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Transportation of Freight along the Trans-Mongolian Railway and Planning for the Rolling Stock Park

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Abstract

The main purpose of this study is to forecast the general trend of the country's economic development, predict the volume of freight transported by railway, and analyze its trends using econometric and algebraic methods. Additionally, the study aims to determine the necessary measures to be taken in the future.

Keywords

GDP, economic growth, railways, transportation freight volume, rolling stock

1. Introduction

The proposal to construct a railway in Mongolia was deliberated and documented in the protocol during the visits of the then Minister of Foreign Affairs, Chin Van Khanddorj, and Prime Minister Sain Noyon Khan T. Namnansuren to Russia in 1912 and 1913, during the reign of the Bogd Khanate of Mongolia. In 1936, during negotiations with the Prime Minister of the Mongolian People's Republic, A. Amar, and the leader of the Soviet Union, Joseph Stalin, the question of constructing a railway in Mongolia was brought up. The project was finalized in 1938, with a 45-kilometer long railway line constructed between Nalaikh and Ulaanbaatar, made possible through loans and technical and economic assistance from the Soviet Union. This process laid the foundation for the development of railways in Mongolia and played a pivotal role in advancing the industrial sector.

In 1946, the Mongolian People's Republic and the Soviet Union signed an agreement promoting friendship, mutual assistance, and economic and cultural cooperation. The agreement officially incorporated the matter of constructing a broad-gauge railway in Mongolia. In 1947, Mongolian leader Marshal Kh. Choibalsan met with Soviet leader Joseph Stalin, raising the issue again, and the Soviet leader agreed. In 1949, the 400 km Naushki-Ulaanbaatar railway was inaugurated. Subsequently, in 1956, over 700 km of railway from Ulaanbaatar to the Chinese border was constructed and brought into service, establishing the primary vertical corridor of the 1100 km long Trans-Mongolian railway.

In accordance with the 1949 agreement between the Government of the Mongolian People's Republic and the Soviet Union, the joint-venture company "Ulaanbaatar Railway" was established, subsequently becoming the primary branch of the country's economy. Major industrial centers, including Darkhan, Khotol, Erdenet, Sharyn Gol, Bor-Ondur, Baganuur, and Shivee-Ovoo, were established along the railway. Consequently, European and global cultures deeply permeated Mongolia, leading to the development of housing, schools, hospitals, kindergartens, and numerous social and cultural institutions. With Mongolia experiencing rapid development, the volume of freight transported by railways has consistently risen. In 1958, transit freight amounted to 1.7 million tons, and by 1988, the overall transportation volume had surged to 17.8 million tons, setting a historical record for that period.

Since 1990, with the transition to a market economy, the social, economic, and political landscape underwent fundamental changes. During that period, both foreign and domestic trade experienced a dramatic decrease, and the amount of freight transported by railway dwindled to 7.0 million tons. Alongside the transition period, the infrastructure and rolling stock that were commissioned between 1950 and 1970 have reached the end of their service life, diminishing the corridor's productivity.

Figure 1. Trans-Mongolian Railway Corridor

By 2005, the World Bank, Asian Development Bank, and the Government of Japan had invested a total of 117.4 million US dollars in projects and programs to enhance the infrastructure, rolling stock, signaling, and transshipment facilities of “Zamiin Uud”. This initiative led to a 30 percent increase in the amount of transported freight, with 5.6 million tons being transit freight, reaching a total of 12.0 million tons per year. Between 2005 and 2012, Mongolia experienced a remarkable surge in foreign trade turnover, increasing fivefold to reach 11.1 billion US dollars, accompanied by an annual economic growth rate of 17 percent. The successful implementation of major projects and programs, such as Tavan-Tolgoi, Oyu-Tolgoi, and Nariin-Sukhait mining initiatives in the desert region, as well as the Bayangol iron ore mining project in Selenge province, significantly contributed to this economic expansion. This growth extended its reach to the energy and construction sectors, directly and indirectly influencing freight transportation. Notably, 20.0 million tons of goods were transported, achieving a remarkable capacity utilization rate of 60 percent.

Figure 2. Railway Network Planning of Mongolia

According to Mongolia's "State Railway Policy", a total of 416 km of Dzungbayan-Tavantolgoi, 234 km of Tavantolgoi-Gashuun Suhait, and 226 km of Dzungbayan-Khangi railways have been constructed.

The "Transit-Mongol" program is planned for development with the goal of enhancing the flow of freight traffic between Asia and Europe. This initiative will also focus on improving transport infrastructure along the Artssuur-Narynsukhait-Shiveehuren (Western Vertical Corridor) and Choibalsan-Khuot-Bich (Eastern Vertical Corridor) directions.

2. The Current State of the "Ulaanbaatar Railway" Joint-venture Company

Railway transportation is crucial for our landlocked country, characterized by an expansive territory, a relatively small population, limited infrastructure development, and an economic structure dominated by mining and agriculture; all while being surrounded by two large neighbors. Approximately 80% of the total freight turnover, along with the majority of consumer goods, is transported through railway transport facilitated by the Ulaanbaatar Railway Association (UBTZ), a joint venture between Mongolia and Russia.

The main line of Ulaanbaatar Railway Association (UBTZ) not only caters to domestic demand but also serves as a crucial component of the international transport corridor connecting Europe and Asia by rail through Russia and China.

Mongolia is actively working to overcome the challenges of the global Covid-19 pandemic, aiming to stabilize the economy, address factors limiting growth, and create opportunities for economic expansion, thereby ensuring stable growth in the medium term. The economy contracted by 4.4 percent in 2020, rebounded to 1.6 percent growth in 2021, and further expanded to 4.9 percent in 2022. Consequently, it is anticipated that the volume of transportation, which experienced a decline, will persist in its upward trend. In 2019, 28.1 million tons were transported, followed by 29.8 million tons in 2020, and 31.2 million tons in 2021, reaching 27.7 million tons in 2022.

The demand for rail freight is shaped by numerous factors, encompassing economic conditions, trade expansion, regional and neighboring market development, and their interdependence. Projections for 2023 indicate an anticipated transportation of 32.0 million tons of freight.

Due to the consequences of the pandemic, China has implemented restrictions on receiving freight. This has had adverse effects on Mongolia's exports, leading to a notable decrease in transportation volume (Note 1). Due to the step-by-step measures implemented by the Ulaanbaatar Railway, the daily train exchange with the Chinese side has been restored to the pre-pandemic level of 15 trains per day. Furthermore, as of 2023, this number has further increased to 17-18 trains.

The Ulaanbaatar Railway infrastructure, including the Bayantumen-Ereentsav line, covers a total length of 1,815 km. The main corridor from Sukhbaatar to Zamyn-Uud extends over 1,110 km and facilitates the operation of more than 6,200 cars of diverse types and over 140 locomotives along the primary route.

The system is equipped with a semi-automatic blocking system for efficient operations.

In preceding years, 60 percent of the rolling stock fleet surpassed its service life, attributed to the failure to conduct essential repairs, major constructions, and investments in fundamental structures, rolling stock, and equipment. Additionally, since 1998, there has been no addition of new wagons to the freight wagon park, and the cumulative length of roads overdue for infrastructure repair has reached 450 km, accounting for 45 percent of the total. The train traffic control system operates under the governance of a semi-automatic blocking system reliant on radio relays from the 1980s. This outdated system adversely affects the safety of train traffic, transportation organization, capacity, as well as overall profitability and competitiveness.

3. Methodology (1): Mongolia's Economic Situation and Gross Domestic Product Projections

Mongolia's economy relies significantly on the mining sector. Positive shifts have been observed in the country's international trade turnover, exports, and imports. In light of the impact of the international trade balance, fiscal equilibrium, and a stringent monetary policy, the economy has commenced its recovery.

The foreign trade balance exhibited a continuous rise, reaching 2.27 billion US dollars in 2020, 2.39 billion US dollars in 2021, 3.83 billion US dollars in 2022, and surging to 4.91 billion US dollars in the first 10 months of 2023. Economic expansion and the magnitude of international trade constitute pivotal macroeconomic indicators directly influencing the demand for rail freight.

In 2021, the Parliament endorsed the "New Recovery Policy" to strategically implement Mongolia's long-term development initiative, Vision 2050, with the objective of enhancing the state's productivity. Over the long term, the policy strives to sustain a 6 percent economic growth rate. The Bank of Mongolia, the Ministry of Finance, and international financial institutions collectively anticipate a 6% GDP growth in the medium term.

Hence, within the scope of this research, our objective is to ascertain the trajectory of GDP growth in the upcoming years, employing the capital growth balance (Note 2), with a focus extending until the year 2040. This will enable the prediction of freight demand.

$$K_{t+1} = (1 - \delta) * K_t + I_t \quad \text{(i)}$$

In economic theory, the aggregate output in an economy is indicative of real GDP. Let the two primary factors of production be represented as labor (L) and capital (K), real GDP as Y, and the production function linking factors K and L as F:

$$Y = F(K, L) \quad \text{(ii)}$$

This equation constitutes the total production function, illustrating the correlation between inputs (labor and capital) and output (GDP). In the equation, an increase in either or both capital and labor leads to a corresponding increase in output. Expressed as a function, the derivative of the production function with respect to both K and L must be positive.

$$F'_K > 0 \text{ буюу } F'_L > 0$$

It is further assumed that while increases in both capital and labor lead to an overall rise in production, the additional contribution of each factor to production, known as marginal output, will gradually diminish. We extend our equation by introducing the parameter A to incorporate advancements in manufacturing technology. The higher the value of A, the greater the total factor productivity. The relationship between L, K, and Y is represented by the following equation:

$$Y_t = A_t * F(K_t, L_t) \quad \text{(iii)}$$

If we assume that the production function takes the Cobb-Douglas form:

$$Y_t = A_t * K_t^{\partial} * L_t^{1-\partial} \quad \text{(iv)}$$

If equation (iv) is transformed from its non-linear form into a linear form using the logarithmic function:

$$ln\, Y_t = ln\, A_t + \partial\, ln\, K_t + (1-\partial)\, ln\, L_t$$

$$ln\left(\frac{Y_t}{L_t}\right) = ln\, A_t + ln\left(\frac{K_t}{L_t}\right) \quad \text{(v)}$$

The growth of capital over time t is determined using equation (i), and labor growth is defined as follows. L_t- The total population of Mongolia, L_{te}- The economically active population, $\Delta\left(\frac{L_t}{L_{te}}\right) = y_t$ the equation will take the following form

$$L_{te} = L_t * y_t \quad \text{(vi)}$$

Utilizing the Exponential Moving Average method (EMA) and expressing y_t for previous periods:

$$y_t = y_{t-1}b_1 + y_{t-2}b_2 + y_{t-3}b_3 + y_{t-4}b_4 + y_{t-5}b_5 + \ldots = \sum_{i=1} y_{t-1}b_i \quad \text{(vii)}$$

Here $b_i = \alpha^{i-1} * (1-\alpha)$ and research usually takes α=0.2, i=5 for calculations. When utilizing this formula:

$$y_t = 0.8y_{t-1} + 0.16y_{t-2} + 0.032y_{t-3} + 0.0064y_{t-4} + 0.00128y_{t-5} \quad \text{(viii)}$$

By employing equations (i) and (viii) and incorporating them into equation (v), our fundamental equation (iv) is elucidated as follows.

$$Y_t = 1.4236 * K_t^{0,86} * L_t^{0,14}$$

In the computation, the total production $Y_t$and total capital K_t of the current year were adjusted to the base price of 2015. $R^2 = 0.8946$.

Table 1. GDP and Economic Growth Projections through 2040

Year	GDP at 2015 constant prices, millions MNT	Economic growth /%/	Year	GDP at 2015 constant prices, millions MNT	Economic growth /%/
2024	34,065,913	4.06%	2033	54,539,967	5.71%
2025	35,603,826	4.32%	2034	57,911,217	5.82%
2026	37,303,656	4.56%	2035	61,554,058	5.92%
2027	39,173,488	4.77%	2036	65,486,122	6.00%
2028	41,222,296	4.97%	2037	69,725,691	6.08%
2029	43,460,181	5.15%	2038	74,292,581	6.15%
2030	45,898,103	5.31%	2039	79,207,828	6.21%
2031	48,548,127	5.46%	2040	84,493,346	6.26%
2032	51,424,029	5.59%			

This forecast matches projections from international financial institutions, the Ministry of Finance, and the Bank of Mongolia.

According to a statistical study, a direct relationship has been identified between GDP growth and the volume of freight transported by railways. The correlation coefficient between rail freight (Note 3) and GDP for the period 1990-2022 is 0.958. The robust correlation coefficient observed implies the potential for predicting future rail freight volumes based on GDP growth.

4. Methodology (2): Future Trends and Rolling Stock Planning for Trans-Mongolian Railway Transportation

The evident strong direct relationship between GDP and Ulaanbaatar Railway freight is depicted by the following linear equation.

$$S_t = \mu + G_t \qquad \text{(ix) (Note 4)}$$

Here, S_t represents the total amount of freight transported in the current year, and G_t denotes the real GDP of the current year

If the aforementioned equation is computed using the econometric method, it can be expressed as follows.

Table 2. Freight Volume Projection to 2040 (Thousand Tons)

Year	Freight Volume	Year	Freight Volume
2023	31,833	2032	48,183
2024	33,040	2033	50,901
2025	34,381	2034	53,842
2026	35,864	2035	57,020
2027	37,495	2036	60,450
2028	39,283	2037	64,149
2029	41,235	2038	68,133
2030	43,362	2039	72,421
2031	45,674	2040	77,032

Given the projected growth in overall freight volume, it raises the question of whether the existing rail capacity can accommodate the growing freight demand. When computing the capacity of the main line of Ulaanbaatar Railway using the two-trains-per-day method, the utilization capacity of the main line stands at 70 percent in 2017, 76 percent in 2020, and 93 percent in 2023. If this growth trend persists, it is anticipated to reach its maximum capacity by 2026. Beyond that point, it will be incapable of adequately meeting the demands for freight transportation, projected to extend until 2040.

Hence, it is imperative to enhance the carrying capacity of railways in order to accommodate the anticipated surge in freight demand.

To achieve this goal, it is recommended to implement the following technical measures.

- Completely automating the train control system
- To build new stations and increase overall capacity
- Automation of loading and unloading technology
- Enhance and fortify infrastructure repair efforts
- Construction of a secondary road entry in certain segments along the main line
- Expand the fleet of rolling stock, including locomotives and wagons.

From these considerations, it is imperative to evaluate the demand for rolling stock to determine the necessary increase in the fleet.

5. Methodology (3): Calculating the Rolling Stock Demand and Needs

The rolling stock quantities for transporting goods until 2030 were calculated using the following methodology.

The volume of freight locomotives in the park:

$$M = \frac{\sum P_i}{365 * \gamma_н * W_л} * \frac{K_p}{1 - \beta_{un}} * \frac{1}{1 - \beta_н}\left(1 + \beta_х + \beta_{пр}\right)$$

$\sum P_i$ freight volume,

$\gamma_н$ freight turnover ratio differentiating between net and gross weight;

$W_л$ locomotive efficiency;

$к_р$ comprehensive resource utilization coefficient within the locomotive park;

$$к_р = к_{мн}(1 + \alpha_p)к_в$$

$к_{мн}$ monthly variability coefficient in freight traffic; average 1.14

$к_в$ daily variability coefficient and emergency resource utilization coefficient for locomotives;1.03 орчим

α_p operational percentage of locomotives within the fleet; average 0.16

$\beta_н$ percentage of non-operational locomotives within the locomotive fleet

β_{un} percentage of operational locomotives in motion

$\beta_x, \beta_{пр}$ percentage of locomotives engaged in other operations

The number of freight wagon cars in the fleet:

$$n = \frac{1}{24}\left(\frac{\sum ns}{v_{уч}} + \sum n_{гр}t_{гр} + \sum n_{тех}t_{тех}\right) * (1 + \beta)$$

$\sum ns$ wagon utilization and wagon-kilometerage

$v_{уч}$ Train schedule avarage speed, km/h (Calculated at $v_{уч}$=50 km/h)

$\sum n_{гр}t_{гр}$ wagon-hour, time for wagon loading operations

$\sum n_{тех}t_{тех}$ wagon-hour, time spent stopping at a wagon technical station

β Coefficient of wagons in non-operational park, β=(0,1-0,3)

Table 3. Rolling Stock Needs

	2025	2030	2035	2040
Locomotive	10	21	38	62
Wagon	701	1695	3123	4983

Based on the calculations above, it is necessary to plan investments to increase the number of locomotives and wagons.

6. Conclusion

The development of any country is inextricably linked with its economic potential, investment landscape, production capacity, and the balance of foreign trade. It is essential to assess the country's freight transportation status and capacity, determining whether the freight transportation sector can meet the demand for future economic growth.

In this study, we analyze the present state and future trajectories of railway freight transportation in conjunction with forecasting total transportation growth.

Based on the study results, a strong correlation exists between GDP and the volume of freight transported by railways. The utilization of the main line is projected to reach its maximum capacity by 2025, beyond which it will be incapable of meeting the demand for freight transportation. By gradually implementing the aforementioned measures until 2035, the main line of the Trans-Mongolian railway is anticipated to have the capacity to transport 50 million tons of freight annually, resulting in an increase of over 40 percent in carrying capacity. Through this approach, there is potential for the mitigation of inefficient expenditures, a lowering of transportation costs, and an increase in transportation revenues.

Hence, it is imperative to establish fresh funding channels and identify suitable investment solutions for the implementation of the proposed measures outlined in this study.

In accordance with the Mongolian proverb, "Prepare the bucket before milking", proactive measures are essential. Anticipating the economic recovery, the execution of significant projects and programs, coupled with an upsurge in foreign and domestic trade, underscores the necessity for targeted planning and phased initiatives to enhance the capacity and quality of railway freight transportation.

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Notes

Note 1. From November 2021 to the third quarter of 2022, there were restrictions on the receipt of mining products by rail at China's Ereen station.

Note 2. Robert J. Barro, a scholar at Harvard University, USA, and Xavier Sala-i-Martin, a researcher at Yale University, USA, introduced the concept of the Capital Growth Balance. This framework was extensively explored in the early 1990s and has been widely employed in practical applications since the 2000s. Barro and Sala-i-Martin are prominent figures in contemporary neoclassical economic theory, serving as key proponents of its principles.

Note 3. Refer to Appendix 2 for details.

Note 4. It is represented by a linear equation of the form S=3320.35+0.00087 * G, where R^2=0.918.

Appendix

Appendix 1

Table 1. Key Economic Indicators of Mongolia

Year	GDP at current prices, millions MNT	GDP at 2015 constant prices, millions MNT	Capital /Assets/ at 2015 constant prices, millions MNT	Labor force /persons/
1990	12,804	7,540,187	23,759,016	783,600
1991	22,601	6,884,678	23,551,965	795,700
1992	56,130	6,247,400	22,728,746	860,067
1993	227,677	6,049,433	22,565,994	837,276
1994	382,103	6,178,551	22,217,799	834,641
1995	651,456	6,572,522	22,148,110	812,745
1996	737,997	6,719,424	22,051,124	825,023
1997	932,926	6,981,261	22,077,275	819,733
1998	945,461	7,214,430	22,339,802	842,407
1999	1,080,532	7,435,940	22,776,967	853,326
2000	1,224,062	7,521,161	23,309,025	847,560
2001	1,391,878	7,743,238	23,564,621	872,655
2002	1,550,610	8,109,724	23,998,494	901,658
2003	1,829,072	8,677,781	24,885,174	959,873
2004	2,361,157	9,599,830	25,783,904	986,360
2005	3,041,406	10,296,171	26,661,884	1,001,241
2006	4,027,559	11,177,134	27,508,085	1,042,848
2007	4,956,647	12,322,569	28,972,139	1,054,002
2008	6,555,569	13,419,323	30,887,946	1,071,555
2009	6,590,637	13,249,086	33,349,052	1,137,858
2010	9,756,588	14,092,411	36,902,994	1,147,162
2011	13,173,763	16,529,099	47,366,853	1,124,699
2012	16,688,420	18,565,454	56,223,907	1,151,181
2013	19,174,243	20,728,128	61,854,837	1,198,308
2014	22,227,054	22,362,588	66,786,252	1,206,555
2015	22,894,781	22,894,781	69,893,223	1,243,887
2016	23,931,343	23,235,864	74,380,419	1,275,658
2017	28,010,711	24,545,641	79,368,070	1,357,444

2018	32,582,629	26,446,671	85,534,318	1,358,654
2019	37,839,225	27,928,278	92,433,416	1,273,893
2020	37,453,275	26,655,377	99,101,789	1,250,608
2021	43,555,484	27,091,664	105,370,059	1,225,373
2022	53,851,544	28,455,109	108,918,444	1,265,211

Appendix 2

Table 2. Rail Freight Volume/in Thousands of Tons/of Mongolia

Year	Freight volume	Year	Freight volume	Year	Freight volume	Year	Freight volume
1990	14,517	2000	9,158.5	2010	16,804	2020	29,840
1991	10,270	2001	10,147.7	2011	18,448	2021	31,261
1992	8,518	2002	11,637.0	2012	20,445	2022	27,725
1993	7,883	2003	12,284.7	2013	21,035		
1994	7,068	2004	14,031.8	2014	21,119		
1995	7,298	2005	15,586.3	2015	19,151		
1996	7,466	2006	14,779.8	2016	19,989		
1997	7,310	2007	14,072.6	2017	22,765		
1998	7,615	2008	14,646.9	2018	25,763		
1999	8,199	2009	14,171.5	2019	28,143		