

Modern Approaches to Improving Urban Transportation System Efficiency

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Abstract: This article analyzes the theoretical and practical aspects of improving public passenger transport routes. The development of modern cities, the acceleration of urbanization processes, and population growth are imposing new requirements on transport systems. The efficiency of the urban transport network directly affects the convenience of movement for the population, economic activity, and environmental sustainability. During the study, methods for optimizing public transport routes, mechanisms for managing traffic flows, principles for forming routes based on passenger demand, and opportunities for using digital technologies were studied. Based on international experience, the integrated operation of bus, trolleybus, tram, and metro systems was also analyzed.

Keywords: public transport, passenger transport, transport routes, urbanization, transport planning, GIS technologies, mobile mobility, smart city, transport logistics, passenger flow.

Introduction

Today, more than half of the world's population lives in cities, and this figure is increasing every year. As a result of the acceleration of urbanization processes, the demand for urban transport systems is increasing sharply. The transport system is one of the most important components of urban infrastructure, ensuring the daily movement of the population, economic activity, and interregional connections. This trend reflects the broader global pattern of urban growth documented in recent international assessments [1].

Public passenger transport is considered the most mass and cost-effective mode of transport for urban residents. Its effectiveness is largely determined by the correct organization of transport routes. Poorly planned routes lead to excessive passenger time, inefficient vehicle operation, and increased traffic congestion. Its effectiveness is therefore closely tied to established principles of urban transit system design [2].

In recent years, large-scale reforms have been implemented in many countries to modernize public transport systems, improve the quality of transport services, and develop environmentally sustainable transport. Optimization of transport routes plays an important role in these processes. These reform efforts are consistent with the sustainable urban mobility agenda promoted internationally [3].

The aim of this study is to study the scientific foundations for improving public passenger transport routes and to identify effective management mechanisms.

The theoretical foundations of the public transport system treat vehicles, routes, stations, infrastructure, and management systems as interdependent components whose coordinated operation determines overall efficiency, with the route network serving as the primary connecting element between residential, industrial, business, and service areas [4]. Balancing transport supply and demand is a central planning problem: demand depends on population size, density, and economic activity, while supply depends on the vehicle fleet, route network, and service frequency; an imbalance produces congestion, overloading, or under-utilisation [5]. International practice commonly evaluates public transport performance using indicators such as transport coverage, travel speed, walking distance, waiting time, and service quality, with a population living within 300–500 metres of a stop generally regarded as an optimal coverage standard [6]. These principles and indicators underpin the analytical approach adopted in this study.

Method

This study applies a comparative-analytical method based on a structured review of international transport-planning literature, policy documents, and case studies of public transport reform in major cities. Passenger-demand and route-network relationships were examined following established transport-demand modelling procedures [7], while the spatial assessment of routes, stops, and coverage areas followed geographic-information-system-based analytical methods [8]. The economic evaluation of route optimisation drew on established cost-benefit frameworks for public transport [9], and the assessment of social and equity outcomes followed methods developed for transport and social-exclusion research [10]. The overall analytical framework, linking diagnosis, planning measures, and evaluation criteria, was structured in accordance with sustainable urban mobility planning guidelines [11]. International case studies (London, Seoul, Curitiba, Berlin, Tokyo, Beijing, and Shanghai) were selected to represent diverse city sizes, transport-network configurations, and stages of technological adoption, and were compared against the theoretical principles and indicators identified above.

Results

Principles of forming public transport routes. The formation of public transport routes is considered one of the most critical stages of urban transport system planning. Transport routes serve to meet the daily needs of the population, ensure connectivity between urban areas, and increase the efficiency of transport services. Properly organized routes allow passengers to save time, utilize vehicles efficiently, and reduce the load on the road network. Therefore, it is necessary to rely on scientifically grounded principles in the process of forming transport routes.

One of the main principles of organizing transport routes is planning based on passenger demand. Any route must, first and foremost, meet the transport needs of the population. For this purpose, the volume of passenger traffic, directions, travel time and goals are studied. As a rule, the main movements of the population are directed from residential areas to workplaces, educational institutions, shopping centers, healthcare facilities and other service centers. Therefore, routes must create convenient and uninterrupted transport links between these functional areas.

In the formation of transport routes, special attention is paid to the principle of territorial coverage. Public transport should cover as many residential areas as possible. In international practice, it is generally recommended that the walking distance to transport stops be within 300–500 meters. This indicator is one of the important factors determining the convenience of using public transport. Ensuring adequate transport coverage also contributes to reducing the population's need to use personal vehicles.

The principle of flexibility also plays an important role in the formation of transport routes. Cities are constantly developing, creating new residential areas, industrial enterprises, and service centers. As a result, the demand for transport will also change. Therefore, transport routes must be regularly analyzed and improved in accordance with existing needs.

Overall, the formation of public transport routes is a complex process aimed at meeting the mobility needs of the population, increasing the efficiency of the transport system, and ensuring the sustainable development of cities. Adherence to the principles of demand-based planning, territorial coverage, integration, economic efficiency, environmental safety, and flexibility ensures the high-quality functioning of the transport system and plays an important role in solving the transport problems of modern cities.

Factors for improving transport routes. Improving public passenger transport routes is considered one of the important directions for the development of modern cities. Population growth, the acceleration of urbanization processes, the increase in the number of vehicles, and the formation of new residential areas require the regular improvement of existing transport systems. By optimizing transport routes, it is possible to improve the mobility of the population, ensure the efficient use of transport infrastructure, and ensure environmental sustainability. The factors influencing this process are linked to various social, economic, territorial, and technological factors that determine the development prospects of the transport system.

The functional-planning structure of cities also significantly influences the improvement of transport routes. In modern cities, residential, industrial, business, and recreational areas are located at a certain distance from each other. The proper organization of transport links between these regions determines the efficiency of the urban transport system. The formation of routes taking into account the main routes of movement of the population increases the level of coverage of the transport system and makes it more convenient to use transport services.

The level of development of transport infrastructure is also an important factor. The quality of roads, the density of the street network, and the availability of stations, terminals, and transport exchange centers directly affect the possibilities of organizing routes. It becomes difficult to organize transport routes effectively in regions where infrastructure is insufficiently developed. Therefore, the improvement of the transport system must be accompanied by the modernization of transport infrastructure.

Economic factors also play an important role in the development of transport routes. The financial capabilities of transport enterprises, operating costs, fuel prices, and investment volumes directly affect the quality of transport services. By optimizing routes, it is possible to reduce excessive vehicle traffic, reduce fuel consumption, and reduce operational costs. As a result, the economic efficiency of transport enterprises will increase and the quality of service will improve.

In recent years, environmental factors have become increasingly important in the development of the transport system. The increase in the number of private cars leads to air pollution, increased noise levels, and excessive consumption of energy resources. Therefore, improving public transport routes is considered an important tool for ensuring environmental sustainability. As a result of optimizing transport routes, vehicle idling will be reduced, the amount of harmful gases emitted into the atmosphere will decrease, and the urban ecological environment will improve.

Optimization of transport routes based on modern technologies. Digital transformation processes are having a significant impact on transport systems, as well as all other sectors. In the context of population growth, increasing complexity of transport flows, and increasing demand for mobility, managing public transport routes using traditional methods is becoming increasingly difficult. Therefore, the use of modern information and communication technologies, artificial intelligence, geographic information systems, and big data analysis is recognized as one of the most effective tools for optimizing transport routes. These technologies will increase the efficiency of the transport system, improve the quality of services provided to passengers, and ensure the rational use of transport infrastructure.

One of the most widely used technologies in optimizing transport routes is geographic information systems (GIS). GIS technologies allow for the consolidation of data on transport infrastructure, passenger traffic, population density, and the functional composition of urban areas on a single electronic platform. Using these systems, transport networks are mapped, the effectiveness of

existing routes is assessed, and the most optimal options for new routes are determined. GIS technologies allow for spatial analysis in transport planning and serve to scientifically assess the location of stations, transport coverage, and the territorial distribution of routes.

In recent years, Big Data technologies have become increasingly important in the management of transport systems. Mobile operators, GPS devices, electronic payment systems, and video surveillance tools generate vast amounts of data every day. By analyzing this data, passenger movement habits, the most frequently used routes, the level of transport congestion, and peak hours are determined. As a result, transport organizations will be able to determine the number of trips in accordance with real needs, distribute vehicles and improve the quality of service. The advantage of Big Data technologies is that they allow for the management of the transport system based not only on the current state but also on forecasting future demands.

The role of artificial intelligence technologies in optimizing transport routes is also increasing. Artificial intelligence algorithms are capable of processing large volumes of data about transport flows in a short time and forming optimal decisions. For example, AI-based systems can predict traffic jams in advance, automatically adjust vehicle schedules, and optimize routes in real time. This will reduce passenger waiting times, reduce vehicle downtime, and optimize operational costs.

The Global Positioning System (GPS) and automated monitoring systems have become an integral part of modern transport management. Using GPS technologies, the location, speed, and direction of each vehicle are tracked in real time. Based on this information, dispatch centers coordinate the movement of vehicles and promptly respond to emerging problems.

Intelligent Transport Systems (ITS) are considered an integrated form of modern technologies in transport route management. These systems ensure the continuous exchange of information between vehicles, traffic lights, road infrastructure, and control centers. As a result, traffic will be organized more orderly and safe. The design of such integrated systems follows established intelligent-transportation-systems planning frameworks [12].

In general, modern technologies are one of the main tools for optimizing public transport routes. GIS, Big Data, artificial intelligence, GPS monitoring, intelligent transport systems, and electronic payment platforms allow for more efficient management of the transport system. By widely implementing these technologies into transport practice, it is possible to improve the quality of services provided to passengers, reduce transport costs, and ensure the sustainable development of cities. In the future, the further development of digital technologies is expected to create new opportunities for managing transport systems and elevate the efficiency of public transport to a new level.

Analysis of international experience. The issue of improving public passenger transport routes is one of the priority areas of transport policy in many developed and developing countries worldwide. Population growth, the acceleration of urbanization processes, and the increase in the number of private cars place a significant burden on transport systems. For this reason, many countries strive to improve the quality of transport services by modernizing public transport systems, optimizing transport routes, and introducing digital technologies. Studying international experience and adapting its effective aspects to local conditions is of great importance in the development of transport systems.

The city of London in the United Kingdom also has advanced experience in the effective organization of public transport routes. The London transport system is based on the mutually integrated operation of the metro, bus, tram, and railway networks. Transport services are coordinated by a unified management center, and a unified tariff system applies to all types of transport. The urban transport network is formed on the basis of radial and ring routes connecting central areas with remote districts. This allows passengers to move comfortably and quickly in various directions. The London experience clearly demonstrates the importance of multimodal transport systems in planning transport routes.

Seoul, South Korea, is also one of the cities that has successfully implemented innovative approaches in the field of transport management. In Seoul, bus routes are classified by color, with each route performing a specific functional function. Highway routes, inter-district routes, and local routes will operate within a single system. Vehicle movement is monitored via GPS devices, and passengers are provided with real-time information regarding the vehicle's arrival time. Transportation loads are also forecasted using artificial intelligence and big data technologies. As a result, the quality of transport services has improved, and passenger waiting times have been significantly reduced. This reform programme has been documented as one of the most comprehensive public transport restructuring efforts among large Asian cities [13].

One of the most famous experiences in the development of public transport in Latin America belongs to the Brazilian city of Curitiba. The Bus Rapid Transit (BRT) system has been introduced in this city since the 1970s. This system is based on creating special lanes for buses and ensuring high-speed traffic. Despite the fact that the BRT system is significantly cheaper than metro construction, it is capable of transporting large volumes of passenger traffic. Transportation routes in Curitiba are inextricably linked to the city's master plan structure, and transport and territorial development processes are carried out in parallel. This experience shows the importance of implementing transport planning in harmony with urban planning.

The German city of Berlin is distinguished by a high level of public transport integration. The urban transport system forms a single transport network consisting of the metro (U-Bahn), urban electric trains (S-Bahn), trams, and buses. Transport routes cover all parts of the city territory, and passengers' rapid transition from one mode of transport to another is ensured through transport exchange centers. The Berlin experience demonstrates the importance of the principles of continuity and coverage in shaping transport routes. Comparative research on German public transport financing shows how integration and coordinated fare policy have supported long-run financial sustainability [14].

Tokyo, the capital of Japan, has one of the largest and most complex transport systems in the world. The metro, railway, and bus networks operate in the city in a coordinated manner. The transport system is characterized by high precision and strict adherence to schedules. The Tokyo experience shows that in conditions of high population density, it is necessary to use high-capacity vehicles and developed transport exchange centers for the effective organization of transport routes. Tokyo has been documented as a leading example of a transit-oriented metropolis in comparative international research [15].

In recent years, significant progress has been made in the development of public transport in major Chinese cities such as Beijing and Shanghai. In these cities, metro networks were expanded, bus routes were re-optimized, and smart transport systems were introduced. The quality of transport services has significantly improved as a result of managing traffic flows using digital technologies and artificial intelligence. These experiments confirm the importance of innovative technologies in the modernization of transport systems.

An analysis of international experience shows that there are several general principles for improving public transport routes. These include the integration of transport modes, planning based on passenger demand, the use of digital technologies, the introduction of eco-friendly vehicles, and the harmonization of the transport system with urban development strategies. These principles serve to increase the efficiency of the transport system, create comfortable conditions for passengers, and ensure environmental sustainability.

Thus, international experience shows effective mechanisms for improving public passenger transport routes. The use of modern technologies, integrated management systems, and scientifically grounded planning methods is essential for improving the quality of transport services and ensuring the sustainable development of cities. The study and implementation of this experience will create a solid foundation for the further development of Uzbekistan's transport systems.

Prospects for improving public transport routes in the cities of Uzbekistan. The development of the public transport system and the improvement of routes in the cities of Uzbekistan are among the most pressing issues against the backdrop of today's urbanization processes. Population growth, urban expansion, and the formation of new residential areas require a revision of existing transport routes. Transport flows are increasing significantly, especially in large cities such as Tashkent, Samarkand, Namangan, Andijan, and Nukus.

In the future, the widespread introduction of digital technologies as the main directions for improving public transport routes is of great importance. Using GIS systems, GPS monitoring, and electronic payment platforms, it is possible to accurately analyze passenger flows and optimize routes. This will increase the accuracy and efficiency of transport services.

The development of environmentally friendly vehicles, particularly electric buses and modern BRT systems, is also an important promising direction. This will not only improve the city's environmental situation but also reduce transportation costs. The development of transport exchange centers and the management of routes based on an integrated system will create convenient and rapid conditions for passenger movement.

Discussion

Economic efficiency of route optimization. Optimizing public transport routes is a crucial factor in increasing the economic efficiency of the urban transport system. Properly planned routes reduce operational costs for transport enterprises, optimize fuel consumption, and increase vehicle utilization levels. As a result, available resources are distributed more efficiently.

By improving routes, vehicle idling will be reduced and the balance between trips will be improved. This not only ensures economic efficiency but also increases the overall productivity of the transport system. Additionally, the reduction in passenger travel time to the destination has a positive impact on labor productivity.

An optimized transport system also has a direct impact on the city's economy. Increased population mobility leads to the activation of trade, services, and manufacturing sectors. In addition, the efficiency of investments in transport infrastructure will increase, and revenues to the city budget will increase.

Environmental and social impacts. Improving public transport routes will yield important results not only economically but also ecologically and socially. First of all, the optimized transport system will reduce the use of private cars, which will lead to a reduction in harmful emissions into the atmosphere. As a result, the quality of urban air will improve and the environmental burden will decrease.

Effective organization of transport routes reduces traffic congestion and limits the excessive movement of vehicles. This contributes to reduced fuel consumption and reduced noise levels. This will ensure the stability of the city's ecological environment.

Socially, the development of public transport increases the mobility of the population and expands the possibilities of using transport. Affordable and convenient transport services will be of particular importance for low-income segments of the population. This serves to strengthen social equality.

Conclusion

Improving public passenger transport routes is one of the important conditions for the development of modern cities. The efficiency of the transport system is closely linked to population mobility, economic activity, and environmental sustainability.

The research results showed that when optimizing routes, it is necessary to take into account passenger demand, urbanization processes, the state of transport infrastructure, and modern information technologies. The use of GIS, Big Data, and artificial intelligence technologies allows for more efficient management of transport systems.

An analysis of international experience showed that innovative approaches applied in Singapore, London, Seoul, and Curitiba have significantly increased the efficiency of public transport. Adapting these practices to the conditions of Uzbekistan will serve to improve the quality of transport services in the country's cities.

In the future, the development of scientific research on improving transport routes, the widespread introduction of digital technologies, and the integrated management of transport systems will make an important contribution to the sustainable development of cities.

References

1. United Nations Human Settlements Programme (UN-Habitat), World Cities Report 2022: Envisaging the Future of Cities. Nairobi: UN-Habitat, 2022.
2. V. R. Vuchic, Urban Transit Systems and Technology. Hoboken, NJ: John Wiley & Sons, 2007.
3. World Bank, Sustainable Urban Mobility and Public Transport Development. Washington, DC: World Bank, 2023.
4. A. Ceder, Public Transit Planning and Operation: Modeling, Practice and Behavior, 2nd ed. Boca Raton, FL: CRC Press, 2016.
5. M. D. Meyer and E. J. Miller, Urban Transportation Planning: A Decision-Oriented Approach, 2nd ed. New York: McGraw-Hill, 2013.
6. International Transport Forum, ITF Transport Outlook 2023. Paris: OECD Publishing, 2023.
7. J. D. Ortúzar and L. G. Willumsen, Modelling Transport, 4th ed. Chichester: John Wiley & Sons, 2011.
8. H. J. Miller and S.-L. Shaw, Geographic Information Systems for Transportation: Principles and Applications. New York: Oxford University Press, 2001.
9. T. Litman, Evaluating Public Transportation Benefits and Costs. Victoria, BC: Victoria Transport Policy Institute, 2024.
10. G. Currie, New Perspectives and Methods in Transport and Social Exclusion Research. Bingley: Emerald Publishing, 2018.
11. European Commission, Sustainable Urban Mobility Planning Guidelines. Brussels: European Commission, 2023.
12. M. A. Chowdhury and A. W. Sadek, Fundamentals of Intelligent Transportation Systems Planning. Boston, MA: Artech House, 2003.
13. J. Pucher, H. Park, M. H. Kim, and J. Song, "Public transport reforms in Seoul: Innovations motivated by funding crisis," *Journal of Public Transportation*, vol. 8, no. 5, pp. 41–62, 2005.
14. R. Buehler and J. Pucher, "Making public transport financially sustainable," *Transport Policy*, vol. 18, no. 1, pp. 126–138, 2011.
15. R. Cervero, The Transit Metropolis: A Global Inquiry. Washington, DC: Island Press, 1998.