# METHODS FOR FORECASTING LOGISTICS SUPPLY ACTIVITIES IN CARGO TERMINALS

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**Abstract**
This article analyzes the logistics processes carried out at cargo terminals in Uzbekistan, in particular the processes of multimodal container transportation. At the same time, a forecasting expression for changes in the flow of multimodal containers transported by road and rail was developed using linear and parabolic equations. The parameters of this forecasting expression were calculated using the least squares method, and the forecast values of container flows for the period 2025-2030 were calculated.

**Keywords**: Cargo terminal, multimodal transportation, time series, least squares method, parabolic equation, forecasting.

## Introduction

In Uzbekistan, the volume of container transportation by road and rail has been increasing year by year in recent years. This increases the importance of multimodal transportation and creates the need to analyze them together.

By translating statistical data into practical values, it is possible to visualize the real logistics volume in container transportation. This, in turn, is important for planning the transport system, developing infrastructure, and effectively managing cargo flows.

The statistics provided show that the volume of cargo transported by container in road and rail transport (thousand tons) is increasing year by year. Based on this data, it is possible to roughly calculate how many 20-foot containers are required each year [1].

**Container transportation by road and rail between 2015 and 2024**Based on this, a statistical analysis is conducted using the time series method, and based on the least squares method, container transportation volumes for 2024-2030 are forecasted based on a model for the Chukursoy logistics center.

Forecasting multimodal transportation will allow for advance planning of cargo flows in the republic, optimization of terminal infrastructure, and ensuring continuity in the transportation system. This will help increase the efficiency of the entire transport and logistics system.

To create a reliable forecast of container transportation, it is necessary to pay attention to their total volume, not to be limited to individual indicators in the section of transport types. Because in the conditions of Uzbekistan, multimodal transportation (road + railway) is increasingly expanding[2].

**Table 1 Chukursay Logistics Center Number of containerized shipments by year, thousand units (2015-2024)**

| Indicator | Years | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| Number of containerized shipments, thousand units | 12456 | 12896 | 13254 | 13870 | 14875 | 14586 | 15246 | 15873 | 16857 | 20467 |

In forecasting, an expression is developed using a time series table using the least squares method. The essence of this method is to find the parameters that are the sum of squares, minimizing the calculated level values with their actual values, that is, the expression is minimized:

$$\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \to \min(i = 1,2,...,n) \qquad (1)$$

Here - the actual values of the levels of the time series;$y_i$

$\hat{y}_i$ – values calculated according to the given formula [3].

In socio-economic statistics, the following two functions are often used to identify and express the trend of analytical time series:

– first-order (linear function)

$$y_t = a_0 + a_1 t \qquad (2)$$

– second degree (parabolic function)

$$y_t = a_0 + a_1 t + a_2 t^2 \qquad (3)$$

Initially, the second-order parabolic equation is written as a system of normal equations a3, a1, and a2 to determine the unknown parameters:

$$\begin{cases} Na_0 + a_1\sum t + a_2\sum t^2 = \sum y; \\ a_0\sum t + a_1\sum t^2 + a_2\sum t^3 = \sum yt; \\ a_0\sum t^2 + a_1\sum t^3 + a_2\sum t^4 = \sum yt^2. \end{cases} \qquad (4)$$

If the sum of odd powers of t is zero, the whole system can be simplified considerably:

$$\begin{cases} Na_0 + a_2\sum t^2 = \sum y; \\ a_1\sum t^2 = \sum yt; \\ a_0\sum t^2 + a_2\sum t^4 = \sum yt^2. \end{cases} \qquad (5)$$

Using the given parameters, it is necessary to predict the future volumes of loading containers into road transport for some enterprises, the initial time series of which is approximately described by a second-order parabola [4].

This approach will lead to a significant increase in the volume of container deliveries by road transport vehicles (ATV) in Uzbekistan in the future.

**Table 2 Determining container transport volume using time series method**

The last column of Table 2 lists the values of the second-order function.

| Years | Container transport volume, TEU, y | t | $t^2$ | $t^4$ | horse | $yt^2$ | $\hat{y}_t$ | $\hat{y}_{t^2}$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| **2015** | 12456 | -9 | 81 | 6561 | -112104 | 1008936 | 11853.6 | 12886.6 |
| **2016** | 12896 | -7 | 49 | 2401 | -90272 | 631904 | 12561.3 | 12905.6 |
| **2017** | 13254 | -5 | 25 | 625 | -66270 | 331350 | 13268.9 | 13096.8 |
| **2018** | 13870 | -3 | 9 | 81 | -41610 | 124830 | 13976.5 | 13460.1 |
| **2019** | 14875 | -1 | 1 | 1 | -14875 | 14875 | 14684.2 | 13995.5 |
| **2020** | 14586 | 1 | 1 | 1 | 14586 | 14586 | 15391.8 | 14703.2 |
| **2021** | 15246 | 3 | 9 | 81 | 45738 | 137214 | 16099.5 | 15583.0 |
| **2022** | 15873 | 5 | 25 | 625 | 79365 | 396825 | 16807.1 | 16634.9 |
| **2023** | 16857 | 7 | 49 | 2401 | 117999 | 825993 | 17514.7 | 17859.1 |
| **2024** | 20467 | 9 | 81 | 6561 | 184203 | 1657827 | 18222.4 | 19255.3 |
| **Total:** | **150380** | **0** | **330** | **19338** | **116760** | **5144340** | **150380** | **150380.1** |

By inserting the calculated values of the parabolic equation parameters from the table into the system of equations, we obtain the following system of equations [5].

$$\begin{cases} 10a_0 + 330a_2 = 150380 \\ 19338a_1 = 116760 \\ 330a_0 + 19338a_2 = 5144340 \end{cases}$$

The equation calculates the parameters (the first equation is multiplied by 33 accordingly):

$$-\begin{cases} 330a_0 + 10890a_2 = 4962540 \\ 330a_0 + 19338a_2 = 5144340 \end{cases}$$

$$-8448a_2 = -181800$$

$$a_2 = \frac{181800}{8448} = 21{,}52$$

$$a_1 = \frac{116760}{19338} = 353{,}818$$

$$a_0 = \frac{150380 - 330 \cdot 21{,}53}{10} = 14327{,}844$$

That is why,

$$\hat{y}_t = 14327{,}844 + 353{,}818t + 21{,}52t^2 \quad (6)$$

A similar first-order equation is as follows::

(7)

$$\begin{cases} Na_0 = \sum y; \\ a_1 \sum t^2 = \sum yt \end{cases}$$

$$a_0 = \frac{150380}{10} = 15038$$





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$$a_1 = \frac{116760}{330} = 353{,}818$$

$$\hat{y}_t = 15038 + 353{,}818t \qquad (8)$$

Some general conclusions can be drawn from the use of the above methods. Extrapolation by smoothing time series using the least squares method should be used with caution, and if the approximate function expressing the development trend is chosen incorrectly, the forecast results may be inaccurate.

The economist's personal experience and knowledge can be of great help in choosing the type of function f(t). In other cases, when the type of function is determined empirically, the resulting trend estimate is considered as some kind of interpolation formula that helps the economist in analyzing time series [6].

In practice, the choice of the type of trend function whose parameters are determined by the least squares method is often made empirically, by constructing a series of functions and comparing them with each other using the following criteria:

-average absolute deviation:

$$|A| = (y_t - \hat{y}_t) \qquad (9)$$

-mean square deviation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (y_t - \hat{y}_t)^2}{N - P - 1}} \qquad (10)$$

-coefficient of variation:

$$\upsilon = \frac{\sigma}{\bar{y}} \cdot 100\% \qquad (11)$$

-Assessment of the closeness of the theoretical process to the original data – correlation coefficient R:$\hat{y}_t$

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (y_t - \hat{y}_t)^2}{\sum_{n=1}^{n} (y_t - \bar{y}_t)^2} \qquad (12)$$

where: - the initial, theoretical and arithmetic mean levels of the time series; n - the number of parameters determined in the trend function.

The calculation of the parameters of functions (8) and (6) is carried out by the method of least squares, the main requirement of which is the minimum sum of the squared deviations of the calculated values from the empirical values. Having performed the necessary calculations, we obtain the following equations:

**Table 3 The delivered container is a developed model table**

| Years | $\hat{y}_t = 15038+353,818t$ | | | $\hat{y}_t = 14327,844 + 353,818t + 21,52t^2$ | | |
|---|---|---|---|---|---|---|
| | $y_t - \hat{y}_t$ | $(y_t - \hat{y}_t)^2$ | $(y_t - \bar{y}_t)^2$ | $y_t - \hat{y}_t$ | $(y_t - \hat{y}_t)^2$ | $(y_t - \bar{y}_t)^2$ |
| **2015** | 602.4 | 362840.0 | -2582 | -430.6 | 185416.36 | 6666724 |
| **2016** | 334.7 | 112041.5 | -2142 | -9.6 | 92.16 | 4588164 |
| **2017** | -14.9 | 222.3 | -1784 | 157.2 | 24711.84 | 3182656 |
| **2018** | -106.5 | 11352.1 | -1168 | 409.9 | 168018.01 | 1364224 |
| **2019** | 190.8 | 36411.5 | -163 | 879.5 | 773520.25 | 26569 |
| **2020** | -805.8 | 649342.6 | -452 | -117.2 | 13735.84 | 204304 |
| **2021** | -853.5 | 728383.7 | 208 | -337 | 113569 | 43264 |
| **2022** | -934.1 | 872524.1 | 835 | -761.9 | 580491.61 | 697225 |
| **2023** | -657.7 | 432603.5 | 1819 | -1002.1 | 1004204.41 | 3308761 |
| **2024** | 2244.6 | 5038399.8 | 5429 | 1211.7 | 1468216.89 | 29474041 |
| **Total:** | -0.1 | 4331976.4 | 0 | -0.1 | 4331976.37 | 49555932 |

These methods not only increase the accuracy of the forecast, but also save time, reduce forecasting costs, and reduce risk in decision-making. This makes it possible to introduce advanced management mechanisms in the development of container transportation and increase the efficiency of the logistics system.
Using the above formulas, the following criteria are calculated: |A|, σ, υ, and R2.

**Table 4 Table for calculating criteria for developed models**

| Developed models | Criteria | | | |
|---|---|---|---|---|
| | \|A\| | σ | υ | $R^2$ |
| $\hat{y}_t = 15038+353,818t$ | 0 | 658.18 | 4.38 | 0.912 |
| $\hat{y}_t = 14327,844 + 353,818t + 21,52t^2$ | 0.1 | 658.17 | 4.37 | 0.913 |

The analysis shows that the model based on the parabolic function meets the requirements for all criteria, therefore, we accept this model for forecasting.
According to the model developed based on the quadratic parabola, the forecast values for the number of containers transported by road for 2025-2030 are as follows:
For the year 2025 (t=10)

$$\hat{y}_t = 14327,844 + 353,818 \cdot 10 + 21,52 \cdot 10^2 = 21450\,kont.$$

For the year 2026 (t=11)

$$\hat{y}_t = 14327,844 + 353,818 \cdot 11 + 21,52 \cdot 11^2 = 23788\,kont.$$

For the year 2027 (t=12)

$$\hat{y}_t = 14327,844 + 353,818 \cdot 12 + 21,52 \cdot 13^2 = 26274\,kont.$$

For the year 2028 (t=13)

$$\hat{y}_t = 14327{,}844 + 353{,}818 \cdot 13 + 21{,}52 \cdot 13^2 = 28910\,kont.$$

For the year 2029 (t=14)

$$\hat{y}_t = 14327{,}844 + 353{,}818 \cdot 14 + 21{,}52 \cdot 14^2 = 31694\,kont.$$

For the year 2030 (t=15)

$$\hat{y}_t = 14327{,}844 + 353{,}818 \cdot 15 + 21{,}52 \cdot 15^2 = 34627\,kont.$$

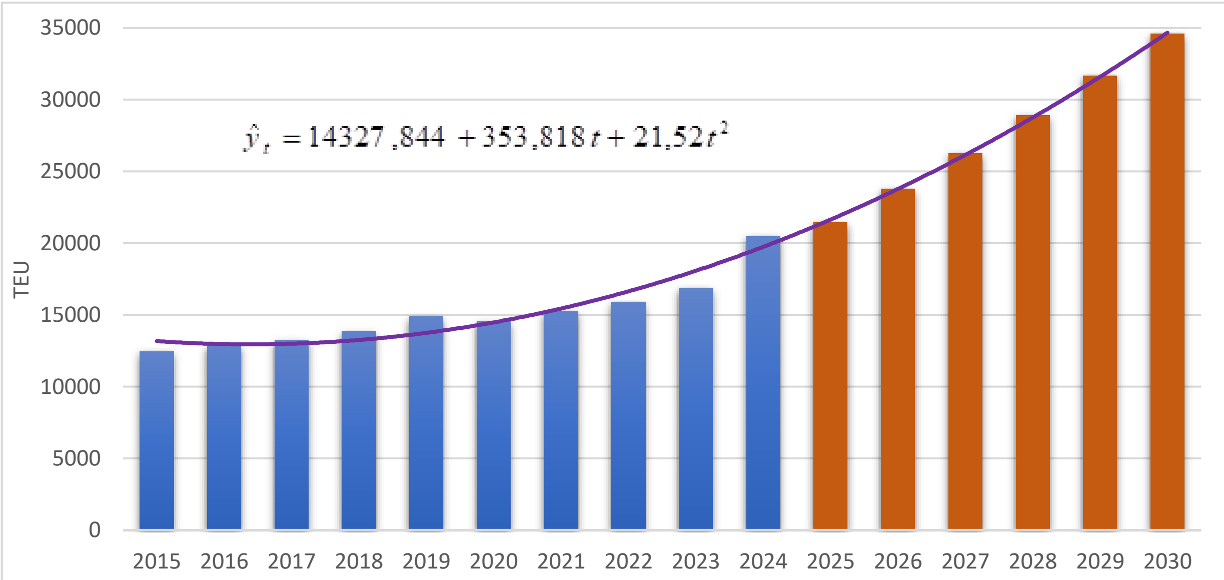


**Figure 1.** Container traffic forecast graph (2015-2030)

A mathematical model of organizing container transportation from terminals to consumers was developed and the volume of container transportation by road transport was forecasted based on dynamic series. This will lead to a significant increase in the supply of containers by ATV in Uzbekistan in the future and the best way to solve the problems of planning and forecasting these transportations. Properly selected methods significantly improve the quality of forecasts, as they ensure the functionality, reliability and accuracy of the forecast, as well as save time and reduce forecasting costs [7].

**Table 5 Container traffic volume forecast table**

| **Years** | **Prophecy** | **Prediction error** | **Confidence interval** | |
|---|---|---|---|---|
| | | | above | below |
| **2025** | 21450 | 0.2078 | 21450 | 21450 |
| **2026** | 23788 | 0.2304 | 23788 | 23788 |
| **2027** | 26274 | 0.2545 | 26275 | 26274 |
| **2028** | 28910 | 0.2800 | 28910 | 28909 |
| **2029** | 31694 | 0.3070 | 31694 | 31693 |
| **2030** | 34627 | 0.3354 | 34627 | 34627 |

**Conclusion**

In order to effectively organize container transportation from terminals to consumers, a mathematical model was developed. Through this model, the process and volumes of container transportation by road were analyzed in depth based on time series (dynamic series) and forecasting was carried out using a second-order trend (parabolic model).

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