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# Multidimensional assessment of transportation sector's performance: Nonparametric analysis of the Azerbaijani economy

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Increasing geopolitical tensions and changing economic relations between East and West are prompting new studies in geographically favorable countries such as Azerbaijan. The Azerbaijani government has significantly improved the country's transport infrastructure since the oil boom period, but the multidimensional performance of the sector is still not well studied in academia, leaving a knowledge and methodological gap that this research attempts to fill. To this end, principal component analysis (PCA) was applied to the collected annual data between 1998 and 2022 to create index-based performance indicators for each transport sector (e. g., railway, aviation, maritime). Variables such as employment, investment, revenue, etc. were used to conduct the performance assessment through the dimensional reduction approach. Then, actual and potential performance were compared by applying the Hodrick — Prescott (HP) filter. The results indicate that the aviation, maritime and road transport sectors have a positive upward trend in their potential performance. Meanwhile, the railway sector has deteriorated significantly and the pipeline sector has slowed down, although the recovery from the COVID-19 pandemic and the Ukrainian-conflict in 2022 has made the Azerbaijani transport sector a viable alternative for international partners. In addition, the railway and maritime sectors are more volatile in their performance compared to the other sectors. Thus, while the railway infrastructure needs urgent reforms, other sectors should also increase their potential and actual performance. This study provides an opportunity to adjust public transportation policies and also contributes to theory through a systematic detailed examination of the performance of each sector.

*Keywords:* Azerbaijani economy, Hodrick — Prescott filter, logistics, principal component analysis, Spearman's rank correlation, transportation.

## Introduction

Few would deny the importance of the transportation system to economic growth, increased efficiency, increased productivity and environmental sustainability (Ahmad et al., 2022). In other words, transportation is critical to logistics and facilitating the movement of goods and resources. Its cost is a major component of overall logistics costs, and any disruption in transportation can cause delays that affect the efficiency of overall trade and logistics (Chislov et al., 2021). In fact, transportation and logistics usually contribute

significantly to a country's overall gross domestic product (GDP) and are a matter of national security.

Efficient transportation systems can improve the competitiveness of countries and regions by reducing transportation costs, improving connectivity and increasing the speed and reliability of the movement of goods (Li and Miller-Hooks, 2023). This is driving the current research direction to study the transportation sector from different angles to support logistical challenges and improve business performance metrics (Kumar and Anbanadnam, 2022). At the same time, the future of transportation is being shaped by several factors, including the rise of automated and autonomous vehicles, sustainable energy systems, and the need for equitable and accessible transportation options. These factors are the driving forces behind the new studies on transportation and the interesting case studies on the development of dynamic economic regions.

Azerbaijan has always been at the center of interest when it comes to the transportation sector due to its optimal geographical location between East and West and North and South. In fact, Azerbaijan was — and is — an integral part of the ancient Silk Road, where it contributed both physically and culturally to the vibrant trade relations between China and Europe for centuries (Lianlei, 2016). The picture is still the same today. Azerbaijan is a balancing power between geopolitical powers such as the European Union (EU) and Russia, while building strong economic ties with China based on projects such as the Belt and Road Initiative (BRI) (Lianlei, 2016). However, on the brink of increasing geopolitical tensions and economic rivalry, transportation in Azerbaijan seems to be stalling, contradicting hopes and expectations for stable and upward development. The recovery from the COVID-19 pandemic and the new military phase of the Ukrainian conflict have boosted the performance of the transportation sector in Azerbaijan, as supply chains have become more active and Azerbaijani trade routes are perceived as an alternative to the former trade routes and corridors that once passed through Russia. In addition, the attractiveness of neighboring Iran as a trade and logistics hub is low due to the constant economic sanctions, which will increase the importance of Azerbaijan in the coming years (Majidi and Zarouni, 2016). Based on this description, the main economic and scientific task of the present study is to assess the past and recent dynamics of the transportation subsectors (e. g., maritime, aviation, road) in Azerbaijan by examining key indicators such as employment rates, investments, turnover and passenger metrics, etc. This would enhance our understanding of the impact of geopolitical factors, economic rivalries and global events such as the recovery from the COVID-19 pandemic and the Ukrainian conflict on Azerbaijan's role as a major transportation hub and its potential to drive economic growth amid changing trade routes and geopolitical influences.

Azerbaijan is an oil-rich post-Soviet country that is mainly dependent on commodity exports via the Baku-Tbilisi-Ceyhan (BTC) oil pipeline and the Baku-Tbilisi-Kars (BTK) natural gas pipeline. The transport sector, especially the pipeline sector, has played a crucial role in increasing Azerbaijan's GDP and economic prosperity. The International Trade Administration of the United States of America (USA) declared the transportation and logistics sector as "…a best prospect industry sector for this country" (International Trade Administration, 2022). According to recent reports, the transportation and logistics sector will experience a significant boost thanks to the BTK railway project, the port of Alat, the port of Baku, etc. (Yusifov, Kulu and Mammadov, 2019). This motivates researchers to study the transportation sector. For example, the competitiveness and performance of the

aviation industry (Imanova, 2022), the role and performance of maritime transportation in economic growth (Akbulayev and Bayramli, 2020) and the environmental and ecological balance (Aliyeva et al., 2021; Atilgan Türkmen, 2022) have been evaluated according to various criteria. In addition, numerous studies focus on international relations (Maharramov, 2021), geopolitics (Ziyadov, 2011) and descriptive assessments of the transport sector as a whole and individually (Ibrahimov, 2010), rather than estimating its long-term actual and potential performance.

To better understand the performance of the transportation sector in the Azerbaijani economy, there is an urgent need to comprehensively examine the extent of these problems and their impact on sustainable economic development and trade partnerships, and how to improve the efficiency and integrity of the sector to realize its full potential. In light of all this, one important research question remains unexplored: How has the performance of Azerbaijan's transportation sector evolved between 1998 and 2022 beyond purely descriptive indicators (i. e., goods turnover, employment, investment, revenue) in terms of its economic performance? The following question was adopted as a secondary research question: What specific socioeconomic channels play a statistically significant role in the overall performance of the transportation subsectors? To answer this research question, this study applies a nonparametric quantitative method, namely principal component analysis (PCA), to the collected secondary data on the transport sector in the Azerbaijani economy. As a theoretical framework, the resource-based view (RBV) was used to systematize and control the selection of variables and to design the entire research process. The following hypotheses were formulated:

- H1: Principal component derived from PCA will effectively reduce the dimensionality of the dataset related to Azerbaijan's transportation subsectors while retaining substantial amount of information.
- H2: All variables of interest (e. g., employment, investments, travel distance) contribute equally and statistically significantly to the derived principal component (or overall performance indicator) among Azerbaijan's transport subsectors.

PCA is a statistical technique that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables, the so-called principal components. PCA usually leads to an index-based dimensional reduction of complex phenomena, which can enable multidimensional performance evaluation. In our case, this method is suitable for capturing the performance levels (measured by employment, investment, income, turnover, etc.) of the individual transportation sectors (e. g., railway, maritime, road). Then, by applying the Hodrick — Prescott filter (HP filter), this study also compares the performance of actual years with potential performance. In the final phase of the study, Spearman's rank correlation coefficients were calculated to answer the secondary research question and determine the specific socioeconomic determinants of the identified performance indicators. This approach improves our understanding of the Azerbaijani economy from the perspective of the transportation and logistics sector, which has not been studied in recent years, leaving a research gap to capture the potential of this sector in a small, oil-rich and strategically located country.

Following significant geopolitical events such as the new phase of the Ukrainian conflict, the Indo-European corridor and international economic cooperation in the field of EU energy security and recovery from the COVID-19 pandemic, this work contributes to estimating the initial performance and potential of Azerbaijan's specific transportation

sectors. Therefore, this study not only improves the literature by analyzing the transportation performance of a single country, but also provides a methodological approach to capture index-based multidimensional aspects of transport sectors in a time- and resource-efficient manner.

## 1. Literature Review and Theoretical Framework

The transportation sector remains one of the key sectors of non-oil GDP in the Azerbaijani economy and previous studies have shown that it is a factor in economic growth and development (Akbulayev and Bayramli, 2020; Mammadli and Gabil, 2017), the development of transportation hubs and corridors (Ziyadov, 2011) and the implementation of energy strategies (Ibrahimov, 2010). It has been proven that the transportation sector in Azerbaijan improves the welfare of households through better access to national roads, which in turn increases value added in the national economy (Yusupov, 2020). In addition, the domestic economy is increasingly benefiting from the development of the transportation sector, as it is experiencing clearly visible gradual structural and logistical improvements (Yusifov, Kulu and Mammadov, 2019). Although the COVID-19 pandemic has disrupted the country's rapid improvements and growth in this sector, the recovery from the pandemic and Azerbaijan's increasing role in international energy supply have played a crucial role in this development and momentum (Bağırzade, 2023). There are also numerous problems and challenges that need to be solved in order to have a sustainable and balanced infrastructure in the long term.

Academic literature emphasizes the continuous and progressive developments in the Azerbaijani transportation sector, especially since the early 1990s. In recent decades, Azerbaijan has embarked on a transformative journey to significantly improve its infrastructure. To facilitate the country's integration into global markets as a new participant and to take advantage of its strategic geographical location, various government programs and agendas have been implemented (Suleymanov, 2023; Rzayev and Aliyev, 2023). Substantial investments have been made in the modernization of road, rail, sea and air transportation infrastructure to upgrade Soviet-era facilities and create new networks that meet today's standards. A vivid example of this commitment is the BTC oil pipeline, inaugurated in 2006, which is a monumental achievement. This infrastructure provides a direct and safe route for oil from the Caspian Sea to world markets and strengthens Azerbaijan's economic position (Mikail, Çora and Çora, 2020; Suleymanov, 2023). However, although the BTC is a positive and strategic achievement that contributes to Azerbaijan's foreign exchange earnings, Y. S. Hwang, S. E. Kim and Y. J. Choi (Hwang, Kim and Choi, 2010) conducted an econometric analysis that highlights certain drawbacks of the project. They claim that the significant development of the pipeline infrastructure has led to a dependence on oil revenue, resulting in a rapid increase in exports, real effective exchange rate and leading to the phenomenon known as Dutch disease (Hasanov, 2013).

V. A. Bittner and M. Ibrahimli (Bittner and Ibrahimli, 2018) examined the BTK railway line, a project completed in 2017 that connects Azerbaijan, Turkey and Georgia. This initiative was a crucial step for Azerbaijan to integrate into the European railway networks and increased the capacity and potential of its railway infrastructure (Suleymanov, 2023). The significance of the BTK goes beyond its domestic impact for Azerbaijan and also includes geopolitical development considerations (Lussac, 2008) and the promotion of

new international economic partnerships, such as the Great Silk Road initiative (Mahmud, 2015). Similarly, the expansion and modernization of the road network through projects such as the construction of the North-South Highway has played a central role in strengthening domestic connectivity and facilitating international trade (Ibrahimov, 2016; Mammadli and Gabil, 2017).

There are few studies that focus specifically on the aviation and shipping industries in the Azerbaijani economy. Nonetheless, Azerbaijan Airlines, or AZAL, stands out as a major player in post-Soviet aviation (Gadimova, 2017). The airline operates 40 hubs in 25 countries worldwide and serves 75 European cities, 37 Asian cities and other destinations such as New York, Morocco and Tunisia (Gadimova, 2017). A notable challenge in this industry is the dominance of one state-owned company, AZAL, as the primary industry leader, leading to concerns about transparency and monopoly, as K. Hashimova and Z. Kadyrov (Hashimova and Kadyrov, 2017) point out. The lack of competition and the resulting lack of innovation hinder the industrial dynamics needed for the future development of the aviation sector. In addition, the aviation sector has been struggling with the effects of the pandemic in Azerbaijan, which has significantly changed the economic and financial landscape of the industry (Özden, Çelik and Gül, 2023).

The Azerbaijani maritime sector is mainly focused on the Caspian Sea. As M. Novruzova (Novruzova, 2020) summarizes, Azerbaijani ships have the opportunity to gain access to the World Ocean via the Volga-Baltic and Volga-Don water systems. All sea routes originating from Azerbaijan are directed from Baku. In international traffic, the Baku-Astrakhan, Baku-Makhachkala, Baku-Anzali, Baku-Bekdash, Baku-Turkmenbashi and Baku-Aktau routes are in operation, with the last three routes being connected by rail ferries. Therefore, the maritime sector in Azerbaijan is mainly used for logistical purposes (Ahmadov, Mirzayeva and Mammadov, 2021) and recent developments in the free economic zones, for example in the Alat free economic zone, promise new prospects for the maritime sector in Azerbaijan (Novruzova, 2020).

A considerable part of the current literature focuses primarily on the assessment of Azerbaijan's position and opportunities within the new international transportation routes and corridors. Notable examples include the Central Eurasian Corridor, the Trans-Caspian International Transport Route (Middle Corridor) and China's BRI (Bogdan and Najdov, 2020). Scholars such as A. F. Çetinkaya and N. Demirel are optimistic and point to the recent development of infrastructure potential in Azerbaijan and other post-Soviet countries, enabling integration into international markets. These advances has played a crucial role in boosting trade with Türkiye and Kazakhstan, while trade with Kyrgyzstan has remained relatively stagnant (Çetinkaya and Demirel, 2024).

Recent studies underline Azerbaijan's crucial role as a supplier and partner in transportation projects. İ. Hilali, Y. Işıker and N. Ulker (Hilali, Işıker and Ulker, 2024) highlight the Trans-Adriatic Pipeline, a component of the Southern Gas Corridor, which owes its existence to significant investments and efforts in the transportation sector. Consequently, due to its progress, challenges and geopolitical importance, the transportation sector in Azerbaijan remains the focus of interest and requires further research efforts. However, as Y. Zabanova (Zabanova, 2017) discusses, there is intense competition for international transportation projects between regional countries such as Armenia, Iran and Georgia. This emphasizes the need for continuous and rapid development of domestic infrastructure to increase performance levels. Nonetheless, various problems in the Azerbaijani

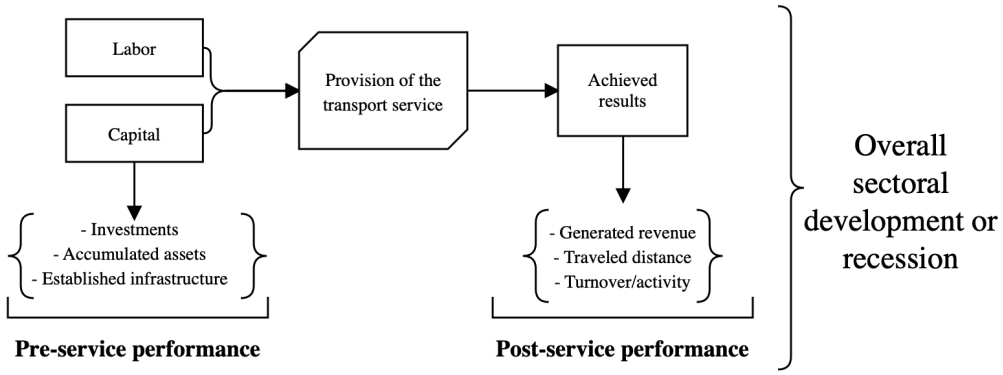


*Fig. 1.* Theoretical framework of the study

transportation remain unresolved, so significant political will is required to improve the potential and actual performance of the specific subsectors.

Some of the Azerbaijani media representatives offer critical perspectives on certain subsectors, such as the railway, which visibly underperforms and becomes a social burden supported mainly by public spending (Azadliq Radiosu, 2023). Similarly, AZAL's natural monopoly contributes to a significant deadweight loss to society through inflated ticket prices and regulatory challenges (Hasanov, 2022). To address these issues, the liberalization of sectors and the implementation of more open trade policies are advocated to promote the growth of both the potential and actual performance of the sector (Seyfullayev, 2020; 2022). The improvement of domestic transportation dynamics is particularly shaped by the experience of neighboring countries and the establishment of optimal transportation payment systems, which are widely discussed in the literature (Mayburov and Leontyeva, 2017; Yefimova, 2007).

This study is primarily based on the theory of RBV. Simply put, RBV provides an inside-out perspective to understand the success and failure of organizations in the marketplace. The theory is primarily concerned with the competitive advantage of organizations based on unique inputs that are valuable, rare, imperfectly imitable and imperfectly substitutable (Madhani, 2010). RBV is typically applied by scholars who focus on private organizations and business management (Madhani, 2010). However, it can also be applied across sectors, as a business sector is essentially a collection of different organizations and businesses (Terziovski, 2010). In particular, A. Lockett and S. Thomson (Lockett and Thomson, 2001) claim that the RBV can be used to evaluate the performance of specific industries or sectors, although it has received little attention in the literature for various reasons. Therefore, in this study, the RBV is adapted to assess the performance of a sector in a small and open economy such as Azerbaijan, taking into account the nature and characteristics of the sector, namely non-tradeable sectors.

The RBV serves to shed light on the complicated relationships between key socioeconomic performance factors by organizing the input variables of the aggregate performance indicator. Figure 1 summarizes the key aspects of how certain variables influence the final performance of the transport sector. First, it is assumed that key inputs such as labor and capital are mobilized to initiate the provision of transport services. These in-

clude total employment, investment, accumulated wealth and established infrastructure, where established infrastructure refers to the length of transport infrastructure such as road or rail networks. Secondly, the actual provision of services takes place, including the transportation of people or goods. Finally, in the post-provision stage, the key outputs of the transport service are transparently presented after the inputs have been used in a particular sector. In other words, this includes the revenue generated, the distance traveled and the turnover. Therefore, the theoretical framework of this study takes an integrative approach that considers both the performance of the transport sector in Azerbaijan before and after the service is provided. The performance of the transport sector is considered as a combination of inputs and outputs over a given period of time.

All relevant data were collected on the basis of the theoretical framework and available official statistical data, taking into account the main research questions and hypotheses of the study. The conceptual framework as well as the detailed data and methodological aspects are described in the Data and Methodology section below. Unfortunately, the literature on methodological assessment of the transport sector in Azerbaijan is still scarce, which this study takes as an opportunity to fill this research gap.

## 2. Data and Methodology

The conceptual framework of the present study aims to assess the performance of the transportation sector in terms of several key factors, including employment (in persons), investment (in million Azerbaijani Manats), turnover of goods (in million tons per kilometer), travel distance (in kilometers), length of infrastructure (in kilometers), revenue from logistics and passenger transport activities (in million Azerbaijani Manats), and asset valuation (in million Azerbaijani Manats). Deliberate consideration was given to selecting variables that collectively provide a comprehensive and nuanced understanding of the performance of the transportation sector in Azerbaijan. The inclusion of employment figures, measured in persons, serves as a vital indicator of the sector's socioeconomic impact, reflecting its role in generating job opportunities and contributing to human capital development. Investment, quantified in million Azerbaijani Manats, was chosen to gauge the financial commitment and resource allocation in the sector, offering insights into its growth potential and sustainability.

The incorporation of turnover of goods, measured in million tons per kilometer, and travel distance, quantified in kilometers, was motivated by the need to assess the operational efficiency and scale of the transport activities. These variables provide a tangible measure of the sector's capacity to facilitate the movement of goods and passengers over varying distances, capturing the essence of its functional role. The length of infrastructure, expressed in kilometers, was considered crucial to understanding the extent and coverage of the transportation network, offering a perspective on the sector's physical reach and connectivity.

Furthermore, the inclusion of revenue from logistics and passenger transport activities, measured in million Azerbaijani Manats, adds a financial dimension to the assessment. These variables encapsulate the economic performance of the transport sector, shedding light on its revenue-generating capabilities in both logistics and passenger services. Lastly, asset valuation, quantified in million Azerbaijani Manats, was chosen to ascertain the overall financial worth of the transport sector, providing a holistic perspective on its economic significance.

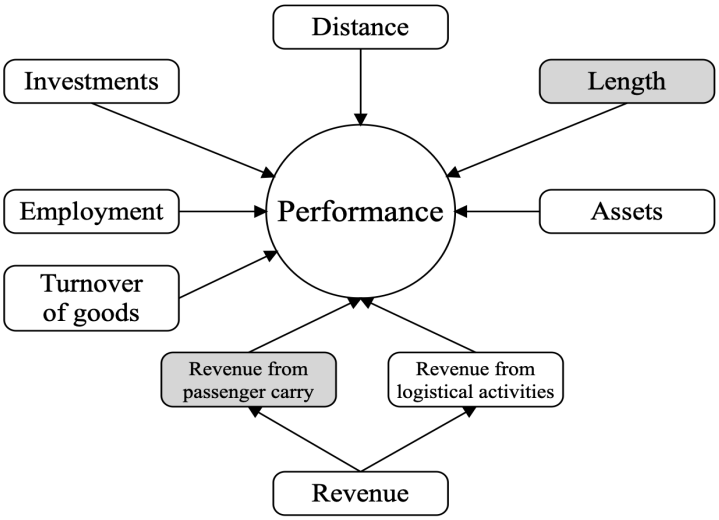


*Fig. 2.* Conceptual framework of the study

A concise illustration of this conceptual framework can be found in Figure 2. The conceptual framework highlights two variables of particular interest, namely "length" and "revenue from passenger carry." These variables are shown in light gray to emphasize their importance, as they have been omitted in the maritime, aviation and pipeline sectors due to the unavailability of the mentioned economic indicators.

The dataset used for this analysis comes from the annual statistical indicators published by the State Statistical Committee of the Republic of Azerbaijan for the period from 1998 to 2022 (SSCRA, 2023). In some cases, missing values for certain years, such as 1998 and 1999, were replaced by a linear interpolation technique. It is worth noting that no significant outliers were identified within the dataset, minimizing the potential for bias in the results. In preparation for PCA, the dataset was standardized. The data were then grouped to organize the variables of interest based on their subsectoral distribution (e. g., railway, maritime, aviation). Subsequently, both PCA and the HP filter were applied as integral parts of the analysis to achieve the overall objectives of the study.

The main method used in this study is PCA, a robust technique for combining multiple variables to derive precise, systematic and unbiased index scores. For simplicity, only a single principal component was generated by PCA, eliminating the need for subsequent rotations such as orthogonal or oblique transformations. In fact, in most cases, the scree plot suggested a single principal component as the optimal number for dimensional reduction.

The suitability of the datasets collected for each specific transport sector was assessed through a series of statistical tests, including the Kaiser-Meyer-Olkin (KMO) measure, Bartlett's test of sphericity, average communalities, and cumulative explained variance. The use of PCA in the context of the transport sector is increasing and motivates its application in the Azerbaijani context. To illustrate, PCA has been used in a variety of transport sector contexts, such as assessing the sustainability of the Chinese transportation sector (Wanke et al., 2023), evaluating the UK transportation sector from a net zero emissions perspective (Vickerman, 2021), and creating an air quality index for the US transportation

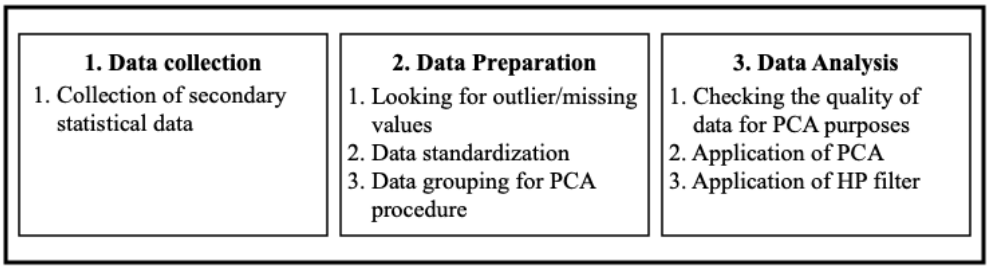


*Fig. 3.* The three stages of the data analysis

sector (Choi, Park and Park, 2015). Figure 3 provides a brief overview of the three-stage process that comprises the data collection and subsequent analysis in this study.

The PCA algorithm was carried out using SPSS (version 23) software. The recommendations and suggestions of M. Sarstedt and E. Mooi (Sarstedt and Mooi, 2014) were followed and the mathematical representation of I. Wingdes, S. Nurfaizi and M. Rifki (Wingdes, Nurfaizi and Rifki, 2022) described below was adopted:

$$\max var\left(\delta_1^T x\right) = \sigma_1^T \Sigma \delta_1; \quad (1)$$
$$s.t.\ \ \delta_1^T \gamma \delta_1 = 1.$$

Lagrange multipliers maximized $\delta_1^T \Sigma \delta_1$ subject to $\delta^T \delta = 1$.

$$\delta_1^T \Sigma \delta_1 - \lambda\left(\delta_1^T \delta_1 - 1\right). \quad (2)$$

Where Lagrange multiplier is $\lambda$ and the following differentiation with respect to д $_1$ gave:

$$\left(\Sigma - \lambda \mathrm{I}_P\right)\delta_1 = 0. \quad (3)$$

Where covariance matrix is $\Sigma$ the and $\mathrm{I}_P$ is another form of $\Sigma\delta_1 - \lambda\delta_1 = 0$. Essentially, $\mathrm{I}_P$ is the $(p \times p)$ identity matrix. The maximization process of the quantity happens as follows

$$\delta_1^T \Sigma \delta_1 = \delta_1^T \lambda \delta_1 = \lambda \delta_1^T \delta_1 = \lambda. \quad (4)$$

To maximize λ, it is important to make the corresponding eigenvector as large as possible. All procedures were performed with SPSS-based PCA algorithms.

The list of variables for sector *i* included in the vector *X* comprises the variables specified in the conceptual framework. Monetary value-expressed variables (i. e., investments, assets, turnover of goods, revenue) underwent inflation adjustment using the producer price index provided by the International Monetary Fund (International Monetary Fund6 2024), with the base year being 2010. Each variable represented the primary and static form within the collected dataset. The final outcome of the algorithm generated a principal component or index variable, using the regression method, to assess the performance of a specific transport subsector.

Fundamentally, the performance index is standardized, having a mean of 0 and a standard deviation of 1. Each performance indicator clarifies a specific percentage of the overall variability present in the dataset, aligning with the primary methodology of PCA.

The selection of the chosen variable is primarily rooted in the RBV approach outlined in the literature review and theoretical framework section. Consequently, the performance indicators gauge the performance of each subsector over time rather than comparing the relative performance of each subsector.

The next part of the analysis involved HP filtering the estimated index values to see which years offered higher or lower performance levels in the transport sectors by dividing the values into cycle and trend components. The HP filtering method allows for variation in the growth rate of the trend and provides more realistic and dynamic potential values that can be compared to actual values. The HP filter method was applied in Microsoft Excel using a publicly available add-in by K. Annen (Annen, 2006) according to the following formula:

$$min_{y_t^*} = \sum_{t=0}^{\infty} \left(y_t - y_t^*\right) + \lambda \sum_{t=2}^{\infty} \left[\left(y_{t+1}^* - y_t^*\right) - \left(y_t^* - y_{t-1}^*\right)\right]^2, \quad (5)$$

where $y_t$ is the actual value for the performance of the transport sector; $y_t^*$ is the potential or trend component of the performance of a given transport sector at time t.

The first part of the formula aims to reduce the discrepancy between the potential value and the actual value of a given transport sector, which is represented as the difference between $y_t - y_t$. The second section of the formula focuses on diminishing the fluctuation in the trend. It is important to note that this component is minimized when the discrepancy between $\left(y_{t+1}^* - y_t^*\right)$ equals the difference between $\left(y_t^* - y_{t-1}^*\right)$. Lastly, smoothening parameter $\lambda$ was set to 1600 due to the annual data. Although the HP filter has some shortcomings (e. g., lack of theoretical basis, endpoint problem), the number of studies using it to estimate cyclical deviations in the transport sector is increasing (see the work of J. Kwon, S. Park, T. Kim and H. Kim (Kwon et al., 2023) for the shipping sector in South Korea; M. K. Anastasia, P. U. Ginting, R. F. Syahrir, O. Hermansyah and M. Shiroth (Anastasia et al., 2023) for an example of the Indonesian economy).

## 3. Results and Discussion

Table 1 shows the results of the KMO values of the individual transportation sectors, the significance of the Bartlett's test for sphericity, the average extraction values measured against the communalities and the explained cumulative variance. The highest KMO value is 0.741 for the railway sector and the lowest value is 0.562 for the road sector. For the maritime, aviation and pipeline sectors, the KMO values are 0.612, 0.691 and 0.630 respectively. The KMO values obtained correspond to the expected average values usually reported in the literature (Ririhena and Loklomin, 2020).

All results of Bartlett's test of sphericity are statistically significant (see Table 1), indicating that there is at least one statistically significant correlation between the variables of interest, and that PCA is an appropriate method for the dataset at hand (Raykov and Marcoulides, 2014). In terms of average communality, maritime transport performed the best with a score of 0.655, while railway sector performed the second best with a score of 0.557. The aviation and pipeline sectors scored 0.511 and 0.529 respectively, while road sector scored 0.456. In general, a high communality indicates that a variable is effectively captured by the principal components, while a low communality indicates that a variable is inadequately represented and may need to be excluded from the analysis (Mishra et al.,

2017). Table 1 shows the average communalities to save space. Although there are no fixed rules for specific values of communalities, the expected and acceptable values should be at least between 0.300 and 0.900 (Umar et al., 2021; Shoyombo et al., 2019). In our case, the average communalities fulfill the specified criteria.

Finally, the sectoral distribution of the explained variance of the variables of interest were examined. The explained variance is a measure of the amount of variation in the data that is explained by each principal component in the PCA. The highest value was found for the aviation sector at 65.6 %, while the lowest cumulative variance explained was for the maritime sector at 45.6 %. The other sectors provided values between 51.1 % and 55.7 %. Published studies show that the explained variance for a one-principal component PCA should be at least 40–41 % (Valsalan, Sadan and Venketachalapathy, 2020). The present results are consistent with this view and allow us to confirm the first alternative hypothesis of the study. This hypothesis suggests an effective and efficient dimensionality reduction without losing important information from the original dataset.

*Table 1.* **Initial PCA results or quality checks of the dataset**

| Transport sector | KMO value | Bartlett's Test | Average communalities | Explained variance, % |
|---|---|---|---|---|
| Railway | 0.741 | 0.000 | 0.557 | 55.7 |
| Road | 0.562 | 0.000 | 0.456 | 51.1 |
| Maritime | 0.612 | 0.000 | 0.655 | 45.6 |
| Aviation | 0.691 | 0.000 | 0.511 | 65.6 |
| Pipeline | 0.630 | 0.000 | 0.529 | 52.9 |

Notes: All sectors had 21 degrees of freedom, except for the railway and road sectors, which had 28 degrees of freedom.

Table 2 shows the component loadings for each transportation sector by the variable of interest. In the railway sector, employment (0.921), length of railway (0.919), assets (0.796), and investment (0.781) were the highest positive loadings, but the revenue from the logistic activities was the highest negative loading (–0.890). Variables such as traveled distance (0.646) and turnover of goods (0.520) had moderate and positive loadings on the principal component, and revenue from passenger transport (0.191) had the lowest loading. The results obtained for the railway sector showed that revenue from logistic activities was negatively correlated with the other variables, while revenue from passenger transportation was weakly but positively related to the variables, which significantly lowered the revenue of the whole sector. In other words: While the financial-related variables did not change along with the other variables, employment and rail distance covaried significantly with the other performance indicators.

In the area of road transportation, the analysis of the most influential factors reveals a pronounced hierarchy in which revenue from logistics activities (0.984), revenue from passenger services (0.964) and the turnover of goods (0.870) are the most important factors. This configuration is in clear contrast to the corresponding scenario in the railway sector. In addition, employment had a significant loading (0.710), while investment (0.622), road length (0.548), and assets (0.425) had a rather moderate or weaker loadings. In contrast,

distance traveled made the smallest contribution to the road sector with a loading of 0.248. From a broader perspective, the road sector shows a balanced development of growth and covariance in its key performance indicators from 1998 to 2022. This trajectory primarily reflects an upward trend, indicating a positive overall performance over this period.

In the case of the maritime and aviation sectors, length was an irrelevant variable that was not included in the analyzes. Thus, while travel distance and assets had the lowest loadings on the principal component at 0.113 and 0.276, respectively, the loadings of all other variables in the maritime sector were between 0.517 and 0.676, indicating moderately positive covariances. However, in the aviation sector, most variables loaded positively and significantly on the principal component (e. g., 0.929 for the revenue from logistic activities or 0.900 for distance), but in the maritime sector, the loadings for these variables were moderate or low. Investments had the lowest loading in the aviation sector at 0.304, but assets had a moderate loading at 0.685.

The pipeline sector showed a minimal loading in terms of employment (0.056) and also in terms of assets (0.138). The volatility of employment and investment in the pipeline sector can be attributed to the transient nature of the sector, which is characterized by dependence on active phases of oil and natural gas projects that lead to fluctuations in the allocation of labor and capital. Conversely, variables such as distance, turnover of goods, revenue from logistics and pipeline length showed remarkably high and positive loadings of 0.980, 0.989, 0.886 and 0.940, respectively. In the Azerbaijani economic landscape, the pipeline sector occupies an important position as a critical infrastructure primarily responsible for generating foreign exchange through the export of crude oil and natural gas. Remarkably, the variability of pipeline sector assets was not fully captured in the principal component, resulting in a relatively small but positive loading of 0.138.

*Table 2.* **Component matrix of the transport sector in Azerbaijan between 1998 and 2022, in component loadings**

| Variable | Railway | Road | Maritime | Aviation | Pipeline |
|---|---|---|---|---|---|
| Employment | 0.921 | 0.710 | 0.676 | 0.859 | 0.056 |
| Investments | 0.781 | 0.622 | 0.517 | 0.304 | 0.265 |
| Distance | 0.646 | 0.248 | 0.113 | 0.910 | 0.980 |
| Turnover of goods | 0.520 | 0.870 | 0.550 | 0.900 | 0.989 |
| Revenue from logistics | –0.890 | 0.984 | 0.674 | 0.929 | 0.886 |
| Revenue from passengers | 0.191 | 0.964 | 0.386 | 0.888 | — |
| Length | 0.919 | 0.548 | — | — | 0.940 |
| Assets | 0.796 | 0.425 | 0.276 | 0.685 | 0.138 |

Figure 4 shows the actual index value-based performance indicators of the individual transportation sectors and their potential trend line determined by the HP filter method. Of the five transportation sectors, only the railway sector shows a gradually decreasing potential and at the same time a lower actual performance from year to year. Between 2002 and 2008 in particular, the railway sector exceeded its potential, but since 2009 the level

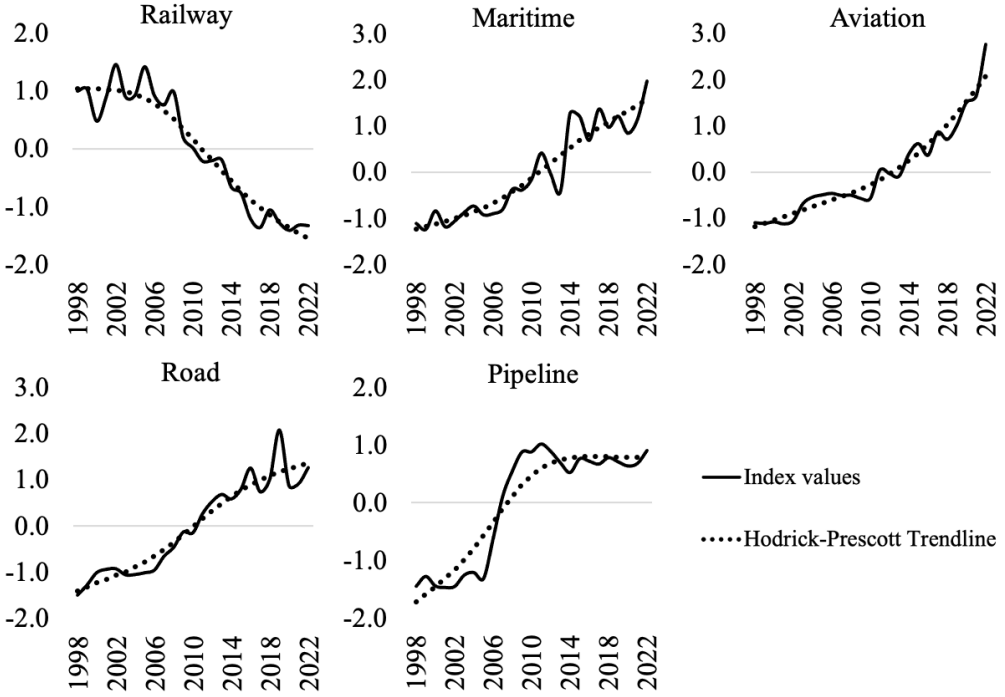


*Fig. 4.* Index values and Hodrick — Prescott trendlines for each transportaton sector in Azerbaijan, in index values (higher values = better performance), 1998–2022

of potential and actual performance has fallen rapidly. In the last two years, i. e. 2021 and 2022, the performance has improved compared to the potential, but the overall picture shows a drastic slump in this sector.

In the maritime sector, performance fluctuated primarily against the backdrop of rising potential performance. The greatest fluctuations occurred between 2011 and 2018, and years such as 2021 and 2022 show a sustained upswing. In contrast to the maritime sector, the aviation sector shows no significant deviations between 1998 and 2021, with only 2022 showing a sharp jump in actual performance.

The road sector mainly exceeded its potential between 1998 and 2002, but fell short of expectations between 2003 and 2010. Since 2015, the road sector has shown a volatile development with strong increases and decreases.

Finally, the significant growth rates in the pipeline sector began in 2006 and continued until 2012. During this period, the pipeline sector exceeded its potential. Between 2013 and 2020, however, the pipeline sector fell short of its potential with slight fluctuations. It was not until 2022 that actual production exceeded the potential level. It is also worth noting that the pipeline sector is the only transport sector to show a flattening of its potential.

Since a typical PCA procedure does not provide information on the statistical significance of the component loadings, the second hypothesis of the study was tested using Spearman's rank correlation coefficient method. The choice of Spearman's rank correlation coefficient was justified by the non-normal distribution of the variables (performance indicators). In accordance with the recommendations of Czech (2018) and in recognition of

the non-normal distribution, the non-parametric correlation approach was therefore chosen instead of the Pearson's R correlation coefficient. Following the findings of H. Yamamoto, T. Fujimori, H. Sato, G. Ishikawa, K. Kami and Y. Ohashi (Yamomoto et al., 2014) on the development of a methodology to evaluate statistical hypotheses related to factor loadings in principal component analysis. Table 3 presents the final results regarding the statistical significance of each variable in relation to the identified performance indicators.

The alternative hypothesis, which states that "all variables of interest (e. g., employment, investment, travel distance) contribute equally and statistically significantly to the derived principal component (or overall performance indicator) of the Azerbaijani transport subsectors", was only confirmed in the case of the aviation subsector. For the other subsectors, at least one statistically non-significant correlation coefficient was found in the following cases: Railway — revenue from passengers; road and maritime — travel distance; and pipeline — employment.

*Table 3.* **Spearman's rank correlation coefficients between the performance indices and their main components**

| Variable | Railway | Road | Maritime | Aviation | Pipeline |
|---|---|---|---|---|---|
| Turnover of goods | 0.41* | 0.84** | –0.68** | 0.94** | 0.83** |
| Distance | 0.57** | 0.39 | –0.36 | 0.90** | 0.77** |
| Employment | 0.88** | 0.68** | –0.73** | 0.91** | –0.07 |
| Investments | 0.90** | 0.65** | 0.74** | 0.53** | 0.45* |
| Revenue from logistics | –0.88** | 0.96** | 0.80** | 0.95** | 0.78** |
| Revenue from passengers | 0.12 | 0.96** | 0.79** | 0.95** | – |
| Length | 0.86** | 0.63** | – | – | 0.84** |
| Assets | 0.81** | 0.66** | 0.58** | 0.74** | 0.57** |

* Correlation is significant at the 0.05 level (2-tailed); ** correlation is significant at the 0.01 level (2-tailed).

Among the statistically significant coefficients, revenue from the logistics was found to have a negative correlation with the performance of the railway subsector. In addition, goods turnover and employment showed a negative correlation with the maritime subsector performance. In contrast, the other statistically significant coefficients showed positive correlations with the identified performance indicators. The presence of statistically non-significant or statistically significant and negative correlation coefficients may indicate that these specific aspects within the subsectors require notable improvements to achieve a higher level of performance.

## Conclusions and Implications

The aim of this study was to evaluate the Azerbaijani transport sector and its subsectors from various aspects such as employment, investment, turnover, etc. Analyzing the multidimensional performance of a sector requires a methodological assessment. There-

fore, this paper proposes a PCA-based index approach to evaluate economic performance and an HP filter-based comparison of annual potential and actual performance. As the theoretical framework, RBV was adopted and two hypotheses were tested.

The results clearly show that it is possible to perform a dimensional reduction analysis of the collected dataset, which contains a large number of key variables relevant to the assessment objective. Similar performance evaluation studies have not yet been conducted for the Azerbaijani economy, leaving a large research gap that was analyzed in this paper with the following research question: How has the performance of Azerbaijan's transport sector evolved between 1998 and 2022 beyond purely descriptive indicators (i. e., goods turnover, employment, investment, revenue)? The corresponding answer to this question provides an efficient approach that can be used in similar studies. Thanks to this approach, it is possible to carry out a brief, systematic and methodological index assessment of the individual subsectors. Government policy and decision makers need a multidimensional approach to sectoral performance in Azerbaijan, and their necessary tools are inadequate when it comes to accurately measuring latent processes such as sectoral performance and diagnosing the problems. This complicates the socio-economic interpretation of sectoral dynamics and thus a reliable forecast of potential and actual performance.

Of the five transport sectors examined, the maritime, aviation and road transport sectors show an increasing performance potential between 1998 and 2022 with fluctuating actual performance levels. However, the railway sector shows a dramatic decline in both potential and actual performance throughout the period, while the pipeline sector started to level off in 2012 and 2013 and mainly underperforms until 2021. In 2022, the maritime and aviation sectors recorded notable jumps in their actual performance, and the railway and pipeline sectors also showed a moderate improvement.

The test for the statistical significance employing Spearman's rank correlation coefficient approach showed that only aviation performance indicator has statistically significant and positive correlations with the individual components. This may indicate a well-balanced and robust performance in the aviation sector, possibly driven by efficient resource allocation and management; however, more detailed analysis of this specific sector should be carried out to have detailed and systematic knowledge. While, the other subsectors displayed at least one statistically insignificant coefficient, some had even negative correlation coefficients. In the railway subsector, the statistically insignificant correlation with revenue from passengers implies a need for a closer examination of revenue-generating mechanisms and potential areas for improvement. Similarly, in the maritime subsector, a negative correlation between turnover of goods, employment and performance of this sector may suggest a need for strategic interventions to boost employment levels despite rising economic performance. Lastly, positive and statistically significant correlations between the individual variables and the ultimate performance indicators suggest that improvements in certain aspects, such as investments or travel distance, are associated with enhanced performance in these subsectors. This information can guide policymakers and industry stakeholders in identifying areas to prioritize for growth and development.

Briefly, the socioeconomic interpretation of these results can be as follows: The positive trajectory of the maritime, aviation, and road transport sectors underscores their potential contributions to economic growth and development. These sectors, displaying increasing performance potential over the years, are likely to foster trade, facilitate logistical operations, and enhance connectivity, all of which are pivotal for a thriving economy.

However, the concerning decline in both potential and actual performance of the railway sector, coupled with the consistent underperformance of the pipeline sector, raises flags. These trends may signify challenges in the efficiency and effectiveness of these transport modes, potentially hindering their ability to contribute optimally to economic activities. Policymakers should consider targeted interventions and strategic planning to revitalize these sectors, ensuring they align with the broader goals of economic development. Therefore, the main policy proposals relate primarily to the railway sector, where immediate reforms and policy decisions need to be implemented to increase both the potential and the actual performance of the sector. This requires efficient mobilization and allocation of resources, drastic measures (e. g., privatization, mergers) and political will. It is also possible to smooth out the volatility and fluctuations in sectors such as aviation, road and maritime transport in order to make logistics and transportation activities more predictable in the near future.

Some limitations of the study and recommendations for future research should also be mentioned. The sample size (N = 25 years) was small and the number of variables of interest could be higher if official statistics would allow it. However, the PCA quality checks yielded acceptable values, so the results of this work can be trusted. Furthermore, rotation in PCA is crucial, and future studies could perform more than a single-factor assessment if the dataset allows it. Future studies should focus on additional nonparametric investigations (e. g., correspondence analysis, multidimensional scaling) of the transportation and logistics sector to shed light on the multi-layered picture of the Azerbaijani economy, as the desired level of academic studies in this area has not yet been reached.

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## Многомерная оценка производительности транспортного сектора: непараметрический анализ экономики Азербайджана

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Усиление геополитической напряженности и изменение экономических отношений между Востоком и Западом побуждают к проведению новых исследований в таких географически благоприятных странах, как Азербайджан. Правительство Азербайджана значительно улучшило транспортную инфраструктуру страны после периода нефтяного бума, однако многомерные показатели этого сектора все еще недостаточно изучены

в научных кругах, что оставляет пробел в знаниях и методологии, который и пытается заполнить данное исследование. С этой целью к собранным данным за период с 1998 по 2022 г. был применен анализ главных компонент (АГК) для создания индексных показателей эффективности каждого транспортного сектора (например, железнодорожного, авиационного, морского). Такие переменные, как занятость, инвестиции, доходы и т. д., использовались для оценки эффективности с помощью метода сокращения размерности. Затем фактические и потенциальные показатели сравнивались с помощью фильтра Ходрика — Прескотта (ХП). Полученные результаты свидетельствуют о том, что авиационный, морской и автомобильный транспорт имеет положительную тенденцию к росту своих потенциальных возможностей. В то же время железнодорожный сектор значительно ухудшился, а трубопроводный замедлился, хотя восстановление после пандемии COVID-19 и конфликта на Украине в 2022 г. сделало азербайджанский транспортный сектор привлекательным для международных партнеров. Кроме того, железнодорожный и морской секторы более волатильны по своим показателям по сравнению с другими секторами. В то время как железнодорожная инфраструктура нуждается в срочном реформировании, другие сектора должны повысить свои потенциальные и фактические показатели. Данное исследование дает возможность корректировки государственной политики в области транспорта, а также вносит вклад в теорию благодаря систематическому подробному рассмотрению эффективности каждого сектора.

*Ключевые слова:* анализ главных компонент, логистика, транспорт, фильтр Ходрика — Прескотта, экономика Азербайджана.

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