Stage of Development of the Railway Section

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Abstract—Railway infrastructure (in this article it is considered as a public way, railway stations and railway tracks) - as a logistics object increases discretely due to the application of technical and technological solutions. The aim of the study is to substantiate the most rational way of gradual development of the Ahangaran-Tukimachi-Syrdarya railway section. The research methodology is based on the theory of phased development of railway networks. Results of the research: variants of the schemes of stage-by-stage development of the Ahangaran-Tukimachi-Syrdarya section were obtained. Conclusions: Based on the results obtained, conclusions were drawn about the need for a more in-depth analysis of possible project solutions.

Keywords: railway transport, railway section, carrying capacity, cargo transportation, stage of development

I. INTRODUCTION

The planned China-Kyrgyzstan-Uzbekistan railway route is the shortest route from China to Europe and the Middle East. However, the dilapidated fixed assets of the railways significantly reduce their reliability and throughput capacity, especially in the context of dynamic growth in freight traffic. This problem is related not only to the development of new or improved existing technical solutions, but also to technological solutions related to the planning, organization and management of traffic flows in the future. After the launch of the China-Kyrgyzstan-Uzbekistan railway line, the Tukimachi station will become a major railway hub at the crossroads of North-South and East-West transport routes. The station is located within the metropolitan area and serves the country's strategic facilities. Therefore, there is no possibility of further development of station parks and tracks.

In this connection, in order to solve the problems of development of perspective volumes of cargo flows, this study proposes the ways of stage-by-stage development of the Ahangaran-Tukimachi-Syrdarya section. They consist in the following:

- determination of current and prospective carrying capacity, as well as throughput capacity;
- prediction of prospective traffic volumes after the launch of the China-Kyrgyzstan-Uzbekistan railway line;
- identification of possible options for technical and technological development of the Ahangaran-Tukimachi-Syrdarya railway section;
- selection of a rational option for cargo flow development in the future;

- to develop a proposal for an alternative railway line that would fully meet the transportation needs taking into account their growth;
- economic assessment of the proposed measures.

II. LITERATURE REVIEW

In recent years, many scientists have been involved in solving the problems of gradual development of railway lines. The authors Park, B. and Kim C. in their study [1] have proposed models to optimize the planning of railway sections, which determine the rational frequency of train departure, which could meet the requirements of passenger departure, minimizing costs. The study examines two tasks of planning railway sections, taking into account stopping schemes. The article [2] considers that an important strategic element in the process of planning a railway operator is the development of a rational routing plan, which is operated at a given interval. The authors of the article [2] presented several models for solving the problems of planning lines. The article [3] describes China's high-speed rail (HSR) as an example. The authors believe that the main factor of HSR development in China is the result of the fact that the Chinese government should develop the competence of strategic technologies. In the paper [4], based on the analysis, the authors developed two new alternatives for the phased development of the railway section. This paper [5] presents a system of support for spatial decision-making for the design of railway sections, which can be built in stages over time. To begin with, a mixed whole-number program is used. Then, since such projects can be built at once or in stages, the authors have developed a heuristic procedure of the reverse sequence of time with a correction factor. The article [6] discusses the optimal choice of railway sections with periodic schedules on the railway. The selected section system should have sufficient capacity to service the traffic flow. The authors introduce the formulation of mixed integer linear programming. This article [7] describes the methodological process of development and evaluation of the interactive railway system. The process is called U-model. The article describes a recent case study in which a U-model has been adapted and used during a project that includes the development of a decision support system for railway investments. The authors of the paper [8] used the "Rail + Property" or R + P model in order to obtain transit costs for financing railway infrastructure. The analysis of sources has shown that to date, the practical application of the proposed ways to increase the carrying capacity does not provide a rational solution to this issue. Therefore, these methods do not take into account all possible measures to increase the carrying capacity of railways, due to the limitations of the schemes under consideration. Now there is
a necessity of development of a technique on the organization and development of freight traffic on a network which has not lost the urgency and is the important scientific problem.

III. CHARACTERISTICS OF THE EXISTING AHANGARAN-TUKIMACHI-SYRDARYA RAILWAY SECTION.

The main characteristics of the technical condition of the railway section, which influence the value of the capacity, include: the number of main tracks of the station, the useful length of the receiving and sending tracks, etc. (See Fig. 1).

IV. DETERMINING THE CARRYING CAPACITY.

Available capacity of single-track sections not equipped with automatic interlocking is determined in train pairs by formula:

\[
N_{avail} = \frac{(1440 - t_{tech}) \cdot \alpha_n}{T_{per}} = \frac{(1440 - t_{tech}) \cdot \alpha_n}{\sum t_x + \tau_a + \tau_b}
\]

where \(T_{per}\) is the period of the travel schedule, min; \(\sum t_x\) is the total travel time of a train pair along the limiting run, taking into account its acceleration and deceleration, min; \(\tau_a\) and \(\tau_b\) is, respectively, the station intervals for separate points, and \(b\) min; \(t_{tech}\) is the duration of the daily budget of the time allocated for scheduled repair and maintenance works, min; \(\alpha_n\) is the coefficient that takes into account the reliability of technical facilities (infrastructure and rolling stock).

In the partial-batch diagram, the capacity value depends significantly on the packet ratio \(\gamma_{pack}\) which is the ratio of the number of trains allowed to pass in packages to the total number of trains, as well as the number of trains allowed to pass in one package, "K".

\[
N_{avail} = \frac{K \cdot (1440 - t_{tech}) \cdot \alpha_n}{(T_{pack} + t_a + \tau_a + (K - 1) \cdot t_x + (T_{pack} + t_a) \cdot \gamma_{pack})}
\]

Carrying capacity depends on train pairs

\[
G_{avail} = \frac{365 \cdot N \cdot \varphi_n}{K_n \cdot 10^6}, \text{mln. ton/year}
\]

Figure 2 shows the changes in the carrying capacity of the Ahangaran-Tukimachi-Syrdarya section depending on the existing and necessary capacity of the section and the calculated values of levels obtained on the basis of two models: linear and parabolic [14].
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Figure 2: Schedule of changes in carrying capacity of the Ahangaran-Tukimachi-Syrdarya section

The graph shows an increase in capacity in the Ahangaran-Tukimachi section from 2000 to 2030. The increase in freight traffic in 2012 was influenced by the electrification of the line, as well as the launch of the Angren logistics center, which serves large enterprises of the Fergana Valley, such as the Assaka Automobile Plant, Fergana Oil Refinery and other economic enterprises. Commissioning of the Angren-Pap line in 2016 affected the growth of cargo traffic at this section. In the long term, the construction of the China-Kyrgyzstan-Uzbekistan railway line will also have an impact on the increase in freight traffic by several times. In addition, the number of local and long-distance passenger trains increases every year. The diagram shows the carrying capacity for each stage of technical and technological development of the section, taking into account the existing and necessary capacity. The increase in freight traffic by 2030 requires the strengthening of the single-track line capacity and the construction of a second main line or a new Ahangaran-Syrdarya railway line. The nature of the sequential development of the railway sections, taking into account the changes in existing and required capacity, will be discussed in Figure 3.

Figure 3: Character of phased development of railway sections

V. RESEARCH METHODOLOGY

Figure 4 shows a fully enclosed directional graph illustrating the described computational process. To simplify the structure of the graph, the index $k$, which fixes the type of cargo, is not taken into account in its construction [15]. Horizontally (abscissa axis) the positions corresponding to successively changing $j$ values are marked; vertically (ordinate axis) for each $j$ the nodes of the graph are indicated. The number of nodes of the graph corresponding to conditionally optimal values $\hat{z}_j$ is determined by the number of combinations $C_{N-r}^N$ or $C_{N-r}/N$. The nodes of the graph contain conditionally optimal values of the target function $\hat{R}_j$.

Figure 4: Searching for a rational option to increase bandwidth

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The critical path marked by a bold line begins at one point, for which \( j = N \), and ends at the point where \( j = 1 \). This path indicates the process and direction of the search. On this path there is a node of the graph corresponding to the optimal parameters of the structure of the park \( \{ j^i \} \) and \( z^i = \{ z^j \} \). You can search through the nodes in the opposite direction (from points \( j = N \) and \( j = 1 \)).

VI. SELECTION OF POSSIBLE STATES OF TECHNICAL EQUIPMENT OF THE AHANGARAN-TUKIMACHI-SYRDARYA RAILWAY SECTION.

To date, the reserve capacity of the Ahangaran-Tukimachi-Syrdarya railway section varies from 5 to 10 pairs of trains on average. To be more precise, the Ahangaran-Tukimachi section ranges from 0 to 5 pairs of trains, and the Tukimachi-Syrdarya section from 11 pairs of trains and above. This primarily depends on the terrain, stationary tracks, as well as the system of regulation of the interval between trains (see Table 1). However, with significant cargo flows after the launch of the China-Kyrgyzstan-Uzbekistan railway line, train downtime at technical stations may increase dramatically, waiting for a congestion to pass through the limiting section, which results in missed delivery times. In the future, there comes a point when the single-track line (Ahangaran-Tukimachi) will not be able to master the growing cargo flow. All possible options are presented in Table 2 to select activities aimed at increasing the capacity.

The choice of measures is based on the following technical and technological solutions:

- the need to increase the useful length of the receiving and shipping lanes. Today, some of the plant tracks are less than 850 m long, which greatly affects the throughput capacity. Here we can also note the inefficiency of further extension of the useful length of the receiving-and-departure lines by 1250 meters due to the weight fracture of less than 2600 t to Pap station (see Table 1);
- the need to construct additional separate points. The average length of the section is approximately 12 km, which also affects the capacity of the section. There is a need to construct a crossing on the restrictive Kuchluk-Jaloir span;
- construction of a second railway line;
- Table 1 shows that part of the Ahangaran-Syrdarya section is equipped with semi-automatic blocking, which indicates the advisability of switching to semi-automatic blocking;
- the expediency of using an auto locking with a partial batch schedule of trains is also considered.

The specified ways of increase of throughput and carrying capacity can be carried out in various combinations of stagnation, proceeding from concrete conditions of work of a researched site. In each specific case, there is a quite definite optimal sequence of possible activities and the most expedient dispersal of technical terms. At the same time, the total transportation costs will be minimized over the entire period of the line operation, up to its conversion into a double-track one.

| Table 2. Possible characteristics of Ahangaran-Tukimachi-Syrdarya railway section |
|----------------------------------|----------------------------------|
| I. Ahangaran - Tukimachi, a single-track railroad line equipped with a semi-automatic locking system (SAL). Useful length less than 850 m (the conditional length of the train is 54 wagons) |
| II. Ahangaran - Tukimachi, a single-track railway line equipped with SAL. Useful length of receiving and dispatching tracks is 850 m (the conditional length of the train will be 57 wagons) |
| III. Construction of a passing-track on the limiting span Kuchluk-Jaloir with useful length of receiving and dispatching tracks - 850 m. |
| IV. Ahangaran - Tukimachi, single-track railway line, transfer from SAL to autolocking (AL), with \( \gamma_{pack} = 0 \). Useful length of receiving and dispatching tracks is 850 m. |
| V. Ahangaran – Tukimachi, single-track railway line, transfer from SAL to AL, \( \gamma_{pack} = 0.3 \). Useful length of receiving and dispatching tracks is – 850 m. |
| VI. Ahangaran – Tukimachi, single-track railway line, transfer from SAL to AL, \( \gamma_{pack} = 0.6 \). Useful length of receiving and dispatching tracks is – 850 m. |
| VII. Ahangaran – Tukimachi, single-track railway line, equipped with AL, with \( \gamma_{pack} = 0 \). Useful length of receiving and dispatching tracks is – 1050 m. |
| VIII. Ahangaran – Tukimachi, single-track railway line, equipped with AL, \( \gamma_{pack} = 0.3 \). Useful length of receiving and dispatching tracks is – 1050 m. |
| IX. Ahangaran – Tukimachi, single-track railway line, equipped with AL, \( \gamma_{pack} = 0.6 \). Useful length of receiving and dispatching tracks is – 1050 m. |
| X. Construction of a second railway line on the section Ahangaran – Tukimachi, equipped with AL. |
| XI. Construction of a new single-track electrified railway line Ahangaran-Сырдарьинская, equipped with AL. |

In order to choose a lot of competitive schemes, it is necessary to define a lot of logical contradictory states, and for the Ahangaran-Syrdarya section they are manifested in the following:

6-7 the contradiction is that at the sixth stage the site is equipped with an auto locking with a patchiness coefficient \( \gamma_{pack} = 0.6 \), and at the seventh stage \( \gamma_{pack} = 0 \).

6-8 the contradiction is that at the sixth stage the section is equipped with an auto locking with a patchiness coefficient \( \gamma_{pack} = 0.6 \), and at the seventh stage \( \gamma_{pack} = 0.3 \).

Based on the above considerations, possible schemes of development of the Ahangaran-Tukimachi-Syrdarya railway direction are given (see Fig. 5).
Further in work the graph of variants of schemes of development of site Ahangaran-Tukimachi-Syrdarya (see figure 6) is resulted set of schemes with an initial condition $C_i$ and with final $C_{911}$. Table 3 shows a fragment of the list of competitive schemes.
On the column of variants of schemes of stage-by-stage development of the investigated site there are numerous schemes with the initial state of $C_1$ and $C_{10}$ with the final state. Table 3 shows a fragment of the list of possible schemes.

**Table 3 - Schemes of development of the investigated area (Fragment of the table)**

<table>
<thead>
<tr>
<th>№ patterns</th>
<th>Possible development patterns</th>
<th>№ patterns</th>
<th>Possible development patterns</th>
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<tbody>
<tr>
<td>S₁</td>
<td>$C_1-C_3-C_7-C_9-C_10$</td>
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<td>$C_1-C_3-C_7-C_9-C_10$</td>
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<tr>
<td>S₂</td>
<td>$C_1-C_3-C_7-C_9-C_{11}$</td>
<td>S₉</td>
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<td>S₄</td>
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<tr>
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<td>S₁₄</td>
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</table>

VII. DISCUSSION OF RESULTS.

The development of the new Ahangaran-Syrdarya railway section proposed in this study is one of the priorities due to the possibility of reducing delivery times. As it represents the hypotenuse of the triangle with the Syrdarya-Tukimachi and Tukimachi-Ahangaran catheters (see Figure 7).

Figure 7 - Example of a plan for a new Ahangaran-Syrdarya railway section

The route of the new Ahangaran-Syrdarya section could be ideal if it was a straight line as in the plan (see figure 8), the length of which is 82.9 kilometers.
However, this is not always possible because of approaches to settlements or cities such as Dustabad, Akkurgan and Pskent (see Figure 8). This is also complicated by bypassing natural (rivers and mountains) and artificial (Sardobinskoye reservoir) obstacles and uneven surfaces, especially from the Ahangaran station.

**VIII. CONCLUSIONS.**

On the basis of the conducted researches on justification of stage-by-stage development of Ahangaran-Tukimachi-Syrdarya railway direction the following conclusions can be made:

1. While forecasting the cargo flow, it was found out that in the near future it will be necessary to increase the throughput and carrying capacity of the existing single-track Ahangaran-Tukimachi-Syrdarya line, which, in turn, is feasible with the use of a number of less expensive measures than the construction of the second main line.

2. The analysis of all possible measures to increase the carrying capacity is carried out taking into account the possible growth of traffic volumes.

3. The new Ahangaran-Syrdarya railway section will allow to unload the Tashkent metropolitan area, excluding motor transport downtime at railway crossings, and will also allow to optimize cargo flows.

4. The results of the study will create conditions for the development of prospective volumes of rail traffic after the commissioning of the China-Kyrgyzstan-Uzbekistan railway line.

5. The new railway line will ensure the development of such cities as Dustabod, Akkurgan and Pskent, as well as the region as a whole.

**REFERENCE**


