A Review: Application of Big Data Analytics in Airlines Industry

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Abstract

Technological advancements have led to the generation of massive amounts of data across industries, including the airline sector. Leveraging big data analytics allows valuable insights to be derived from these vast datasets. A total of twenty research papers were reviewed, and electronic databases such as Web of Science, ScienceDirect, Google Scholars, and IEEE Xplore were utilized to gather relevant studies. The search keywords included "big data analytics," "airlines industry," "data mining," "predictive analytics," and "machine learning." The findings highlight the diverse application areas of Big Data Analytics (BDA) in the airline industry, including airline operation and optimization, service quality and customer satisfaction, risk management and safety, and aircraft maintenance. The review also identifies key challenges associated with BDA implementation in the airline industry: data integration, regulatory compliance, and data privacy and security concerns. Overall, this review paper provides valuable insights into the application of BDA in the airline industry and the associated challenges. It contributes to the existing knowledge base and offers a foundation for future research and practical implementations in this domain.

Keywords: *Big Data Analytics, Airlines industry, Applications, Machine Learning*

1. Introduction

Technological advancements have led to the generation of massive amounts of data across industries, including the airline sector. Valuable insights can be extracted from these massive datasets with the help of big data analytics. Data analysis is a structured procedure encompassing several steps, such as clarifying the objective, gathering data, processing and refining the data, and conducting the analysis. Data analysis can take different forms, including predictive analysis to forecast future outcomes, exploratory analysis to uncover patterns and relationships, diagnostic analysis to identify causes of observed phenomena, and prescriptive analysis to recommend actions or solutions [1]. As big data analytics continues to revolutionize how businesses operate, the airline industry is not far behind in recognizing its potential. Today, organizations predominantly employ big data to gain deeper customer insights [2]. The objectives of this paper include identifying the various applications and challenges in leveraging big data analytics within the airline industry and highlighting the applications and challenges of implementing big data analytics in the airline industry. This review will provide an overview of the

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research landscape, guiding future studies and facilitating informed decision-making in the industry.

This paper will delve into the areas where big data analytics plays a crucial role in the airline industry and assess the impact on decision-making processes and business outcomes in the airline sector. The scope of the research, focusing on studies that employ big data analytics to derive insights and drive improvements within the airline industry, is defined in this review. This review contributes to the existing body of knowledge by highlighting the research gaps and providing valuable insights to industry stakeholders. The findings of this review will help researchers, industry professionals, and policymakers gain a comprehensive understanding of the current state of big data analytics in the airline sector, ultimately fostering innovation and growth in the industry.

2. Methodology

This section explains the steps involved in reviewing prior research work, which include the following actions: a search strategy, a research selection process, data extraction, and conclusion synthesis. Detailed explanation concerning these processes is as follows.

2.1. Search Strategy

A comprehensive search strategy was designed to find relevant papers and articles. Electronic databases, including Web of Science, ScienceDirect, Google Scholars, and IEEE Xplorer, were searched with controlled vocabulary and keywords combined. The search terms used included "big data analytics," "airlines industry," "data mining," "predictive analytics," and "machine learning." Only articles released in English from 2018 to 2023 were included in the search of relevant publications. Additional studies were found by manually reviewing included papers' reference lists and pertinent literature reviews.

2.2 Study Selection

The selection of studies followed a two-step process. The first step involved screening the titles and abstracts of extracted publications using preset selection and exclusion requirements. Studies that were thought to be possibly significant or that offered information on how big data analytics are being used in the airline sector proceeded to the full-text review.

2.3 Data Extraction

A standardized data extraction template was created to gather relevant data from the included research. The template captured details such as study authors, research objectives, data sources, and analytical techniques related to utilizing big data analytics in the airline industry.

2.4 Synthesis of Findings

The findings from the included studies were synthesized using a narrative approach. Key themes, trends, and patterns related to applying big data analytics in the airline industry were identified and analyzed. The synthesized information provided insights into the current state of knowledge and potential challenges in this field.

3. Result & Finding

The results and findings of this report are divided into three parts, covering the trends of reviewed publications, the applications of BDA categorized by the key themes, and the challenges in employing BDA in the airline sector.

3.1 Publication Trends

The review paper examining the application of BDA in the airline industry analyzed 20 articles and papers. The highest number of publications was recorded in 2020, with six publications, as shown in Figure 1.

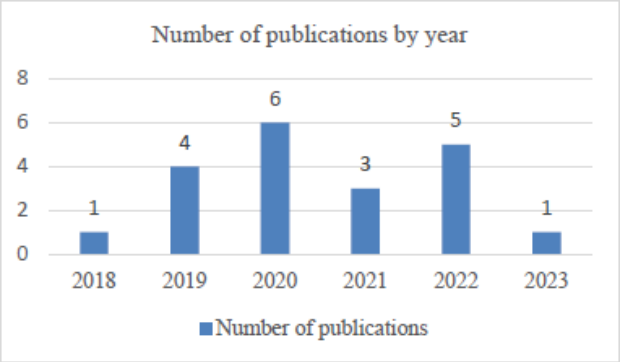

Figure 1. Number Of Publications by Year

Regarding the analytical techniques used in Figure 2, predictive analytics was employed in 11 publications, showcasing the industry's interest in utilizing data to forecast future trends and make informed decisions. Additionally, nine publications focused on descriptive analytics, emphasizing the importance of analyzing historical data to gain insights into current operational scenarios.

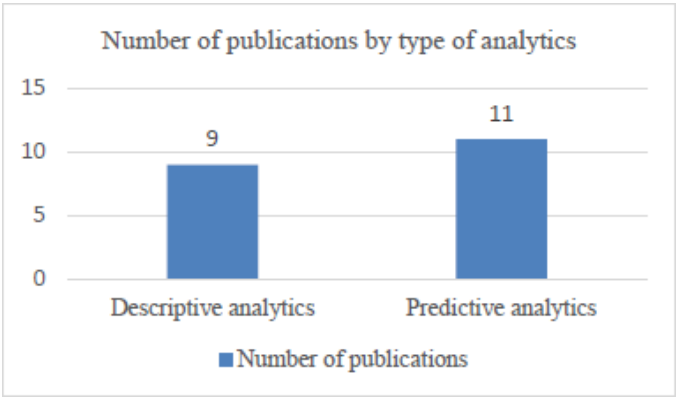

Figure 2. Number Of Publications by Type of Analytics

The first theme, airline operation and optimization, was represented by nine publications highlighting the industry's efforts to enhance various aspects of airline operations. The second theme, service quality and customer satisfaction encompassed five publications, indicating the growing recognition of BDA's potential to improve the overall customer experience and enhance customer satisfaction. The third theme, risk management, and safety included three publications demonstrating the industry's application of BDA to identify and mitigate risks proactively. Lastly, the fourth theme, aircraft maintenance, was represented by three publications illustrating how BDA can optimize maintenance processes and improve aircraft reliability. The review paper further classified the publications into four key themes, as shown in Figure. 3.

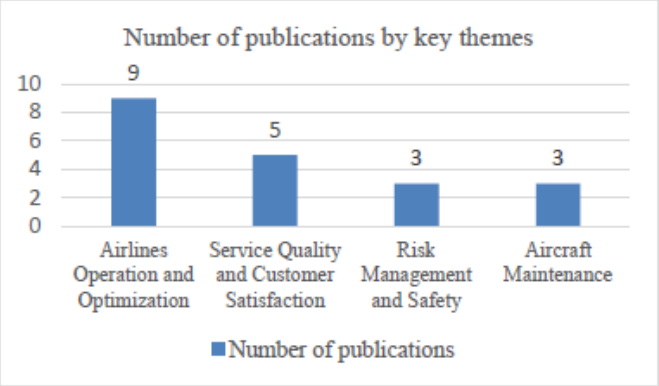

Figure 3. Number Of Publications by Key Themes

3.2 Application of BDA in the Airlines Industry

Airline services have widely used BDA to support and improve their activities. BDA provides many benefits and challenges to the services. This section discusses four themes of the current applications of BDA in the industry: (1) airline operation and Optimization, (2) Service Quality and Customer Satisfaction, (3) Risk Management and Safety, and (4) Aircraft maintenance.

3.2.1 **Airlines Operation and Optimization:** Nine publications were categorized under this theme. Table I summarizes the authors, type of BDA, and techniques or algorithms used in the selected nine papers. Two papers focus on descriptive analytics, while seven focus on predictive analytics.

Table I
Airlines Operation and Optimization Publications

Author	Purpose	Type of Analytics	Technique
[3]	To explore the potential of machine learning in improving the accuracy and timeliness of flight delay predictions	Predictive	Machine Learning
[4]	To find the correlation between airline delays in the United States and other possible factors such as weather, airport, and employment information.	Descriptive	Data visualization

Author	Purpose	Type of Analytics	Technique
[5]	To propose a model which can capture variability between different factors affecting the cost of a flight ticket	Predictive	Machine Learning
[6]	Present a real-time flight delay prediction system that leverages big data technology.	Predictive	Machine Learning, Spark, Kafka, Streaming, Cassandra
[7]	Determine the most fitted model to forecast future demand for airline passengers.	Predictive	Machine Learning
[8]	Propose a Data Mining approach to extract market knowledge from industry players' or competitors' databases.	Descriptive	Data Mining, Data visualization
[9]	Explore a broader scope of factors that may influence flight delay and compare several machine learning-based models in designed generalized flight delay prediction tasks.	Predictive	Machine Learning
[10]	Predict customers' willingness to consume additional airline services using big and incomplete data.	Predictive	Machine Learning
[11]	To propose and evaluate a novel approach to choose modeling through the use of machine learning techniques	Predictive	Machine Learning

[3] focused on improving the accuracy of flight delay predictions using machine learning algorithms. The analysis of aviation data demonstrated the importance of big data in accurate delay prediction. Machine learning models, such as Multilayer Perceptrons and Convolutional Neural Networks, achieved high prediction accuracy, highlighting the potential of BDA in this context.

[4] investigated the correlation between airline delays in the United States and other factors such as weather, airport, and employment information using data visualization and analysis. Their analysis identified that airlines' carrier and departure time strongly contribute to airline delays. [5] proposed a model to capture the variability of factors affecting flight ticket costs. The study emphasized the significance of feature engineering and data preprocessing techniques in improving prediction accuracy. Variables such as travel dates, flight durations, and advanced booking periods were identified as influential factors in fare prices.

[6] presented a real-time flight delay prediction system that utilized big data technology. The system incorporated Apache Kafka and Apache Spark to process large volumes of data and produce real-time prediction results. The practicality of the system was a focal point, highlighting the application of BDA in real-time scenarios. [7] aimed to forecast future demand for airline passengers. Passenger data from a significant Indonesian airline was used to develop predictive models. The findings emphasized the importance of accurate demand forecasting for developing effective strategies.

[8] proposed a data mining approach focused on visualization to extract market knowledge from industry databases. The study demonstrated the capabilities of the approach using historical data from US passenger airlines, allowing for general observations and insights into market trends and events. [9] explored factors influencing flight delays using machine learning models. The analysis integrated automatic dependent surveillance-broadcast (ADS-B) messages with weather conditions, flight schedules, and airport information. The proposed random forest-based model achieved high prediction accuracy and addressed overfitting issues.

[10] aimed to predict customers' willingness to consume additional airline services using high-dimensional and incomplete data. The findings suggested that predictive models can assist airlines in targeted marketing and service customization to meet customer preferences and increase revenue. [11] focused on understanding customer choices between different flight itineraries. The study utilized machine learning techniques and identified price sensitivity, stay duration, trip duration, and departure/arrival times as essential factors in customer decision-making. The proposed random forest approach outperformed other models regarding accuracy and computation time, providing insights for travel providers.

Additionally, although the studies highlight the BDA and machine learning algorithms in improving accuracy and prediction, there is a gap in research that explores the challenges and limitations associated with applying BDA in the aviation industry. Understanding the potential biases, data quality issues, and scalability concerns when working with large-scale aviation datasets is essential for practical implementation and further advancements in this field. Furthermore, while the studies provide insights into influential factors and predictive models, research is needed to investigate the impact of external factors, such as economic conditions, government regulations, and social trends, on service quality and customer satisfaction in the aviation industry. Understanding the broader context in which these factors operate can enhance the effectiveness of predictive models and decision-making processes. Lastly, the studies primarily focus on data analysis and predictive modeling, but there is a gap in research that explores the findings' practical implications and implementation strategies. Further investigation is needed to examine how airlines and other industry stakeholders can effectively utilize the insights derived from BDA to improve operational efficiency, customer experience, and overall business performance.

3.2.2 **Service Quality and Customer Satisfaction:** Table II summarizes the paper, authors, type of BDA, and techniques or algorithms used in the selected five papers. All papers focus on analytics of big data in the airline industry.

Table II
Service Quality and Customer Satisfaction Publications

Authors	Purpose	Type of Analytics	Technique
[12]	Investigate how big data analysis can improve understanding of factors influencing customer satisfaction within the aviation sector.	Descriptive	Data analysis
[13]	Understand airline passengers' satisfaction trends by analyzing the most influential factors before and during the COVID-19 pandemic.		Text Mining, Sentiment Analysis
[14]	To explore both general and concrete components of customer satisfaction with airline services.		Structural Equation Modelling
[15]	Analyze and classify the sentiment expressed in tweets to gain insights into customer opinions and attitudes towards airlines.		Deep Learning, Sentimen t Analysis
[16]	Investigate customers' satisfaction with airline services and explore their affective values as the antecedents of satisfaction.		Structural Equation Modelling

[12] The analysis of large-scale datasets aimed to enhance understanding of customer satisfaction factors in the aviation industry. The study employed descriptive analytics techniques and identified key service quality dimensions, such as flight punctuality, baggage handling, in-flight service, and staff attitude, significantly impacting customer satisfaction. Big data analysis enabled a comprehensive understanding of each dimension's specific factors contributing to customer satisfaction.

[13] focused on understanding airline passenger satisfaction trends by analyzing influential factors before and during the COVID-19 pandemic. The study highlighted the staff's behavior as influencing passengers' satisfaction. While the pandemic brought few changes to passenger satisfaction, the overall sentiment became more negative. The findings emphasized the need for airlines to adjust their strategies to meet customer expectations.

[14] explored the components of customer satisfaction and investigated its role in customers' intention to reuse airline services. The study incorporated perceived cost values and utilized descriptive analytics techniques. The findings highlighted the significant role of customer satisfaction in influencing reuse behavior and loyalty. Key factors contributing to customer satisfaction included flight punctuality, in- flight services, customer service quality, and overall travel experience.

[15] analyzed and classified sentiments expressed in tweets to gain insights into customer opinions and attitudes toward airlines. The study demonstrated the practical applications of sentiment analysis and the effectiveness of the Dropout model in classifying sentiments. Airlines can gain valuable insights into customers' opinions and experiences by analyzing their sentiments.

[16] investigated customer satisfaction with airline services and explored the affective values as antecedents to satisfaction. Descriptive analytics techniques, including sentiment analysis, were employed. The findings highlighted the significance of customers' positive emotions as determinants of their satisfaction with airline services. Service providers should focus on creating positive effective experiences to shape customer satisfaction. The existing research on service quality and customer satisfaction in the aviation industry has provided valuable insights into various aspects. However, several gaps need to be addressed for a more comprehensive understanding of customer satisfaction factors and effective strategies for enhancing customer experiences.

Firstly, while studies [12] have explored customer satisfaction factors through the analysis of large-scale datasets, there is a need for further research that integrates multiple data sources. This would involve combining customer feedback, social media data, and operational data to better understand the factors influencing customer satisfaction in the aviation industry. By considering diverse data sources, researchers can identify comprehensive patterns and trends, leading to more accurate insights.

Secondly, [13] highlighted the impact of the COVID-19 pandemic on passenger satisfaction. However, further research is required to understand the long-term effects of the pandemic on customer satisfaction and how airlines can effectively adapt their strategies to meet evolving customer expectations in the post-pandemic period. Examining the changes in passenger sentiment and preferences over time will provide valuable guidance for airlines to shape their service offerings.

Additionally, while the studies have primarily focused on descriptive analytics and identifying factors that contribute to customer satisfaction, there is a need for research that delves into causal relationships and employs predictive analytics techniques. By implementing predictive analytics models, airlines can proactively address customer needs and enhance satisfaction. Furthermore, there is a gap in the research regarding cultural and regional variations in customer satisfaction. Understanding how cultural and regional contexts influence customer preferences and satisfaction levels is crucial for tailoring services to specific customer segments. Research that examines the impact of cultural factors and regional variations on customer satisfaction will help airlines develop strategies that resonate with diverse customer groups.

Lastly, bridging the gap between research insights and practical implementation is essential. While the studies have provided valuable insights into customer satisfaction factors, there is a need for research that focuses on translating these insights into actionable strategies for airlines. This includes developing

implementation plans and evaluating the effectiveness of customer satisfaction improvement initiatives. By providing airlines with actionable guidance, researchers can facilitate the implementation of strategies that effectively enhance customer satisfaction.

3.2.3 **Risk Management and Safety:** Table III summarizes the paper, authors, type of BDA, and techniques or algorithms used in the selected three papers. Two papers focus on predictive analytics, while one focuses on descriptive analytics using big data.

Table III
Risk Management and Safety Publications

Authors	Purpose	Type of Analytics	Technique
[17]	Explore the potential of data mining in discovering the existing flight quality problems using Quick Access Record (QAR) data.	Descriptive	Data Mining
[18]	Predict crashes due to bird strikes using data mining techniques on National Transportation Safety Board (NTSB) data.	Predictive	Machine Learning
[19]	Investigate the possibility of using ML in order to generate novel, safety-relevant knowledge from existing flight data.	Predictive	Machine Learning

[17] aimed to explore the potential of data mining in identifying flight quality problems using Quick Access Record (QAR) big data. The findings demonstrated that analyzing QAR big data, for example, the study identified a specific aircraft with a problem related to its take-off pitch angle being too small. It plays a significant role in detecting safety issues. However, there is a potential research gap in further exploring the application of advanced predictive analytics methods in this context. Incorporating predictive analytics techniques, researchers could develop models or algorithms that identify existing safety issues and predict potential problems before they occur, enabling proactive maintenance and risk mitigation strategies.

[18] focused on predicting airline crashes caused by bird strikes using data mining techniques on National Transportation Safety Board (NTSB) data. Predictive analytics was utilized in this study. The analysis considered aircraft damage, engine attack, and landing gear. The best algorithm identified for this problem was Gaussian naïve Bayes. The author highlights that accurately predicting bird strike- related crash risks can help airlines take proactive measures to minimize such incidents. A research gap exists in investigating additional factors or attributes that could contribute to more accurate predictions. Exploring a broader range of variables, such as weather conditions, geographical locations, and bird migration patterns, could enhance the predictive models and provide deeper insights into the risk factors associated with bird strike-related incidents.

[19] investigated machine learning (ML) methods to extract safety-relevant knowledge from flight data. Predictive analytics techniques were applied in this study. The analysis of monitoring information recorded in the dataset revealed the potential to identify novel occurrence types previously undetected by conventional flight data monitoring systems. Applying the LoOP algorithm enhanced existing Flight Data Monitoring (FDM) data analysis. By examining the applicability of ML algorithms and techniques across a broader range of flight datasets and scenarios, researchers can assess the robustness and effectiveness of these approaches in different operational contexts.

3.2.4 **Aircraft Maintenance**: Table IV summarizes the paper, authors, type of BDA, and techniques or algorithms used in the selected three papers. Two papers focus on predictive analytics, while one focuses on the descriptive analytics of big data in the airline industry.

Table IV
Aircraft Maintenance Publications

Authors	Purpose	Type of Analytics	Technique
[20]	Monitor and predict the air conditioning performance of A320 aircraft.	Predictive	Data statistics and fitting
[21]	Review the applicability of data analytics for health monitoring and predictive analysis of aircraft maintenance and optimization.	Descriptive	Review
[22]	Construct a flight fuel consumption prediction model using a classical ML algorithm based on many heterogeneous flight data.	Predictive	Machine Learning

[20] focuses on monitoring and predicting the air conditioning performance of A320 aircraft using the big data analytics platform Event Measurement System (EMS). The study developed a performance prediction that can reflect alarms based on the actual characterization of air conditioning performance in various working modes, can avoid blind monitoring areas, and can recognize flight data of abnormal pack components using a self-learning approach.

[21] reviews the applicability of data analytics for health monitoring and predictive analysis in aircraft maintenance and optimization. The study examines various techniques, tools, infrastructure, and application architecture associated with data analytics in the general aviation context. By analyzing sensor readings, flight data, and historical maintenance records, the researchers aim to identify patterns and insights that can improve maintenance planning and enhance performance.

[22] focuses on constructing a flight fuel consumption prediction model using classical machine learning algorithms based on a large volume of heterogeneous flight data. The study employs predictive analytics to characterize flight fuel consumption using historical flight plans, operation, risk control, and aircraft performance data. The study findings can assist flight dispatchers in making flight

plans and provide valuable references for determining the appropriate amount of fuel required for flights.

Although the studies mentioned focus on utilizing big data analysis and predictive analytics in various aspects of aircraft maintenance and performance optimization, there seems to be a gap in the research regarding the integration and holistic analysis of multiple factors. Specifically, there may be an opportunity to explore the interconnectedness and interdependencies between air conditioning performance, health monitoring, maintenance planning, and fuel consumption prediction.

3.2.5 **Challenges of BDA in the Airlines Industry:** This section highlighted three challenges identified in the deployment of BDA as follows:

A) **Data Integration**: Data integration and data quality are major challenges in the airline industry's utilization of BDA. The aviation industry deals with diverse data sources from various systems and processes. Ensuring the seamless integration of these data sources and maintaining data quality is crucial for obtaining accurate insights. [23] highlighted that the cooperation of national organizations is essential in providing a new solution for trafficking and monitoring real-time aircraft conditions.

B) **Regulatory Compliance**: Regulatory compliance poses another challenge in the context of BDA in the airline industry. As airlines gather and analyze large volumes of passenger data, they must adhere to data protection regulations, such as the General Data Protection Regulation (GDPR), and comply with legal frameworks. [23] stated that macro planning and construction from the national level is required to construct big data platforms in the airline industry.

C) **Data Privacy and Security**: One significant challenge in the airline industry's implementation of BDA is data privacy and security. With the collection and analysis of vast amounts of passenger data, protecting sensitive information and addressing privacy concerns have become critical.
[24] concluded that numerous instances occurred where unethical organizations obtained consumers' data without consent and sometimes failed to safeguard the information adequately. The airline industry, in particular, witnessed several data breach incidents, leading to the unauthorized disclosure of sensitive information.

4. Conclusion

The review of big data analytics in the airline industry has revealed important insights and implications for research and practice. The main findings and implications can be summarized by systematically examining relevant literature. The literature analysis has shown that big data analytics plays a significant role in the airline industry, offering immense opportunities for improving various aspects of operations, customer experience, and decision-making. Airlines leverage big data to optimize flight schedules, enhance safety measures, personalize customer services, and maximize revenue management. Using big data analytics has become a competitive advantage for airlines, allowing them to stay ahead in the dynamic and highly competitive industry. However, it is crucial to acknowledge the limitations of the review process. The scoping review methodology enabled an exploration of the topic, incorporating a wide range of studies and perspectives. Nevertheless, the review relies on the availability and quality of existing literature, which may introduce bias and limit the generalizability of the findings.

In light of the findings, several recommendations can be put forth for future research and practice. Firstly, further studies are needed to delve deeper into specific applications of big data analytics in the airline industry, such as predictive maintenance and customer segmentation. These focused investigations will contribute to a more comprehensive understanding of each application's potential benefits and challenges. Additionally, given the increasing concern over data challenges, future research should address the ethical considerations and regulatory implications of utilizing big data in the airline industry. The development of frameworks and guidelines for data governance, consent management, and data protection will ensure the responsible and transparent use of passenger and operational data.

In conclusion, this review has shed light on the role and potential of big data analytics in the airline industry. It has provided a foundation for future research endeavors and offered valuable insights for industry practitioners. Leveraging the power of big data analytics, airlines can optimize their operations, enhance customer experiences, and drive innovation, ultimately leading to improved performance and competitiveness in the dynamic aviation landscape.

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