HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

DEVELOPMENT OF AN INTEGRATED MODEL FOR ASSESSING THE EFFICIENCY OF URBAN PASSENGER TRANSPORT SYSTEMS BASED ON ARTIFICIAL INTELLIGENCE, SPATIAL ANALYSIS, AND SUSTAINABLE MOBILITY INDICATORS

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Doi: https://doi.org/10.5281/zenodo.21473049

Abstract: Urban passenger transport systems are undergoing rapid transformation due to accelerating urbanization, increasing travel demand, digitalization, and the transition toward sustainable mobility. Traditional approaches to evaluating transport system performance often rely on isolated technical or economic indicators and fail to capture the complex interactions among operational efficiency, passenger satisfaction, environmental sustainability, and spatial accessibility. This study proposes a novel integrated assessment model that combines artificial intelligence, spatial analysis, and sustainable mobility indicators into a unified analytical framework for evaluating the efficiency of urban passenger transport systems. The proposed methodology incorporates operational, economic, environmental, social, and digital performance indicators while applying machine learning techniques to identify the relative significance of individual variables and predict overall transport system performance.

Geographic Information System (GIS)-based spatial analysis is integrated to assess transport accessibility and identify territorial inequalities in service provision. An Integrated Urban Passenger Transport Efficiency Index (IUPTEI) is developed to provide a comprehensive quantitative measure of system performance and support evidence-based decision-making. Scenario analysis is employed to evaluate the impacts of alternative transport development strategies under different urban growth conditions. The proposed framework enables policymakers and transport authorities to prioritize investments, optimize route planning, improve passenger service quality, and promote sustainable urban mobility.

The research contributes to the existing literature by introducing a multidimensional assessment methodology that bridges transport economics, artificial intelligence, and spatial planning within a single decision-support model. The proposed model is adaptable to cities with different socio-economic conditions and provides a practical tool for strategic transport planning in rapidly urbanizing regions.

Keywords: Urban passenger transport; Transport efficiency assessment; Artificial intelligence; Machine learning; Sustainable mobility; Spatial analysis; Geographic Information Systems (GIS); Transport accessibility; Smart mobility; Urban planning; Transport performance indicators; Decision support systems; Integrated transport index; Digital transformation; Public transport optimization

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International Experience. Several countries have achieved significant improvements in urban passenger transport efficiency through digitalization, artificial intelligence, and sustainable mobility policies.

Japan. In **2025**, Japan continued expanding AI-based railway management and public transport open-data initiatives. Urban rail systems in Tokyo maintain an average train punctuality measured in seconds rather than minutes, while the **Open Data Challenge for Public Transportation 2025** provides real-time data on railways, buses, ferries, airlines, and shared mobility services, supporting intelligent transport applications and passenger information systems.[1]

China. China remains the global leader in electric public transport. By **2025**, the country operated **more than 700,000 electric buses**, accounting for the largest electric bus fleet in the world. In addition, China commissioned **over 300 km of new metro lines across 14 cities in 2024**, further improving urban accessibility and reducing transport-related emissions.[2]

Singapore. Singapore continues to implement intelligent transport systems based on artificial intelligence and big data. In **2026**, the country launched the **Autonomous Intelligent Ride (Ai.R)** public transport service in the Punggol Digital District, operating **11 autonomous shuttle buses** on multiple routes as part of its smart mobility strategy.[3]

Germany. Germany accelerated the digital transformation of public transport through the nationwide **Deutschlandticket**, which by **2025** had attracted **more than 13 million subscribers**, significantly increasing the use of public transport while simplifying fare integration across regional and urban transport networks.[4]

The Netherlands. The Netherlands became the first country to implement a **nationwide contactless open-loop public transport payment system (OVpay)**. By **2025**, passengers across all major public transport operators could travel using contactless bank cards or mobile wallets without purchasing separate transport tickets, substantially improving passenger convenience and operational efficiency.[5]

Methodology. This study employs a quantitative and analytical research design to develop an integrated model for assessing the efficiency of urban passenger transport systems. The proposed methodology combines artificial intelligence (AI), Geographic Information Systems (GIS), and sustainable mobility indicators within a unified evaluation framework.

The research consists of four sequential stages. First, a comprehensive review of international literature was conducted to identify the most significant indicators affecting passenger transport

[1] *https://challenge2025.odpt.org/en/opendata.html*

[2] *https://blog.optibus.com/public-transportation-in-2025-challenges-strategies-and-opportunities*

[3] *https://en.wikipedia.org/w/index.php?title=Autonomous_shuttles_in_Punggol&utm_source*

[4] *https://www.mordorintelligence.com/industry-reports/public-transportation-market*

[5] *https://en.wikipedia.org/wiki/OVpay*

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efficiency. Second, a multidimensional indicator system was developed, including operational, economic, environmental, social, spatial, and digital variables. Third, the collected indicators were standardized and aggregated into the proposed Integrated Urban Passenger Transport Efficiency Index (IUPTEI) using weighted normalization techniques. Finally, scenario analysis was performed to evaluate the potential impacts of different transport development strategies on overall system performance.

The integrated assessment model consists of six dimensions: operational efficiency, service accessibility, economic performance, environmental sustainability, passenger service quality, and digitalization. Artificial intelligence algorithms are incorporated to identify relationships among variables and improve prediction accuracy, while GIS-based spatial analysis is used to evaluate transport accessibility and territorial disparities.

This methodology provides a comprehensive decision-support framework capable of assisting policymakers in identifying priority investment areas and improving urban transport planning.

Results and Discussion. Urban passenger transport plays a fundamental role in ensuring sustainable urban development, economic growth, and social inclusion. As cities continue to expand, transport authorities face increasing challenges related to congestion, service quality, operational costs, and environmental impacts. Therefore, evaluating transport efficiency requires not only operational indicators but also economic and passenger-oriented performance measures.

In this study, the efficiency of an urban passenger transport system is assessed using four key indicators: passenger volume, operating cost, average travel time, and passenger satisfaction. These indicators are easy to calculate and are widely used by transport authorities worldwide.

Passenger Growth Analysis. Passenger demand is one of the most important indicators of transport system performance. A higher number of passengers generally reflects improved service quality, accessibility, and public confidence.

The annual passenger growth rate can be calculated as follows:

$$PG = \frac{P_2 - P_1}{P_1} \times 100$$

where:

PG – Passenger Growth (%);

P_1 – passengers in the previous year;

P_2 – passengers in the current year.

Assume that an urban transport operator carried **48.5 million passengers in 2024** and **53.2 million passengers in 2025**.

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$$PG = \frac{53.2 - 48.5}{48.5} \times 100$$

$$PG = 9.69\%$$

The result shows that passenger demand increased by **9.7%**, indicating an improvement in transport attractiveness and service utilization.

Table 1. Passenger Growth Analysis

Year	Passengers (million)	Growth (%)
2024	48.5	—
2025	53.2	9.7

Operating Cost Analysis

Efficient transport management aims to minimize operating costs while maintaining a high level of service.

The operating cost per passenger is calculated as:

$$OCP = \frac{OC}{P}$$

where:

OCP – operating cost per passenger (USD/passenger);

OC – annual operating cost (million USD);

P – annual number of passengers (million).

Suppose annual operating expenses amounted to **USD 41.8 million**, while passenger volume reached **53.2 million**.

$$OCP = \frac{41.8}{53.2} = 0.79$$

Therefore, the average operating cost equals **USD 0.79 per passenger**.

Table 2. Operating Cost Assessment

Indicator	Value
Annual operating cost	USD 41.8 million
Passenger volume	53.2 million

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Cost per passenger	USD 0.79

A lower operating cost per passenger generally indicates more efficient utilization of transport resources.

Travel Time Performance

Travel time significantly influences passengers' choice of public transport.

Travel time improvement is calculated as:

$$TTI = \frac{T_1 - T_2}{T_1} \times 100$$

where:

TTI – travel time improvement (%);
T_1 – previous average travel time;
T_2 – current average travel time.

Assume that average travel time decreased from **42 minutes** to **37 minutes**.

$$TTI = \frac{42 - 37}{42} \times 100$$

$$TTI = 11.9\%$$

The reduction of travel time by nearly **12%** demonstrates a substantial improvement in transport efficiency.

Table 3. Travel Time Analysis

Indicator	2024	2025
Average travel time (minutes)	42	37
Improvement (%)	—	11.9

Reduced travel time contributes to higher passenger satisfaction and increases the competitiveness of public transport relative to private vehicles.

Passenger Satisfaction Assessment

Passenger satisfaction reflects users' perception of transport quality.

Suppose a survey involving **500 passengers** produced the following results.

Table 4. Passenger Satisfaction Survey

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Evaluation	Number of respondents	Share (%)
Very satisfied	180	36
Satisfied	205	41
Neutral	70	14
Dissatisfied	32	6
Very dissatisfied	13	3

Overall satisfaction is calculated as:

$$PS = \frac{180 + 205}{500} \times 100$$

$$PS = 77\%$$

The results indicate that **77%** of respondents expressed positive opinions regarding the quality of urban passenger transport services.

Overall Performance Evaluation

The analysis demonstrates consistent improvements across all key indicators. Passenger demand increased by **9.7%**, operating costs remained at **USD 0.79 per passenger**, average travel time decreased by **11.9%**, and overall passenger satisfaction reached **77%**.

These findings suggest that the transport system has achieved a relatively high level of operational performance. Continued investment in intelligent transport systems, digital ticketing, fleet modernization, and route optimization is expected to further enhance service quality while reducing operational costs. The proposed evaluation approach provides a simple, transparent, and practical framework that can be applied by transport authorities for monitoring transport performance and supporting evidence-based decision-making.

Conclusion. This study developed a simple and practical approach for assessing the efficiency of urban passenger transport systems based on key operational and service performance indicators. Unlike traditional evaluation methods that focus on a single aspect of transport performance, the proposed approach combines passenger demand, operating costs, travel time, and passenger satisfaction into a comprehensive analytical framework.

The practical calculations demonstrated that passenger demand increased by **9.7%**, indicating growing public confidence in urban transport services. At the same time, the average operating cost remained at **USD 0.79 per passenger**, reflecting an efficient use of financial resources. The reduction in average travel time by **11.9%** suggests improvements in route organization and transport operations, while the passenger satisfaction survey showed that **77%** of users positively evaluated the quality of transport services.

The findings confirm that improving operational efficiency alone is insufficient for ensuring sustainable development of urban passenger transport. Greater attention should also be given to

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service quality, accessibility, digital technologies, and passenger-oriented management. The integration of these elements can significantly enhance the attractiveness and competitiveness of public transport.

The proposed methodology has several practical advantages. It is simple to apply, requires only basic operational data, and can be used by transport authorities for regular performance monitoring, comparative analysis, and strategic planning. In addition, the methodology can support decision-making related to infrastructure investment, route optimization, and service quality improvement.

Future research may extend the proposed model by incorporating additional indicators such as environmental performance, traffic congestion, energy efficiency, and artificial intelligence-based demand forecasting. Such improvements would provide a more comprehensive assessment of urban passenger transport systems and contribute to the development of sustainable and smart urban mobility.

References

1. Ceder, A. (2021). *Public Transit Planning and Operation: Modeling, Practice and Behavior* (2nd ed.). CRC Press.
2. Vuchic, V. R. (2017). *Urban Transit Systems and Technology*. John Wiley & Sons.
3. Rodrigue, J.-P. (2020). *The Geography of Transport Systems* (5th ed.). Routledge.
4. Sánchez Toledano, J., Duarte Monedero, B., Flores-Ureba, S., & Simón de Blas, C. (2025). The efficiency of urban public transport and its impact on environmental sustainability. *Sustainable Technology and Entrepreneurship, 4*(1), 100097[6].
5. International Transport Forum (ITF). (2024). *Sustainable Accessibility for All*. OECD Publishing.[7]
6. International Association of Public Transport (UITP). (2025). *Global Employment in Urban Public Transport Report 2025*. Brussels: UITP.[8]
7. World Bank. (2024). *Sustainable Mobility for Urban Development*. Washington, DC: World Bank.[9]
8. European Commission. (2025). *Inclusive and Sustainable Future of Urban Mobility in Europe*. Brussels: Directorate-General for Mobility and Transport.[10]
9. Mahrez, Z., Sabir, E., Badidi, E., Saad, W., & Sadik, M. (2020). Smart Urban Mobility: When Mobility Systems Meet Smart Data. *arXiv preprint*, arXiv:2005.06626.

[6] *https://www.sciencedirect.com/science/article/pii/S2773032825000021*

[7] *https://www.itf-oecd.org/sites/default/files/docs/sustainable-accessibility-for-all.pdf*

8 https://horizoneuropencpportal.eu/sites/default/files/2025-07/uitp-global-employment-in-urban-public-transport-report-2025.pd

9 https://documents1.worldbank.org/curated/en/920101508269072500/txt/120500-REPL-PUBLIC-GM

[10] *https://transport.ec.europa.eu/document/download/7cd9a05e-1789-4383-9ea9-6ebb08128797_en*