

Research on the Application of Machine Learning in Urban Public Transport Scheduling

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Abstract

As a fundamental component of the urban transportation system, the frequency of bus departures significantly influences the commuting experience of residents along transit routes and the overall efficiency of urban ground transportation. However, in certain cities, challenges such as morning and evening rush-hour traffic, urban spatial planning around transit corridors, and continued reliance on manual dispatching systems hinder the timely and efficient scheduling of buses in accordance with real-time road conditions and passenger demand. On the basis of field observations of bus operations in City A, the author reported that during peak hours, long intervals between buses result in excessive passenger loads per vehicle, whereas during off-peak hours, low passenger demand leads to a high rate of underutilized seating capacity. This paper presents a comparative analysis between the traditional manual static dispatching method and an intelligent dispatching approach based on machine learning. Through a demonstration of the capabilities of machine learning in urban bus dispatching, the study highlights that a machine learning-integrated dispatching system offers superior performance in terms of route efficiency and dynamic adaptability to changing traffic conditions compared with conventional manual dispatching methods.

Keywords

transportation, urban transportation, intelligent scheduling, machine learning, public transportation system

1. Introduction

Buses are an important means to address urban road traffic congestion and connect different places. Taking 2024 as an example, the total urban passenger volume nationwide for the whole year was 106.797 billion person-times, an increase of 5.7% compared with the previous year. Among them, the urban passenger volume of public buses was 38.670 billion person-times, an increase of 1.6%, the urban passenger volume of urban rail transit was 32.209 billion person-times, an increase of 9.6%, the urban passenger volume of taxis was 35.841 billion person-times, an increase of 7.1%, and the urban passenger volume of urban ferries was 0.77 billion person-times, a decrease of 6.9%. The urban passenger volume of public buses ranks first, accounting for 36.2% (Ministry of Transport of the People's Republic of China, 2025). (Note: The statistics of Hong Kong, Macao Special Administrative Regions and Taiwan Province are not included.)

However, in recent years, with the rapid development of cities, existing bus line planning in many cities has relied mostly on static data analysis, ignoring the dynamic changes in urban traffic flow and the complexity of residents' travel behaviors. This traditional planning method fails to fully utilize modern intelligent transportation technologies and big data analysis methods and is unable to capture the dynamic changes in

urban traffic flow distribution and residents' travel demands in real time, resulting in insufficient adaptability of bus lines (Dong, 2025). Machine learning technology has the ability to implement reasoning and wide adaptability and can provide new solutions for bus scheduling problems. Currently, machine learning has been widely applied in multiple fields; for example, Lei Chengtao, Zhang Li, Han Tengfei, etc., proposed a regional comprehensive resource scheduling and optimization algorithm based on machine learning, which can obtain and process emergency resource data in real time, improve resource utilization efficiency and response speed, and enhance the overall efficiency and reliability of scheduling plans (Lei et al., 2025). Therefore, this paper introduces machine learning algorithm technology and combines it with the current situation of City A to illustrate that machine learning algorithms have more advantages over manual scheduling.

2. Traditional Bus Dispatching Methods:

2.1 Static and Dynamic Dispatching Methods

In traditional dispatching methods, the combination of static and dynamic dispatching is the most commonly used approach. Static dispatching refers to determining the route plan before the operation starts and not being affected by other demands during the operation period; dynamic dispatching refers to dynamically adjusting the unexecuted path plans during the vehicle's execution of the plan, considering new demands (Jin et al., 2025). The dispatcher calculates the second-day departure schedule on the basis of the passenger flow and transportation situation the previous day. On the second day of operation, on the basis of the feedback from the drivers who are responsible for the passenger transport task on the day, dynamic dispatching is carried out along the route. However, from the departure point to stations with a large number of passengers, this process takes a long time, and there may be problems such as insufficient transportation vehicles because the number of passengers at the station is large.

2.2 Pain Points of Traditional Dispatching

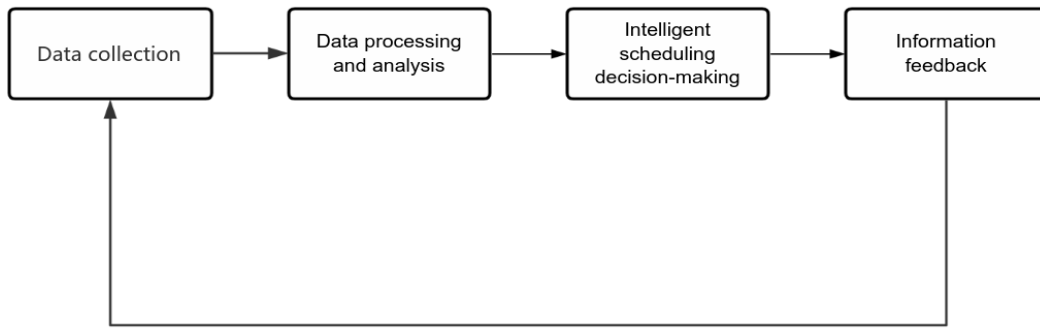
In daily operations, traditional dispatching methods plan the second-day departure time on the basis of the current day's schedule. However, during off-peak and peak hours, the number of passengers at the stations along the route is not the same. During actual investigations, at a certain middle school station on the B line in City A, the number of passengers waiting for the bus within 20 minutes reached more than 70 people; however, at 20 minutes, only 2 buses passed through this station on the B line and were unable to meet the travel needs of all passengers. At this time, when the driver reported that the number of passengers at this station was large, due to the long route, dispatching could not promptly dispatch vehicles to the station to relieve the passenger flow, which easily caused passenger congestion.

3. Machine learning algorithm scheduling method:

3.1 Machine learning method concept

Machine learning algorithms are introduced into the scheduling system to predict the road passenger flow in real time. Carry out real-time scheduling when approaching off-peak and peak hours. The machine conducts autonomous learning to obtain feedback on the effect and thereby achieves a closed loop. The application block diagram of machine learning technology in the scheduling system is shown in Figure (1).

Figure 1: The application of machine learning technology in the scheduling system.



3.2 Application Ideas and Practical Cases of Machine Learning Methods

First, through the full coverage of GPS devices, the real-time positioning information of all buses can be viewed and scheduled through GPS monitoring software, thus changing the practice where dispatchers rely on experience to depart buses, significantly improving the accuracy and efficiency of dispatching (Yin et al., 2025). Second, cameras are installed in the buses and remotely linked to the dispatching center, allowing the dispatching center to view the number of passengers in the bus compartments and the road conditions in real time. Machine learning algorithms are used for future passenger flow prediction to conduct reasonable dispatching. For example, the intelligent dispatching system for urban rail transit in a certain city integrates multiple data sources, such as the Automatic Fare Collection (AFC) system, station (including onsite video surveillance), and train (such as in-car video surveillance, train axle load, etc.), to introduce machine learning technology to obtain the passenger flow at different locations of the network and dispatch vehicles to carry passengers (Liu et al., 2025).

3.3 Comparison of Machine Learning Dispatching Methods and Traditional Dispatching Methods

The real-time passenger flow prediction system based on 5G MEC edge computing technology can quickly process massive amounts of data and accurately predict the trend of passenger flow changes. Data collection is carried out through onboard sensors, station monitoring equipment, etc., and real-time passenger data are collected, including passenger numbers, boarding and alighting times, line congestion degree, etc. Edge computing uses 5G MEC technology to perform rapid processing at the data source, reducing data transmission delay. Through machine learning models, the patterns of passenger flow changes are analyzed, and future passenger demand is predicted. Dynamic dispatching adjusts the vehicle departure intervals and routes on the basis of the predicted results (Song, 2025).

With respect to traditional dispatching methods, traditional dispatching methods are mostly a combination of static dispatching and dynamic dispatching. However, the traditional demand-responsive bus dynamic dispatching method essentially considers only the existing demand in the current stage and the dynamic demand during the execution planning process, ignoring the potential demand in subsequent stages that may affect current-stage decision-making. The potential demand is defined as the order demand that does not appear in the system at the decision moment but may occur in the future (Lei et al., 2025).

Therefore, through comparison, in machine learning methods, at the dispatching center, machine learning models can be used on the basis of passenger flow data to analyze passenger flow for dispatching. Using the dynamic prediction results, the departure intervals of vehicles can be adjusted. In static dispatching, the dynamic dispatching of buses often departs on the basis of experience and current-stage demand and is unable to predict future possible situations in a timely manner. In data processing, machine learning has stronger computing power, faster processing speed, and higher accuracy than manual methods do. It can predict future possible demands in advance.

4. Research and application of machine learning technology in scheduling systems at home and abroad

4.1 Research and application of machine learning technology in domestic scheduling systems

Under the continuous dissemination and influence of machine learning technology, many domestic teams have also begun to conduct research on the application of machine learning in bus scheduling. For example, Zeng Jiehua, Wang Xianghua, Wu Guang, et al. proposed a bus scheduling model based on simulated annealing, and the allocation algorithm of this model is simple, feasible, controllable, and suitable for the operation of multiple buses. Only real-time bus GPS positioning information and bus speed information are needed, which is suitable for large-scale bus simulation scheduling allocation on a map. The simulation results show that, regardless of short-term or long-term scheduling, the reasonable application of the simulated annealing algorithm can increase the bus running speed by more than 10%, save energy, and improve bus travel satisfaction (Zeng et al., 2024). Yin Wei, Zuo Zhongyi, Zhang Yunqi, et al. proposed a method for optimizing bus intervals in a vehicle networking environment and established an optimization model for the bus departure schedule on the basis of the objective function of minimizing the passenger waiting time, passenger comfort, and operating cost of the bus company (Yin et al., 2018). Long Yun, Zhou Jianfeng, Fang Kan, et al. proposed a flexible route bus scheduling optimization model with uncertain travel time. Through experimental results, it has been shown that the distributed robust optimization model of flexible route bus scheduling can effectively reduce the delay level at stations and the congestion during the journey and results in a smaller increase in one-way travel time than can the deterministic model, which can better improve passengers' travel experience and, to a certain extent, enhance the service level of flexible route buses (Long et al., 2024).

4.2 Research and application of machine learning technology in foreign scheduling systems

With the development of machine learning technology, foreign teams have also conducted research on the application of machine learning in scheduling systems. For example, Barrera Hernandez J E and Tarazona Torres L E, Tabares A, et al. proposed an algorithm that integrates machine learning demand prediction into the discrete-time planning cycle and adjusts scheduling decisions in real time. Research has shown that this method has greatly promoted the development of medium-sized public transportation management. It combines the precise machine learning prediction with dynamic operational decisions. This balance ensures the effective utilization of resources while meeting the needs of passengers (Barrera Hernandez et al., 2025). Kost V, Merakou M, Gkiotsalitis K. After constructing a mixed-integer linear programming model with probability constraints (Kost et al., 2025). Research has shown that the construction of this model can reduce the waiting time for passengers at the vehicle.

5. Conclusion

This paper compares the traditional bus scheduling method with the machine learning algorithm scheduling method. Through practical applications in different regions and the research of domestic scholars, it is concluded that the introduction of machine learning methods into the bus scheduling system of City A is more advantageous.

The traditional scheduling method has made significant contributions to the development of public transportation in the past and the construction of public transportation in small cities and rural areas in contemporary times. However, with the continuous development of cities and the increasing number of passengers choosing to take public transportation, the traditional scheduling method has been unable to efficiently cope with the pressure caused by high passenger flows. In the context of large passenger flows in urban systems, manual scheduling consumes a great deal of resources and has no as strong predictive and handling capabilities for future events as machines do. In the face of massive passenger flows and large amounts of data, the advantages of machine processing speed and precise results are more suitable for the scheduling of public transportation in cities.

The application of machine learning technology in bus scheduling is a topic worthy of further research. How to better integrate big data with machine learning to achieve high fault tolerance and low error rates, how to quickly respond to passenger flow issues, how to better connect with other transportation modes, and how to smoothly and quickly handle every unknown factor that may cause problems in the city are all issues that require further study.

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Conflicts of Interest

The authors declare no conflict of interest.

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