ANALYSIS OF THE NETWORK OF LOGISTICS CENTERS IN UZBEKISTAN USING ECONOMIC AND MATHEMATICAL MODELLING

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Abstract: The article considers the development of a network of logistics centers (LC) in Uzbekistan using the method of economic and mathematical modelling. The application of this method allows optimizing the location of LC, forecasting cargo flows and increasing the efficiency of transport infrastructure. Calculations confirming the need to modernize the existing logistics system are presented.

Key words: logistics centers, transport infrastructure, economic and mathematical modelling, cargo flows, forecasting, optimization.

Introduction

The development of transport and logistics infrastructure plays an important role in the economy of Uzbekistan. However, the existing network of LC is unevenly distributed, which creates barriers to efficient freight transport. This analysis is based on the method of economic and mathematical modelling, which allows to determine the optimal location of logistics centers to reduce time and financial costs[1].

Research Methodology

Economic and mathematical modelling was used to solve the following problems:

- determination of the optimal number and location of LC, taking into account the density of cargo flows.

- forecasting changes in freight traffic volumes up to 2030;

- assessing the impact of logistics centers on reducing transport costs;

Uzbekistan's economy has performed well in recent years due to the impact of a favorable external environment and improved infrastructure.

A consistent territorial policy aimed at creating the necessary conditions for economic growth in the regions through the effective and rational use of natural and economic potential, modernization and technical re-equipment of leading industries and structural transformation, and improvement of the quality and living conditions of the population has made it possible to ensure sustainable development of virtually all regions of Uzbekistan in 2021-2023, which is reflected in the indicators of socio-economic development of the of Uzbekistan.

In such relatively underdeveloped regions as Surkhandarya, Namangan, Khorezm oblasts and the Republic of Karakalpakstan, a trend of sustainable and progressive economic development has emerged. High rates of GRP growth in recent years have been observed in Andijan, Kashkadarya oblasts and the city of Tashkent, which is due to an increase in the growth rates of value added in industry and services.

There have been certain changes in the territorial structure of the gross regional product. Thus, the contribution of Andijan, Kashkadarya, Samarkand, Tashkent and Fergana oblasts to the growth of the country's economy has increased over the past period. The specific weight of Andijan, Kashkadarya, Samarkand oblasts and Tashkent city increased in industry.

As a result of structural transformations aimed at increasing the production of competitive

industrial products with high added value, the share of industry in GRP increased in most regions. Significant growth of the share of industry in the structure of the economy was ensured in Andijan, Kashkadarya, Navoi, Samarkand, Tashkent and Fergana regions, which was due to the development of the electric power, chemical and petrochemical, fuel, light, food, machine-building and construction materials industries. In the conditions of increasing demand, special attention was paid to the growth and saturation of consumer goods in both domestic and foreign markets. High growth rates of consumer goods production were observed in Andijan, Jizzak, Namangan oblasts and Tashkent city.

Sustainable development of agriculture in the regions is mainly associated with the activities of farms, which make a high contribution to the increase in agricultural production. The growth rates in Andijan, Kashkadarya, Namangan, Syrdarya and Tashkent oblasts have noticeably increased.

The territorial structure of agriculture has not undergone dramatic changes, which is explained by the general decline in the industry's share in the country's GDP.

Thus, due to increased investment activity, the economic potential of the regions increased. Investment growth rates for 2021-2023 in 9-10 regions out of 14 were higher than the national average (109.6%).

Tashkent city (19.9 per cent and Kashkadarya province (19.2 per cent) are the most "invested" in the structure of investments. High specific weight is also noted in Tashkent (8.8 per cent), Navoi (5.5 per cent), Bukhara (8.9 per cent), Fergana (5.6 per cent) oblasts, and the Republic of Karakalpakstan (9.4 per cent). In recent years, there has been a trend of redistribution of investments to the regions. Thus, if for 2018-2020, 22.0% of the country's investments were allocated to Tashkent City, then for 2021-2023, this indicator has decreased - 18.7%.

The investment attractiveness of Syrdarya, Jizzak and Khorezm oblasts remains low, which is why the share of industry in these regions in the total volume of industrial production of the republic is traditionally small.

High growth rates are observed in retail turnover, especially in the Republic of Karakalpakstan, Jizzak, Bukhara, Navoi, Samarkand, Syrdarya and Tashkent regions. During the analyzed period, all regions provided stable growth rates for paid services. The growth of turnover and paid services was greatly influenced by the growth of effective demand of the population due to the growth of their incomes. Over the years of independence, the incomes of the population have increased tenfold, especially due to the development of entrepreneurship and small business.

The territorial structure of retail turnover and paid services did not undergo cardinal changes, which is explained by insufficiently accelerated development and restructuring of the services sector, especially in the territorial context.

During the analyzed period, the export potential of the regions has significantly increased due to the growth of such export goods as energy resources, services, cotton-fiber, machinery and equipment, non-ferrous metals, mineral fertilizers. The same regions traditionally remain the main exporters of domestic products.

It should be noted that, despite the stable rates of development, interregional differentiation in the real sector of the economy increased in almost all territories of the country in 2021-2023. Only in agriculture the differentiation decreased. However, in 2022-2023 there is a positive trend towards a decrease in interregional differentiation in the production of industrial products (from 20.6 times to 19.9 times), consumer goods (from 15.1 times to 13.6 times), retail turnover (from 7.6 times to 6.9 times) [1]

The reasons for the growth of interregional differentiation are, on the one hand, objective (differences in the natural and economic potential of the regions), on the other hand, subjective - insufficient consideration of territorial factors in the development and implementation of targeted sectoral programmers, as well as insufficient activity of regional administrative bodies to support and stimulate local producers, development of trade and paid services.
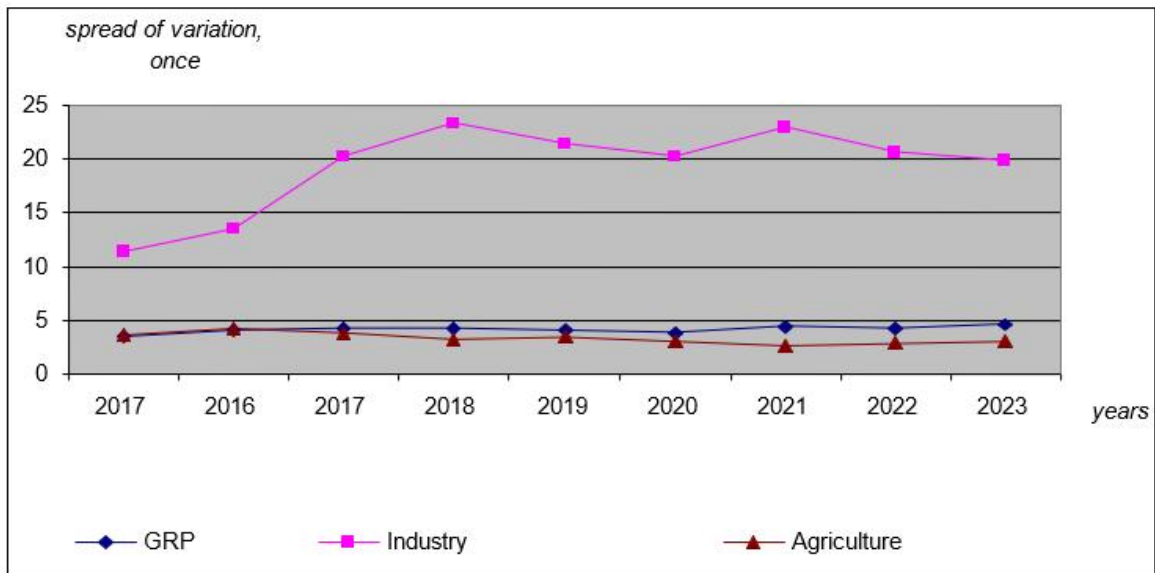
Fig.1. Dynamics of changes in the level of differentiation of socio-economic development of regions

To characterize the main indicators of socio-economic development of the Republic of Uzbekistan, let us present graphs showing the change in these indicators for the period 2021-2023 (Fig.1).

The change in gross regional product (billion sums) is presented in the graph (Fig.2).
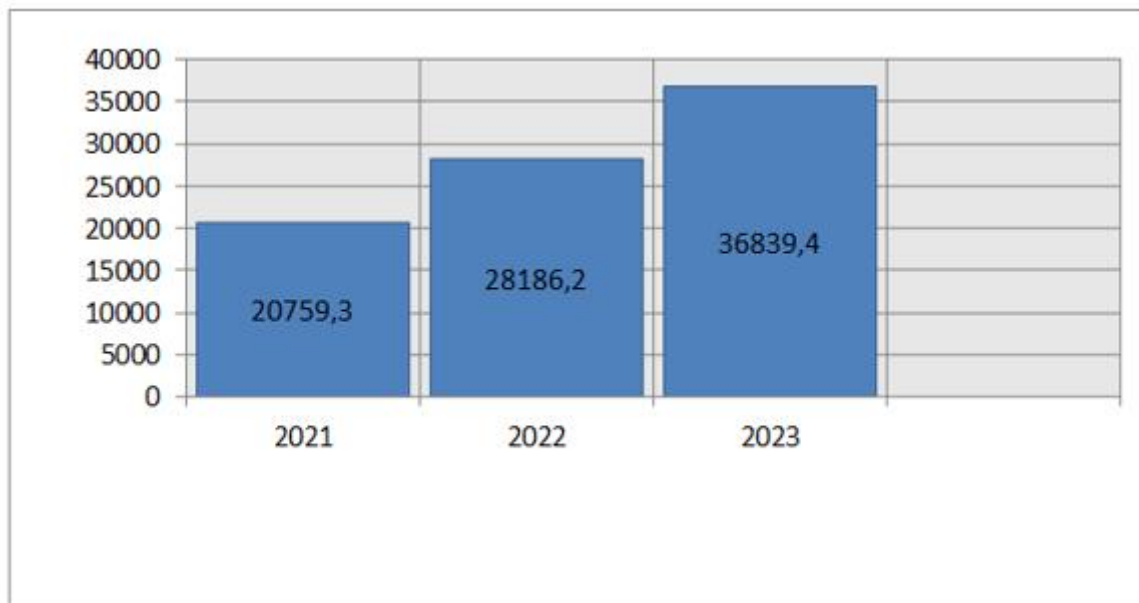

Fig.2. Graph of changes in gross regional product for the period 2021/2023

The change in industrial production for the same period is presented in the following graph (Fig.3).
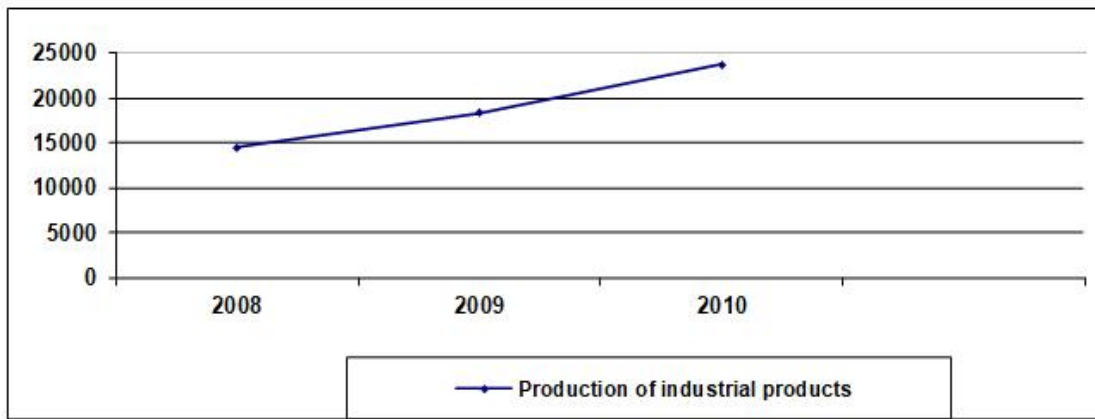
Fig. 3. Industrial output (billion UZS)

One of the main types of products produced in the republic is agricultural production. Its dynamics for the period 2021-2023 is characterized by the following diagram (Fig.4).
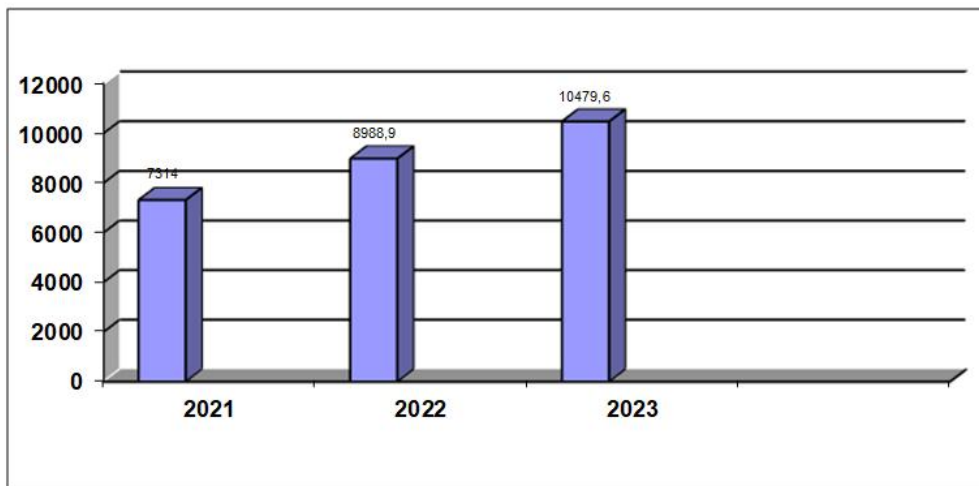

Fig. 4. Graph of changes in agricultural production

Every year in the republic, budgetary funds are invested in various sectors. In general, in 2023 the amount of investments totaled 8483.7 billion sums. At the same time, the investment growth rate in 2023 was 128.3 per cent compared to 2022, while in 2022 the investment growth rate was 122.9 per cent.

The volume of paid services provided to the population is growing from year to year. Thus, in 2023, their value totaled 4474.6 billion sums, which is 20.6% more than the level of 2021.

The value of exports from the Republic of Uzbekistan can be characterized by the following values: 11572.9 million USD. The value of exports from the Republic of Uzbekistan can be characterized by the following values: 11572.9 million USD and 128.7 % growth rate compared to 2022[1,2,8].

Mathematical programming techniques were used for the analysis, including:

1. Linear programming to minimize the cost of freight transportation[3,4,6,7].

The aim is to minimize transport costs:

$$Z = \sum_{i-1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \rightarrow \min \qquad (1)$$

constraints:

$$\sum_{i-1}^{m} x_{ij} \quad d_j, \quad \forall_j = 1, ..., n$$

$$\sum_{i-1}^{m} x_{ij} \quad s_i, \quad \forall_j = 1, ..., n$$

$$x_{ij} \quad 0, \quad \forall_{i,j}$$

Where:

c_{ij} - cost of transporting cargo from point i to point j;

x_{ij} - the volume of cargo being transported;

s_i - is the available cargo volume at point i;

d_j - is the required volume of cargo at point j.

2. The gradient descent method is used to optimize freight flows and minimize costs:

$$\theta = \theta - \alpha \frac{\partial J(\theta)}{\partial \theta} \tag{2}$$

Where:
θ - parameters to be optimized;
α - learning rate coefficient;
$J(\theta)$ - cost function.

3. Stochastic modelling to account for uncertainties in freight flows, Markov chain model is applied[5]:

$$P(X_{t+1} = s_t / X_t = s_i) = p_{ij} \tag{3}$$

Where:

p_{ij} - probability of transition from state s_i to state s_j at time $t+1$;

X_i - state of cargo flow at time t.

4. Sensitivity analysis was used to determine the degree of influence of key parameters on the location of LC. The parameters investigated were:
- change in freight tariffs. A modelling exercise was conducted in which rail tariffs were increased by 10% and decreased by 10%. The results showed that when tariffs are increased, the load on road transport increases, while when they are decreased, the demand for railway LC increases;
- changes in transport accessibility. Scenarios of road network modernization in regions with low logistics activity (e.g. Khorezm and Surkhandarya regions) were considered. Improved infrastructure in these regions allowed redistributing some of the freight flows, reducing the load on the central hubs;
- cargo flow density. The sensitivity to a 15% upward and downward change in the volume of cargo flows was analyzed. It was revealed that an increase in cargo traffic requires additional modernization of existing LC in Tashkent and Navoi oblasts, while a decrease in traffic allows redistributing the load without significant investments.
Thus, the method of sensitivity analysis allowed us to identify critical factors affecting the location of LC and to propose adaptive strategies for their development.
Statistical indicators on freight transport in Uzbekistan for 2021-2023 are applied as input data, including:

- Traffic Transportation volume (1,095.7 million tons in 2023, up 13.4% from 2022);
- Cargo turnover (78.1 billion ton-km, down 6.9%);
- Share of railway transport (24.2 billion ton-km, up 3.4%).

Results of the study
The analysis showed that a rational reallocation of LC would:
- Reduce the average cost of transport by 12-15% by reducing the empty mileage of wagons and trucks;
- Increase the capacity of the logistics system by 20% through redistribution of cargo flows;
- Optimize transport routes, resulting in an 8-10% reduction in delivery time.
The use of the model also made it possible to identify optimal points for the construction of new LC, taking into account the coefficients of freight traffic density, transport hubs and foreign trade flows. According to the calculations, the strategically important areas for the creation of new LC are:
1. Tashkent region - as a central hub for cargo distribution (15% growth in cargo traffic in 2023);
2. Navoi - taking into account integration with an international multimodal center and an 18% increase in export traffic;
3. Termez - due to increased transit traffic to Afghanistan (22% increase over 2021-2023).

Conclusion
Application of economic and mathematical modelling allowed to identify key areas for the expansion of the LC network and determine their impact on logistics processes in Uzbekistan. The use of mathematical programming and sensitivity analysis methods ensured route optimization, cost reduction and development of the country's multimodal transport infrastructure. Further application of the model can become the basis for long-term planning of the logistics network and increasing the competitiveness of the transport complex of Uzbekistan.

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