

The Exigency of Big Data Analytics to Maximize Airline Revenues: Biman Bangladesh Airlines Perspective

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Abstract

Big Data Analytics (BDA) is transforming industries worldwide, including the airline sector, by enabling data-driven decision making that improves operational efficiency and profitability. This research focuses on the application of BDA in Biman Bangladesh Airlines, a key player in Southeast Asia's aviation market where adoption of such technologies is still emerging. Revenue management systems, crucial for airline profitability, benefit significantly from big data insights that influence fleet planning, fare structuring, and operational management. Using a mixed-methods approach, data were gathered from airline professionals and managers across Bangladesh, complemented by detailed case studies of Biman Bangladesh Airlines. The study examines how Biman leverages BDA to enhance flight punctuality, optimize passenger and cargo load factors, improve fuel efficiency, and increase customer satisfaction. Results demonstrate that effective use of big data analytics enables better decision-making, helping airlines respond flexibly to operational challenges and market demands. Despite these advantages, the research also highlights challenges related to building analytics capabilities and managing complex data environments in the airline industry. Overall, this study contributes to a better understanding of how airlines in developing markets can harness BDA strategically to boost revenue, improve competitiveness, and support sustainable growth.

Keywords

Big Data, Big Data Analytics (BDA), Full Service Carriers (FCC), Low Cost Carriers (LCC), Network Planning, International Air Transportation

Association (IATA), Airline Tariff Publishing Company (ATPCO), Frequent Flyer Program (FFP), iPython, Jupyter Notebook, Python Library, Airline OTP, Route Operation, Biman Bangladesh Airlines

1. Introduction

In today's data-driven world, the volume, velocity, and variety of data being generated have reached unprecedented levels commonly referred to as Big Data. From digital transactions and sensor readings to social media interactions and mobile applications, massive datasets are being produced continuously, often in unstructured or semi-structured formats. Big data encompasses more than just large datasets; it represents a paradigm shift in how organizations collect, store, manage, and extract value from information. Businesses and institutions worldwide are increasingly harnessing big data to gain deeper insights into customer behavior, optimize operations, reduce costs, and gain a competitive edge. As the technological landscape evolves, smart organizations now invest heavily in big data analytics tools and infrastructure to unlock hidden patterns and make informed, real-time decisions. The aviation industry, in particular, is a fertile ground for big data applications [1]. Airlines collect vast amounts of data from sources such as onboard sensors, booking systems, customer feedback, and loyalty programs. Proper analysis of these data streams can enhance safety, improve operational efficiency, and deliver more personalized services to passengers. For example, modern aircraft generates terabytes of data during a single flight, yet much of it remains underutilized without robust analytical frameworks [2]. This research explores the significance and application of big data analytics in the airline industry, with a specific focus on Biman Bangladesh Airlines [3]. By examining case-specific data and utilizing analytical tools, this study aims to demonstrate how big data can drive better decision-making, optimize pricing strategies, and improve customer satisfaction. Ultimately, it highlights the strategic necessity of big data adoption in transforming traditional airline operations into intelligent [4], responsive, and competitive systems [5].

2. Operational Definitions of Key Terms and Variables

Big Data Analytics (BDA):

The process of collecting, processing, and analyzing large and complex datasets generated by various airline operations to extract meaningful insights for decision-making and performance improvement.

Passenger Name Record (PNR):

A digital record in the airline reservation system that contains a passenger's itinerary, personal details, and ticketing information used for managing bookings and customer profiles.

Airline Revenue Management:

A strategic approach that uses data analysis and forecasting to sell the right seat to the right customer at the right price and time, thereby maximizing total revenue.

Yield Management:

A technique to optimize the revenue generated per available seat mile by adjusting prices and seat availability based on demand fluctuations.

Cabin Factor:

Also known as load factor, it is the percentage of available seating capacity that is filled with paying passengers on a flight.

Block Fuel:

The total amount of fuel loaded onto an aircraft prior to departure, used as a key input for fuel management and cost control.

Full Service Carriers (FSC):

Airlines that provide a wide range of services, including in-flight meals, baggage handling, and various cabin classes.

Low Cost Carriers (LCC):

Airlines that offer lower fares by reducing operational costs and often eliminating some traditional services.

Network Planning:

The process of designing airline routes, schedules, and frequencies based on data analytics to optimize fleet utilization and profitability.

Frequent Flyer Program (FFP):

A loyalty program designed to reward repeat customers with points or benefits, helping airlines retain customers and increase revenue.

Fuel Management:

Strategies and processes involved in monitoring, forecasting, and optimizing fuel consumption for cost efficiency and environmental compliance.

On-Time Performance (OTP):

A measure of an airline's punctuality, indicating the percentage of flights that depart or arrive on schedule.

Conceptual Framework

The conceptual framework focuses on how airlines, particularly Biman Bangladesh Airlines, can use big data analytics to maximize revenue. In this model, large-scale airline data serves as the independent variable, while data visualization of key performance metrics acts as the dependent variable. The framework relies on advanced prediction algorithms and analytical tools to evaluate operational and financial data. Through this approach, the study aims to demonstrate how big data can support informed decision-making, boost efficiency, and enhance revenue generation in the airline industry in **Figure 1** ([6]-[8]).

3. Sources of Big Data in Airlines

Airlines generate vast volumes of data from various sources, primarily through

onboard sensors that monitor flight conditions, aircraft systems, and performance metrics such as speed, pressure, altitude, temperature, and fuel usage. Advanced high-end sensors (HES), especially in modern aircraft like the Airbus A350 and A380 [9], produce terabytes of data daily, forming a crucial foundation for big data analytics in aviation.

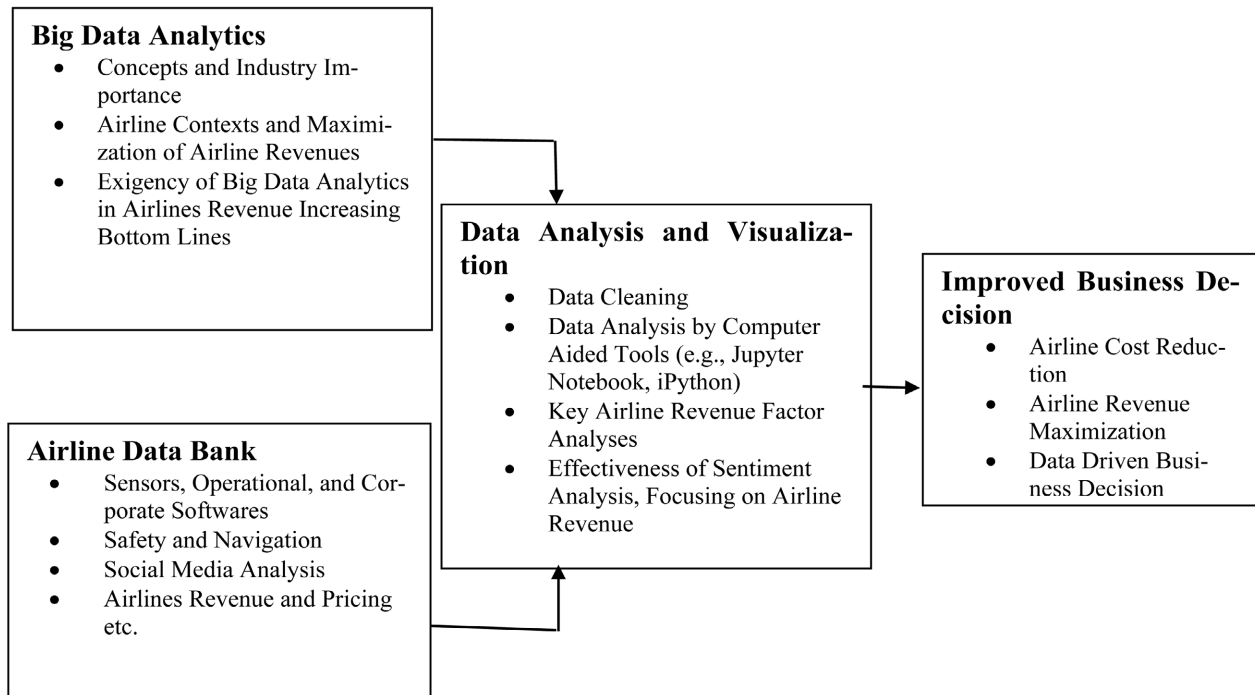


Figure 1. Conceptual framework of the BDA in airline revenue maximization.

In addition to sensor data, airlines collect information from customer interactions, loyalty programs, ticketing systems, social media, and third-party platforms. These data sources are vital for real-time decision-making, improving customer service, optimizing flight operations, route planning, revenue management, and strengthening CRM systems [10]. Big data analytics thus enables airlines to operate more efficiently, reduce costs, and enhance safety and customer experience in **Figure 2**.

3.1. Impacts of Big Data Analytics on Airlines' Revenue

Big data analytics plays a crucial role in improving airline revenue management by enabling better demand forecasting, dynamic pricing, and customer behavior analysis. It helps minimize revenue loss and reduce operational costs through optimized fuel usage and resource allocation. Additionally, big data enhances customer experience with personalized services and targeted marketing, ultimately boosting airline profitability and competitiveness.

3.2. Big Data Analytics for Maximizing Airline Revenue

In this **Figure 3**, big data analytics enables airlines to optimize pricing, flight

schedules, and revenue management, improving customer retention and satisfaction. Tools like AI-driven demand forecasting help dynamically adjust fares, boosting revenue significantly. Low-cost carriers have benefited notably, while legacy airlines still face challenges due to complexity. Analytics also reduce operating costs and support strategic decision-making across airline operations, ultimately enhancing profitability and competitiveness [11].

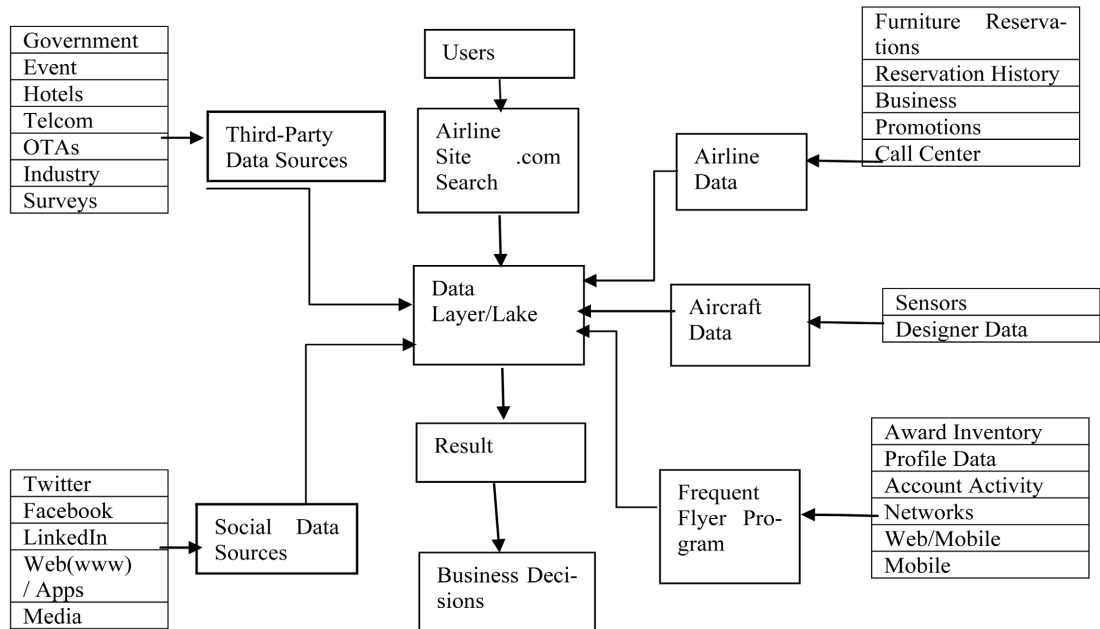


Figure 2. Data sources and big data practices in the airlines.

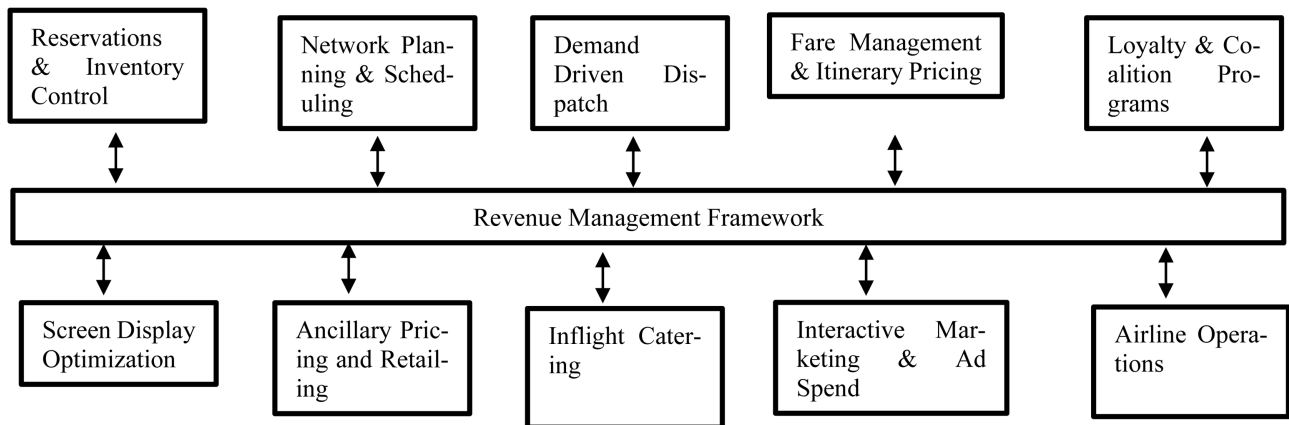


Figure 3. Key influencers in revenue management decisions in airlines.

3.3. Big Data Systems to Analyze Airlines' Bottom-Line Revenue

The airline revenue-related structured data is generated from internal or external sources. These areas are

3.3.1. Airline Revenue and Pricing systems

Airline revenue management uses big data and dynamic pricing to optimize seat

sales and maximize profits. By analyzing passenger booking data and customer behavior in real time, airlines can adjust fares based on demand and customer preferences. Advanced analytics improve forecasting accuracy and enable faster decision-making compared to traditional methods. This data-driven approach helps airlines respond quickly to market changes, enhance customer segmentation, and stay competitive in a rapidly evolving industry [12].

3.3.2. Customer Segmentation and Analytics

Airlines use advanced analytics on extensive customer data, especially from Passenger Name Records (PNRs) and frequent flyer programs, to create more accurate, value-based customer segments. This approach moves beyond traditional fare-based segments to better capture passenger behavior and profitability. Airlines like Delta employ this data to personalize marketing, improve loyalty, and optimize pricing. Machine learning and data mining further enhance insights into customer preferences, enabling smarter business decisions [13].

3.4. Leveraging Big Data Analytics to Increase Airline Ancillary Revenue

Airlines use big data analytics to understand customer preferences and forecast trends, helping them boost ancillary revenues. By analyzing various data sources, they tailor products like branded onboard food and innovate duty-free sales through e-commerce platforms from. This data-driven approach enables airlines to capitalize on new revenue opportunities and improve profitability [14].

4. Python for Data Analysis

The Python programming language is one of the most popular programming languages for its scripting or small programs. Python has built a big and active scientific computing and data analysis community over the previous decade. Python's popular libraries improved its standing among other open source and commercial programming languages for data analysis, interactive computing, and data visualization [12].

4.1. iPython and Jupyter Notebook

iPython is an interactive Python shell, and Jupyter Notebook is its web-based successor that supports multiple programming languages. Jupyter offers a user-friendly environment for data exploration, visualization, and sharing computational work, making it ideal for handling big datasets. Python 3 is often used as the programming kernel within Jupyter.

4.2. Python Library Requirements [15]

This research utilized key Python libraries essential for data analysis and visualization:

- **NumPy**: A foundational library for numerical computing in Python, providing efficient array data structures and mathematical functions essential for sci-

tific applications.

- **pandas**: Offers high-level data structures and tools to work with structured/tabular data, enabling easy data manipulation, slicing, aggregation, and time series analysis. It integrates well with NumPy and is widely used for data wrangling in environments like Jupiter Notebook.
- **matplotlib**: The most popular Python library for creating 2D plots and visualizations. It supports high-quality figures suitable for publications and integrates smoothly within the Python data ecosystem.

5. Cabin Factor Analysis

Cabin factor measures seat occupancy on flights, with data showing high demand on Dhaka-Jeddah routes and full capacity on Sylhet-Jeddah flights in **Table 1**. Big data analytics enables quick insights for planning and marketing, while predictive analytics helps forecast demand. Evaluating cabin conditions also supports optimizing fleet use and enhancing passenger experience [16].

Table 1. Average passengers obtained and cabin factor.

Route	Average Cabin Factor	Average Pax Obtained
Dhaka-Jeddah	95.27	399.052817
Jeddah-Dhaka	89.03	371.805405
Chattogram-Jeddah	92.78	388.751825
Jeddah-Chattagram	80.97	339.246154
Jeddah-Sylhet	83.54	350.02381
Sylhet-Jeddah	100	419

Analysis of Biman's large-scale data revealed inconsistencies affecting the cabin factor in August and September 2019, with values exceeding the expected scale due to poor data quality [17]. The cabin factor stayed above 85 during the first half of the year but declined starting July, influenced by a data mismatch in June. This issue was quickly identified using simple code, saving time and enabling faster business decisions in **Figure 4**.

5.1. Block Fuel Consumption Analysis

Fuel costs are a major and unpredictable expense for airlines, making fuel efficiency crucial for reducing both costs and carbon emissions. Software that enhances fuel efficiency can deliver quick savings. For a typical 50-aircraft airline consuming about 600,000 tons of fuel annually and spending \$600 million, even a modest 2% reduction in fuel use could save \$11 million. Block Fuel includes all usable fuel onboard an aircraft before engine start, covering taxi, trip, contingency, alternate, reserve, and additional fuel. Analysis of Biman's data shows the lowest Block Fuel consumption on the Sylhet-Jeddah route and the highest

on the Chattogram-Jeddah route. Notably, the consumption rate on the Chattogram-Jeddah route is 12.24% higher than the return route in **Table 2**. Data analytics helps identify such variations in fuel consumption even on similar routes [18].

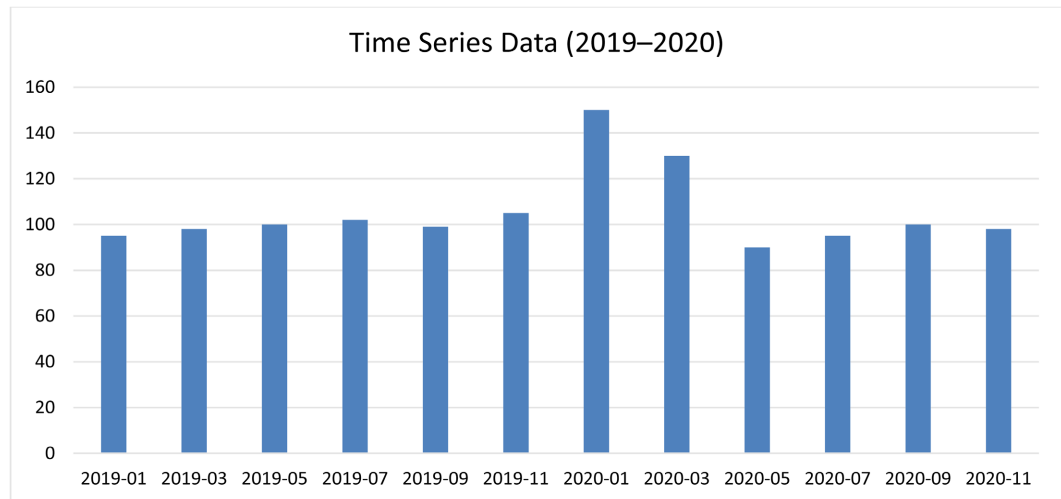


Figure 4. Time series analysis of cabin factor for Biman Dhaka-Jeddah route.

Table 2. Average block fuel consumption in kilogram.

Route	Block_Fuel_Consumption_KG
CGP-JED	54371.60584
DAC-JED	52804.82394
JED-CGP	48442.30769
JED-DAC	51012.34054
JED-ZYL	48233.61905
ZYL-JED	47850

Fuel costs greatly affect airline profitability, influenced by factors like wind speed, temperature, aircraft weight, and altitude, all monitored in real-time by sensors. Big data analytics enables airlines to analyze these factors to determine the most fuel-efficient routes and perform preventive maintenance. For example, Southwest Airlines uses integrated sensors to track fuel consumption and conditions, while Boeing analyzes millions of daily incidents to prevent delays and reduce repair costs, saving significant amounts.

5.2. Airline On-Time Performance Analysis

Unexpected aircraft maintenance due to technical issues is the main cause of flight delays and cancellations, leading to customer dissatisfaction and revenue loss. Jeddah airport experiences significant delays, while Dhaka terminal has the fewest.

Limited flights cause inconsistent results at Sylhet. Big Data Analytics, combined with predictive analytics, helps monitor aircraft health through sensor data, enabling timely maintenance and reducing delays [19].

Big Data Analytics supports early delay detection, aircraft health monitoring, maintenance planning, and failure prediction to reduce delays and increase passenger satisfaction and revenue. It also aids financial and strategic decision-making by providing comprehensive data insights. Unscheduled maintenance causes nearly 30% of delays, and predictive analytics can mitigate these impacts in this **Table 3**. Delay-related costs are significant, with airport delays costing the U.S. economy \$6 billion annually; broader big data adoption could save up to \$400 billion globally by reducing infrastructure needs.

Table 3. On-time performance analysis for the specified routes.

Route	Departure Difference	Arrival Difference	Delay Difference
CGP-JED	34.153285	43.051095	34.153285
DAC-JED	28.098592	27.605634	28.098592
JED-CGP	71.269231	58.592308	71.269231
JED-DAC	70.837838	67.27027	70.837838
JED-ZYL	79.964286	63.940476	78.488095
ZYL-JED	-2.5	6.5	-2.5

5.3. Route Operation Analysis

Vacant airline seats represent lost revenue, and big data analytics is essential to understand why seats remain unfilled and to inform marketing and route decisions. By analyzing metrics like cabin (load) factor, airlines can assess route profitability. Big data has revolutionized revenue management, enabling data-driven decisions to keep airlines competitive. This study analyzed 2019 flight performance data from Biman Bangladesh Airlines to evaluate routes between Bangladeshi airports and Jeddah in **Table 4** [20].

Table 4. Flight operations Ex-BD to/from Jeddah.

Route	Flight Operation
Dhaka-Jeddah	284
Jeddah-Dhaka	185
Chattogram-Jeddah	137
Jeddah-Chattogram	130
Jeddah-Sylhet	84
Sylhet-Jeddah	2

The data reveals that 35% of flights from Dhaka to Jeddah do not return directly to Dhaka, indicating route changes. This rerouting issue is less pronounced for Chattogram-Jeddah flights, with about 5% variation. The Sylhet-Jeddah route shows an extreme disparity, with flights departing Jeddah to Sylhet vastly outnumbering the reverse route by 4100%. Despite most aircraft returning to their original terminals via multi-station connections, the Chattogram-Jeddah route is the most consistent. By analyzing such route performance metrics, airline executives can make informed decisions to enhance revenues, optimize aircraft occupancy, and maximize capacity by focusing on the most profitable routes through big data analytics.

5.4. Analysis of Observations on Big Data Analytics in the Airline Industry

Online questionnaires offer advantages such as faster data processing, reduced fieldwork, the ability to include visuals, and lower research costs. To ensure credibility and consistency, coding was performed independently on the collected data. IBM SPSS software analyzed responses from 19 male Bangladeshi airline industry professionals across various departments from **Figure 5**. Participants' years of experience were also recorded to provide deeper insights into the role of Big Data Analytics in optimizing airline revenue [21].

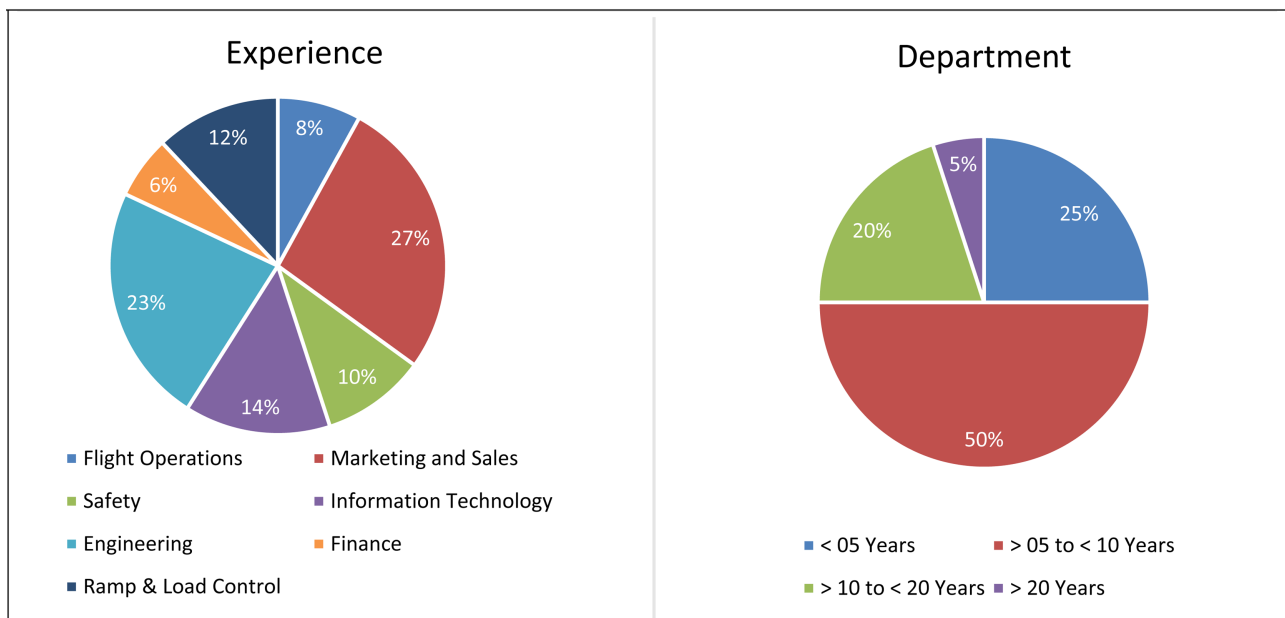


Figure 5. Pie charts depicting the responses of participants from various working departments and with years of airline industry experience.

5.5. Assessment of the Likert Scale Opinions

The first survey question examined whether Big Data Analytics can optimize airline revenue management systems. Analysis using SPSS showed that about 47.4% of participants support Big Data for revenue optimization, and 36.8% endorse its

use in revenue management systems. However, 15.8% expressed skepticism about its applicability in key revenue areas. Experienced professionals, especially those with over 10 years in the industry, showed stronger support, indicating growing acceptance of Big Data Analytics with increased familiarity in **Table 5** [22].

Table 5. Observations of BDA in the airline revenue management systems.

Question 1		
	N	%
“Strongly Disagree”	3	15.8%
“Agree”	9	47.4%
“Strongly Agree”	7	36.8%

Experienced airline professionals, particularly those with 10 to 20 years or more, increasingly recognize the value of Big Data Analytics (BDA) in optimizing airline revenue management and operations. Although adoption begins cautiously with emerging technologies, support grows as professionals gain more experience from **Figure 6**. BDA is transforming airlines by enabling better customer experience, operational efficiency, and predictive insights, especially in areas like segmented pricing and network planning. However, its success depends heavily on the quality of platforms and expertise invested in data analysis. In a survey, 42.1% strongly supported BDA’s role in route operations and network planning, while 15.8% disagreed in **Table 6**.

Meanwhile, all airline industry professionals are fully compliant with the agreement and extremely satisfied with the Big Data Analytics system’s ability to boost airline revenues in order to optimize airline route operation and the airline network planning mechanism. The surveillance groups were present in this study to provide feedback on their assessment, but their disapproval rate was significantly lower than the other groups of observers in **Figure 7**.

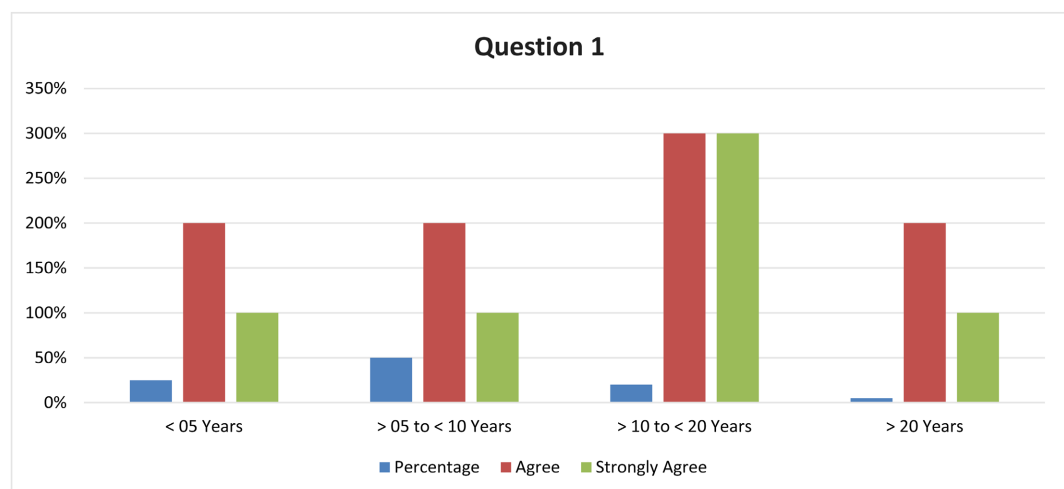


Figure 6. Observations of the industry analyst in airline revenue management systems through BDA.

Table 6. Observations of BDA in airlines route operations.

Question 2		
	N	%
“Strongly Disagree”	3	15.8%
“Agree”	8	42.1%
“Strongly Agree”	8	42.1%

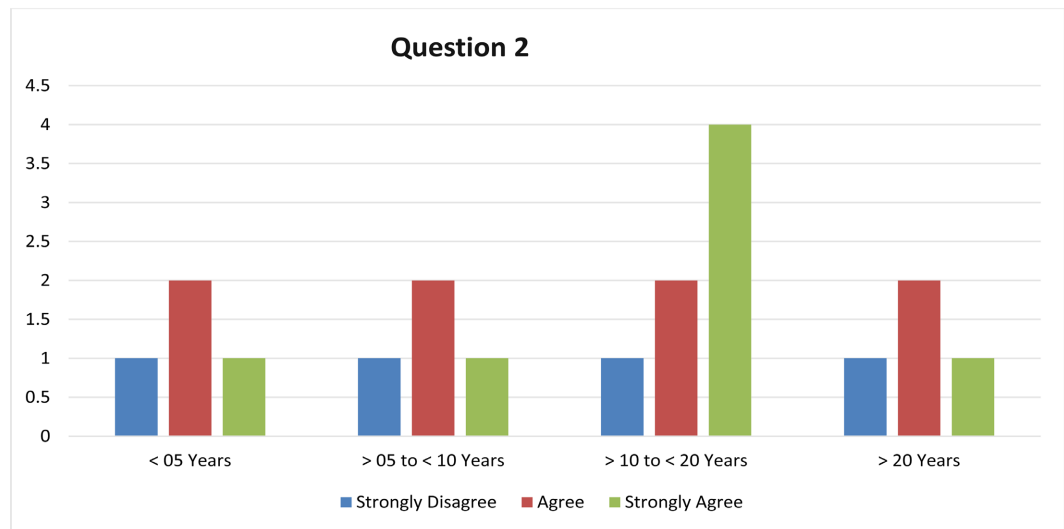


Figure 7. Observations of the industry analyst in airlines route operations through BDA.

The usefulness of using big data analytics to efficiently manage aircraft fuel usage is the subject of the third question. Similar to the earlier findings, the majority of respondents believe that airline will run their aircraft more efficiently and provide better customer service if they employ big data analytics to manage with more expensive fuel. According to the underlying bar chart, mid-level specialists have shown a significant interest in using big data analytics to manage aircraft fuel in **Table 7** [23].

Table 7. Observations of BDA in airlines fuel efficiency.

Question 3		
	N	%
“Strongly Disagree”	2	10.5%
“Neutral”	2	10.5%
“Agree”	9	47.4%
“Strongly Agree”	6	31.6%

From **Figure 8**, fuel efficiency is critically important for airlines, as fuel costs now account for 30% - 50% of operating budgets amid rising prices and the end

of cheap oil [24]. In a survey about the role of a data-driven culture in airlines, most experienced professionals strongly supported adopting data-driven approaches to optimize operations and gain valuable insights. However, some less experienced participants were less familiar with these concepts, highlighting the need for greater industry-wide awareness and implementation in **Table 8** [25].

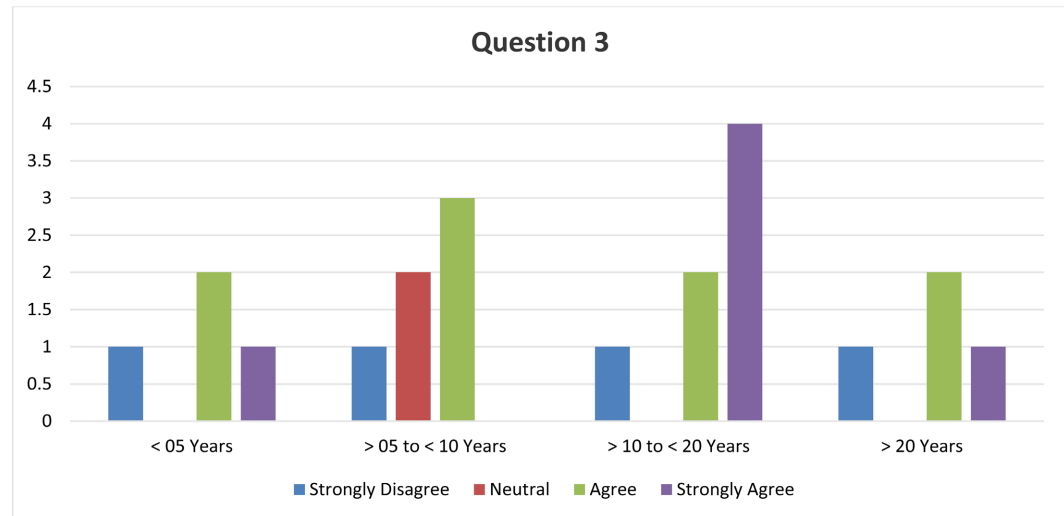


Figure 8. Observations of the industry analyst in the airlines fuel efficiency through BDA.

Table 8. Observations of data-driven culture in the airlines industry.

Question 3		
	N	%
“Strongly Disagree”	2	10.5%
“Neutral”	3	15.8%
“Agree”	6	31.6%
“Strongly Agree”	8	42.1%

In **Table 9**, Big data analytics enables airlines to make informed, data-driven decisions rather than relying on intuition. Key industry data sources like Sabre MIDT and OAG [26] provide essential commercial insights for performance tracking and forecasting [27]. Leadership commitment and proper tools are critical for cultivating a data-driven culture. Experts strongly support using big data analytics to maximize airline revenue, particularly through improved revenue management systems in this **Figure 9**.

Airlines must make numerous operational decisions—such as flight planning, customer engagement, and baggage handling—that can be enhanced through effective data analytics. Revenue Management Systems (RMS) leverage vast amounts of data to optimize pricing, availability, and overbooking strategies, improving demand prediction and revenue generation. For instance, Biman Bangladesh Airlines

uses advanced revenue management software like airRM to control pricing, analyze performance, identify sales opportunities, and make swift, data-driven business decisions in a competitive market in this **Figure 10** [28].

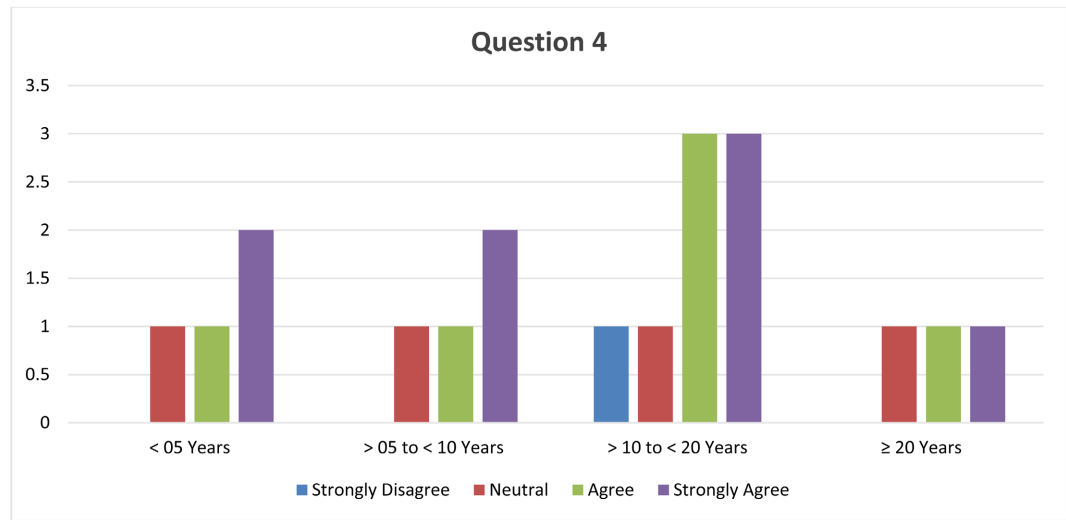


Figure 9. Observations of the industry analyst in the airlines data-driven cultures.

Table 9. Observations of leveraging BDA to maximize revenues in the airlines industry.

Question 3		
	N	%
“Strongly Disagree”	2	10.5%
“Neutral”	1	5.3%
“Agree”	9	47.4%
“Strongly Agree”	7	36.8%

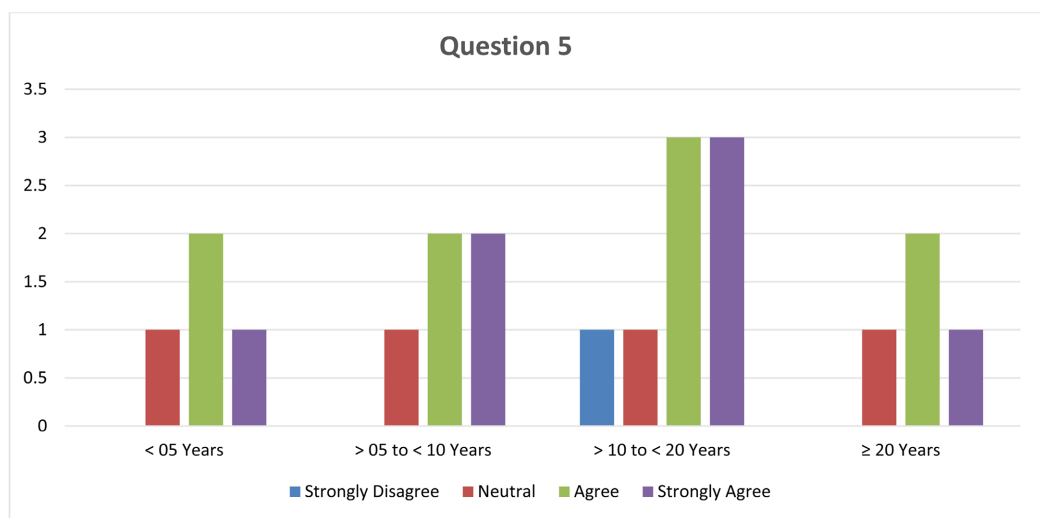


Figure 10. Observations of the industry analyst in the leveraging of BDA to maximize revenues in the airlines industry.

5.6. Sentiment Analysis of Biman Bangladesh Airlines Concerning Big Data Analytics

Sentiment analysis interprets emotions and opinions within text data, helping businesses gauge customer feelings about products, brands, or services. It enhances data analysis efficiency by identifying recurring topics and sentiments. In the airline industry, experts highlighted key areas where Biman Bangladesh Airlines should focus Big Data Analytics to maximize revenue, while also noting challenges in managing these analytics processes. These expert insights were incorporated into the research findings in **Table 10** [30].

Table 10. Sentiment analysis of the specified questionnaires of BDA in airlines.

Challenges of BDA in airlines	Bottom line: using BDA to maximize airline revenue	BDA is worth mentioning in terms of increasing Biman Bangladesh Airlines' revenue
Skilled manpower & resources	To improve yield & load factor	Biman needs to first prioritize living on its own, going out of government support.
Skill manpower	Focus on dynamic pricing decisions	Mitigation of delay and early operation of flight
Shortage of qualified human resources, absence of data-driven culture, data privacy and security concerns, dealing with and processing huge amounts of data	Predictive measures to reduce costs and minimize risks	Social media platforms can be used as an easy tool
Finding additional carrier data is required to plan a competitive strategy for profit maximization and cost management	Customer preferences and needs, determining airfares, in-flight service requirements, route efficiency, and cost minimization	Getting market feedback and applying efficient decisions in a timely manner to grab an opportunity
No response	Security of personal and organizational data	No response
Getting proper data	Determining ticket prices and assessing public capability	Determine ticket prices while keeping people's financial capabilities in mind, and try to increase sales. Aside from introducing a simple, user-friendly process for purchasing online tickets
Expertise and skills in human resources	Route expansion and profitability	Biman may establish a data center or hub to facilitate data access
Proper data administration and management	Schedule maintenance	No response
Expertise in properly analyzing data	Data quality and accuracy	Management has made a firm commitment to putting the analysis' findings into action
Making progress by utilizing data effectively	Customers support	Analysis for customer satisfaction

Continued

No response	Maximum participation	Market trends and awareness
Data collection and analysis in real-time or near-real-time	Using the right tool and knowledge	No response
Data collection and information management in a big data system	Passenger information	No response
Inadequate actionable information	No response	Ground handling management employing benchmark facilities
No response	Important for maximizing airlines revenue	No response
Data collection and management through customer service	Focus on fuel costs and lower the fuel rate	Revenue will skyrocket if customers are pleased with the service
No response	Better customer services	No response
On-time performance and customer service	Collecting customer data	Increase worker training and financial support
Data management	No response	No response

6. Discussions and Analysis

The study highlights the critical role of big data analytics in increasing airline revenue, emphasizing that its applications vary across different operational areas. Respondents agreed that big data is a fundamental resource for airlines like Biman to enhance profitability and support decision-making. It is particularly valuable in managing ground operations, airspace, passenger services, and maintenance. Overall, big data analytics improves decision-making speed, operational efficiency, and customer satisfaction, thereby strengthening competitiveness, brand loyalty, and ultimately boosting airline revenues.

7. Limitations and Future Research Directives

Big data analytics is expected to become increasingly important in aviation, offering vast untapped value for airlines, manufacturers, airports, and other stakeholders. While manufacturers benefit in areas like engineering and supply chain management, airlines gain from improvements in operations, maintenance, and crew management. Future research should explore emerging technologies, their impact on the aerospace industry, and strategic applications of big data for profit maximization, cost control, dynamic pricing, revenue integrity, and network planning.

8. Conclusion

Big Data Analytics plays a crucial role in enhancing airline revenue by enabling smarter decision-making, improving operational efficiency, and personalizing customer experiences. For Biman Bangladesh Airlines, leveraging big data offers op-

portunities to overcome challenges like workforce skill gaps and data management issues. Effective use of analytics—supported by advanced tools and technologies—can optimize pricing, maintenance, and marketing strategies to increase profitability. Embracing a data-driven culture and investing in expertise are essential for airlines to fully benefit from big data and stay competitive in today’s dynamic aviation industry.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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