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Analysis of Modern Methodological Approaches to Determining the Quality of Urban Public Transportation by Bus

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Abstract. This article analyzes modern methodological approaches to assessing the quality of bus passenger transport services in urban areas. The study places particular emphasis on identifying the key factors that directly or indirectly influence the efficiency and reliability of bus networks. Based on the research data, it can be concluded that within the four frequency groups examined, the most significant factors affecting the level of service quality (ranging from 1 – minimum to 4 – maximum) are those determined either directly or indirectly by the infrastructure of the directional bus route network. These findings confirm that infrastructural conditions and organizational factors remain central to shaping passenger satisfaction and the overall quality of urban bus transportation.

INTRODUCTION

In recent years, increasing attention has been paid to the development and improvement of urban passenger transport. The main reason for this trend is the continuous growth of the mobility of the population, which directly leads to a rise in the demand for efficient, reliable, and comfortable transport services. As cities expand and urbanization accelerates, the need for well-organized transportation systems becomes not only a convenience but also a critical necessity for ensuring the daily activities of citizens. This has made passenger transport a key component of sustainable urban development and modernization efforts.

In Uzbekistan, the President and the Cabinet of Ministers have recognized the strategic importance of this sector and therefore adopted a number of policy decisions aimed at reforming the urban passenger transport system. The objective of these reforms is to provide residents with transport services that meet global standards, increase the overall accessibility of mobility, and ensure that transportation infrastructure aligns with international practices. A significant milestone in this regard was the Presidential Resolution of February 16, 2023, No. 59, entitled “On Measures to Reform the Public Transport System” [1]. This document laid the foundation for comprehensive modernization initiatives and highlighted the role of public transportation in enhancing the quality of urban life.

The effectiveness of passenger transportation services in cities can, above all, be evaluated by those who use them on a daily basis. Ordinary passengers, as direct consumers of transport services, are best positioned to provide objective and independent assessments of the quality of service delivery. At the same time, alongside social evaluation, the economic dimension of transport services is equally important. Passenger transport represents a crucial element in the structural development of regional economies, as the growth of a modern urban agglomeration cannot be imagined without a highly developed transport network and infrastructure. This factor not only facilitates the movement of people but also directly influences the pace of development of industry, trade, business activities, and the overall urban economy [2].

Moreover, modern approaches to passenger transport reform emphasize not only physical mobility but also sustainability, inclusivity, and digital transformation. Advanced technologies such as intelligent transport systems, real-time passenger information services, and environmentally friendly vehicles are increasingly being integrated

into the public transport sector worldwide. Uzbekistan's reforms aim to adopt such innovations step by step, ensuring that urban residents are provided with safer, more comfortable, and eco-friendly modes of travel. By doing so, the country is moving toward aligning its transportation standards with those of developed nations, while also addressing the unique local challenges of rapid urbanization, environmental sustainability, and social equity.

MAIN PART

One of the most important limitations to the effective development of bus passenger transportation in Uzbekistan is the insufficient level of financing provided from local municipal budgets. Municipal bus transport services, which are an essential component of urban mobility and daily life, often operate at a financial loss, making it difficult to ensure sustainable development of the sector. This financial deficit creates a strong need to optimize the scale and structure of investments directed toward the development of urban transport infrastructure. Without such optimization, modernization initiatives remain slow and fragmented, while the overall efficiency of the system continues to decline. In fact, municipal passenger transport throughout the country is widely characterized by unprofitability, which has become one of the central issues of public transport reform and urban planning strategies.

The insufficient allocation of financial resources from local budgets not only limits the capacity of municipalities to improve the quality of bus services but also prevents the renewal of outdated vehicles, the upgrading of infrastructure, and the introduction of new technologies. As a result, municipal transport enterprises are unable to compete effectively with private commercial operators that often attract passengers through greater flexibility and adaptability. The lack of balance between public and private services aggravates the financial instability of municipal bus networks, making the search for new investment mechanisms and public–private partnership models even more urgent. In this context, optimizing the volume and effectiveness of investments is not simply an economic requirement but a condition for the long-term sustainability of the entire urban mobility system.

The financial losses faced by municipal bus enterprises are primarily explained by the redistribution of passenger flows toward commercial bus routes. These routes, which are usually operated by private companies, are able to respond more flexibly to passenger demand and adapt to shifting travel patterns. As a result, they attract a significant portion of the urban population, leaving municipal services with declining ridership and higher per-passenger costs. Although this trend creates problems for municipal transport, it also reveals an important opportunity: the integration of greater flexibility and mobility into the planning of passenger transport could significantly improve the overall quality and attractiveness of bus services. In other words, if municipal systems adopt innovative planning practices and adapt to changing travel behavior, the process of transportation could become more efficient, convenient, and sustainable [3].

In these circumstances, the classical task for a municipal urban transport enterprise is to maximize the total amount of transport work while simultaneously improving the quality of passenger service delivered on buses. To accomplish this, resources must be utilized as efficiently as possible, with particular attention paid to cost minimization and the elimination of unnecessary expenditures. Such an approach reflects the social responsibility of municipal transport providers, whose mission is not only to guarantee mobility but also to ensure equitable and affordable access for all categories of citizens, including those who depend exclusively on public services [4].

By contrast, for private commercial transport companies the main objective is formulated differently. Their priority is profit maximization, which is considered a fundamental condition for sustainable business development. For these enterprises, efficiency and competitiveness are at the forefront: by focusing on profitable routes and maximizing passenger flows, they aim to increase the overall value of their business operations and secure long-term stability in the market [5].

According to A.S. Terentyev's research, these issues can be mathematically expressed as follows:

- **For municipal transport enterprises**:

$$\begin{aligned} Z - D &\rightarrow min \\ K &\geq K_{min} \end{aligned} \quad (1)$$

- **For private commercial companies**:

$$\begin{aligned} S_a &\rightarrow max \\ K &\geq K_{min} \end{aligned} \quad (2)$$

Here:

- K – the established level of service quality for passengers;
- K_min – the minimum acceptable level of service quality below which transport services are no longer viable;
- Z – the total expenditures of municipal bus enterprises for providing passenger services (thousand UZS);

• D – the total revenues of municipal bus enterprises from passenger services (thousand UZS);
• S_a – the business value of private bus companies (thousand UZS).

These formulas clearly illustrate the different strategic focuses of municipal and private enterprises. For municipal organizations, the primary task is to minimize the gap between expenditures (Z) and revenues (D), while maintaining at least the minimum acceptable quality of service (K_min). In other words, their concern lies in financial balance and social responsibility. For private companies, however, the goal is to maximize the overall business value (S_a), again under the condition that service quality remains above the threshold K_min. This ensures that even profit-oriented operators are obliged to adhere to a certain standard of service provision, thereby aligning business objectives with the needs of the urban population.

Through this dual framework, Terentyev highlights the fundamental tension between public service obligations and market-driven incentives. It also demonstrates the importance of regulatory oversight and strategic policy development in reconciling these different objectives, so that both municipal and private actors can contribute effectively to the sustainability and modernization of urban transport systems.

In the tasks described above, the subjective parameter is represented by the level of quality in passenger service. This factor cannot be measured purely in financial or operational terms, since it directly reflects the personal perceptions and experiences of bus passengers themselves. For this reason, in his research A.S. Terentyev proposed identifying the most important qualitative and quantitative indicators that characterize the quality of bus transport services provided to the population. By defining these indicators, it becomes possible to measure and evaluate service quality more objectively, even though the parameter originates from subjective user perceptions.

To achieve this, a comprehensive sociological survey was carried out among passengers, designed to capture their evaluations of the services they received. The survey methodology was based on a structured questionnaire that listed a wide range of potential factors influencing service quality. Respondents were asked to select six key factors that, in their view, best defined the level of quality in bus transport services. In this way, the study ensured that the chosen parameters were not imposed externally but rather emerged directly from the opinions of the service users themselves.

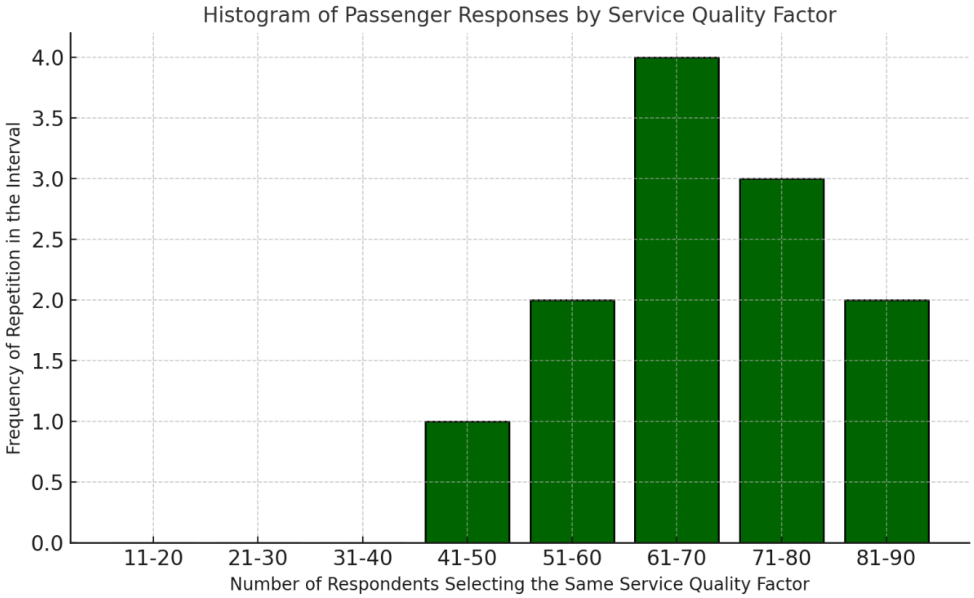

Figure 1. Factors Influencing the Level of Service Quality in Urban Bus Transportation [6]

Once the data were collected, the results were processed using statistical methods to ensure accuracy, reliability, and the elimination of bias. The statistical treatment made it possible to rank the factors in order of importance and to identify both the strengths and weaknesses of municipal and commercial bus operations. Moreover, the survey results provided valuable feedback for policymakers, enabling them to understand which aspects of bus services passengers considered most critical for satisfaction, comfort, and reliability.

The findings of the survey were presented visually in the form of a histogram (Figure 1) and summarized in a comparative statistical table (Table 1). These visualizations clearly demonstrated the distribution of passenger preferences, allowing researchers to see at a glance which factors dominated in shaping perceptions of service quality. For example, issues such as frequency of buses, punctuality, vehicle comfort, safety conditions, driver professionalism, and ticket affordability could be directly compared to determine their relative influence on overall satisfaction.

In summary, Terentyev's approach highlighted that while financial and operational indicators are essential for evaluating the sustainability of bus services, the subjective perceptions of passengers play an equally important role. Only by combining these two perspectives—economic efficiency and user satisfaction—can the development of bus passenger transport be guided toward models that are both socially equitable and economically viable.

Table 1. Factors Influencing the Level of Service Quality in Urban Bus Transportation

№	Factor Name	Number of Preferences
1	Time expenditure	89
2	Tariff level	84
3	Dinsity of route network	77
4	Accident safety	75
5	Frequency of movement	73
6	Number of transfers	68
7	Bus oerating speed	66
8	Bus occupancy (crowding)	64
9	Regularity of movement	61
10	Environmental safety	57
11	Reliability of buses	51
12	Level of information services	42

At the next stage of the study, it is proposed to distinguish a set of **local indicators** (five in total) and the factors that determine them. Once these have been identified, the **integral service quality indicator** can be calculated using the following formulas:

$$K=\sum_{i}^{5} \alpha_i P_i, \quad (3)$$

$$P_i=\sum_{i}^{m} \beta_i k_{ij} \quad (4)$$

subject to the conditions:

$$\sum_{i}^{n} \alpha_i = 1, \text{ and } \sum_{j}^{m} \beta_j = 1 \quad (5)$$

Here:

- K – the integral indicator of the overall level of service quality;
- P_i – the local indicator of the level of transport service provision;
- α_i and β_j – weighting coefficients reflecting the relative importance of the local indicators (P_i) and factors (k_{ij});
- k_{ij} – the indicator reflecting the degree of conformity of the factor to its optimal or reference value, defined as:

$$k_{ij} = \frac{n_{ij}}{n_{ij}^{E}} \quad (6)$$

where $\mathbf{n_{ij}}$ is the actual value of factor *j* during the analyzed period, and $\mathbf{n_{ij}^e}$ is the corresponding benchmark or reference value of the same factor.

This formulation provides a structured and mathematically grounded method for aggregating both qualitative and quantitative characteristics of passenger service into a single composite index. The approach makes it possible to

evaluate service quality more comprehensively by combining subjective perceptions (such as passenger comfort or satisfaction) with objective indicators (such as bus frequency, travel speed, or safety conditions).

To determine the values of the weighting coefficients (α_i and β_j), the well-known **Analytic Hierarchy Process (AHP)** method is recommended [7]. The idea of AHP is to form pairwise comparison matrices of the selected indicators within different groups of criteria, thereby allowing researchers to derive relative importance weights. Through this procedure, both direct and indirect relationships between indicators can be incorporated into the final evaluation of service quality.

However, the AHP method is not without limitations. Its principal shortcoming lies in the subjectivity of decision-making: since pairwise comparisons are based on expert judgment or respondent opinions, the results may vary depending on the evaluator's perspective. Furthermore, AHP has been repeatedly criticized by scholars due to certain mathematical inconsistencies, particularly the violation of the **consistency property** of pairwise comparison matrices. These violations can lead to distortions in the calculation of weight vectors, thereby reducing the reliability of the results. As a result, while AHP remains a powerful and widely used method for multi-criteria decision analysis, its application requires careful attention to methodological rigor and consistency checks [8].

Overall, the integration of hierarchical analysis with the proposed formulas (1.3–1.6) provides a balanced framework for measuring service quality. It allows both quantitative performance indicators and qualitative passenger perceptions to be aggregated into a single index, enabling policymakers, municipal transport authorities, and private operators to identify strengths, diagnose weaknesses, and prioritize interventions for improving urban bus services.

Nogin V.D. proposed a simplified version of the analytic hierarchy process (AHP), based on the nonlinear aggregation of criteria, in which the problem of inconsistency in pairwise comparison matrices is addressed. This approach offers an alternative to the traditional AHP by reducing some of its methodological weaknesses while still enabling the systematic evaluation of multiple decision-making criteria. By resolving the issue of matrix consistency, Nogin's method provides researchers with a more stable and mathematically reliable tool for comparing diverse indicators of service quality and for constructing balanced decision models.

Another critical challenge in applying such methods is the construction of a model for forming the **integral (generalized) criterion**. When attempting to integrate different indicators into a single composite measure, researchers are confronted with the question of how exactly to combine them. Several aggregation methods exist: the most common are additive approaches, which rely on summation, and multiplicative approaches, which rely on product-based formulas. While both are widely used in practice, they have been subject to significant criticism.

The main weakness of these aggregation methods is that "the advantages (or disadvantages) of indicators under one criterion are often offset by or suppressed due to the values of indicators under another criterion" [9]. In other words, a strong performance in one area can mask deficiencies in another, thereby producing a distorted picture of the overall quality of service. For example, a bus transport system may perform very well in terms of low fares or travel speed, but if it performs poorly in terms of safety or environmental standards, the aggregate measure may still appear acceptable, even though passengers remain dissatisfied. This demonstrates why careful methodological choices are necessary when constructing generalized indices.

Despite these criticisms, the simplified method proposed by Nogin remains highly relevant under current conditions in the urban bus transport market. Its strength lies in its adaptability to real-world contexts where both municipal and private bus operators coexist, and where passengers represent the ultimate consumers of transport services. By explicitly incorporating passenger goals and interests into the evaluation process, the method ensures that service quality is assessed not only from the operator's perspective but also from the standpoint of those who rely most heavily on public transport.

In this respect, the approach highlights the importance of aligning service quality indicators with passenger needs, such as affordability, safety, comfort, and reliability. Even if the method has its limitations, its orientation toward integrating user perspectives into decision-making makes it particularly suitable for today's reform-oriented environment in Uzbekistan's public transport sector. The recognition of passengers as the central actors in shaping service evaluation marks a shift from operator-focused metrics to consumer-focused metrics, which is consistent with modern practices in transport planning and service delivery.

CONCLUSION

Based on the research data, it can be concluded that within the four frequency groups analyzed, the factors with the most significant influence on the level of service quality (ranging from 1 – minimum to 4 – maximum frequency

of repetition) are directly or indirectly determined by the infrastructure of the directional bus network. These factors illustrate the critical importance of infrastructure-related characteristics in shaping the passenger experience. The ranking of key factors is presented as follows:

1. **Number of transfers** – *n = 68 (repetition frequency = 4)*
2. **Bus operating speed** – *n = 66 (repetition frequency = 4)*
3. **Degree of bus occupancy (crowding)** – *n = 64 (repetition frequency = 4)*
4. **Regularity of bus movement** – *n = 61 (repetition frequency = 4)*
5. **Density of the route network** – *n = 77 (repetition frequency = 3)*
6. **Frequency of bus operations** – *n = 73 (repetition frequency = 3)*
7. **Total time expenditure** – *n = 89 (repetition frequency = 2)*

The analysis shows that factors associated with the organization and reliability of bus services—such as the number of transfers required, travel speed, and service regularity—are those most frequently identified by passengers as critical to the overall quality of urban bus transport. These findings confirm that infrastructural characteristics and operational planning remain the dominant determinants of passenger satisfaction.

At the same time, it is essential to note that the **level of information services**, which was also included in the survey results (see Table 1), represents an innovative component of modern digital transport systems. Although its current importance appears to be relatively modest compared to infrastructural factors, its significance is expected to grow rapidly in the coming years. This is due to the increasing role of real-time information technologies—such as mobile applications, GPS-based tracking, and intelligent passenger information systems—in shaping passenger perceptions of service quality.

Thus, the study highlights two main dimensions of improvement. On the one hand, traditional infrastructure-related indicators, such as speed, regularity, and network density, remain essential for enhancing passenger comfort and efficiency. On the other hand, the development of advanced **digital information services** will become a decisive factor in future reforms, as it directly links service efficiency with accessibility, transparency, and user satisfaction. Integrating these dimensions is crucial for designing a sustainable and innovative urban bus network infrastructure capable of meeting both current and future mobility demands.

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