Sustainable pricing of tariffs for rolling stock operators: principles and mathematical analysis

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Abstract. An analysis of the sustainability of tariff pricing by operators of rolling stock in the railway industry has been conducted. The paper covers various aspects, including an analysis of wagon turnover, changes in the prices of leasing rolling stock, and the influence of market demonopolization on tariff rates. The dynamics of changes in leasing prices for various types of rolling stock, such as flatwagons, tank wagons, covered wagons, and platforms, are being investigated. The analysis presented in this paper is of significant importance for understanding and optimizing the management processes of railway transport, as well as for the development of sustainable pricing strategies that contribute to more efficient and economically sustainable activities in the railway transportation sector.

1 Introduction

In an ever-changing market and competitive environment, rolling stock operators are faced with the need to effectively manage pricing to ensure long-term sustainability and competitiveness. Determining optimal tariff rates, taking into account multiple factors such as transaction costs, changing demand and competitive strategies, poses significant challenges to the railway industry.

Rolling stock operators play a key role in the railway industry by ensuring the efficient operation of freight transport. Their activities cover a wide range of tasks, including managing a fleet of wagons, providing their maintenance, and managing tariffs. Rolling stock operators have a direct influence on the formation of tariff rates, determining prices for transportation services and rental rates for the provision of wagons.

At the same time, the impact of market demonopolization on tariff rates is important for ensuring a competitive environment and protecting the interests of customers. Demonopolization helps create a more open and competitive market, where different operators are able to compete with each other based on quality of service and pricing policy. This, in turn, encourages rolling stock operators to reduce tariff rates and improve the quality of services in order to attract customers and maintain a competitive advantage.

Demonopolization of the market also contributes to more effective regulation of tariffs and the prevention of the formation of monopolistic pricing positions, which has a beneficial

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effect on consumers and stimulates economic growth in the industry. As a result, market
demonopolization helps to reduce tariff rates and increase the availability of railway
transportation services, which ultimately contributes to economic development and increased
competitiveness in the railway industry.

This paper examines the problem of sustainable tariff pricing in the rolling stock sector,
based on the principles of system analysis and the application of mathematical analysis. The
main goal of our research is the integration and analysis of methods that can ensure a balance
between optimal tariffs and meeting consumer requirements, while maintaining a long-term
sustainable tariff policy of operators.

In recent decades, issues of sustainable tariff pricing in the railway industry have attracted
increasing attention from both researchers and practitioners. This is due not only to the
constantly changing competitive environment, but also to the desire to optimize
transportation processes and ensure long-term sustainability for operators.

Let us give a brief review of papers that are, to one degree or another, devoted to the
research of these issues [1-16].

In [2], the authors of the paper explore a methodology for forecasting the future
development of unregulated industries, especially in the transport sector, in particular,
assessing how competition in the field of rail freight transport is developing in Finland, and
analyzing different views on rail transport policy using a Delphi questionnaire.

Paper [3] examines the planning of the structure and volume of rolling stock from the
perspective of two methods. The first method allows you to determine the quantitative
parameters of rolling stock (i.e. kilometers traveled, efficiency, turnover, etc.). The second is
based on specially developed mathematical models based on qualitative characteristics, such
as relative costs, the efficiency of a particular train, the relative consumption of resources,
the cost of trains, etc.

This research investigates how to design three-part tariffs, which are pricing plans that
are widely used in transportation or telecommunications industries, by formulating a mixed-
integer nonlinear programming optimization model [5].

Research into the sustainability analysis of tariff pricing for rolling stock operators in the
railway industry remains relevant in light of the constantly changing structure of wagon
turnover and the indicators of the total and working fleet of wagons on the Russian Railways
network. Given market dynamics and changing external factors such as tariff policies, the
competitive environment and technological innovation, pricing sustainability analysis is
essential to understand the current market position and develop strategies to improve the
competitiveness and performance of rolling stock operators.

Researching the structure of wagon turnover allows us to determine current trends in
demand for transport services and take into account changes in customer preferences, which
helps operators adapt to market needs and effectively manage their wagon fleet. Indicators
of the total and working fleet of wagons on the Russian Railways network reflect the current
state of infrastructure and readiness to service traffic flows, and analysis of these indicators
helps to predict possible changes in the long term.

Data on the growing volume of the freight wagon fleet indicate the dynamic development
of the railway industry. An increase in the total fleet by 3.7 thousand units compared to the
previous year indicates a desire to expand infrastructure and improve opportunities for
wagon transportation. The increase in the working fleet of freight wagons by 7.3 thousand
units emphasizes the increase in operational activity and load of railway transportation (Fig.
1).

These results can be seen as a positive indicator of economic growth, as freight volumes
often serve as an indicator of economic activity. An increase in the freight wagon fleet may
indicate increased consumption and production, as well as the development of industries
related to rail transportation.
Therefore, analyzing the sustainability of tariff pricing of rolling stock operators in the railway industry plays an important role in creating more flexible and adaptive strategies that contribute to the efficient functioning of railway transport.

Fig. 1. Dynamics of the general and working fleet of wagons (all types of rolling stock) in 2021 - 2022, thousand units

2 Materials and Methods

To analyze the sustainability of tariff pricing for rolling stock operators in the railway industry, various methods and approaches are used. A systems analysis that examines pricing issues in the context of the wider railway infrastructure, taking into account the many interrelated factors that influence pricing. Also a systematic approach, which allows you to consider the issue not only from the point of view of pricing, but also take into account other key aspects, such as customer needs, technological capabilities, competitive advantages and infrastructure requirements.

An important element of the research is the integration of methods, including the use of different approaches to data collection and analysis, such as analytical and statistical methods, as well as risk assessment and forecasting of industry trends. This provides a comprehensive understanding of the current state of affairs and possible development scenarios, which in turn contributed to the development of sustainable pricing strategies.

The pricing sustainability analysis of rolling stock operator tariffs in the railway industry includes various methods such as correlation analysis and autocorrelation analysis. These methods make it possible to research the degree of relationship between various indicators and identify patterns of data change over time.

Correlation analysis plays an important role in the research of dependencies between various variables. In the context of this research, it is used to examine the relationship between freight wagon rental rates and prices of large rail wagon castings. High values of the correlation coefficient indicate a strong relationship between the variables, while low values indicate their independence. At the same time, the significance of these dependencies is also taken into account using appropriate statistical tests (Spearman in particular). Correlation analysis makes it possible to determine how a change in one parameter affects a change in another, which is important for identifying the factors influencing pricing in a given industry.

Autocorrelation analysis is aimed at researching the relationship between the values of a variable and its lags over time. In this research, it is used to examine temporal patterns and seasonal variations in freight wagon rental rates and prices for large rail wagon castings.
Autocorrelation allows you to determine whether there is a tendency for the values of a variable to repeat at certain intervals. This analysis makes it possible to identify cyclical and seasonal patterns in the data, which helps to better understand and predict long-term trends in the rail transportation industry.

Thus, correlation analysis and autocorrelation analysis play an important role in the research of pricing stability in the railway industry, allowing us to identify relationships and patterns that influence the formation of tariffs and prices for rolling stock.

According to Fig. 2, the process of stabilization of rolling stock rental rates observed in the fourth quarter of 2022, as well as the noted increase in rates for some types of wagons, indicates the dynamism and complexity of the current situation in the railway transportation market. The period of stabilization in the middle of the year, after a prolonged increase at the beginning of 2022, and the subsequent increase at the end of the year indicate the need for a more in-depth analysis of the factors influencing the dynamics of rental rates and their trends.

The presented data indicate an important consequence of the demonopolization of the wagon supply market, namely a reduction in the tariff burden on shippers. The dynamics of decreasing rental rates in the context of many independent rolling stock operators can represent a significant advantage for shippers, as it provides more flexible and competitive conditions for transportation.

However, rising rental rates for specific types of rail wagons, such as gondolas and tanks, indicate a potential increase in demand for certain types of freight services or for more specialized rolling stock. This may be due to changes in consumption and production patterns, as well as specific customer requirements and demands in the freight transport sector.

Therefore, analysis and monitoring of the dynamics of rolling stock rental rates are important for effective planning and management of railway transportation. Understanding the factors influencing rate changes, such as changes in supply and demand, market competition, economic factors and changes in the regulatory environment, can help take the necessary steps to optimize costs and ensure sustainability in the rail freight sector.

![Fig. 2. Rental rates for freight wagons](image-url)
3 Results and Discussion

The results of these research are presented in the form of heat maps of correlations. Heat maps help you visualize the degree of correlation between different variables in your data. They are used to identify relationships and understand the impact of various factors on prices and other characteristics in the rail transportation industry.

Fig. 4 provides information on the correlation between rental rates and prices for large rail wagon castings, and also identifies cases with strong correlations, which allows us to better understand the relationships between various indicators in the data.

Fig. 4. Heat maps of correlations

As a result of the analysis, we note the level of correlation between rental rates for various types of wagons and prices for large wagon castings. Correlation values indicate the strength and direction of the linear relationship between two variables. In addition, p-values provide information about the statistical significance of the correlation.

1. Gondola car:
   • Wheel: 0.761 - Strong positive correlation (p=7.2E-08).
   • Side Frame: 0.949 - Strong positive correlation (p=1.5E-18).
   • Support beam: 0.947 - Strong positive correlation (p=2.8E-18).
   • Car (Wagon)-set: 0.753 - Strong positive correlation (p=1.1E-07).
   • KP (new axis): 0.670 - Positive correlation.
• KP (old axis): 0.674 - Positive correlation.

2. Tanks:
• Wheel: 0.617 - Positive correlation.
• Side frame: 0.790 - Strong positive correlation (p=1.0E-08).
• Support beam: 0.793 - Strong positive correlation (p=8.3E-09).
• Car (Wagon)-set: 0.675 - Positive correlation.
• KP (new axis): 0.629 - Positive correlation.
• KP (old axis): 0.599 - Positive correlation.

3. Covered wagons:
• Wheel: 0.725 - Positive correlation.
• Side frame: 0.742 - Positive correlation.
• Support beam: 0.740 - Positive correlation.
• Car (Wagon)-set: 0.758 - Strong positive correlation (p=8.8E-08).
• KP (new axis): 0.718 - Positive correlation.
• KP (old axis): 0.795 - Strong positive correlation (p=6.9E-09).

4. Platforms:
• Wheel: 0.579 - Positive correlation.
• Side Frame: 0.821 - Strong positive correlation (p=8.9E-10).
• Support beam: 0.826 - Strong positive correlation (p=5.4E-10).
• Car (Wagon)-set: 0.648 - Positive correlation.
• KP (new axis): 0.605 - Positive correlation.
• KP (old axis): 0.525 - Positive correlation.

The results of the correlation analysis provided valuable numerical indicators reflecting the degree of relationship between the various parameters influencing rental prices of rolling stock.

High correlation values and low p-values indicate a significant relationship between rental rates for various types of wagons and prices for large wagon castings. This may be useful in predicting changes in rail wagon rental prices and their relationship to casting prices in the future.

For example, a strong correlation (value close to 1) between rental prices for gondola car and prices for wagon casting components such as side frames and bolsters indicates a direct and proportional relationship between these variables. This means that changes in prices for rail wagon casting components strongly influence changes in rental prices for gondola car.

On the other hand, a weaker correlation (value close to 0.6-0.7) between tank rental prices and some wagon casting components may indicate a less direct relationship between these variables. This may indicate that tank rental prices may be more resilient to changes in prices for rail wagon casting components compared to other types of rolling stock.

To visualize the degree of autocorrelation between different time periods, a graph was constructed for each type of freight wagon rental rate (Fig. 5). It helps determine if there is seasonality or other time patterns in rental rate data.
Calculation and visualization of autocorrelation for prices for large rail wagon castings is presented in Fig. 6.

Price autocorrelation analysis helps in identifying seasonality or other time patterns in large rail wagon casting price data. It can also be useful for predicting future changes in casting prices based on historical data.

The identified seasonal variations and temporal patterns in the autocorrelation data may indicate seasonal factors influencing the demand for rail transportation, which affects the price level. This may be due to the seasonality of the industries that use rolling stock, as well as fluctuations in demand for transport services at different periods of the year.

4 Conclusions

In conclusion, research into the sustainability of rolling stock operator tariff pricing in the railway industry represents an important step in understanding the factors influencing the formation of prices and tariffs in this industry. Using the example of an analysis of changes in rental prices for rolling stock and the impact of market demonopolization on tariff rates, it was revealed that pricing in the railway industry is closely related to various economic, technological and structural factors.

The analysis highlights the complexity of factors influencing pricing in the railway industry and the need to consider various variables when developing sustainable pricing.
strategies and market price management. The findings can serve as a basis for optimizing railway transport management processes and developing more effective pricing strategies.

References