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Efficiency of Transport Infrastructure in Asian Russia, China, Mongolia, and Kazakhstan in the Context of Creating New Trans-Eurasian Transport Corridors

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Abstract: This article discusses the efficiency of transport infrastructure and cooperation of neighboring regions located in Asian Russia, China, Mongolia, and Kazakhstan in the context of creating new international economic corridors from the Silk Road and trans-Eurasian transport corridors. This study aims to highlight the possible ways of strengthening cross-border cooperation in the field of transport infrastructure. We evaluated the current state of the transport infrastructure, the dynamics of its development, and its influence on the territorial–production complex. Using quantitative data and the unified indicator for the efficiency of transport infrastructure, we also characterized the territorial differentiation, its causes, and prerequisites for further economic and trade cooperation between these countries. The main results are as follows: (1) The lowest levels of the efficiency of transport infrastructure are typical for the northeast of Asian Russia, as well as for the border regions of China, Mongolia, and Kazakhstan. (2) For Asian Russia, Kazakhstan, and Mongolia, the highest levels of the unified indicator are typical for regions located along the main transport routes and for regions with a developed mining industry. This is due to the strong unevenness of the socio-economic development of the territories. (3) The largest industrial and economic centers have been developing along the main transport corridors primarily due to the accumulated potential of equivalent freight turnover and export potential. This study can be useful for authorities and business, as well as for other users of transport infrastructure to improve its regulation and efficiency.

Keywords: transport infrastructure; international cooperation; transport corridors; border areas

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1. Introduction

In the modern world, transport infrastructure is an important economic system that facilitates main social processes, domestic production, and international cooperation [1,2]. In the context of globalization, the improvement of transport infrastructure is the key to economic well-being and successful integration into the world economic system with its standards [3]. From this perspective, the improvement of transport infrastructure together with active involvement in the newly announced international transport corridors along the Silk Road and the Tea Route are among the priority areas of cooperation between Russia, China, and Mongolia [4].

For the first time, such new cooperation projects have been officially mentioned in a Memorandum of Understanding between Russia, China, and Mongolia, which was signed by the heads of states in Ufa, Russia, on 9 July 2015. It stipulates the intention of the parties to develop a program for the creation of the China–Mongolia–Russia economic corridor. The program itself was signed a year later in Tashkent on 23 June 2016, with annexes that included a list of 32 projects for creating the China–Mongolia–Russia economic corridor, 13 of which are related to transport infrastructure. It was specially noted that this program is not an international treaty, shall not create rights and obligations governed by international law, and shall not affect the rights and obligations of the parties under international treaties [5].

The program provides for strengthening of cooperation in the following areas:

- Integrated development of transport infrastructure;
- Modernization of checkpoints, customs, and quarantine control;
- Industry and investment;
- Trade and economic relations;
- Environmental protection and ecology;
- Regional and cross-border cooperation [6].

In addition, the program calls for the modernization of old lines and the construction of new meridional transport routes from China to Russia through the Mongolian territory [7,8]. However, such megaprojects require an analysis of the existing transport infrastructure and scientific rationale for long-term development plans [9,10].

Improving transport infrastructure is of paramount importance for cooperation among countries along the international transport corridors of the Silk Road and the Tea Route. The successful implementation of these important projects as well as the growing competition among key economic corridors, such as the Trans-Siberian Railway, the Baikal–Amur Mainline, and the Sino–Kazakh border route for cargo transshipment from Far Eastern ports to Europe, have aroused great scientific interest for further study.

First, there is a need for scientific assessment of the infrastructure readiness and competitive advantages of these territories. Secondly, it is crucial to evaluate the existing risks that may affect the profitability of the highways due to increasing competition, as well as their socio-economic and environmental implications within the studied regions.

Against the backdrop of expected growth in trade and economic relations and increased infrastructural connectivity, the transit and economic importance of the border areas between the three countries is increasing. This trend has the potential to stimulate the resolution of prevailing ethno-cultural, socio-economic, and environmental issues.

Thus, the hypothesis of this study is that the efficiency of transport infrastructure is influenced by factors such as the geographical location, presence of main transport routes, and level of industrial development in a region.

This study aims to identify the possible ways of strengthening cross-border cooperation in the field of transport infrastructure.

To achieve this goal, several tasks have been undertaken: (1) An assessment of the current state and development trends of the transport infrastructure has been conducted, along with an examination of their impact on the territorial–production complex. (2) Using quantitative data and a unified indicator for measuring the efficiency of transport infrastructure, a characterization of territorial differentiation has been undertaken, along with an exploration of the underlying causes. (3) The study seeks to identify the prerequisites for further economic and trade cooperation between the countries involved.

2. Literature Review

A literature review revealed a number of studies on the effectiveness of transport infrastructure and the formation of international transport corridors. Recent studies focus on the integration of national transport systems into the international ones to develop cross-border economic relations [11–14]. The authors of [15] evaluate the possibility of creating alternative routes to take the competitive advantages of cross-border transit through the national territory. It was found that the most important nodes of the existing railway transport networks have varying accessibility in different territories [16]. Some research studies analyze the regional processes in the key areas for the Russian transit potential [17], and international economic competition for participation in transport cross-border projects [18]. Among infrastructure problems, a number of researchers note the need to improve the efficiency of existing international transport routes [19–21].

A number of studies devoted to the analyses of efficiency of transport infrastructure have been carried out in the last decades. They consider the transport infrastructure connectivity using data envelopment analysis (DEA) [22]; review the regional development context [23] and influence on urban land use [24]; and evaluate railways and highways [25,26]. The theoretical background of the transport infrastructure development [27] and sustainable transportation aspects [28] are considered.

However, there are virtually no studies devoted to a comprehensive assessment of the effectiveness of the transport system that take into account the level of development of international cooperation. The vast majority of studies focus on local assessment without considering the prospects of international integration for the development of international transport corridors. We believe it is important to comprehensively characterize the regions and territories under study, to analyze the state of the transport systems of border territories, and to suggest proposals for improving the efficiency of the systems. It is necessary to expand and justify the framework of evaluation indicators. This shows the importance of using new approaches based on quantitative assessment for managing the development of transport infrastructure of the region and the relevance of this study.

The scientific novelty of this study lies in a comprehensive assessment of the effectiveness of transport infrastructure in the Asian part of Russia, China, Mongolia, and Kazakhstan by means of an integral indicator. We characterized the transport infrastructure not only by indicators of availability and accessibility, but also by its productivity for an in-depth study of the mutual influence of infrastructure and the economy of a region. Using the selected basic and derived indicators, we assessed the current state and efficiency of transport infrastructure in these countries and made recommendations to increase the economic efficiency of their transport infrastructure. The results of this research can be used to improve development programs and for methodological recommendations, development strategies for Russian regions, and cross-border cooperation.

3. Materials and Methods

3.1. Study Area

In the study area investigated (Figure 1), we consider the transport infrastructure facilities, which play an important role in the territorial and economic structure and the transport connection between Asian Russia, China, and Mongolia [29–34].

To estimate the mutual influence of infrastructure and economy of the region, we studied the performance indicators of the transport infrastructure facilities with typical availability and accessibility characteristics [35–37]. Official statistical data from State Statistical Offices of the countries under study for 2019 (by region) were used [38–40]. We defined the current state and efficiency of the transport infrastructure in Asian Russia, China, and Mongolia using selected basic and derived indicators.

Figure 1. Location of study area.

3.2. Methodological Tools

In this study, we used methods of formal logic, a systematic method, statistical techniques, and a cartographic method; the analysis of socio-economic indicators was conducted using a cluster approach.

The efficiency of transport infrastructure was assessed through three main indicators reflecting the production, social, and communication functions of infrastructure facilities [41]. These indicators were calculated on the basis of source data on the region's population and performance of the transport infrastructure facilities [42,43]. We propose to use the methodological tools for comprehensive assessment of transport infrastructure development based on the social-economic approach. This differs from the sectoral approach in that it considers not only the level of development of transport infrastructure, but also its impact on development of the economic sectors, production, and social sphere of a region [44].

The analysis of the transport infrastructure performance is based on the development indicators, conventionally divided into three main groups:

1. Transport mobility of the population (T_H)—a social indicator for the transport infrastructure development ('social' component).

The transport-mobility-of-the-population indicator is equal to:

$$T_H = \frac{\sum HL_{pass}}{H} \tag{1}$$

where $\Sigma\ HL_{pass}$—passenger turnover, in passenger-kilometer; and H—population of a region [41].

2. Equivalent freight turnover (T_F)—an indicator for level of transport infrastructure development, showing the spatial distribution of productive power ('productive' component).

The equivalent-freight-turnover indicator is given by the formula:

$$T_F = \frac{\sum Q_i}{L} \tag{2}$$

where Q_i is the volume of freight transported, in thousands of tons, and L is the equivalent length of transport lines of a region, in kilometers [41].

3. Level of interregional cooperation ($C_{E/I}$)—an indicator characterizing transport availability in a region ('regional' component) [41,44,45].

The level-of-interregional-cooperation indicator can be calculated by using the equation:

$$\mathrm{C}_{E/I} = \frac{(P_E + P_I) * 10,000}{H} \tag{3}$$

where P_I—volume of imports in a region, in millions USD; P_E—volume of exports, in millions USD; and H—population [41].

Secondly, the standardized values were calculated, giving a unified indicator (I_j) that characterizes transport infrastructure availability and its efficiency. The formula for calculating the unified indicator takes the form of:

$$\mathrm{Ij} = \sum_{i=1}^{5} \frac{\mathrm{I_{ij}}}{\max\{\mathrm{I_{ij}}\}} \tag{4}$$

where I_{ij}—the partial indicator of density of infrastructure of *i*-type (railway, roads, etc.) for *j*-subnational entity (aimag, region, etc.) [41].

Finally, we grouped the studied areas depending on the values of the indicators used.

4. Results

4.1. Transport Mobility of the Population of Asian Russia, China, Mongolia, and Kazakhstan

The obtained data on the transport mobility of the population (Figure 2) generally reflect the current demographic processes. The highest rates of transport mobility are typical for provinces of China with a high population and corresponding passenger turnover (especially the most densely populated provinces of the central and eastern coastal parts of the country).

The increased territorial and socio-economic inequality in Russia and Mongolia result in lower transport mobility rates. The changes in the political and economic systems (the transition from a planned economy to a market economy) has intensified a number of transformation processes. Changes in the structure and sectoral specialization of the economy, changes in the population of settlements, the migration outflow of the population from small towns and rural areas, the growth of regional centers, and other factors have influenced the size, territorial concentration of the population, and, accordingly, passenger traffic. In Asian Russia, the main settlement zone along the Trans-Siberian Railway is characterized by the highest rates of the transport mobility of the population. Its relatively lower rates are typical for regions with high transport costs (due to the remoteness from the main highways, the large area of the territory, low population density, and an isolated position in terms of the territorial division of labor) [46].

Figure 2. Transport mobility (T_H) of the population of Asian Russia, China, Mongolia, and Kazakhstan.

Mongolia is currently undergoing the second wave of the band of settlement formation, when the population keeps concentrating along the south–north meridional corridor, which consists of the main line of Ulaanbaatar Railways and the highway. Along this corridor lives 77% of the country's population. The first wave was associated with the construction of Ulaanbaatar Railways and the emergence and growth of the main industrial centers of Mongolia: Ulaanbaatar, Darkhan, Erdenet, and other settlements along the railway [10,39,47]. The second wave of formation of the so-called main band of settlement has continued and increased significantly due to the socio-economic transformations after the collapse of the USSR. Intensification of desertification processes and deterioration of the socio-economic situation enhances migration of the population, especially young people [48]. There are some processes that eventually affect the rates of transport mobility of the population: an outflow of the rural population, the development of large cities and surrounding suburban areas, and the concentration and multiple growth of the population near the country's capital and large regional centers (Figure 2).

In Kazakhstan, the highest rates of transport mobility of the population are noted for areas located along the main meridional transport routes: Shymkent–Almaty–Astana–Petropavlovsk–Omsk (Russia) and Shymkent–Aktobe–Uralsk–Samara (Russia), as well as for two border regions: Turkistan and Pavlodar. These fairly high rates are explained by the territorial gap between the capital, Astana, and the more densely populated southern regions of the country. In addition, Kazakhstan is a transit country for passenger traffic between Kyrgyzstan, Uzbekistan, and Russia.

4.2. Equivalent Freight Turnover Rates for Asian Russia, China, Mongolia, and Kazakhstan

The levels of T_F demonstrate significant variations between the countries and regions studied (Figure 3). In Russia, the highest T_F rates are typical for the main industrial centers of the Urals, Western Siberia, and Kuzbass. The industrial production plays a greater role in the economy of the regions of Asian Russia than in the rest of Russia. In such a way, the share of industry in the GRP of the regions of the Urals, Siberia, and the Far East is on average 45–50% [38,49,50], which influences the T_F rates. Increased freight traffic volumes are typical for the constituent entities of the Russian Federation, in which resource-based and export-oriented industries are well developed. Traditionally, the level of development of transport networks significantly decreases from west to east. On the territory of the Far Eastern Federal District, the highest T_F rates are usual for the regions along the Trans-Siberian Railway.

Figure 3. Equivalent freight turnover (T_F) rates for Asian Russia, China, Mongolia, and Kazakhstan.

In China, the highest T_F rates are observed in the eastern coastal part of the country with large seaports and in the central well-industrialized territories. The rates significantly decrease from east to west, but high values are typical for the Chinese part of the Silk Road, the Beijing–Urumqi corridor.

In Mongolia, high T_F rates are observed along the Ulaanbaatar Railways, with the maximum values for the main industrial centers in the following aimags: Orkhon (city of Erdenet), Darkhan-Uul (city of Darkhan), and Umnugovi (Tavan Tolgoi and Oyu Tolgoi deposits).

In the territory of Kazakhstan, the T_F rates are quite high due to increased freight traffic volumes against the background of the low density of the transport network. The highest T_F rates are observed along the meridional transport routes: Shymkent–Almaty–Astana–Petropavlovsk–Omsk (Russia) and Shymkent–Aktobe–Uralsk–Samara (Russia). These are the main routes of communication between the densely populated southern regions and the most industrially developed northern regions. They are used both for the export of manufactured products and raw materials to Russia and as the main transit routes between Kyrgyzstan, Uzbekistan, and the Russian Federation.

The highest T_F rates are typical for the most industrially developed regions of Kazakhstan.

4.3. Level of Interregional Cooperation for Asian Russia, China, Mongolia, and Kazakhstan

The schematic map (Figure 4) shows the level of interregional cooperation ($C_{E/I}$), based on data on exports and imports.

In the territory of the Russian Federation, high $C_{E/I}$ levels are typical for regions with competitive industries, in particular the export of goods with a favorable price environment on world markets (primarily, the export of mineral raw materials, nonferrous and ferrous metallurgy products, and bioresources). At the same time, low $C_{E/I}$ levels are observed for regions with non-competitive industrial specialization or with a high share of non-manufacturing sectors in GRP. The northern regions are characterized by higher industrial and export potentials of economic sectors against the background of a low population density, which consequently leads to higher $C_{E/I}$ levels, in comparison with the regions located along the Trans-Siberian Railway. Despite this, the last-named regions are characterized by high T_H and T_F rates, which may be due to the prevalence of the transit potential over the export potential.

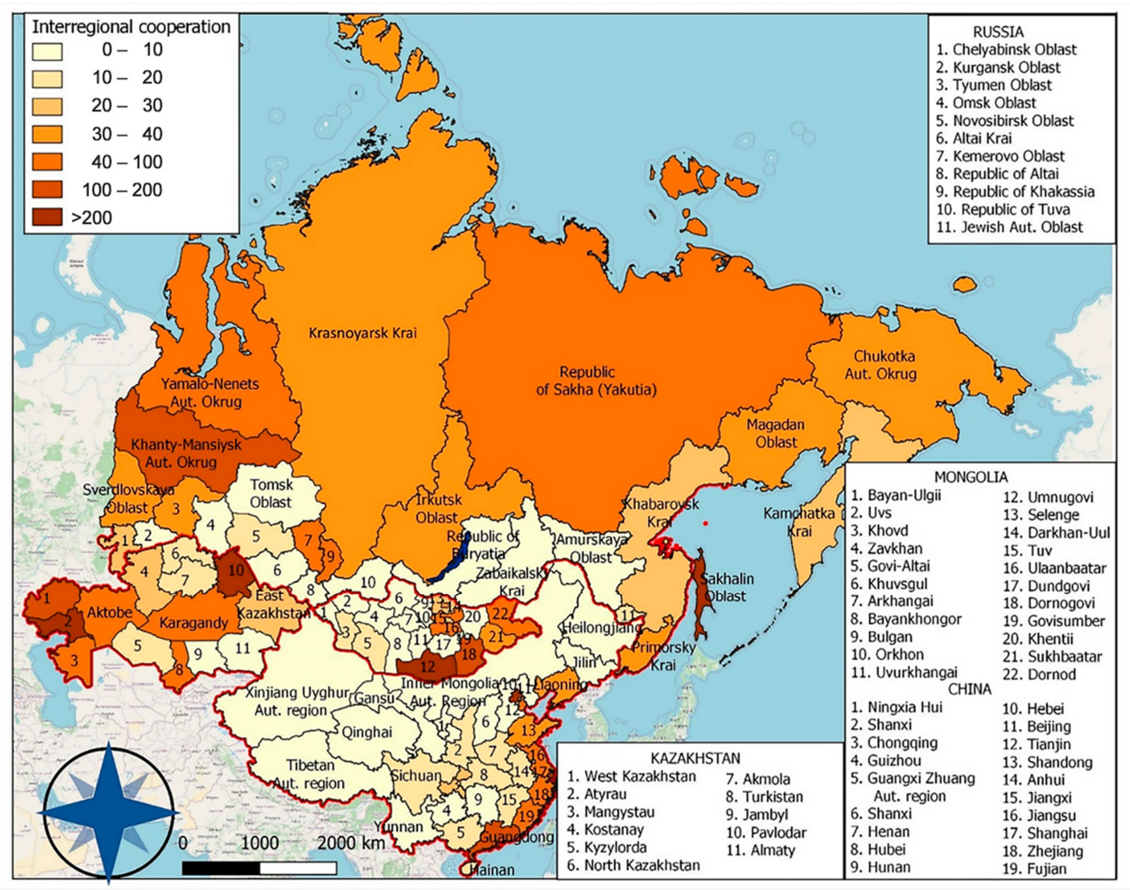

Figure 4. Level of interregional cooperation ($C_{E/I}$) for Asian Russia, China, Mongolia, and Kazakhstan.

In China, the maximum $C_{E/I}$ levels are typical for areas with high concentration of the world's industrial and logistics centers in the eastern coastal and central provinces. It should be noted that there is a high contrast between $C_{E/I}$ levels for, on the one hand, the economically developed eastern and central provinces, and, on the other hand, the outlying southwestern, western, and northwestern provinces and autonomous regions of China [51].

In Mongolia, the maximum $C_{E/I}$ levels are observed for the southern border aimags Umnugovi, Dundgovi, Dornogovi, Dornod, and Ulaanbaatar, the border aimag Selenge, and the Darkhan-Uul–aimag enclave. The observed export–import asymmetry between aimags is partially related to the specifics of statistical reporting, which is maintained by the main border checkpoints and customs posts. It means that a part of the products exported and imported by an aimag is preferably accounted for at the nearest customs post. Nevertheless, taking into account the border position (with border-crossing points) of 14 out of 21 aimags, the data obtained can be considered as reliable (and possible distortions—insignificant) [39].

In Kazakhstan, the $C_{E/I}$ levels, determined based on the exports and imports data, are quite variable. The highest $C_{E/I}$ levels are typical for the Pavlodar region bordering Russia; the western oil and gas production areas of the North Caspian; and the industrial centers in the northern Kazakhstan and Turkistan region bordering Uzbekistan and Kyrgyzstan.

4.4. Unified Indicator for the Efficiency of Transport Infrastructure in Asian Russia, China, Mongolia, and Kazakhstan

One of the most important results, in our opinion, is the characterization of the efficiency and availability of transport infrastructure facilities on the basis of the comprehensive assessment of territorial differentiation using the unified indicator (Figure 5).

Figure 5. Levels of the unified indicator (I_j) for the efficiency of transport infrastructure in Asian Russia, China, Mongolia, and Kazakhstan.

The lowest levels of the unified indicator for the efficiency of transport infrastructure are typical for the northeast of Asian Russia, as well as for the border regions of all the studied countries. These territories traditionally have poorly developed transport infrastructure, an uneven density of development, and difficult climatic conditions [52].

For Asian Russia, Kazakhstan, and Mongolia, the highest levels of the unified indicator are typical for regions located along the main transport routes and for regions with a developed mining industry. This is due to the strong unevenness of the socio-economic development of the territories due to the protracted systemic crisis after the collapse of the USSR. Almost throughout the entire territory of the former USSR and Mongolia, there was a decline in production, the consequences of which have not yet been overcome. The economic crisis has led to the destruction of production chains and changes in traditional sales markets and operating costs.

At the same time, some regions lost most of their industrial potential and former functions, which affected the socio-economic situation and infrastructure efficiency in these regions [53]. The recovery dynamics of the indicators during the 2000–2010 decade was largely due to the development of industrial production, mainly the raw materials sector. Production reallocation has led to the growth of industry in some regions and recession in others, aggravating territorial imbalances. Favorable conditions in the world commodity markets contributed to the growth of the economies of regions oriented to the export of mineral resources and the redistribution of socio-economic potential between regions [54]. This process has undoubtedly influenced the performance of the transport infrastructure.

Thus, the largest industrial and economic centers have been developing along the main transport corridors primarily due to the accumulated potential of equivalent freight turnover and export potential.

5. Discussion

The optimization of the transit potential of the largest transport routes is necessary in the light of strong competition in the field of export transportation in Russia. Among the possible ways are increasing freight and passenger traffic, increasing customs clearance capacity, development of the network of access roads, development of cross-border cooperation, and increasing the transport infrastructure capacity. The shortest railway line between Europe and Beijing may appear as a result of the 'Steppe Road' project implementation by Russia, Mongolia, and China.

The stimulation of traffic flow along the Northern Sea Route, as well as the growth of container traffic from China to Europe through the Sino–Kazakh border, may lead to a decrease in the profitability of the Trans-Siberian Railway and the Baikal–Amur Mainline Railway for the transshipment of freight from Far Eastern ports to Europe. Taking this into account, among the main economic priorities of the Russian export policy should be, first of all, radical modernization (electrification and laying of the second track according to Russian standards) of the Ulan-Ude–Ulaanbaatar–Zamyn-Uud railway, the shortest one between Europe and Beijing, and second, an increase in traffic flow through the customs posts of Zabaikalsk and Naushki.

Thus, Russia can still minimize the risks of 'implementation of projects of international transport corridors in neighboring countries, that reduce the attractiveness of the transit potential of the Russian Federation', which from the risk category is gradually turning into a real threat to the country's economic development [9,46].

The implementation of projects for direct transport links between Russia and China via Mongolia (as well as the possible construction of a gas pipeline) would provide all regions with the necessary energy and infrastructure conditions for the development of raw material resources and the growth of industrial production and promising investment prospects.

China's active participation in a variety of infrastructure projects in Mongolia points to growing competition in the region. For Russia, this could be a factor for increasing its industrial and export potential, active use of international logistics corridors, strengthening transit opportunities, and cross-border cooperation between Russia and Mongolia.

Some proposed routes of economic corridors of the Belt and Road Initiative, including the Silk Road Economic Zone and the 21st Century Maritime Silk Road projects, coincide with the Russian–Mongolian transboundary area. This creates conditions for the further strengthening of trilateral cooperation between China, Mongolia, and Russia [55] and creates prerequisites for building cost-effective value chain connections between the countries [56].

Against this background, the expected several-fold increase in trade–economic ties and partnership interaction can lead to a significant enhancement in the economic and geopolitical role of the border territories of the three countries. The implementation of such large-scale projects can lead to the mitigation of existing ethno-cultural, socio-economic, and environmental issues.

In this regard, cooperation between these countries in the areas of military and border security, environmental protection, and combating emergencies seems crucial. In particular, the following tasks are of high priority: combating international terrorism and organized crime (organized cattle rustling groups, smuggling); emergency management (forest fires, steppe fires, transboundary transfer of pollutants, floods, epidemics, and epizootics); environmental monitoring; sustainable use of water and other resources; and organization of corridors for seasonal migration of animals. At the same time, the growth of in-country transport infrastructure should help to reduce interregional asymmetry in economic development.

According to the obtained results, however, the regions characterized by high T_F values do not demonstrate high export potential as well. In other words, these regions are transit ones for transported freight. Under these conditions, a significant increase in the efficiency of the Russian economy along with a reduction in the export of raw materials is possible through an increase in the manufacturing of deeply processed and high-tech products.

6. Conclusions

The indicators, calculated according to the research methodology described above, reflect well the infrastructure development processes. Using these data, we characterized the functional and structural dynamics of transport development and the reasons for changes, assessed the socio-economic effects, and confirmed the hypothesis of the study. The main results are as follows: (1) The lowest levels of the efficiency of transport infrastructure are typical for the northeast of Asian Russia, as well as for the border regions of China, Mongolia, and Kazakhstan. (2) For Asian Russia, Kazakhstan, and Mongolia, the highest levels of the unified indicator are typical for regions, located along the main transport routes and for regions with a developed mining industry. This is due to the strong unevenness of the socio-economic development of the territories. (3) The largest industrial and economic centers have been developing along the main transport corridors primarily due to the accumulated potential of equivalent freight turnover and export potential.

The current focus on increasing freight turnover and expanding the transport network without significant changes in export policy dramatically reduces the efficiency of the entire transport logistics complex. To ensure the efficiency of economic processes, the main measures should be aimed at reducing the impact of difficult natural and climatic conditions, diversifying production, and moving away from the prevailing raw material economic model.

Thus, the proposed methodological tools enable effective decision-making and regulation of transport infrastructure development, not only at the level of an individual region, but also at the state level.

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