cooperate with carriers and the infrastructure operator, including on the basis of contracts during the transportation process [1, 7]. Universal containers can belong to railway transport (infrastructure owner, carrier), shippers (consignees) or transport companies (private containers) [2, 8].

It is important to correctly select the location of terminals for processing and design their technical equipment based on the calculated parameters of the terminal. With its help, an analysis of the appropriate types of resources is carried out and the required amount of resources is determined. The location of reloading points during the delivery process is determined and the organization of transportation is planned.

The routes of Uzbekistan with high container flows are mainly associated with international trade, transport and logistics processes. Table 1 presents the main routes of Uzbekistan.

Table 1. Transport flow directions and their position

Direction	The position he held
Tashkent - Andijan route	Cargoes are delivered to large industrial and commercial centers located in the eastern regions of Uzbekistan.
Tashkent - Samarkand	Samarkand's tourist importance and regional economy are leading to an increase in container traffic in this direction.
Tashkent - Bukhara	The transport infrastructure and economic activities of the city of Bukhara contribute to the high flow of containers in this direction.
Tashkent - Fergana	Large industrial enterprises and shopping centers located in the Fergana Valley will increase container traffic.
Tashkent - Nukus	Nukus' strategic location and trade ties with Afghanistan will increase cargo flow in this direction.
Samarkand - Termez	Increases container flow to southern regions of Uzbekistan.
Andijan - Termez	Trade links between southern and eastern Uzbekistan will increase container flows.

The above routes of Uzbekistan are important for container flows. They play a role in the development of economic activities within the country, as well as in strengthening international trade and transport ties. It is necessary to effectively manage cargo transportation processes on these routes, increase container flows, and improve transport logistics.

Main part. The problem of increasing the overall efficiency of the railway system is solved by optimizing the rational use of resources, improving operational practices and introducing modern technologies. The study uses a mixed method and analyzes the performance of the main terminals in Tashkent and Navoi based on data from railway operators, national statistics and observations. A number of variables

ISSN 3060-4567

were used to assess the performance and efficiency of railway terminals. The main indicators related to cargo include the total volume of cargo transported through the terminals, as well as separate categories of cargo such as grain products, oil products, ferrous metals, wood products, coal, fruits and vegetables, cement, flour products, sugar, chemical fertilizers, construction materials, industrial products, machinery, non-ferrous metals, aluminum oxide and other cargo. These variables reflect the diversity of cargo processed at the terminals and serve as the basis for assessing their throughput and capacity. Below is a review of various methods for optimizing the efficiency of container terminals.

Pearson correlation coefficient (also known as linear correlation): This is the most common type of correlation and measures the linear relationship between two continuous variables [3, 9]. It assumes that the relationship between the variables is linear and that the data is normally distributed. This is usually represented by the letter r. The formula for the Pearson correlation coefficient between two variables X and Y is:

$$r = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{(X_i-\bar{X})^2(Y_i-\bar{Y})^2}} \qquad (1)$$

where, r - Pearson correlation coefficient;

X_i and Y_i - Separate data points for variables X and Y;

$\bar{X}$ and $\bar{X}$ - The mean values of the variables X and Y;

n - number of data points (sample size).

The value of the Pearson correlation coefficient varies from -1 to +1. When r = 1, it indicates an absolute positive correlation, that is, as X increases, Y also increases in absolute proportion [4, 11]. Similarly, when r = -1, this indicates an absolute negative relationship, meaning that as X increases, Y decreases in absolute proportion. If r = 0, this indicates that there is no linear relationship between the two variables; a change in X does not correspond to a consistent change in Y.

Spearman's rank correlation: This is a nonparametric measure of correlation and is used when the assumptions of Pearson's correlation (such as linearity or normality) are not met [6, 10]. Spearman's rank correlation coefficient (often denoted as ρ or rs). Spearman's rank correlation coefficient formula:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \qquad (2)$$

where, r_s - Spearman correlation coefficient;

d_i - the difference between the levels of corresponding values of two variables X and Y;

n - number of data points (sample size).

Kendall's Tau: This is another nonparametric measure of correlation used when working with ordinal data. It measures the relationship between two variables by estimating the strength of the monotonic relationship between them. It is more robust in the presence of outliers and provides greater accuracy with strong correlations in small samples [5, 12, 13]. The most common variant is Kendall's Tau-β (τ) coefficient, which takes into account the same degrees. Its formula is as follows:

$$\tau = \frac{C-D}{\sqrt{(C+D+T_X)(C+D+T_Y)}} \qquad (3)$$

where, C = Number of concordant pairs (pairs in which the levels of both variables match, i.e. if one is higher in X than the other, Y will also be higher);

D = Number of discordant pairs (pairs in which the levels of both variables do not match, i.e., one is higher in X than the other, while Y is lower);

T_X= Number of links in X (pairs with the same values in X);

T_Y= Number of links in Y (pairs with the same values in Y).

Correlation is one of the basic tools in statistics, helping to identify and quantify relationships between variables. This serves as an important basis for further analysis and decision-making.

To analyze the performance of railway terminals in Uzbekistan by cargo category, the study can cover several variables. These variables help to assess the efficiency and volume of different types of cargo passing through the terminals. The analysis of the performance and efficiency of railway terminals in Uzbekistan, especially in key locations such as Tashkent and Navoi, has revealed important information about how various factors contribute to the operational success of these terminals.

Table 2. Correlation matrix of freight factors affecting the efficiency of railway terminals in Uzbekistan

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Total cargo	1.00	-0.51	-0.41	-0.81	0.94	0.95	0.83	0.12	0.96	0.94	0.83	0.90	0.84	0.93	0.82	0.87	0.51
2. Cereal products	-0.51	1.00	0.81	0.77	-0.62	-0.65	-0.40	0.47	-0.64	-0.64	-0.76	-0.62	-0.77	-0.65	-0.69	-0.49	0.23
3. Petroleum products	-0.41	0.81	1.00	0.85	-0.58	-0.61	-0.19	0.76	-0.50	-0.60	-0.83	-0.40	-0.80	-0.58	-0.65	-0.29	0.07
4. Ferrous metals	-0.81	0.77	0.85	1.00	-0.87	-0.92	-0.64	0.47	-0.83	-0.87	-1.00	-0.78	-0.99	-0.91	-0.92	-0.71	-0.17
5. Wood materials	0.94	-0.62	-0.58	-0.87	1.00	0.90	0.65	-0.05	0.98	0.89	0.89	0.87	0.87	0.86	0.78	0.75	0.48
6. Coal	0.95	-0.65	-0.61	-0.92	0.90	1.00	0.83	-0.12	0.91	0.97	0.92	0.87	0.94	0.99	0.91	0.85	0.35
7. Fruits and vegetables	0.83	-0.40	-0.19	-0.64	0.65	0.83	1.00	0.07	0.73	0.73	0.66	0.88	0.72	0.89	0.85	0.97	0.10
8. Cement	0.12	0.47	0.76	0.47	-0.05	-0.12	0.07	1.00	0.02	-0.02	-0.45	-0.04	-0.44	-0.16	-0.40	-0.01	0.54
9. Flour products	0.96	-0.64	-0.50	-0.83	0.98	0.91	0.73	0.02	1.00	0.88	0.86	0.93	0.85	0.89	0.80	0.83	0.41
10. Sugar	0.94	-0.64	-0.60	-0.87	0.89	0.97	0.73	-0.02	0.88	1.00	0.87	0.77	0.87	0.93	0.80	0.74	0.47
11. Chemical fertilizers	0.83	-0.76	-0.83	-1.00	0.89	0.92	0.66	-0.45	0.86	0.87	1.00	0.82	1.00	0.92	0.93	0.75	0.18
12. Building materials	0.90	-0.62	-0.40	-0.78	0.87	0.87	0.88	-0.04	0.93	0.77	0.82	1.00	0.84	0.91	0.89	0.96	0.14
13. Industrial products	0.84	-0.77	-0.80	-0.99	0.87	0.94	0.72	-0.44	0.85	0.87	1.00	0.84	1.00	0.94	0.96	0.79	0.13
14. Machines	0.93	-0.65	-0.58	-0.91	0.86	0.99	0.89	-0.16	0.89	0.93	0.92	0.91	0.94	1.00	0.96	0.91	0.23
15. Non-ferrous metals	0.82	-0.69	-0.65	-0.92	0.78	0.91	0.85	-0.40	0.80	0.80	0.93	0.89	0.96	0.96	1.00	0.90	0.00
16. Aluminum oxide	0.87	-0.49	-0.29	-0.71	0.75	0.85	0.97	-0.01	0.83	0.74	0.75	0.96	0.79	0.91	0.90	1.00	0.09
17. Other cargo	0.51	0.23	0.07	-0.17	0.48	0.35	0.10	0.54	0.41	0.47	0.18	0.14	0.13	0.23	0.00	0.09	1.00

ISSN 3060-4567

The correlation matrix in Table 2 provides information on the interrelationships between various freight indicators that are important for understanding the resource efficiency of railway terminals in Uzbekistan. According to the results of the analysis, a strong positive correlation was found between the total freight volume and wood products (0.94), coal (0.95) and flour products (0.96). This indicates that these goods have a significant impact on the total freight volume. In addition, the high correlations between Coal, Machinery and Industrial products (0.99, 0.94, 0.96) indicate that these goods often move together and can benefit from common logistics strategies. In contrast, the negative correlation between total freight volume and grain products (-0.51), oil products (-0.41), and ferrous metals (-0.81) suggests that these commodities have different transportation patterns. This may be due to seasonal variations or infrastructure constraints. The inverse correlation between ferrous metals and chemical fertilizers (-1.00) suggests that there is competition for the allocation of limited resources for these commodities. Understanding these relationships can help develop strategies to optimize terminal operations. For example, focusing on areas such as prioritizing high-value cargo types and reducing inefficiencies in handling negatively correlated commodities. The results of the study will serve to improve resource management at rail terminals in accordance with best practices in transport logistics.

Conclusion. Despite the fact that the randomness of the time of motor transport service in the terminal activity, variability and technological uncertainties in loading and unloading complicate the process, the possibility of analytically placing the terminal infrastructure for the development of the container transportation system, simplifying processes by comparing various options and selecting the optimal solution, as well as ensuring uninterrupted communication between vehicles, has been scientifically substantiated. The models considered in the work and built on the basis of the proposed method make it possible to determine the number of parking spaces at the terminal, optimize the number of cranes, and assess time efficiency.

REFERENCES

1. Law "On Railway Transport". 27.11.2024. https://www.lex.uz/uz/docs/-7239390.

2. Rules for the carriage of goods by rail. 21.09.2023. https://www.lex.uz/ru/docs/-6615163.

3. K. H. Zou, K. Tuncali, and S. G. Silverman, "Correlation and simple linear regression," Radiology, vol. 227, no. 3, pp. 617–628, 2003.

4. E. I. Obilor and E. C. Amadi, "Test for significance of Pearson's correlation coefficient," Int. J. Innov. Math. Stat. Energy Policies, vol. 6, no. 1, pp. 11–23, 2018

5. S. Arndt, C. Turvey, and N. C. Andreasen, "Correlating and predicting psychiatric symptom ratings: Spearmans r versus Kendalls tau correlation," J. Psychiatr. Res., vol. 33, no. 2, pp. 97–104, 1999.

6. J. P. Verma and J. P. Verma, "Non-parametric correlations," Stat. Res. Methods Psychol. with Excel, pp. 523–565, 2019

7. Ziyoda Mukhamedova, Diyor Boboev. Research on improving the modern transport system in the process of cargo delivery. Railway transport: current issues and innovations, 3(1), 2022/3/28, 15–24.

8. J Shihnazarov, D Boboev, M Dehkonov, D Ikramova. Choice of an efficient mode of transport on the basis of comparison of technical and economic indicators of types of transport. - E3S Web of Conferences, 2023, 1-7

9. Ziyoda Mukhamedova, Diyor Boboyev, Shukhrat Saidivaliev, Rustam Abdullaev, Jamshid Kobulov, Sardorbek Akhmedov, Sherzod Fayzibayev. Mathematical modeling of fastening conditions in piggyback transport: ensuring safety and stability across different transport modes. Discover Applied Sciences: 2025/6/8, 619. https://link.springer.com/article/10.1007/s42452-025-07188-7

10. Bozorov R Sh, Boboev D Sh. Methods of installation of wire rope and binder when securing loads. Pedagogs: 2025/5/30, 76-84.

11. D Do'labov, Boboyev D Sh. Stages of development of the organization of wagon flows. Editorial board: 2024/10/7, 219.

12. Ziyoda Adilova, Diyor Boboyev, Navruz Axmatov. Mathematical model of fastening conditions in container transportation taking into account various conditions. Transport bulletin: 2024/9/30, 98-103.

13. Boboyev Diyor Shomurotovich. Placing vehicles on the railway platform when organizing counter-trailer transportation. Journal of new century innovations: 2022/12/7, 17-21.