Development of the fundamentals for organizing the transportation of local goods on the railways of the republic of Uzbekistan

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Abstract. Target: The article discusses the approach to variant calculations of a phased increase in line capacity, modeling of a traffic management system aimed at meeting transportation needs and finding a balance between schedules of various categories of trains in the train schedule configuration to improve the efficiency of local freight transportation. **Methods:** The article uses methods from the theory of operational work, development of train schedules, graph theory, methods of system and cluster analysis, mathematical statistics, economic and mathematical modeling. **Results:** two-level model of transport and logistics regional network; iterative algorithm for assigning reference stations; approach to calculating the optimal weight of a local train; algorithm and recommendations for drawing up daily train schedules with local cargo. **Practical significance:** the results will make it possible to develop rational options for the movement of trains with local cargo on schedule in conditions of increasing transit freight traffic.

1 Introduction

Transport corridors of Central Asia passing through the territory of the Republic of Uzbekistan are key links in trade, economic and transit relations between Europe and Asia, where rail transportation plays an important role in increasing the efficiency and sustainability of the flow of goods, determining modern Central Asian transport policy. In the context of an increase in the level of transit freight traffic, Uzbek railways face the problem of maintaining the achieved volumes of transportation of local goods, ensuring a stable position of the industry in the domestic market of transport services. Solving the problem requires the implementation of new technologies for organizing local transportation, aimed at improving the quality of transport services in the regions and, in particular, reducing delivery times and reducing the time spent by goods along the route [1, 3, 5].

As a rule, acceleration of cargo delivery time is achieved through intensive development of railway infrastructure, train routing and organization of freight traffic on schedule.

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2 Local transport organizations

In conditions of increasing the level of transit freight traffic, Uzbek railways face the problem of maintaining and increasing the volume of transportation of local goods, which in the main nomenclature of bulk cargo in recent years show an increasing trend, and in the category of other (consumer goods, semi-finished products, household appliances, etc.) are sharply declining, a trend towards a sharp reduction (Fig. 1), leaving volumes of motor transport [2, 4, 6].

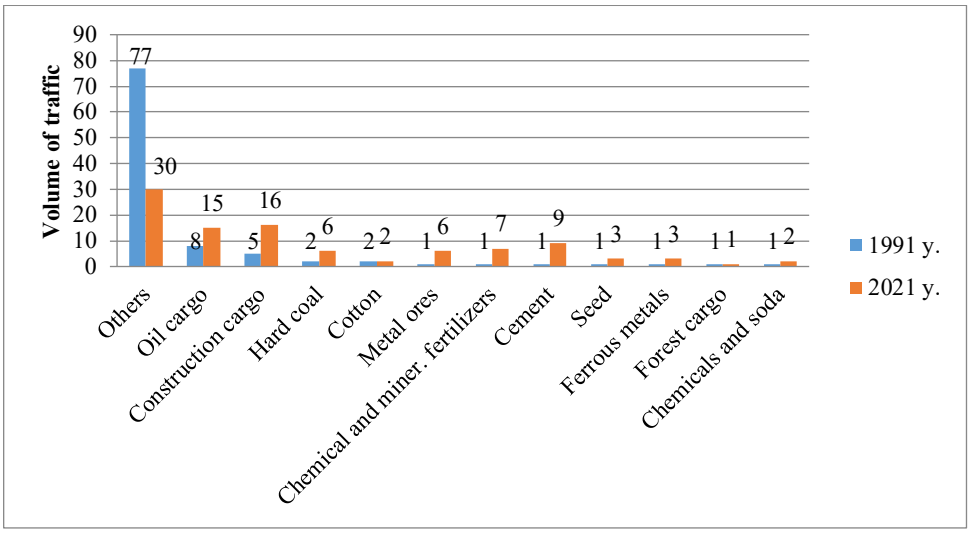

Fig. 1. Change in the volume of transportation of local goods by "Uzbekistan Temir Yullari" JSC

The problem of local transportation is associated with the insufficient development of railway infrastructure, the lack of terminals in inland regions and poor convergence of technologies, which creates bottlenecks for the passage and processing of local freight traffic. The analysis shows that with the total length of the railways of the Republic of Uzbekistan being 6950 km, the length of double-track lines is 680 km (10%), electrified lines are 2500 km (36%). Capacity in some sections, such as the Pap-Marakand section, is close to exhaustion [11, 13, 15].

3 Approach to assessing the gradual strengthening of the capacity of sections of railway lines of the Republic of Uzbekistan

To generate a forecast estimate of cargo flow Q_t comparative calculations were carried out fortwo polynomial models: linear and parabolic, and, ultimately, the parabolic model (1) was used with the best convergence with the supposedly uniformly accelerated development of traffic volumes:

$$\begin{cases} \sum Q_t = a_0 \cdot n + a_1 \cdot \sum t + a_2 \cdot \sum t^2 + \ldots + a_p \cdot \sum t^p, \\ \sum Q_t \cdot t = a_0 \cdot \sum t + a_1 \cdot \sum t^2 + a_2 \cdot \sum t^3 + \ldots + a_p \cdot \sum t^{p+1}, \\ \ldots, \\ \sum Q_t \cdot t^{p-1} = a_0 \cdot \sum t^{p-1} + a_1 \cdot \sum t^p + a_2 \cdot \sum t^{p+1} + \ldots + a_p \cdot \sum t^{2p-1}, \\ \sum Q_t \cdot t^p = a_0 \cdot \sum t^p + a_1 \cdot \sum t^{p+1} + a_2 \cdot \sum t^{p+2} + \ldots + a_p \cdot \sum t^{2p}. \end{cases} \quad (1)$$

where *ai* – the parameter of the polynomial, $i = 0, 1, \ldots, p$; t – time, $t = 1, 2, \ldots, n$, Q_t – actual cargo flow, million tons; $\overline{Q}_t$ – estimated values of cargo traffic, million tons; n – the number of levels of the dynamic series.

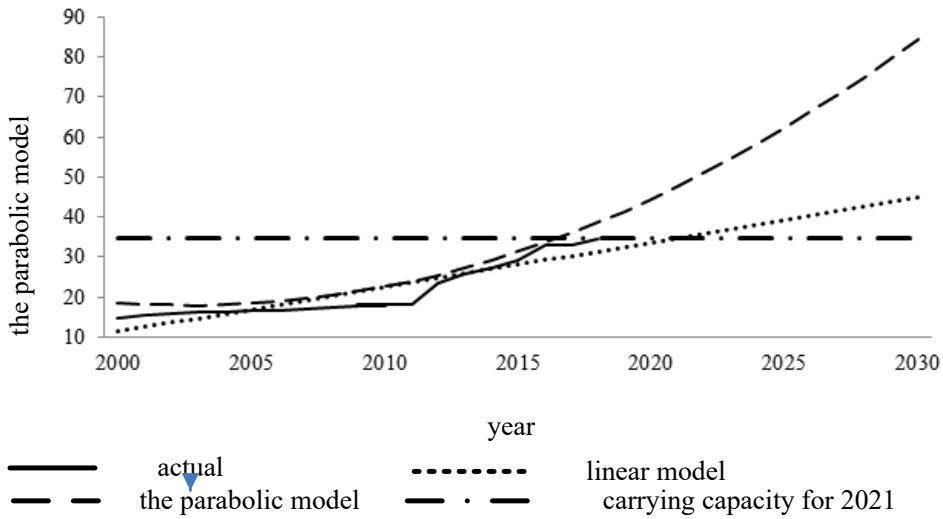

Fig. 2. Comparison of the forecast growth of freight traffic obtained from linear and parabolic polynomial models on the Akhangaran -Tukimachi - Syrdarya line

Based on the received models $\overline{Q}_t = 21.36 + 1.12 \cdot t + 0.09 \cdot t^2$ forecast built changes in freight traffic in relation to the most heavily loaded sections of the Uzbek railways along the Akhangaran -Tukimachi - Syrdarya line (Fig.2).

In accordance with the forecast data, an option has been justified for strengthening the throughput and carrying capacity of the sections under consideration, characterized by minimal construction and operating costs Эcarr with maximum net present value (NPV):

$$\begin{cases} Э_{carr} = \sum_{t=0}^{T} \frac{K_t}{(1+E_r)^t} + (1-\gamma) \sum_{t=0}^{T} \frac{C_t}{(1+E_r)} \to min \\ \text{NPV} = \sum_{t=0}^{T\sum} \frac{R_t - З_t}{(1+E_r)^t} - \sum_{t=0}^{T} \frac{K_t}{(1+E_r)^t} \to max \end{cases} \quad (2)$$

where T – the duration of the billing period; Er – discount rate (in fractions of one); Kt – – capital investments at the t-th step of calculation; Ct – annual operating costs in the t-th

year; γ – share of tax deductions from profits, Rt – results (income) achieved at the t-th step of the calculation; Ct – costs (current costs) incurred at the t-th step [6, 8, 10].

As a basis for assessing the stages of development of local transportation on the railway lines of the Republic of Uzbekistan, a two-level model of the transport and logistics network is proposed, where the 1st levelis formed by a set of logistics storage and distribution centers (LSDCs) with production/consumption centers (PC) linked to them; and the 2nd level - by transport logistics centers (TLC) at support stations (SS), connected with consignees and shippers by road transport (Fig. 3).

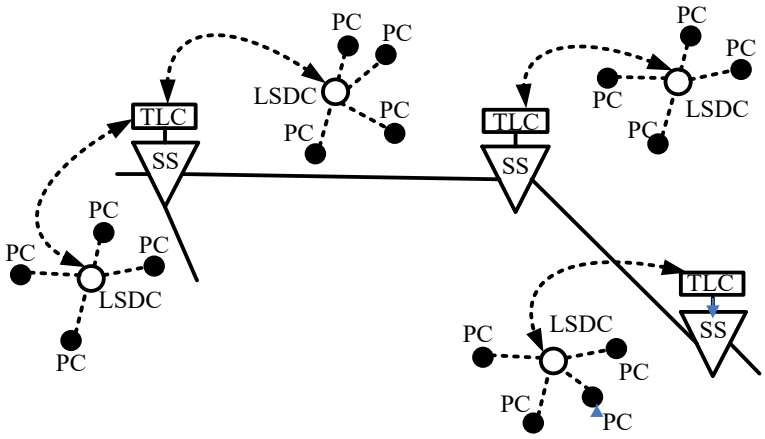

Fig. 3. Two-level model of the transport and logistics network of local transportation

An iterative algorithm for assigning operating systems is proposed for a given location of SS and their production weights (volumes of local cargo sent and received) on a given topology of the transport and logistics network, consisting of 3 stages.

The initial data for the operation of the algorithm are: a set of CP objects C = {c1,…, cn}, their production weights V = {v1, …, vn} and admissible set of LSDCs B= {b1, …, bp}, where each j-th PC and each LSDCs are specified in the G-dimensional space RG, i.e. cj = (cj1,…,cjG) and br = (br1,…,brG).

At the first stage of iterations using the k-means cluster analysis method, the partition S* is found based on known PC location point S* = {S*1,…,S*k} set C into the k-th regions of gravity of the PC with undisplaced centers – LSDCs, where D*⊆ B, B={D*, C}, and possible locations of the LSDCs are determined [7, 9, 17].

At the second stage, using the expert assessment method, primary assessments of the purpose of the SS are given according to 6 groups of criteria: 1) location of the station on the railway line network; 2) the presence of rational connections between the station and the road network; 3) the nature and scope of the station's work; 4) track development of the station; 5) the presence of existing and newly created freight yards and/or terminals at the station; 6) proximity of the station to existing and/or created TLCs.

The obtained results of assigning SS according to the proposed groups of criteria, their comparison with the results of using the single "loading/unloading" criterion are shown in Fig. 4.

At the third stage of iteration, the nearest distances between the TLCs interacting with pre-assigned SSs and the LSDCs on a given topology of the transport network are determined using the single link method.

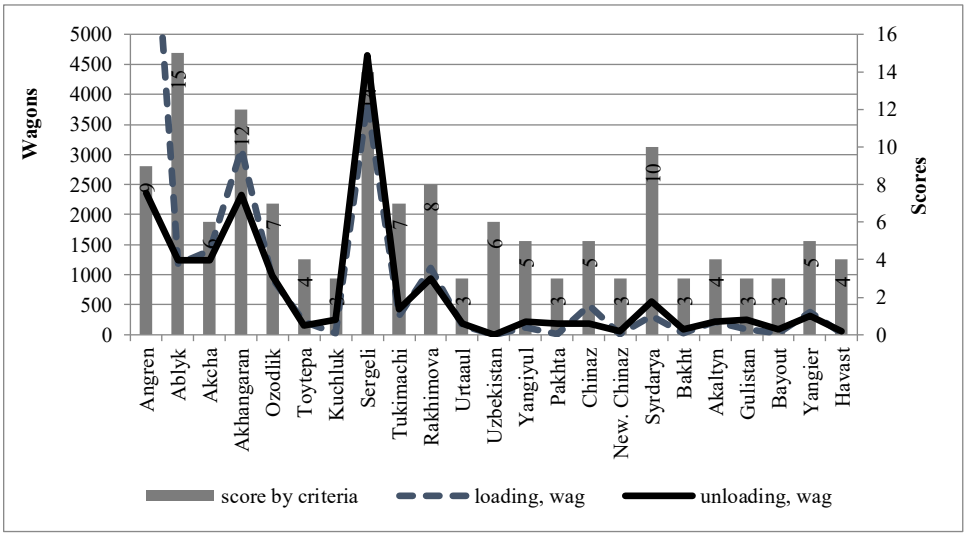

Fig. 4. Results of expert assessments of the purpose of the SS

The criterion for completing iterations is the amount of total costs for the transportation of goods and the development of infrastructure facilities. Taking into account the degree of proximity of the SS to the PC guarantees minimization of transportation distances, and taking into account the production scales of the PC optimizes the costs of developing the LSDC and TLC [10, 12, 14, 16].

Further search for rational options strengthening the throughput and carrying capacity of lines with assigned OS is carried out within the framework of a closed directed graph (Fig. 5).

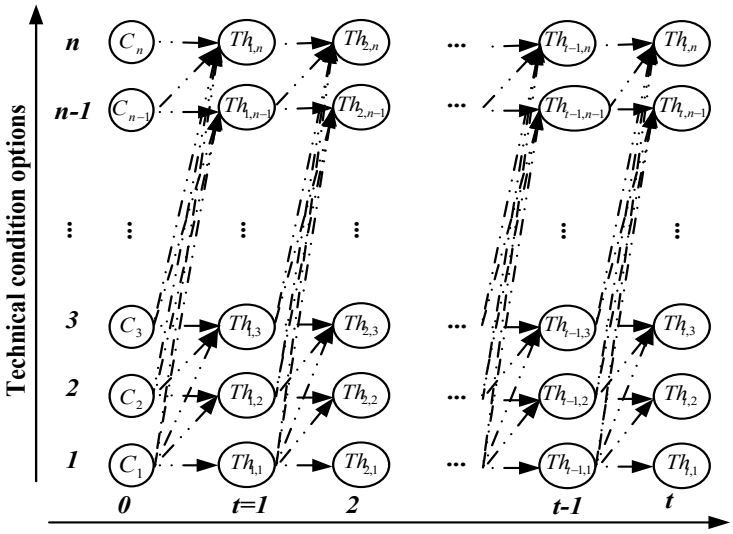

Fig. 5. Search graph for a rational option for increasing capacity

Within the graph, determining the conditionally optimal throughput S_j at step t is carried out in accordance with (2) according to the objective function

$$O_{t,j} = \min(O_{t-1,j} + \Delta O_{t,j}(S_i^j)), \tag{3}$$

Where $O_{t,j}$ - minimum annual construction and operating costs to achieve in a year t values S_j; $O_{t-1,j}$ - the same for the previous year $t-1$ (meaning - S_i); $\Delta O_{t,j}(S_i^j)$ - increase in costs when moving from value S_i to S_j; $\Delta O_{t,j}(S_i^j) = C_{i\to j}\alpha_t - Th_{t,i}\alpha_t$, Where - $C_{i\to j}$ capital costs for transition from i - th to j - th throughput value; $Th_{t,i}$ - operating costs for i - th value of throughput; α_t - cost discounting factor. Thus, for each throughput value (variant of the technical condition) of the section at each step t there is a single transition that gives minimization (3).

4 Development of the basics for organizing the transportation of local goods

The model for organizing freight transportation is determined by the transportation capacity of the lines, which depends on the number of freight trains and their weight. In accordance with this, to build the foundations of the technology for organizing local transportation, a formula is used to determine the optimal gross weight of freight trains:

$$Q_{br}^{opt} = \sqrt{\frac{Tf_{acc}Le_{cr}\left(\frac{1}{v_{\text{acc}}}+\frac{T_{\text{st}}}{L_{tech}}\right)}{\alpha\left(\frac{e_{id}^{acc}c}{q_{\text{br}}}+\frac{c_c e_c \alpha}{q_n}\right)}} \tag{4}$$

where Tfacc – the traffic flow of local cargo per day (in one direction), t; L – total travel distance of the freight train, km; ecr – cost of 1 hour of work of locomotive crews; vacc – running speed of a freight train with local cargo, kmph; Tst – crew work time at turnover points, h; Ltech – length of the traction arm, km; α – the ratio of the net weight of the composition to the gross weight; eidacc – costs per 1 wagon-hour of idle time for wagons with local cargo; c – accumulation parameter; qbr – gross weight of one car, t; cc – parameter characterizing the process of cargo accumulation in the cargo terminal; ec – expenses per 1 hour of cargo being in the cargo terminal, in an amount equal to the carrying capacity of the car; qn – average weight of one car, i.e.

It is proposed to set the running speed of trains with local cargo in order to parallelize the traffic schedule in accordance with the running speeds of transit freight trains. It is proposed to determine the route speed of trains in accordance with the result of the delivery time T_{del}^{rw}:

$$T_{del}^{rw} = \frac{L}{v_{loc}} + \sum t_{sup} + \sum t_{tech}$$

Where L - the distance between the SS of departure and destination; v_{loc} - local train speed; t_{sup} - time spent on SS for uncoupling and trailering along the route; t_{tech} - time spent on technical operations at technical stations along the route to find t_{sup} It is proposed to use the calculated dependence presented in Fig. 6.

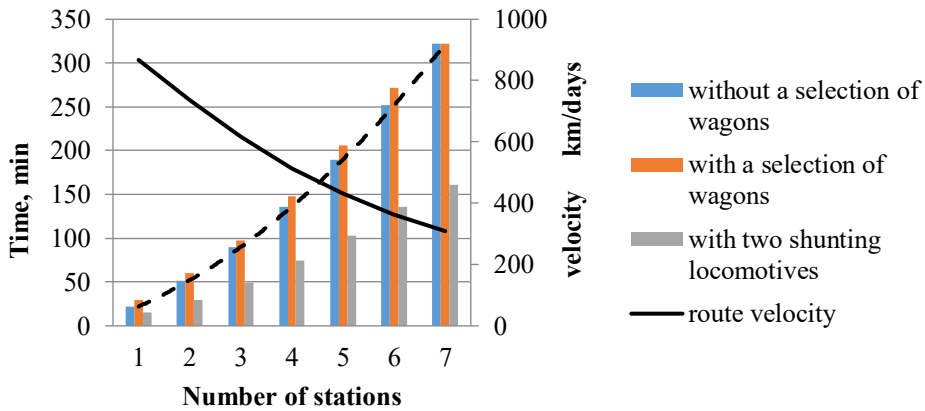

Fig. 6. Time spent at reference stations

Based on the above, an algorithm has been constructed (Fig. 7) for compiling a daily schedule for trains with local cargo based on developed traffic patterns along bypass and parallel lines of the direction in question under the conditions of providing "windows".

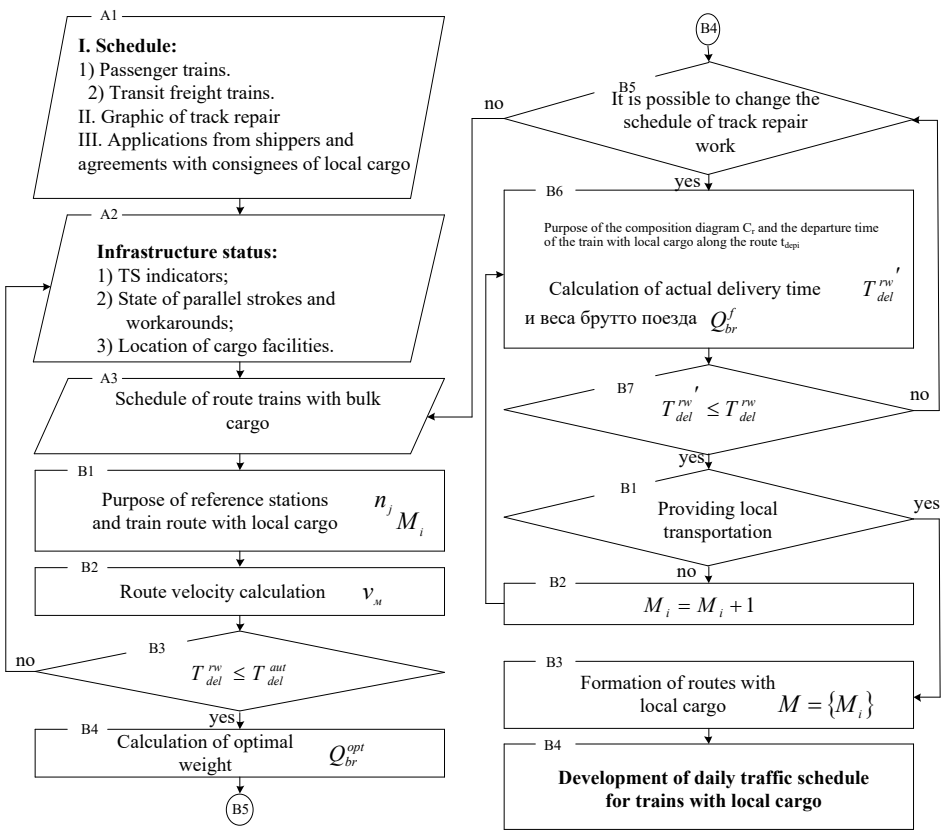

Fig. 7. Algorithm for compiling the daily schedule of trains with local cargo.

Blocks A – Initial data; blocks B – Route formation; blocks B – Development of daily cargo

5 Conclusion

Thus, the difficulty lies in finding the optimal balance between phased reinforcement plans capacity of sections, based on the development of individual stations, and a system for organizing the required volumes of transportation. In this regard, the problem is to determine the criteria and algorithm for assigning reference stations that interact with the logistics centers being created to build a scheme for the phased development of infrastructure and form the foundations of a model for organizing local transportation in the context of the implementation of the line reconstruction plan.

Based on the results of modeling the technical condition of the sections, it is necessary to select a competitive local transportation scheme and develop a new approach to organizing the transportation of local goods for the railways of Uzbekistan. The proposed principles for organizing the transportation of local goods on the railways of the Republic of Uzbekistan generally correspond to the basics of the Freight Express technology used on the railways of the Russian Federation.

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