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The study on the Internet of Things' implication in improving the punctuality of air transportation in bad weather

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Abstract. Air travel is a popular choice for people who seek to travel outside in the present. It greatly promotes communication and economic development. However, flight delays can have seriously disappointing effects on various aspects. For passengers, they not only need a long time to wait and additional expenses, but they also experience more psychological stress. And airlines face economic losses, reduced customer satisfaction, and disruptions in flight scheduling, which further affect operational efficiency. Therefore, this paper aims to explore potential methods that are combined with the Internet of Things to improve the punctuality of air transportation in order to ease the hard situation of flight delays caused by bad weather. And based on the previous related papers, the author of this paper thinks a kind of meteorological monitoring and early warning system can be built based on the Internet of Things to improve real-time weather monitoring and flight scheduling, as well as ground service optimization. Hence, people can improve the punctuality of air transportation by optimizing resource utilization and cost management so that the whole industry can bring significant economic benefits to airline companies and improved travel experiences to passengers.

Keywords: Internet of Things, air transportation, flight delay, punctuality.

1. Introduction

Nowadays, air transportation plays an important role in modern society. Air transportation connects regions worldwide, promoting cultural exchange, tourism, and international cooperation. It also provides a fast and efficient means of transporting goods and people, facilitating international trade and global economic growth.

However, according to statistics from the 2023 Civil Aviation Development Statistical Bulletin, China's passenger airlines carried out a total of 4.6717 million flights, of which 4.1019 million were normal flights, with an average normality rate of 87.80%. If the arrival and departure time of the flight are more than 15 minutes later than the time on the flight schedule or the flight is canceled, it is called a flight delay [1]. And weather was the leading cause of abnormal flight classification statistics in 2023, accounting for 60.42% [2].

Overall, adverse weather conditions can have an impact on the entire flight route, affecting both pilot control and aircraft performance, according to Cheng's "Research on the Influence Factors of Flight Delay" [3]. Inclement weather such as rain, thunderstorms, and snow can significantly reduce visibility levels. Thi reduction in visibility poses challenges for pilots during takeoff as it hampers their ability to

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safely operate and navigate the aircraft. Lower visibility also tends to increase pilot anxiety. Many reports from pilots indicate that prolonged periods of low visibility often lead them to choose either returning or diverting to alternative airports until the weather improves before resuming their journey. Furthermore, landing and aircraft spacing have to be widened, which puts strain on airport airspace capacity. Consequently, this will reduce the overall efficiency of operations at the airport and may disrupt ground signal transmission between aircraft resulting in flight delays [3].

The consequences of delayed flights extend beyond inconvenience; they can also disrupt business activities such as important meetings thereby affecting business cooperation and economic exchanges negatively. Moreover, delays can particularly affect the tourism industry during peak travel seasons or holidays by causing inconvenience for travelers. Therefore, it is of vital importance to figure out some strategies that enable avoidance of areas with unfavorable weather conditions in order to reduce the frequency of flight delays so that people can improve efficiency and resource utilization and promote the economic development of society.

2. Internet of Things and its application in transportation

2.1. Internet of things

The Internet of Things means that according to the agreed protocols, use the information sensing equipment to make sure that objects are connected to the network so that the objects can realize information exchange and communication through the information communication media in order to achieve intelligent identification, positioning, tracking, supervision and other functions.

The term Internet of Things (IoT) was first used in 1999 by British technology pioneer Kevin Ashton to describe a system in which objects in the physical world could be connected to the Internet by sensors. He coined the term to illustrate the power of connecting Radio-Frequency Identification (RFID) tags used in corporate supply chains to the Internet in order to count and track goods without the need for human intervention.

Today, the Internet of Things has become a popular term for describing scenarios in which Internet connectivity and computing capability extend to a variety of objects, devices, sensors, and everyday items [4].

2.2. Application in transportation

To begin with, in terms of high-speed railways, the application of the Internet of Things can help with safety monitoring on high-speed railways [5]. Sensors are installed on tracks, trains, bridge tunnels, communication signal equipment, and so on to detect real-time status information on high-speed railways like temperature, vibration, pressure, and other data. This data is analyzed through the Internet of Things platform, which can aggregate and process the data at the local monitoring unit, then predict and identify anomalies in advance to reduce the risk of accidents and provide decision-making suggestions for driving safely. In addition, the use of Internet of Things technology can improve the quality of service and, hence, the passenger experiences. For example, for intelligent ticket inspection, the railway stations can improve the ticket generating, selling, and verification equipment with Internet of Things technology. Therefore, passengers' in-and-out station, identity authentication, self-service ticketing, information binding, and verification can be automatically realized, which greatly saves labor costs and reduces unnecessary time for passengers. What's more, it will improve the potential abilities of the railway stations to satisfy a large number passengers' travel needs.

So far, the Internet of Things has been applied in air transportation in some aspects as well [6]. For health monitoring and predictive maintenance, the Internet of Things can help airlines optimize their operations and services. Sensors can be installed on each key part of the aircraft to monitor the operating status and performance of engines, tires, electronic equipment, and so on, so that they can help collect data in real time through the devices of the Internet of Things and predict equipment failures and maintenance through data analysis algorithms, thereby enabling predictive maintenance and reducing unnecessary downtime and repair costs. And by using the technology of the Internet of Things,airports

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can monitor and optimize aircraft fuel consumption to reduce operating costs, which will contribute significantly to improving the efficiency, safety, and quality of air transport services.

What's more, the Internet of Things brings significant benefits in terms of baggage tracking and management. In the past, baggage tracking was often confusing and inaccurate, resulting in lost or delayed baggage. Nevertheless, with the use of the Internet of Things and RFID technology, luggage can be tracked and controlled throughout the process. These systems allow airlines and passengers to be really engaged when tracking the location of luggage and quickly identify and resolve issues. For passenger experience enhancement, using the devices of the Internet of Things and data analysis can provide personalized services based on passenger preferences, such as seat preferences, dining options to make passengers enjoy the journey on the plane.

3. Mechanism

3.1. The Internet of Things used in current weather prediction

Meteorological data acquisition is the basis for building an integrated meteorological observation system to monitor and predict weather changes. And the Internet of Things technology can provide a guarantee for this foundation.

According to the locations of different sensors, the meteorological observation system can be divided into ground-based observation, atmosphere-based observation, and space-based observation. All types of observation equipment are distributed with a large number of sensors, which can monitor and collect various meteorological elements such as temperature, humidity, pressure, and wind speed in the areas where the equipment is employed, and can also monitor and track the evolution trend of the weather systems in real time [7].

In recent years, the application, combined with the Internet of Things and a variety of remote sensing and telemetry technologies, has promoted the development of comprehensive meteorological observation in various countries. Some countries have established a relatively integrated ground-based, air-based, and space-based stereo observation system, which has successfully established advanced ground-based, ocean-based, and atmosphere-based baseline climate monitoring networks and realized automatic observation based on the technology of the Internet of Things [7].

3.2. Flight delays predicting based on weather prediction's data of the Internet of Things

Based on weather prediction, which also takes advantage of the Internet of Things, one solution is the framework of meteorological monitoring and early warning system based on the Internet of Things.

To begin with, data can be collected through a network of monitoring points distributed across different spatial regions, which typically consist of a large number of sensors, collectors, and communication interfaces that can sense and monitor meteorological elements such as air pressure, temperature, humidity, wind speed, and so on [7]. And then, these meteorological elements should be fully analyzed and translated into information that represents the evolution trend of the present weather. Next, through various communication networks like wireless networks and wired networks, this information can be realized through real-time transmission and interactive sharing about its data and implications. Hence, this information can be stored in some large data sources, such as Weather Underground [8].

Therefore, a system for effectively predicting flight delays based on weather prediction's data from the Internet of Things can be built. To begin with, there are numerous aspects of the meteorological information and data that need to be obtained, which can be reported by a variety of distributed devices on the Internet of Things and accessed via Web services. The process of finding and identifying such data sources involves leveraging Web Mapping such as Google Maps [9]. And it can also identify relevant Internet of Things data sources such as flight tracking site FlightRadar24, weather data source Weather Underground, and real-time Air Quality Index data sources [8-9].

Secondly, a platform on the Internet of Things that includes a crawler engine that automatically collects real-time data from many data sources and performs data consolidation and pre-processing can

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be designed and developed to deal with the heterogeneity of the data sources. By defining appropriate criteria, features from different data sources are integrated to form datasets that comprehensively reflect the factors affecting flight delays. On the basis of data collection and integration, data analysis and modeling can also be carried out [9]. By pre-processing and feature extraction of the collected data from the Internet of Things, the correlation between flight delay and various meteorological features is studied. Then, logistic regression and support vector machines (SVM) were used to model and analyze the factors affecting flight delay. After a large amount of meteorological information and data in datasets is analyzed by a variety of meteorological scientific methods, meteorological forecasting, disaster early warning, and further transmission to the information releasing system can be realized.

4. Results

Consequently, this analyzed weather change information and potential trends can be promptly transmitted to airlines and pilots in real time, enabling swift response. This enhanced responsiveness facilitates flight adjustment in terms of flight paths or waiting times when encountering adverse weather conditions, thereby reducing the likelihood and mitigating the impact of delays. Moreover, real-time meteorological data aids in optimizing flight scheduling and ground services by allowing for reconfiguration of ground operation plans, including gate allocation, baggage handling, and crew scheduling, among others. Additionally, proactive strategies should be prepared beforehand for different weather conditions, such as changing flight times or changing boarding gates if a storm is approaching.

All in all, by integrating real-time weather information gained by the way of the Internet of Things into their operational processes, airlines can enhance overall safety and efficiency. Pilots can receive timely updates on weather conditions, leading to safer flight operations. Ground staff can be better prepared to handle the impacts of weather changes, reducing turnaround times and improving overall efficiency. And with better forecasting and planning, airlines can keep passengers informed about potential delays or changes in real time, improving communication and managing passenger expectations more effectively.

5. Potential challenges

While the Internet of Things technology shows great potential for improving on-time performance in air transport, its implementation still faces some practical challenges that require in-depth thinking and effective responses.

To begin with, successful employment of the Internet of Things systems requires seamless integration of multiple technologies, including but not limited to sensor technology, cloud computing, big data analytic, artificial intelligence, and more. The integration of these technologies requires not only high investment but also cross-domain expertise and skills. Therefore, how to effectively control the cost while ensuring the advanced technology has become an urgent problem to be solved.

In addition, with the widespread adoption of the Internet of Things in air transport, a large amount of sensitive data will be collected and transmitted. This data includes, but is not limited to, flight status, passenger information, airport operation data, and so on. How to ensure the privacy and security of these data in the transmission and storage process to prevent data leakage and illegal use is an important challenge that the applications of the Internet of Things must face.

Last but not least, in the present, the field of the Internet of Things has not yet formed unified technical standards and protocols, and interoperability between different vendors and devices is poor [10]. This can lead to problems such as device incompatibilities and inconsistent data formats when building a comprehensive monitoring and early warning system for the Internet of Things. Therefore, promoting the development and implementation of technical standards of the Internet of Things is the key to improving the overall efficiency and compatibility of the system.

6. Conclusion

This paper explores the potential of leveraging the Internet of Things to improve air transportation punctuality, particularly in the face of bad weather conditions. By utilizing the technology of the Internet

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of Things, this paper proposes the establishment of a meteorological monitoring and early warning system to improve real-time weather surveillance, flight scheduling, and ground service optimization.

While the theoretical framework and proposed system hold the potential to significantly improve flight punctuality and efficiency, there are still some limitations to consider carefully. First, the study is based on theoretical analysis and does not include actual experimental simulation. Further empirical studies are needed to validate the feasibility and effectiveness of the proposed system. Besides, more comprehensive data on airline company operations and detailed flight schedules were not available for this study. Future research should strive to incorporate more comprehensive datasets to improve the accuracy and reliability of the system. Lastly, weather systems are highly complex and dynamic, and their predictions are subject to inherent uncertainties. Despite the advanced technologies employed, achieving 100% accuracy in weather forecasting and flight delay prediction remains challenging.

To sum up, the Internet of Things offers significant potential for improving the punctuality of air transportation in bad weather conditions. While further research and practical implementation are needed to address the existing limitations, the theoretical framework and proposed system presented in this paper provide an ingenious framework for future development and improvement in this important area.

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