ANALYSIS OF THE MAIN INDICATORS OF FREIGHT AND TRAIN TRANSPORTATION AT THE "KARSHI" STATION

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Abstract: *This article provides a detailed analysis of the freight and train transportation performance of the Karshi railway station in recent years. Based on these analyses, it was noted that there were delays in several directions at the station. In this regard, it was determined that there is a need to improve the station's work processes. To solve these problems, a multi-criteria regression mathematical model of the station's turnaround time was developed. According to it, it was determined that the turnaround time depends on the length of the loading and unloading front, the speed of loading and unloading, and the volume of work at the stations.*

Keywords: *Freight and passenger trains, load cycling, load front length, regression model, least squares method.*

During the study of the workflow of the "Qarshi" station, the work performed at the station between 2022 and 2023 was carried out, that is, the analysis of the main indicators of the station-that is, the amount of cargo flows loaded from the station, the amount of wagons loaded, the amount of transit processed, the amount of wagons not processed it will be possible to get acquainted with the analysis of these indicators in the cross section of years from the table at the well (Table 1).

Table 1

Performance indicators of the "Karshi" station

Indicators	2022 report	2023 plan	2023 report	to the report		to the plan	
				%	(+,-)	%	(+,-)

Loading, tons	275165	261189	268942	97,7	-6223	103,0	7753
Day	1007,9	956,7	985,1	-	-	-	-
Loading, wagon	5046	4675	4584	90,8	-462	98,1	-91
Day	18,5	17,1	16,8	-	-	-	-
Static loading	54,5	55,9	58,7	107,6	4,1	105,0	2,8
Unloading, wagon	16425	16520	16494	100	69	99,8	-26
Day	60,2	60,5	60,4	-	-	-	-
Wagon dispatch	209094	213533	240236	114,9	31142	112,5	26703
Day	765,9	782,2	880,0	-	-	-	-
Working fleet	186910	242965	192823	96,9	5913	126,0	-50142
Day	684,7	890,0	706,3	-	-	-	-
Empty wagon	20,0	20,0	20,0	100,0	-	100,0	-
Transit non-recyclable	1,0	1,0	1,0	100,0	-	100	-
Transit recyclable	18,0	18,0	18,0	100,0	-	100	-
Recyclable fleet	384050	380800	384198	100,0	148	100,9	3398
Day	1406,8	1394,9	1407,3	-	-	-	-
CNG wagons	1654	5172	2188	76	534	236,4	-2984
Day	6,1	18,9	8,0	-	-	-	-
Production.	1389,7	1382,0	1430,5	102,9	40,8	103,5	48,6
Contingent	198	189	188	94,9	-10	99,5	-1

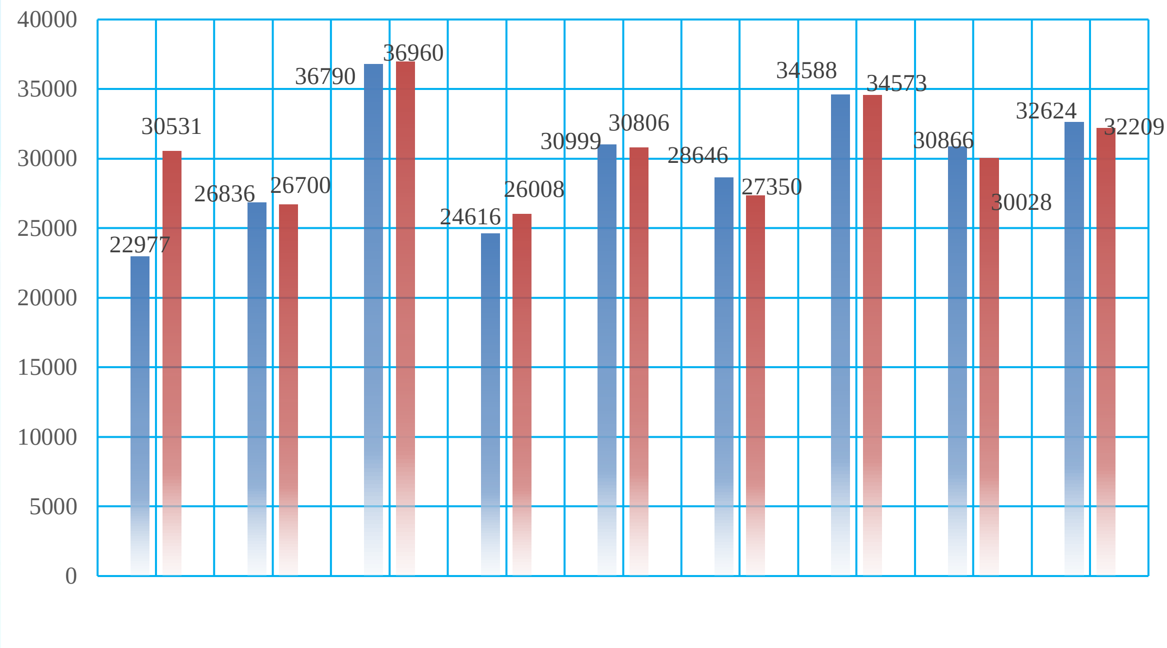

Figure 1. Load tonnage diagram

Table 2

Loading tons

	January	February	March	April	May	June	July	August	September	In 9
2023	22977	26836	36790	24616	30999	28647	34588	30866	32624	268942
2022	30531	26700	36960	26008	30806	27350	34573	30028	32209	275165
+\-	-7554	136	-170	-1392	193	//1297	15	838	415	-6223
%	75,2	100,5	99,5	94,6	100,6	104,7	100,0	102,8	101,2	97,7

An analysis of the activities of the “Karshi” workstation shows that the main load increase is 97,7% less than the 2022 target of 6,223 tons, and 103,0% less than the 2023 plan of 7,753 tons.

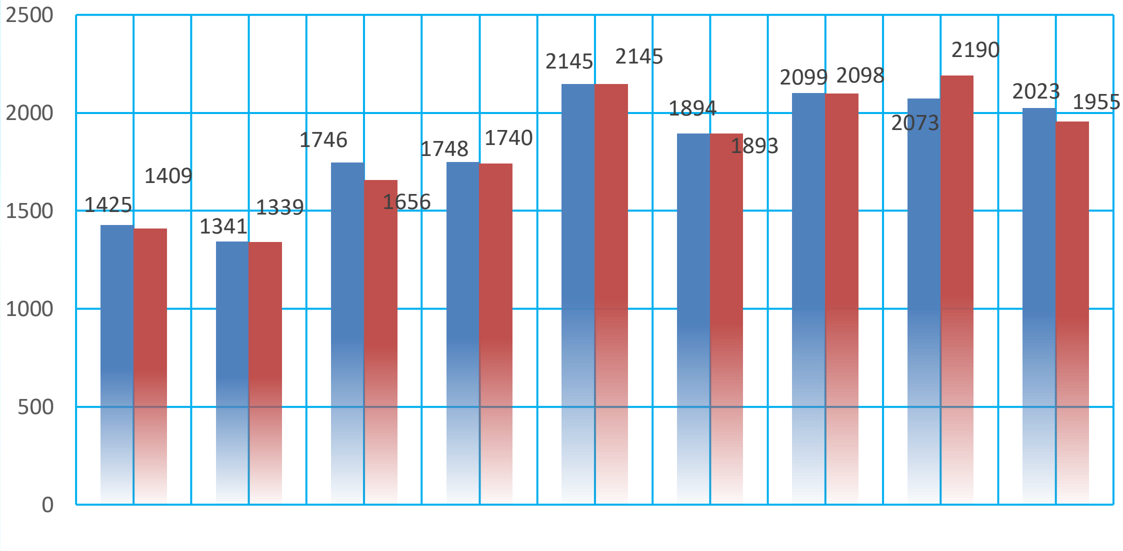

Figure 2. Diagram of the number of unloaded wagons

Table 3

Number of unloaded wagons

	January	February	March	April	May	June	July	August	September	In 9 months
2023 report	1425	1341	1746	1748	2145	1901	2099	2073	2023	16494
2022 report	1409	1339	1656	1740	2145	1893	2098	2190	1955	16425
+\-	16	2	90	8	0	8	1	-117	68	69
%	101,1	100,1	105,4	100,4	100,0	100,3	100,0	94,6	103,5	100,0

Unloading of wagons at the “Karshi” station was 462 wagons more than last year, or 90,8 percent, and 91 wagons less than the plan, which affects the increase in statistical load. Statistical load was fulfilled by 107,6 percent compared to last year, and by 105,0 percent compared to the plan (Figure 1-3).

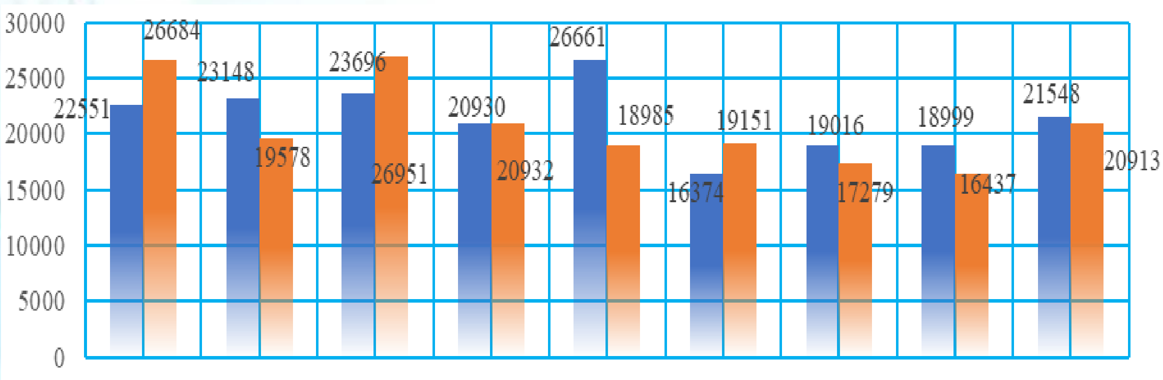

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Figure 3. Workforce chart

According to the data, the number of CIS cars is 76,0% more and 236,4% less than planned. The quality indicators of the downtime of wagons per 1 cargo operation are 100,0% compared to the previous year, 100,0% compared to the plan, transit downtime with processing is 100,0% compared to the report, 100,0% compared to the plan. The downtime of transit without processing was 100% compared to the previous year and 100% compared to the plan; Labor productivity was reported by 102,9%, the plan was fulfilled by 103,5%. In order to more effectively organize the productivity of station work processes, it is advisable to use various mathematical modeling methods in the organization of station work processes. Mathematical modeling processes are certainly used in every field of production, especially in the field of railway transport, for this purpose, let us consider the issue of finding an empirical function for wagon turnover using regression modeling and the method of least squares for the "Karshi" station. That is, let the empirical function for determining wagon turnover be the function of the dependence of the station's cargo flow, the number of wagons to be shipped, the length of the section and the speed of the wagons:

$$\theta = \theta(Q, N, L, V) \qquad (1)$$

For this purpose, let's write the objective function of regression modeling and the least squares method (Figure 4),

$$\Delta\theta = \sum_{i=1}^{n}\left(\theta_i - \overline{\theta}_i\right)^2 \to \min \Rightarrow \Delta\theta = \sum_{i=1}^{n}\left(\theta_i - a\cdot Q - b\cdot N - c\cdot L - d\cdot V - e\right)^2 \to \min \qquad (2)$$

$$\begin{cases} \dfrac{\partial\theta}{\partial a} = \theta_a(Q, N, L, V) = 0 \\ \dfrac{\partial\theta}{\partial b} = \theta_b(Q, N, L, V) = 0 \\ \dfrac{\partial\theta}{\partial c} = \theta_c(Q, N, L, V) = 0 \\ \dfrac{\partial\theta}{\partial d} = \theta_d(Q, N, L, V) = 0 \\ \dfrac{\partial\theta}{\partial e} = \theta_e(Q, N, L, V) = 0 \end{cases} \qquad (3)$$

$$\begin{cases} \frac{\partial\theta}{\partial a} = 2\sum_{i=1}^{n}(\theta_1 - a\cdot Q_1 - b\cdot N_1 - c\cdot L_1 - d\cdot V_1 - e)\cdot(-Q) = 0 \\ \frac{\partial\theta}{\partial b} = 2\sum_{i=1}^{n}(\theta_2 - a\cdot Q_2 - b\cdot N_2 - c\cdot L_2 - d\cdot V_2 - e)\cdot(-N) = 0 \\ \frac{\partial\theta}{\partial c} = 2\sum_{i=1}^{n}(\theta_3 - a\cdot Q_3 - b\cdot N_3 - c\cdot L_3 - d\cdot V_3 - e)\cdot(-L) = 0 \\ \frac{\partial\theta}{\partial d} = 2\sum_{i=1}^{n}(\theta_4 - a\cdot Q_4 - b\cdot N_4 - c\cdot L_4 - d\cdot V_4 - e)\cdot(-V) = 0 \\ \frac{\partial\theta}{\partial e} = 2\sum_{i=1}^{n}(\theta_5 - a\cdot Q_5 - b\cdot N_5 - c\cdot L_5 - d\cdot V_5 - e)\cdot(-1) = 0 \end{cases} \quad (4)$$

$$\begin{cases} \frac{\partial\theta}{\partial a} = 2\sum_{i=1}^{n}(10 - 765{,}9a - 873b - 2c - 50d - e)\cdot(-765{,}9) = 0 \\ \frac{\partial\theta}{\partial b} = 2\sum_{i=1}^{n}(12 - 894{,}5a - 818b - 2{,}5c - 52d - e)\cdot(-818) = 0 \\ \frac{\partial\theta}{\partial c} = 2\sum_{i=1}^{n}(14 - 1226{,}3a - 1074b - 3{,}5c - 55d - e)\cdot(-2) = 0 \\ \frac{\partial\theta}{\partial d} = 2\sum_{i=1}^{n}(17 - 820{,}5a - 992b - 4c - 60d - e)\cdot(-60) = 0 \\ \frac{\partial\theta}{\partial e} = 2\sum_{i=1}^{n}(19 - 1033{,}3a - 959b - 5c - 64d - e)\cdot(-1) = 0 \end{cases} \quad (5)$$

The above expressions were determined in C++ using the least squares method and Cramer's equations as follows:

```
#include <iostream>
#include <vector>
#include <iomanip>
using namespace std;
vector<double> gaussElimination(vector<vector<double>>& A, vector<double>& B) {
    int n = A.size();
    for (int i = 0; i < n; i++) {
        int maxRow = i;
        for (int k = i + 1; k < n; k++) {
            if (abs(A[k][i]) > abs(A[maxRow][i])) {
                maxRow = k;
    }
```

```
          for (int k = i; k < n; k++) {
        swap(A[maxRow][k], A[i][k]);
      }
      swap(B[maxRow], B[i]);
      if (abs(A[i][i]) < 1e-12) {
        throw runtime_error("There is a zero pivot element, the system has no solution or has multiple solutions.");
      }
      for (int k = i + 1; k < n; k++) {
        double c = A[k][i] / A[i][i];
        for (int j = i; j < n; j++) {
          A[k][j] -= c * A[i][j];
        }
        B[k] -= c * B[i];
      }
    vector<double> x(n);
    for (int i = n - 1; i >= 0; i--) {
      x[i] = B[i];
      for (int j = i + 1; j < n; j++) {
        x[i] -= A[i][j] * x[j];
      }
      x[i] /= A[i][i];
    }
    return x;
  }
  int main() {
    // 5 coefficients of a system of unknown equations
    vector<vector<double>> A = {
      { 765.9,  873, 2, 50, 1},
      { 894.5,  818, 2.5, 52, 1},
```

```
        { 1226.3,  1074, 3.5, 55, 1},
        { 820.5,  992, -2, 4,5, 60,1},
        { 1033.3,  959,  1, 5,  64,1}
    };
    vector<double> B = { 10, 12, 14, 17, 19 };
    try {
        vector<double> result = gaussElimination(A, B);
        cout << “Solution to the system of equations:” << endl;
        cout << “a”<< “ = “ << setprecision(6) << result[0] << endl;
        cout << “b”<< “ =” << setprecision(6) << result[1] << endl;
        cout << “c”<< “ =” << setprecision(6) << result[2] << endl;
        cout << “d”<< “=” << setprecision(6) << result[3] << endl;
        cout << “e”<< “ = “ << setprecision(6) << result[4] << endl;
          } catch (const runtime_error& e) {
        cout << “Error:” << e.what() << endl;
    }
    return 0;
}
```

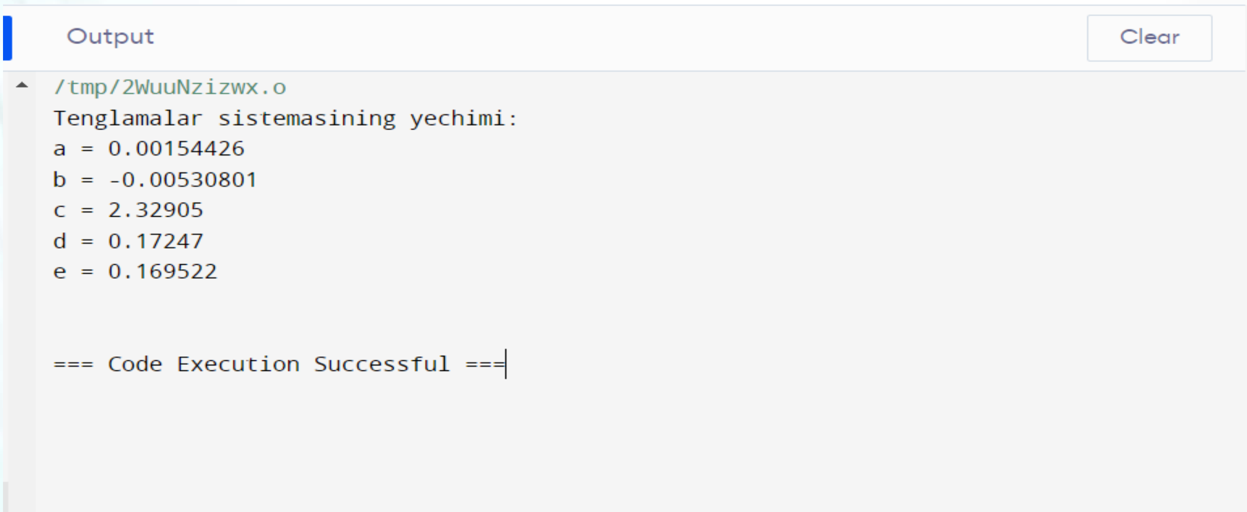

Figure 4. The result of determining the wagon turnover in a C++ program using a regression model and ECCU

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Based on the results obtained during the modeling process, the following universal function was generated:

$$\theta = 0{,}00154426Q - 0{,}00530801N + 2{,}32905L + 0{,}17247V + 0{,}169522 \quad (6)$$

As a result, the following graphs were generated (Figures 5-8)

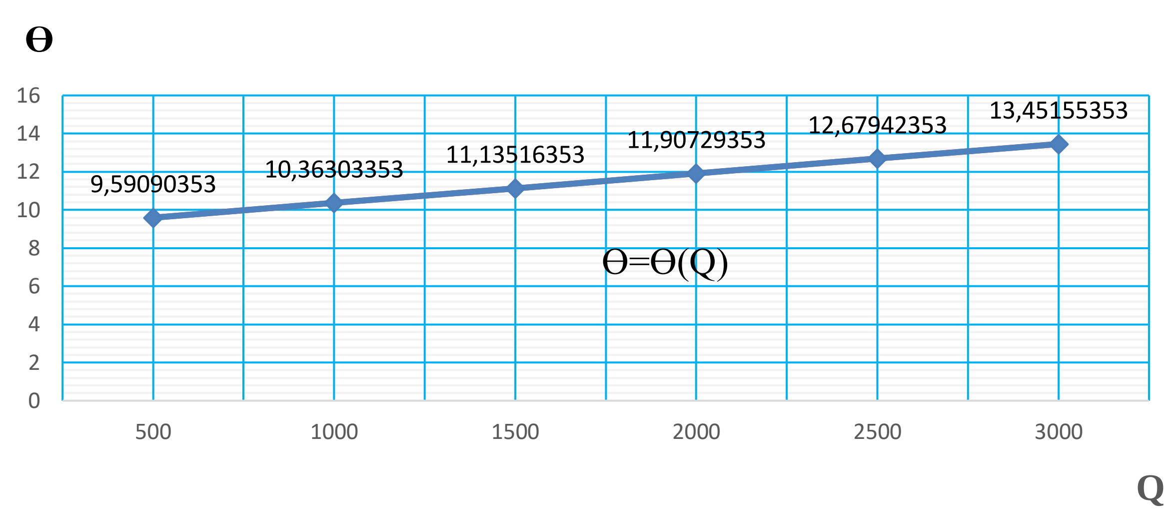

Figure 5. Graph of wagon turnover versus cargo volume

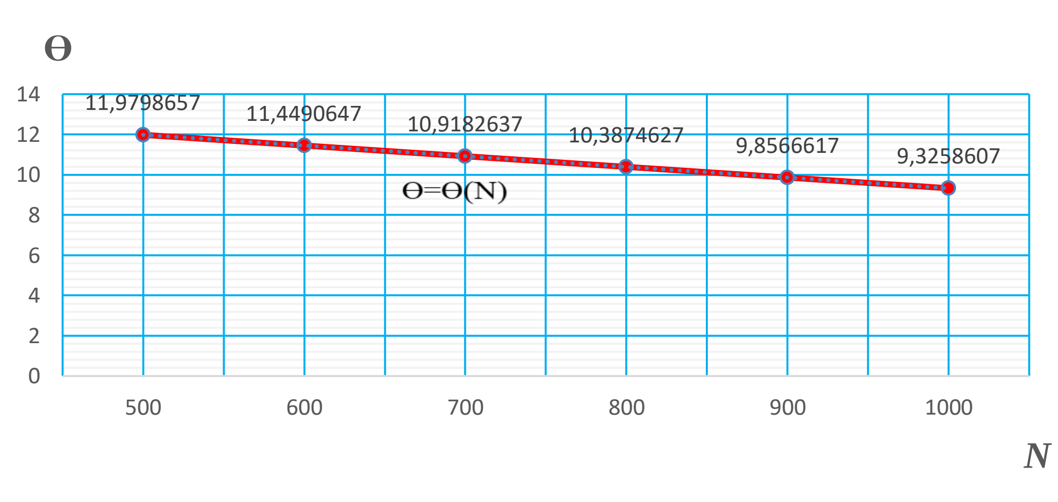

Figure 6. Graph of wagon turnover versus wagon volume

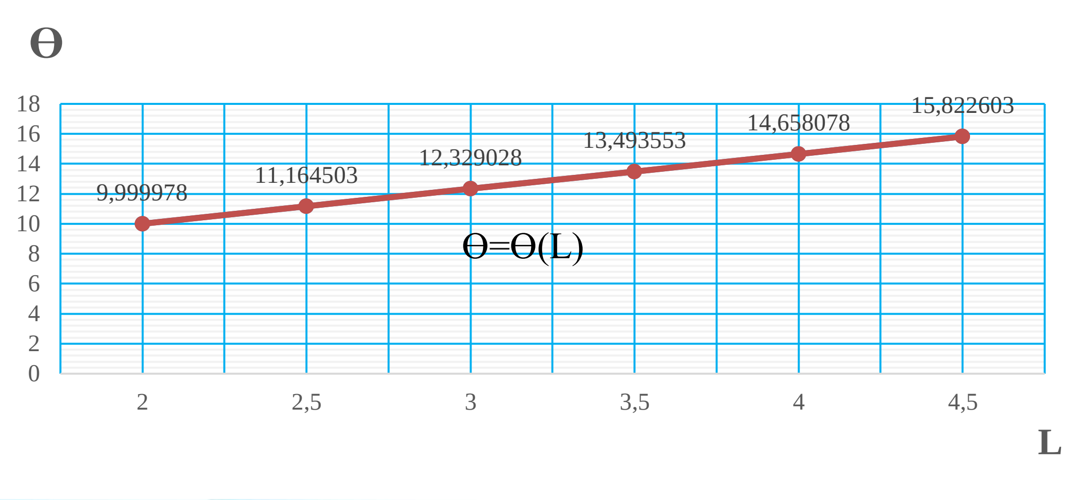

Figure 7. Graph of the dependence of the wagon turnover on the length of the branch line

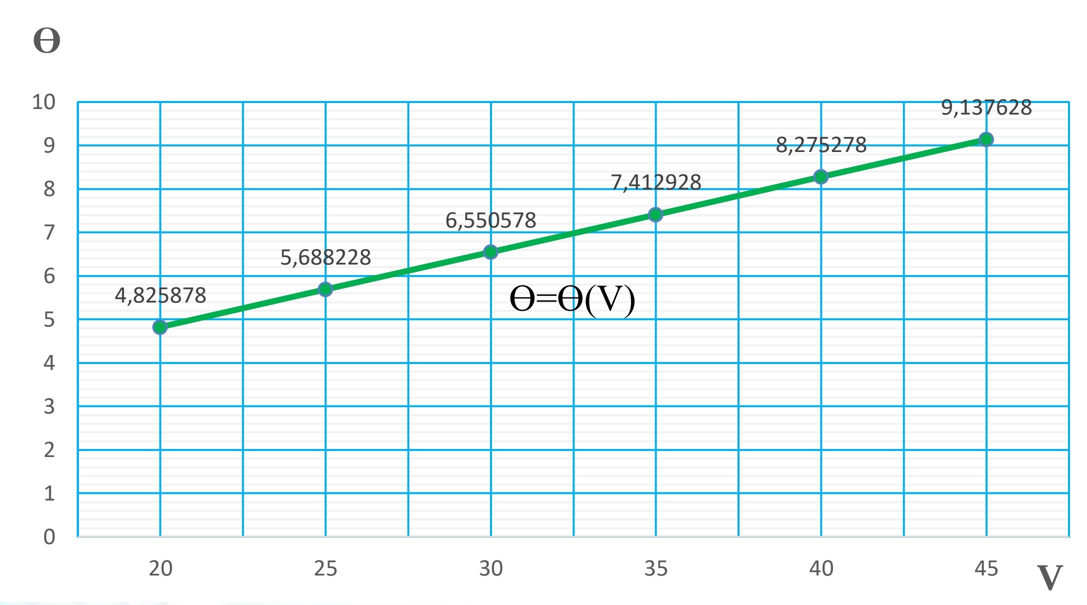

Figure 8. Graph of the dependence of the wagon turnover on the section speed

The calculation results showed that there is a need to improve the work processes of the “Karshi” station. Taking this into account, a multi-factor empirical function of the wagon turnover time at the station was developed using regression modeling and the least squares method, which are considered mathematical modeling methods for improving the station’s work processes. Based on this function, it is possible to determine the wagon turnover time proportionally to the length of the tracks, the length of the loading and unloading front, the station's cargo and wagon turnover, and the speed of the train.

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