

MidOcean University

College of Management

Master of Business Administration (MBA)



The Role of Artificial Intelligence in Improving the Operational Efficiency of Baggage Handling Systems in International Airports in Saudi Arabia

Prepared by: Mohammed Alawadi

Supervised by:

Dr. Al-Faisal Abdulhamid Mohammed Hassan

Dr. Fayez Jarrad

Academic Year: 2026

DECLARATION

I hereby declare that this thesis entitled "The Role of Artificial Intelligence in Improving the Operational Efficiency of Baggage Handling Systems in International Airports in Saudi Arabia" is entirely my own work and has never been submitted, either in part or in full, anywhere else for any degree or diploma.

The APA (7th Edition) referencing style has been followed in this study with all the sources of information correctly acknowledged and referenced. Furthermore, I certify that this thesis is the result of my own research efforts and research work conducted by other people, which I cited, is properly referenced.

Student Name: Mohammed Alawadi

Signature: 

Date: 07/14/2026

DEDICATION

I would like to thank my loving parents who have always been the source of my strength and determination, giving me unconditional love, endless encouragement and continuous prayers.

I also dedicate this work to my family for their patience, understanding and constant support throughout the course of my studies.

Last but not least, I dedicate this research to all of those who have inspired me in knowledge and excellence, and hope that this research will help to advance science and intelligent technology in the aviation industry.

ACKNOWLEDGEMENTS

I would first like to express my thanks to Allah for giving me the strength, patience, wisdom and perseverance to successfully complete this research.

I would like to thank my supervisor of this work, Dr. [Supervisor Name] for guiding me through this research in every aspect, giving me useful suggestions and comments, and academic support. His advice and guidance were extremely helpful in the successful completion of this thesis.

I would also like to thank the members of the Faculty of Business and Finance of [University Name] for the excellent academic environment provided which helped me to improve my knowledge and research skills.

Special thanks to the Manager and staff of the Saudi international airports for their cooperation in this study. Their co-operation and willingness to share their experiences enabled this research.

Last but not least, I would like to thank my parents, the members of my family and my friends for their constant encouragement, patience, understanding and support during my postgraduate studies that I had in this country.

ABSTRACT

Background : Artificial Intelligence (AI) has become one of the most transformative technologies in the aviation industry, particularly in airport operational management. The increasing volume of passenger traffic and baggage movement has created significant operational challenges for airport baggage handling systems, including equipment failures, baggage misrouting, operational delays, and system downtime. Consequently, airport authorities are increasingly adopting Artificial Intelligence technologies such as predictive maintenance, intelligent baggage tracking, and automated monitoring systems to improve operational efficiency and support digital transformation initiatives aligned with Saudi Vision 2030.

Aim of the Study: This study aimed to investigate the role of Artificial Intelligence in improving the operational efficiency of baggage handling systems in international airports in the Kingdom of Saudi Arabia. Specifically, the study examined the effects of Artificial Intelligence technologies, predictive maintenance, intelligent baggage tracking, and automated monitoring systems on operational efficiency.

Methodology: The study adopted a quantitative research approach using a descriptive and explanatory research design. Data were collected through a structured questionnaire distributed electronically to employees working in airport operations, baggage handling, maintenance, logistics, and technical departments at major international airports in Saudi Arabia. A total of 280 questionnaires were distributed, 257 were returned, and 250 valid questionnaires were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, Cronbach's Alpha, Pearson correlation analysis, and multiple regression analysis were employed to analyze the data and test the research hypotheses.

Results : The findings revealed that all Artificial Intelligence dimensions achieved very high mean scores, indicating strong agreement among respondents regarding their contribution to baggage handling operations. Predictive maintenance emerged as the strongest predictor of operational efficiency ($\beta = 0.339$), followed by intelligent baggage tracking ($\beta = 0.281$), automated monitoring systems ($\beta = 0.256$), and Artificial Intelligence technologies ($\beta = 0.207$). The regression model explained 70.9% of the variance in operational efficiency ($R^2 = 0.709$), and all proposed hypotheses were statistically supported. The results further indicated that Artificial Intelligence technologies significantly improve system reliability, reduce operational downtime, enhance baggage tracking accuracy, strengthen operational monitoring, and improve overall airport operational performance.

Conclusion: The study concludes that Artificial Intelligence has become a strategic necessity for modern airport baggage handling systems rather than merely a technological innovation. The integration of predictive maintenance, intelligent baggage tracking, and automated monitoring systems contributes substantially to improving operational efficiency, supporting data-driven decision-making, and enhancing the quality and reliability of airport operations. The findings also demonstrate that Artificial Intelligence plays a significant role in supporting the digital transformation of Saudi Arabia's aviation sector and contributes directly to achieving the objectives of Saudi Vision 2030.

Recommendations : The study recommends expanding the implementation of Artificial Intelligence technologies across airport baggage handling systems, increasing investment in predictive maintenance and intelligent baggage tracking technologies, strengthening automated monitoring capabilities, providing continuous training programs for airport employees, and encouraging collaboration between airport authorities and technology providers to accelerate innovation and improve operational excellence.

Keywords: Artificial Intelligence, Airport Operations, Baggage Handling Systems, Predictive Maintenance, Intelligent Baggage Tracking, Automated Monitoring Systems, Operational Efficiency, Saudi Arabia.

الملخص

الخلفية: أصبح الذكاء الاصطناعي أحد أهم التقنيات الحديثة التي أحدثت تحولاً جذرياً في قطاع الطيران، ولا سيما في إدارة العمليات داخل المطارات. ومع الزيادة المستمرة في أعداد المسافرين وحركة الأمتعة، تواجه أنظمة مناولة الأمتعة العديد من التحديات التشغيلية، مثل أعطال المعدات، وسوء توجيه الأمتعة، وتأخر العمليات، وارتفاع فترات توقف الأنظمة. لذلك اتجهت المطارات إلى توظيف تطبيقات الذكاء الاصطناعي، مثل الصيانة التنبؤية، والتتبع الذكي للأمتعة، وأنظمة المراقبة الآلية، بهدف رفع الكفاءة التشغيلية ودعم التحول الرقمي بما يتوافق مع مستهدفات رؤية المملكة العربية السعودية 2030.

هدف الدراسة: هدفت هذه الدراسة إلى التعرف على دور الذكاء الاصطناعي في تحسين الكفاءة التشغيلية لأنظمة مناولة الأمتعة في المطارات الدولية بالمملكة العربية السعودية، من خلال دراسة تأثير تقنيات الذكاء الاصطناعي، والصيانة التنبؤية، والتتبع الذكي للأمتعة، وأنظمة المراقبة الآلية على الكفاءة التشغيلية.

منهجية الدراسة: اعتمدت الدراسة المنهج الكمي باستخدام التصميم الوصفي والتفسيري، وتم جمع البيانات من خلال استبانة إلكترونية وزعت على العاملين في إدارات العمليات، ومناولة الأمتعة، والصيانة، والخدمات اللوجستية، والدعم الفني في المطارات الدولية بالمملكة العربية السعودية. وقد تم توزيع (280) استبانة، واسترجاع (257) استبانة، واعتماد (250) استبانة صالحة للتحليل باستخدام برنامج الحزم الإحصائية للعلوم الاجتماعية (SPSS). واستخدمت الدراسة الإحصاءات الوصفية، ومعامل كرونباخ ألفا، وتحليل ارتباط بيرسون، وتحليل الانحدار المتعدد لاختبار فرضيات الدراسة.

النتائج: أظهرت النتائج أن جميع أبعاد الذكاء الاصطناعي حققت متوسطات مرتفعة جداً، مما يعكس اتفاق أفراد العينة على أهمية تطبيقاته في تحسين أداء أنظمة مناولة الأمتعة. كما تبين أن الصيانة التنبؤية كانت أكثر الأبعاد تأثيراً في الكفاءة التشغيلية، تلتها أنظمة التتبع الذكي للأمتعة، ثم أنظمة المراقبة الآلية، ثم تقنيات الذكاء الاصطناعي بصورة عامة. وأوضحت نتائج تحليل الانحدار أن المتغيرات المستقلة فسرت ما نسبته (70.9%) من التباين في الكفاءة التشغيلية، كما تم قبول جميع فرضيات الدراسة. وأكدت النتائج أن تطبيقات الذكاء الاصطناعي تسهم في رفع موثوقية الأنظمة، وتقليل الأعطال، وتحسين دقة تتبع الأمتعة، وتعزيز المراقبة التشغيلية، ورفع الأداء التشغيلي للمطارات.

الاستنتاج: خلصت الدراسة إلى أن الذكاء الاصطناعي أصبح ضرورة استراتيجية لتطوير أنظمة مناولة الأمتعة في المطارات الحديثة، وليس مجرد تقنية مساندة، حيث يسهم بصورة مباشرة في تحسين الكفاءة التشغيلية، ودعم اتخاذ القرار، وتعزيز جودة الخدمات، وتحقيق أهداف التحول الرقمي في قطاع الطيران، بما يدعم مستهدفات رؤية المملكة العربية السعودية 2030.

التوصيات: أوصت الدراسة بالتوسع في تطبيق تقنيات الذكاء الاصطناعي في جميع مراحل مناولة الأمتعة، وزيادة الاستثمار في الصيانة التنبؤية وأنظمة التتبع الذكي، وتعزيز أنظمة المراقبة الآلية، وتوفير برامج تدريبية مستمرة للعاملين، وتشجيع التعاون بين إدارات المطارات ومطوري تقنيات الذكاء الاصطناعي لتحقيق التميز التشغيلي.

الكلمات المفتاحية: الذكاء الاصطناعي، المطارات الدولية، أنظمة مناولة الأمتعة، الصيانة التنبؤية، التتبع الذكي للأمتعة، أنظمة المراقبة الآلية، الكفاءة التشغيلية، المملكة العربية السعودية.

Contents

DECLARATION.....	2
DEDICATION	3
ACKNOWLEDGEMENTS.....	4
ABSTRACT.....	5
الملخص.....	6
CHAPTER ONE	12
1. INTRODUCTION	12
1.1. Study Background.....	15
1.2. Problem Statement.....	17
1.3. Research Objectives.....	18
1.4. Research Questions	19
1.5. Research Hypotheses	19
1.6. Significance of the Study	20
1.7. Definition of Terms	21
1.8. Thesis structure	23
CHAPTER TWO	26
.2 LITERATURE REVIEW	26
Introduction. 26	
2.1. Artificial Intelligence in the Aviation Sector	27
2.2. Baggage Handling Systems in Airports	28
2.3. Artificial Intelligence in Baggage Handling Systems.....	29

2.4.	Predictive Maintenance in Airport Systems.....	29
2.5.	Intelligent Baggage Tracking Technologies.....	31
2.6.	Operational Efficiency in Airport Management.....	31
2.7.	Previous Studies.....	32
2.8.	Research Gap	34
2.9.	Conceptual Framework.....	35
2.10.	Development of Hypothesis.....	36
CHAPTER THREE		38
.3	RESEARCH METHODOLOGY.....	38
3.1.	Research Design.....	39
3.2.	Research Methodology	39
3.3.	Study Population.....	40
3.4.	Sampling Technique.....	42
3.5.	Data Collection Techniques	42
3.6.	Reliability and Validity	44
3.7.	Techniques of Analyzing Data	45
CHAPTER FOUR.....		46
4.	DATA ANALYSIS AND RESULTS.....	46
4.1.	Response Rate.....	46
4.2.	Demographic Characteristics of Respondents.....	47
4.2.1.	Gender.....	47
4.2.2.	Age.....	48
8		

4.2.3.Educational Level.....	48
4.3.Job Position.....	49
4.4.Years of Experience.....	49
4.5.Predictive Maintenance	50
4.6.Mean, Standard Deviation, Rank and Level of Predictive Maintenance.....	51
4.7.Intelligent Baggage Tracking.....	52
4.8.Automated Monitoring Systems	54
4.9.Mean Interpretation Scale.....	56
4.10.Descriptive Statistics.....	56
4.11.Reliability Analysis	56
4.12.Correlation Analysis.....	57
4.13.Multiple Regression Analysis.....	58
Model Summary.....	58
4.14.ANOVA Results.....	59
4.15.Regression Coefficients.....	59
4.16.Hypothesis Testing	60
4.17.Discussion of Key Findings.....	60
CHAPTER FIVE	62
5.DISCUSSION.....	62
5.1.The concept of Artificial Intelligence Technologies... ..	63
5.3.Intelligent Baggage Tracking.....	67
5.4.Automated Monitoring Systems.....	70
9	

CHAPTER SIX.....	75
6.CONCLUSION AND RECOMMENDATIONS	75
6.1.Key findings of study.....	76
6.2.Conclusion.....	77
6.3. Implications.....	78
6.3.1.Theoretical Implications.....	78
6.3.2.Practical Implications.....	78
6.4. Recommendations.....	79
6.5.Limitations.....	81
7.References.....	82
8.Appendix A	85
8.1.Questionnaire.....	85
Demographic Information	85
Variables and Measurement.....	86
Artificial Intelligence Technologies	87
Predictive Maintenance	87
Intelligent Baggage Tracking	87
Automated Monitoring Systems.....	88
Operational Efficiency of Baggage Handling Systems	88

TABLE OF FIGURE

Figure 1:Conceptual Framework	36
-------------------------------------	----

TABLE OF CONTENT

Table 1:Response Rate	47
Table 2:Gender Distribution	47
Table 3:Age Distribution.....	48
Table 4:Educational Level	48
Table 5:Job Position.....	49
Table 6:Years of Experience	49
Table 7:Mean, Standard Deviation, Rank and Level of Predictive Maintenance	51
Table 8:Frequency and Percentage Distribution of Intelligent Baggage Tracking (n = 250) ..	52
Table 9:Mean, Standard Deviation, Rank and Level of Intelligent Baggage Tracking	53
Table 10:Frequency and Percentage Distribution of Automated Monitoring Systems (n = 250)	54
Table 11:Mean, Standard Deviation, Rank and Level of Automated Monitoring Systems	55
Table 12:Descriptive Statistics.....	56
Table 13:Reliability Analysis.....	57
Table 14:Pearson Correlation Matrix.....	57
Table 15:Model Summary.....	58
Table 16:ANOVA Results	59
Table 17:Regression Coefficients	59
Table 18:Hypothesis Testing Results	60

CHAPTER ONE

1. INTRODUCTION

The aviation sector is experiencing an unprecedented digital revolution, with technology developments and growing operational needs transforming the way the sector is run. Airport infrastructure is under more strain than ever to be both more efficient and better served, be able to handle increased numbers of passengers and cope with safety and reliability requirements. Airport systems are becoming more and more innovative to optimize some of the key processes needed to operate an airport system and to generate better airport performance, as global air transport keeps growing. One of the most powerful and game-changing technologies is Artificial Intelligence (AI), which can revolutionize airport operations through automation, predictive analysis, intelligent decision-making, and real-time monitoring.

Artificial Intelligence (AI) is the term used to describe computer systems and technologies that are able to perform tasks that normally require human intelligence, such as learning, reasoning, problem-solving, pattern recognition and decision making. In recent years, the field of transportation and aviation has also seen significant progress in the application of AI technologies, particularly machine learning, deep learning, computer vision, and big data analytics. The use of AI in transportation and aviation has also seen significant advances in recent years, with machine learning, deep learning, computer vision, and big data analytics being prominent areas of focus. In the aviation sector, AI has been used in flight planning, passenger management, airport security, air traffic control, predictive maintenance and operational planning.

These applications have proven to have great potential to increase efficiency, lower operational expenses and increase the quality of services.

The Baggage Handling System (BHS) is one of the most important operational parts of an airport infrastructure. Baggage handling systems handle the transport, sorting, tracking and

12

delivery of passenger bags in the airport environment. These systems are comprised of various technologies and equipment, such as conveyor belts, barcode scanners, sensors, sorting equipment and monitoring systems that are integrated together to move baggage from the check-in counters to aircraft and from the aircraft to the baggage claim area, in a timely and correct manner. Baggage handling systems have a direct impact on airport performance, flight on-time performance, customer satisfaction and quality of airport service.

Although significant improvements in technology have been made, there are still many challenges to be addressed in the baggage handling arena. The airport baggage systems can be prone to equipment failures, congestion in the conveyor systems, misrouting, delays in operations, and inadequate tracking systems.

These challenges can result in higher operating costs, lower system reliability, passenger dissatisfaction and disruption of airport operations. The traditional methods of baggage control are based on a reactive maintenance strategy and manual monitoring, which are sometimes not enough to deal with the complexity of contemporary airport operations and the increasing passengers' demand.

AI can provide valuable answers to these operational problems. Predictive maintenance systems driven by AI can use data from equipment performance to forecast potential failures, which decreases unexpected equipment breakdowns and minimizes downtime. Likewise, advanced baggage tracking systems powered by machine learning, computer vision and real-time analytics can help to increase baggage visibility, accuracy of baggage tracking and minimize lost or delayed bags. Additionally, AI-powered automation solutions can detect operational anomalies, identify congestion points, optimize baggage routing, and aid in real-time decision-making, enhancing overall airport baggage handling efficiency and reliability.

The need for adopting advanced technologies in airport operations has grown more and more critical in the Kingdom of Saudi Arabia. The Kingdom is striving to become a major Asian, European and African hub for transportation and logistics under the Saudi Vision 2030. The National Aviation Strategy will lead to increased passenger traffic and expand airport infrastructure, as well as improve the competitiveness of Saudi airports to the international level. The major international airports such as King Abdulaziz International Airport in Jeddah, King Khalid International Airport in Riyadh, and King Fahd International Airport in Dammam are witnessing continued growth in passenger numbers and activities. This has made the efficient and effective management of baggage handling systems a major concern for airport and aviation operators.

Although, there are studies to explore the role of artificial intelligence in aviation industry, airport management and transportation systems, limited studies have been conducted to explore the effect of artificial intelligence technologies on the performance of baggage handling system especially in the context of Saudi Arabia aviation industry. The above gap in the literature underscores the necessity of empirical studies that can explore how AI technologies can support the improvement of baggage handling operations and operational efficiency in Saudi international airport.

Thus, the aim of this study is to analyze the impact of Artificial Intelligence on baggage handling systems at International Airports in the Kingdom of Saudi Arabia (KSA) with the intention to find a solution to achieve operational efficiency. In particular, the research focuses on the role of AI technologies, like predictive maintenance, intelligent baggage tracking, and automated monitoring systems, in enhancing system reliability, minimizing operational disruptions, baggage processing accuracy, and overall operational performance of an airport. This study's outcomes are anticipated to enhance academic knowledge and enrich the application of artificial intelligence technologies in the context of

airport baggage handling for decision-making and to enable the current digital transformation of the Saudi aviation sector.

1.1. Study Background

Airports function as highly complex operational environments. They require the integration and interplay of multiple systems for the central tasks of managing the movement of people, planes, and bags. One of the critical systems for operational efficiency and service quality and ensuring that people are not delayed in boarding or experiencing high levels of lost luggage, is the Baggage Handling System (BHS). In addition to dealing with the operational challenges and constraints, global air travel has been expanding for the past two or more decades and is putting increasing pressure on airports to develop, implement, and justify the use of advanced technology solutions for managing baggage flow.

Artificial intelligence (AI) is predicted to play a dominant role in the transformation of the aviation industry. AI technologies have the potential to be the most powerful tools in the planning and automation of operational functions in BHS. AI technologies can facilitate accurate and timely predictive maintenance and intelligent automated monitoring and real-time data analytics for operational performance and system disruptions.

The implementation of Saudi Vision 2030 and the overall expansion in the Kingdom of Saudi Arabia's Aviation sector has influenced the rapid development of the Kingdom's international airports. The vision aims for Saudi Arabia to become a global logistics and transportation hub that connects three continents. Consequently, this has caused a rise in the volume of air traffic at the Kingdom's international airports, specifically at the King Abdulaziz International Airport in Jeddah, King Khalid International Airport in Riyadh, and King Fahd International Airport in Dammam. As a result, the improvement of airport operational systems, specifically for the handling of baggage, has become an operational priority for airport management.

The airport baggage handling systems (BHS) are a crucial component of the logistical systems of an airport. The systems facilitate the flow of luggage by moving and sorting luggage from the check-in counters to the airplane holds then from the holds to the claim. The systems are made of several components such as belts, bar code scanners, sensors, sorters, and monitors, all of which are interconnected. The efficiency of a given BHS is directly related to the operations of an airport, the punctuality of flights, and the satisfaction of customers (Kazda & Caves, 2015).

Predictive maintenance is one of the most important applications of artificial intelligence in baggage handling systems. AI algorithms help to predict maintenance and repair needs by examining operational data from the motors and sensors used in handling equipment. These systems also help to analyze and understand the patterns of breakdowns. AI predictive maintenance systems identify equipment failure and suggest repair tasks ahead of time. Such predictive maintenance strategies help to decrease the frequency of sudden equipment breakdowns and increase the reliability of the entire system (Lee, Bagheri, & Kao, 2015).

Artificial intelligence (AI) can also be integrated into baggage documentation to overcome challenges associated with those systems, as well as respond to specific issues within a given airport environment, such as improving the reliability of baggage handling equipment, minimizing operational disruptions, optimizing the efficiency of equipment, and enhancing the capability of automated systems to support real-time decision-making.

In this regard, it is crucial to recognize the implications of AI technologies for operational improvements within baggage handling systems. This will facilitate the digital transformation of the aviation sector and the sustainable operation of airports in Saudi Arabia.

1.2. Problem Statement

Unplanned equipment failures, and interruptions, in the system, are further challenges in the baggage handling systems. Issues with conveyor belts, sensors, and the large scale baggage backlog (congestion) can greatly impede the operation of an airport, and cause delays in the takeoff of planes. Many airport baggage handling systems rely on reactive maintenance. This type of maintenance is done after a piece of equipment fails. This type of maintenance increases the amount of time the equipment is not operational and can be greater for the entire airport (Lee et al., 2015).

Predictive maintenance, intelligent routing of baggage, automation of anomaly detection, and real-time data analytics are just some of the many attributes Artificial Intelligence (AI) technologies are capable of tackling the above-mentioned challenges. AI systems are capable of processing enormous quantities of data produced by operational systems, baggage handling systems, and tracking systems which means airports are able to predict and adjust operational systems before issues arise (Russell & Norvig, 2021).

Saudi Arabia is rapidly expanding its aviation industry in conjunction with its Vision 2030 strategy. This will allow the Kingdom to become the world's leading aviation and logistics center. Major international airports in Saudi Arabia—namely King Abdulaziz International Airport, King Khalid International Airport, and King Fahd International Airport—are expanding their passenger and operational capacity. Per the Saudi aviation strategy, it is projected the Kingdom will be able to accommodate an annual throughput (aka passenger processing) of 330 million by the year 2030. This will be operationally demanding to the degree that it will be overwhelming to Saudi Arabia's airports, specifically to the Kingdom's systems' abilities to handle and process baggage (GACA, 2022).

Most studies focus on (1) passenger experience, (2) security of airports, and (3) operational efficiencies of airlines. Very few studies focus on the operational efficiency of baggage logistics and the use of AI. With this in mind, there is an obvious deficit of the operational efficiencies of BHS systems and the AI technologies of such systems at Saudi Arabia's international airports.

Hence, this study aims to explore the impact of Artificial Intelligence on the operational efficiency of baggage handling systems, in international airports in Saudi Arabia. More specifically, the research aims to understand the extent AI-based technologies aids in predictive maintenance, accuracy of baggage tracking, reduction of system downtime, and operational performance of airports.

1.3. Research Objectives

The purpose of this study is to analyze how Artificial Intelligence (AI) can enhance efficiency within the baggage handling systems at Saudi Arabian international airports. To achieve this goal, the study intends to achieve the following specific objectives:

1. Assess the operational design and quality of performance of Saudi Arabian international airports' baggage handling systems.
2. Determine the primary operational difficulties and deficiencies of the baggage handling systems within airports.
3. Examine how AI influences the enhancement of various facets of baggage handling processes (predictive maintenance, smart routing, and automated supervision).
4. Determine the aim of AI technologies on the primary measures of operational efficiency, such as system dependability, the time involved in processing baggage, and the precision of tracking baggage.
5. Assess the impact of AI technologies on the efficiency and operational systems of airport baggage handling systems.\

6. Provide guidance to the airport authorities and policymakers in Saudi Arabia on the areas of improvement to be focused on in the existing systems of incorporation of AI technologies in baggage handling systems.

1.4. Research Questions

Considering the research problem and objectives, the study proposes the following questions:

- 1- How do baggage handling systems in international airports in Saudi Arabia operate at the moment?
- 2- What are some operational challenges that impact how baggage handling systems operate in airports?
- 3- In what ways can operational efficiency of baggage handling systems be improved by the use of artificial intelligence?
- 4- What are some ways artificial intelligence can improve the accuracy and reliability of operations in regard to the tracking of baggage?
- 5- In what ways can the use of artificial intelligence decrease the frequency and duration of downtime and disruptions of systems within baggage handling networks?
- 6- What are some possible reasons or challenges that come with using or including artificial intelligence in the systems that are used to handle baggage at airports in Saudi Arabia?

1.5. Research Hypotheses

Considering the objectives of this research and the theory that is related to it, the following hypotheses are proposed:

H1: The use of artificial intelligence in systems that handle baggage in international airports is expected to have major positive changes in how efficiently the systems operate.

H2: The use of artificial intelligence that is based on predictive analytics has been proven to decrease the frequency and duration of downtime in systems that handle baggage.

H3: The use of artificial intelligence in systems that handle baggage in airports is expected to improve the accuracy of tracking baggage by a significant amount.

H4: The use of artificial intelligence that is based on the principles of automation has been shown to improve the reliability of baggage handling systems.

H5: The use of artificial intelligence is expected to improve the accuracy and reliability of operations in regard to the tracking of baggage.

1.6. Significance of the Study

The significance of the study comes from the value it adds to both theory and practice in the aviation industry. This study is particularly important from the perspective of airport operational management and the digital transformation of the airports.

This research contributes to the literature concerning the integration of artificial intelligence technologies in airport operational management and logistics. The last few years have seen a rise in scholarly interest in the application of artificial intelligence in aviation. For example, there have been numerous studies focused on the optimization of flight scheduling, predictive safety management, and the management of passenger flows (Davenport & Ronanki, 2018; Russell & Norvig, 2021).

However, the literature on artificial intelligence in aviation is scarce, despite the numerous studies on the application of AI in aviation, and none of them have focused on the role of artificial intelligence in enhancing the efficiency of the operations within the baggage handling system at airports. Airport baggage handling operations are a vital logistical aspect of the airport's overall operational performance, and yet, the literature on the digital transformation of airports is silent on them. Thus, this study attempts to address the literature gap on the application of artificial intelligence to the operational performance of baggage handling systems in international airports.

The study also aims to address a gap within airport logistics by applying elements of artificial intelligence, operational efficiency, and airport systems. The study also proposes a framework for analyzing the impact of artificial intelligence on the performance of baggage handling systems, thereby contributing to the body of knowledge on the digital transformation of logistics and operations within the airport ecosystem.

From a practical standpoint, the results of the study are of relevance to airport managers, aviation policymakers, and operational technology innovators, and provide the underlying theory for increased airport operational efficiency. This study examines the opportunities presented by artificial intelligence, including predictive maintenance, automated monitoring, and intelligent baggage routing to provide airport managers with actionable insights to enhance the reliability and operational performance of airport systems (Lee et al., 2015).

Within this framework, AI technology's potential to automate and optimize baggage handling systems is invaluable to the ongoing digital metamorphosis of Saudi Arabia's aviation industry. The productivity of airports as well as the quality of service provided to passengers is significantly enhanced by the incorporation of AI technologies, which serve to minimize unplanned service interruptions. Therefore, this study's findings may guide Saudi Arabia's airport and aviation authorities and serve to integrate and optimize AI technologies at airports, thus supporting the backward integration of the Kingdom's aviation industry.

1.7. Definition of Terms

This section aims to present an unambiguous definition for some of the principal terms for use in the context of the present study.

- Artificial Intelligence (AI)

Artificial Intelligence (AI) refers to the ability of a computer, or a computer-controlled robot, to perform tasks usually done by humans. Such tasks comprise capturing, learning, and

analyzing data and making decisions to use that data to make predictions. In this regard, AI incorporates a wide range of technology that includes, but is not limited to, algorithm-based machine learning, deep learning, and data analytics (Russell & Norvig, 2021).

- Baggage Handling System (BHS)

An example of a baggage handling system is an airport baggage handling system. Such a system is an example of an integrated system of both mechanical and digital elements, and is utilized to transport, sort and track the baggage of passengers. The system is used to track luggage from the check-in counters to the loading areas of the aircraft, and from the aircraft to the baggage claim area. Almost all systems rely on conveyor belt, bar code, and sensor based and sorting and monitoring systems to ensure that adequate and prompt processing of luggage is done to ensure efficient operations of airports (Kazda & Caves, 2015).

- Operational Efficiency

Operational efficiency involves the ability of a system or organization to implement an effective system to carry out its functions while decreasing resources, time, and operational costs. In instances of operational efficiency of the airport baggage handling system, operational efficiency might involve quick, precise, dependable, and cost-effective servicing of the baggage processing systems.

- Predictive Maintenance

Predictive maintenance involve a maintenance approach based on data analytics and systems, and artificial intelligence to track the system, and predict probable failures before they occur. Predictive maintenance allows the system to identify malfunction signs before and avert unforeseen breakdowns while enhancing the operational reliability of the system (Lee, et al., 2015).

- Baggage Tracking

Baggage tracking involves the monitoring of movement and location of the passenger baggage in airport handling systems. Tracking systems are designed to enhance accuracy and lessen the likelihood of luggage being misplaced or routed to the wrong destination.

Barcodes, RFID systems, and artificial intelligence-based computer vision have been adopted to enhance tracking accuracy (SITA, 2023).

- Airport Operational Systems

Airport operational systems include various technologies and components that enable the effective functioning of airports and include passenger processing systems, security screening systems, and aircraft ground handling systems, as well as systems for the handling of baggage and air traffic control. Operational systems work together for the optimized functioning of airports.

1.8. Thesis structure

This thesis adopts a layout typical of academic research in aviation management, operations management, and information systems. It comprises various chapters aimed at investigating the impact of artificial intelligence on the operational efficiency of baggage handling systems at international airports in Saudi Arabia. Each chapter covers a distinct element of the research, starting with the background to the research and concluding with the final recommendations.

The thesis begins with preliminary pages with important information about the study. These sections include a title page which displays the thesis title, researcher, academic institution and supervisor's name. Then, a declaration is made to confirm the originality of the research. Some preliminary pages include a dedication and/or a set of acknowledgments in which the researcher thanks individuals and/or institutions that helped them complete the study.

Additionally, the thesis contains an abstract that summarizes the research problem, objectives,

methodology and main results of the study. The preliminary pages of the thesis include a table of contents that lists all sections and subsections in the thesis, as well as lists of tables, lists of figures, and a glossary of abbreviations.

Chapter one presents an introduction to the study. The chapter presents the general context around the topic of study and justifies the need to study the influence of the artificial intelligence technology on the operations of baggage handling systems at airports. The chapter also identifies the research problem by stating the operational issues of baggage handling systems at airports. Additionally, the chapter presents the study's aims and objectives, the research questions and hypotheses that the study seeks to answer. To further enhance the understanding of the readers, the chapter discusses the significance of the study to both the academic and the practice. Lastly, the chapter presents the scope and limitations of the study and clarifies the definitions of the study's key terms.

The second chapter centers on the literature review, which highlights existing research on the application of artificial intelligence within aviation, the digital transformation of airports, and systems pertaining to baggage handling. Furthermore, this chapter addresses the pertinent theories and articulates the integration of artificial intelligence within airport systems and logistics. Moreover, it reviews past literature on operational efficiency, predictive maintenance, intelligent baggage tracking, and airport management systems. The chapter wraps up by discussing the literature on this subject and devising the conceptual framework to be utilized throughout this research.

The third chapter articulates the research methodology implemented to carry out the study. This chapter describes the research design and the overarching strategy undertaken regarding the collection and analysis of the data. It also specifies the sample frame of the study as well as the sampling method employed. Furthermore, this chapter elaborates on the data collection tool, which is a structured questionnaire constructed to determine the

correlation between artificial intelligence systems and operational efficiency within systems of baggage handling. This chapter outlines the steps taken to assure the validity and consistency of the research tool and describes the quantitative analysis employed on the data collected. Chapter four details the findings from the conducted data analysis.

The chapter opens with the response rate along with the demographic profile(s) of the research participants. Following that, the chapter provides the descriptive statistical analysis from the collected data along with the reliability tests that measure the consistency of the measurement scales employed in the questionnaire. The chapter details the correlation and regression analyses that examine the relationship(s) between the AI applications and the operational efficiency metrics in the BHS (baggage handling systems) before concluding with the results of the hypothesis tests and the rest of the critical statistical results from the study. Chapter five will discuss the study results in relation to the research study objectives and the existing literature from chapter two. This chapter attempts to offer an interpretation to the statistical results and demonstrates how the findings help in understanding the role of AI in BHS operational improvements and contrast the results of this study with previous studies in the field of aviation management and airport operations.

The last chapter of the study contains the study's conclusions and recommendations. This chapter restates the study's findings and contributions to both the airline industry and academia. This chapter touches on recommendations for airport authorities and policymakers for the adoption of machine learning practices to the baggage handling system. This chapter also mentions study limitations and identifies areas related to artificial intelligence and operational efficiency of airports where further study is needed.

Included in the thesis are the references cited in the study, formatted in APA style. The last part of the thesis contains appendices with related materials to the study, including the interview questions, statistical data, and all study-related documents.

CHAPTER TWO

2. LITERATURE REVIEW

Introduction

The literature review serves as a critical foundation for understanding the theoretical and empirical background of a research study. It provides a comprehensive examination of existing knowledge, theories, and previous studies relevant to the research topic while identifying gaps that justify the need for further investigation. Through a systematic review of the literature, researchers can establish the conceptual basis of the study, develop research hypotheses, and position their work within the broader academic context.

The rapid advancement of Artificial Intelligence (AI) technologies has transformed numerous industries, including transportation and aviation. Airports around the world are increasingly adopting AI-based solutions to improve operational performance, enhance service quality, and address the growing complexity of airport operations. Among the various operational systems within airports, baggage handling systems represent one of the most critical components that directly influence operational efficiency, passenger satisfaction, and overall airport performance. As passenger traffic continues to increase globally, airport operators are seeking innovative technological solutions capable of improving baggage processing, reducing operational disruptions, and enhancing system reliability.

This chapter reviews the existing literature related to Artificial Intelligence and its application within the aviation sector, with particular emphasis on baggage handling operations. The chapter begins by discussing the theoretical foundations underpinning the study and examining the role of Artificial Intelligence in modern aviation environments. It then explores the concept and operational significance of baggage handling systems in airports and reviews the major AI applications that support baggage handling operations, including predictive maintenance, intelligent baggage tracking technologies, and automated

monitoring systems. Furthermore, the chapter discusses the concept of operational efficiency and its importance in airport management.

In addition, the chapter critically reviews previous empirical studies related to Artificial Intelligence, airport operations, logistics management, and baggage handling systems. The review of previous studies provides insights into the current state of knowledge, highlights areas of agreement and disagreement among researchers, and identifies gaps in the existing literature. Based on these findings, the chapter establishes the research gap addressed by the present study and develops the conceptual framework illustrating the relationship between Artificial Intelligence technologies and the operational efficiency of baggage handling systems in Saudi Arabian international airports.

Finally, the chapter develops the study hypotheses based on theoretical arguments and empirical evidence from previous research. The literature reviewed in this chapter provides the academic foundation for the research methodology presented in the subsequent chapter and supports the investigation of the role of Artificial Intelligence in improving the operational efficiency of baggage handling systems within the Saudi aviation sector.

2.1. Artificial Intelligence in the Aviation Sector

The incorporation of artificial intelligence into the aviation sector eclipses all prior attempts at technological advancements. AI fosters operational superiority, bolstered safety, and the optimization of resources, as well as aids in decision making in complex aviation environments. Artificial intelligence, as defined by Russell and Norvig (2021), perform tasks that would normally require human thinking by means of a computer system. These tasks include, but are not limited to, decision making through the analysis and evaluation of available data, and problem solving of a predictive and analytical nature.

The various operational areas AI is applied to within the aviation sector include, but are not restricted to, flight scheduling, management of air traffic, predictive system

maintenance, system security, and the management of services offered to customers at various airports. The operational processes of AI in aviation are a function of the data available, which is a result of the operational systems that are embedded into the aircraft, the airport, and the technology employed to process the passengers, as expressed by Davenport and Ronaki (2018).

The artificial intelligence operational systems of airports also foster the emergence of smart airports, which utilize various digital technologies for better operational integration and enhanced passenger experience. The smart airport concepts revolve around artificial intelligence, extensive data analytics, and automation to construct a more adaptable and efficient airport ecosystem.

2.2. Baggage Handling Systems in Airports

Baggage handling systems represent one of the most important logistical infrastructures within the airport ecosystem. These systems are responsible for the movement of passenger baggage from check-in points to the aircraft loading bays and from the arriving aircraft to the baggage reclaim areas. A baggage handling system is made up of a series of interlinked components, including conveyor belts, x-ray scanners, sorting machines, and various sensors and control systems (Kazda & Caves, 2015).

When checking in, some systems recognize bags by their identification tags. Tags define how systems track bags and how the routes are directed to the appropriate planes. After checking in, bags are moved to a conveyor belt system and are directed to the right flights.

With the baggage handling system, monitoring system operational problems is cumbersome. Operational problems are an area airport management is trying to use advanced technology to improve (Schwarz, 2021).

2.3. Artificial Intelligence in Baggage Handling Systems

Artificial Intelligence technologies can greatly improve the efficiency and reliability in the BHS. Some example AI applications include predictive maintenance, intelligent tracking, automated system monitoring, and decision-making support.

Intelligent tracking is an equally important AI application in the BHS. Computer vision technology empowered by AI is capable of automatically identifying the movement of bags in the conveyor system in an airport and even can detect in real time if a bag is wrongly routed. These systems enhance the accuracy of tracking and the number of bags that are lost is significantly decreased.

Automated monitoring systems that utilize Artificial Intelligence are capable of identifying operational anomalies in baggage handling systems. For example, machine learning models can detect, and learn, deviations in baggage flow, identify congestion of the conveyor belt systems, and disrupt the flow of operational teams. Such abilities enhance the operational response capability of the airport, and, in turn, reduce the downtime of the systems.

2.4. Predictive Maintenance in Airport Systems

One of the most noteworthy uses of artificial intelligence in both the industrial and transport sectors is predictive maintenance. Predictive maintenance is becoming increasingly useful in airport settings because of the need to constantly operate and maintain infrastructural systems in an airport setting safely and efficiently. Baggage handling systems contain both electronic and mechanical components such as conveyor belts, motors, sensors, and sorters. Therefore, a failure in any of these components will hinder operational processes, create delays, and increase maintenance costs.

In airport systems, the predictive maintenance of systems and processes is still in its infancy. Systems such as reactive maintenance and scheduled maintenance have traditionally been implemented. Where reactive maintenance is concerned, systems are repaired once they have failed whereas scheduled maintenance entails the consistent maintenance of systems at intervals determined in advance. Both of these systems, however, have weaknesses such as creating unanticipated operational system failures or creating maintenance tasks that in the end are counterproductive and increase operational costs. In providing a solution to such problems, predictive maintenance uses artificial intelligence to evaluate operating systems and forecast the likelihood of system failure (Lee et al., 2015).

The implementation of predictive maintenance systems enables the use of certain technologies like artificial intelligence, machine learning, and data analytics, which allow the system to analyze the data collected from sensors embedded in baggage handling equipment. The sensors track various parameters for the equipment, such as temperature, vibrations, and activity of the motors. The presence of artificial intelligence and machine learning allows the systems to recognize and analyze data trends and provide predictive alerts for equipment degradation or failure. This allows maintenance to be performed before system failure, minimizing downtime, and maximizing operational reliability.

The evidence shows that operational effectiveness in the airport industry can be improved with the use of predictive maintenance systems in equipment breakdown prevention and less maintenance costs. As predictive maintenance systems identify system anomalies and allow maintenance teams to take preventative actions, AI-based systems have been shown to eliminate downtime due to maintenance (Davenport & Ronanki, 2018). Because of this, predictive maintenance has emerged as one of the most important aspects of the ongoing digital transformation in aviation.

2.5. Intelligent Baggage Tracking Technologies

An essential component of airport logistics systems is effective baggage tracking. Tracking is imperative for effective movement of passenger luggage from check-in stations to boarding, and from arriving flights to baggage claim. Poor tracking can result in misplaced, delayed, or lost luggage, negatively impacting the experience of the customers and the operations of the airline.

Inefficient tracking systems that use barcode technologies are common in traditional tracking systems. At check-in, passengers are given barcode tags that contain information about the passenger and the flight. Automated scanners are used in baggage conveyor systems to read barcodes and direct bags to the appropriate aircraft. Although tracking systems have increased the precision of baggage handling, they are limited in handling the varying complexities of airport systems where scanning may skip tags or the tags may become damaged (SITA, 2023).

Airports that invest in advanced technology for tracking baggage obtain operational gains and have improved the incidence of misdirected baggage within their airport as reported in the SITA Baggage IT Insights report (SITA, 2023). Therefore, intelligent baggage tracking systems are now a vital component of the logistics management systems of modern airports.

2.6. Operational Efficiency in Airport Management

Managing airports involves a high degree of complexity in a time-sensitive manner and operational efficiency remains the primary goal. To achieve this goal, the different systems that are involved in the management of the airports including the passenger processing systems, baggage systems, aircraft ground operations, and air traffic management systems must all work together. A lag in one system will invariably lead to delays in operational performance of the airport as a whole.

Airport operational efficiency can be measured using various key performance indicators, such as time taken to process bags, reliability of the system, accuracy of tracking components, and total operational costs. When assessing operational efficiency, it should be noted that the purpose of baggage handling is to ensure that bags are transported quickly and accurately throughout the airport system while not causing delays to the flight schedules. The use of certain Artificial Intelligence (AI) technologies can improve operational efficiencies at airports. AI technologies allow for empirical decision-making (i.e. using facts, statistics, and data) and automated process oversight. AI can pick out the inefficiencies in the operational data pulled from different airport systems, redistribute resources, and improve process interactions (Russell & Norvig, 2021).

AI-enabled constructive systems can make recommendations regarding optimal routes for bags based on the number of bags and the number of people at the airport. These systems can also be used to anticipate demand, so that people won't get stuck in baggage handling systems. AI also improves operational efficiencies at airports in coordination and process design.

AI can also detect and report any process system disruptions or irregular processing in a timely manner, which helps airport operators mitigate any operational impacts. This is essential in airports that have a lot of passengers. Even the smallest delays can be very disruptive.

2.7. Previous Studies

Kazda and Caves (2015) have analyzed the operational framework of airport systems and pointed out the crucial role of airport performance of an efficient baggage handling system. Their study indicated that handling baggage is inefficient and an operational challenge that multiple airports face. They claim more technology is needed for baggage handling systems to become more reliable and operationally less disruptive.

SITA (2023) analyzed the prevailing trends and technological advancements in the management of baggage in airports. The study found that airports that utilized advanced baggage tracking technology such as RFID and AI real-time monitoring recorded a low rate of baggage mishandling. The study also found that the use of advanced digital technologies in airports improved operational efficiency and effectiveness and increased passenger satisfaction.

Schwarz (2021) studied airport logistics and stressed the need to combine advanced technology and baggage systems monitoring. The researcher found that automated and control monitoring systems gave managers enhanced operational visibility and improved the identification of operational system defects.

Geske (2024) evaluated how artificial intelligence (AI) impacts operational efficiency within air transport. The study concluded that real-time data analytics and predictive decision-making boosts operational performance in complex aviation environments.

Hassan et al. (2019) evaluated automated bag detection using computer vision tech in airport security. The study showed operational errors in baggage handling can be significantly reduced and the accuracy of baggage identification increased using deep learning models.

Tan and Masood (2021) completed a systematic literature review of Industry 4.0 tech in airport contexts. The study concluded that airport operation systems can be transformed and systems efficiencies improved with the adoption of artificial intelligence, big data analytics, and automation.

The economic impact of artificial intelligence (AI) technologies was analyzed by Brynjolfsson and McAfee (2017) where it was noted that AI systems provide a means for organizations to enhance workforce productivity and improve operational efficiency by adopting data-driven decision-making.

The last of the studies looked at IATA's 2023 report and the global trends in the aviation industry and the need for the use of digital technology in managing the increase in the number of passengers. The report stated that digital technology, including artificial intelligence, will be essential for enhancing the operational efficiency of airports in the coming decades.

All the studies mentioned above show that artificial intelligence has great potential to be used to increase the efficiency of complex systems such as airport baggage handling systems. The majority of studies, however, focus on general aviation activities or the digital transformation of airports and few studies focus on the use of artificial intelligence to enhance baggage handling systems in Saudi Arabian Airports.

2.8. Research Gap

Despite the emphasis placed on the value of artificial intelligence in transforming airport operations, the literature is deficient in many areas. Most literature concentrates on the use of artificial intelligence in aviation safety, air traffic management, and passenger processing systems. There is a glaring absence of studies that focus specifically on the role of artificial intelligence in baggage handling systems.

Second, nearly all previous studies focused on developed airline markets, notably Europe and North America, while research on the application of artificial intelligence technologies in airport environments in the Middle East remains scarce.

Third, most previous studies have concentrated solely on the technological components of digital transformation in airports without exploring the connection between artificial intelligence technologies and the operational efficiency of individual components within the baggage handling systems.

Hence, this study aims to fill these gaps by investigating the impact of artificial intelligence technologies on the operational efficiency of baggage handling systems in international airports in Saudi Arabia.

2.9. Conceptual Framework

In view of the literature reviewed in this chapter, this study presents a conceptual framework attempting to determine the relationship between artificial intelligence technologies and operational efficiency of airport baggage handling systems.

In this framework for the study, artificial intelligence technologies are treated as an independent variable. Some of these technologies include predictive maintenance systems, smart baggage tracking systems, automated monitoring systems, and AI decision support systems. With these technologies, airports are able to collect, analyze, and make predictions about operational data and system failures, as well as optimize the entire baggage handling process.

Operational efficiency is defined as the capacity of airport baggage handling systems to process passenger luggage with the utmost accuracy and efficiency while keeping system downtime, operational delays, and baggage mishandling to a minimum.

The conceptual framework based on the theory of operational efficiency indicates that the integration of artificial intelligence systems will operationalize efficiency through the improvement of reliability, baggage tracking accuracy, reduction of operational failure of the system, and improvement of the decision-making process.

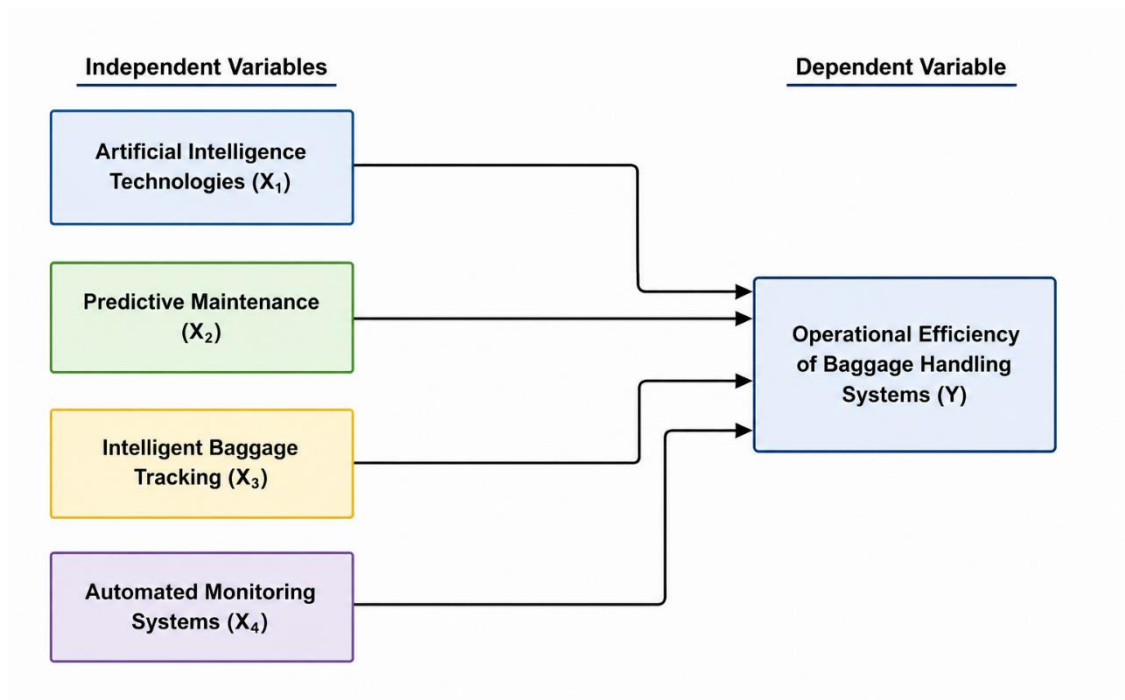


Figure 1: Conceptual Framework

2.10. Development of Hypothesis

This section will develop the research hypothesis based on empirical evidence and theories already established in the literature.

□ Artificial Intelligence and Operational Efficiency

The impact of artificial intelligence (AI) technologies is undeniable when it comes to operational efficiency. This is particularly the case with the transportation and aviation industries. AI technologies provide the means to process and analyze big data, identify operational inefficiencies and provide evidence-based solutions to operational challenges. AI technologies provide the ability to monitor operational systems, identify and resolve issues, and provide optimum functionality to operational processes in real time. This is particularly important in airports.

Davenport and Ronanki (2018) noted that the use of artificial intelligence (AI) in the workforce allows the simplification of intricate tasks and improves the quality of decision-making within the organization. This is also the case with Russell and Norvig (2021), where

36

AI-based systems are able to interpret and assess the levels of complexity within the organization and provide insight and recommendations to better the overall management of the organization.

AI within the systems of automated baggage handling in airports can improve and optimize the routing of AI and can also detect and address issues that arise within the operational units and the overall system. All of these things maintain the operational system and lower the inconsistencies faced with system reliability.

With these assertions in mind, the following hypothesis is put forward.

H1: There is a considerable positive influence of AI on the operational efficiency of baggage handling systems in international airports.

H2: The reliability of baggage handling systems at international airports improves significantly through predictive maintenance driven by artificial intelligence.

H3: Intelligent baggage tracking technologies improve the accuracy of baggage handling within airport baggage handling systems.

CHAPTER THREE

3. RESEARCH METHODOLOGY

Introduction

The research methodology that was used to explore the role of Artificial Intelligence (AI) in enhancing the efficiency of BHS in international airports of Saudi Arabia is presented in this chapter. The methodology chapter is part of the research process that explains the procedure and technique applied in gathering, analyzing and interpreting data to reach the objectives of the research and to answer the research question. Use of a well-designed methodology ensures that the research findings are valid, reliable and credible, and it offers a systematic structure for conducting the research.

The overall research approach, research design, the target population, sampling techniques, and data collection procedures used in the study are described in this chapter. It also provides an explanation of the construction of the research instrument, methods for validity and reliability, and statistical analysis technique of the data collected. The study aims to analyze the correlation between Artificial Intelligence technologies and system efficiency in the baggage handling process, so the quantitative research method was used in order to make it possible to measure and analyze the variables that will be studied objectively. Additionally, this chapter addresses ethical issues that were noted throughout the research process to ensure that the participant's identity is kept confidential, they have chosen to participate, and that the data gathered are handled responsibly. The methodological processes that are presented in this chapter are used to conduct the empirical investigation and help in producing coherent and credible results for the effects of Artificial Intelligence applications on the baggage handling works in the Saudi aviation sector.

3.1. Research Design

Research design represents the blueprint or road map for a study. Research design is like a road map for a research process that guides all the phases of a research study in a systematic and logical manner. It outlines how data will be collected, measured and analysed to answer the research questions and fulfil the study goals. Saunders et al. (2019) define research design as the overall plan that shows the researcher how to answer the research questions and to control factors that can affect the validity and reliability of the research results.

The type of research used in the present study is descriptive and explanatory research. The descriptive aspect is designed to help create a comprehensive picture of current Artificial Intelligence (AI) usage in the baggage handling system of Saudi Arabian international airports. It describes the current operating environment, AI technologies and the perceptions of airport employees on those technologies. The explanatory aspect aims to uncover the causal relationships between the AI technologies and the operational efficiency, by exploring how predictive maintenance, intelligent baggage tracking and automated monitoring systems can enhance the performance of the baggage handling systems.

This design is deemed suitable because it provides for a description of current conditions and an explanation of how AI technologies affect the key operational outcomes. This method allows the study to analyze the correlation between variables and provide empirical evidence-based conclusions on the effectiveness of the implementation of AI in an airport's baggage-handling system.

3.2. Research Methodology

Research methodology is the systematic approach by which the data is collected, analyzed and interpreted to solve a research problem and to attain the goal of a research

work. The method employed in research depends upon the problem in research and the aim of the study, the type of data needed.

There are typically three types of research methodologies: qualitative, quantitative, and mixed methods. Qualitative research is used to gain an understanding of human experiences, perceptions and behaviors through interviews, observations and textual analysis. In quantitative research the variables are measured numerically, and related variables are tested and analyzed statistically. Mixed-method research is a research method that uses more than one approach, both qualitative and quantitative, to gain a wider understanding of the problem at hand.

The methodology used in the present study is quantitative research due to the measurement of the impact of Artificial Intelligence technologies in operational efficiency of the airport baggage handling system. The quantitative method enables the researcher to obtain numerical data from many respondents and to obtain numerical data from many respondents and to analyze the relationship between the independent and dependent data objectively. The quantitative approach is appropriate for this study as the research aims to test a set of hypotheses based on the literature review and conceptual framework. Statistical techniques will be used to determine the extent to which AI technologies influence operational efficiency indicators such as system reliability, baggage tracking accuracy, reduction of downtime, and overall operational performance. In addition, quantitative methods offer more objectivity, reliability and generalizability of the results than qualitative methods.

3.3. Study Population

The population is the group of all the elements, groups, or individuals that have the characteristics of interest for the research problem under study. This study investigated the target population that includes all employees in the domain of airport operational

management and baggage handling at major international airports in the Kingdom of Saudi Arabia.

The study is targeted to operators directly involved in the planning, operation, maintenance, supervision and management of baggage handling systems. These people should have enough knowledge and hands-on experience with implementing and evaluating AI technologies in airport operational systems.

The target groups are:

- Airport Operations Managers
- Baggage Handling Supervisors
- Maintenance Engineers
- Technical Support Staff
- Airport Logistics Personnel
- Airport Operations Officers
- Baggage Handling Technicians

These workers will be instrumental in the smooth operation of baggage handling systems and can offer valuable insights into the performance of AI systems.

The study is carried out at three major airports in Saudi Arabia namely:

The airport of King Abdulaziz International Airport (Jeddah)

- ALANAFRIQA Airport (Dubai)

The airport of King Fahd International Airport (Dammam)

The airports chosen were those with the highest capacity and volume of passenger/baggage volumes in Saudi Arabia, and they serve a major share of the Kingdom's traffic. They are a great arena in which to explore the potential for implementation of Artificial Intelligence to enhance the efficiency of the baggage handling process, given their complexity of operation and the growing volume of passengers.

3.4. Sampling Technique

The selection of a subset of individuals from the target population for the research study is called sampling. It is often impractical to collect data from all of the individuals in the population; therefore, researchers employ sampling techniques to get representative data that can be generalized to the population.

The data collection method used in this study is purposive sampling as a non-probability sampling technique which selects the respondents based on the appropriate criteria to the research objectives. Purposive sampling is suitable method because the study needs people who have firsthand experiences with the operations of the airport and the technologies of AI used with baggage handling.

Selection criteria are people involved in baggage handling activity, system maintenance, airport logistics, operations monitoring and airport management. These respondents are expected to give relevant and accurate information about the implementation of Artificial Intelligence technologies and their effect on the operational efficiency.

Saunders et al (2019) have stated that sample size of 150 to 300 respondents is generally acceptable for quantitative study which includes multiple regression and correlation analysis. So, this study is designed to gather the information from a minimum of 250 respondents from the selected airports. The size of this sample is believed to have enough power to test the research hypotheses and obtain dependable results.

3.5. Data Collection Techniques

Data collection is an important part of research process since it helps to answer the research questions and fulfill the goal of the study. Primary data will be gathered using a structured questionnaire from the employees involved in the two key areas for data collection which are the baggage handling and airport operational departments.

A questionnaire will be sent electronically, via online survey platforms, to allow access for participants in various airport locations. Electronic distribution has many benefits as it will reduce costs, request responses faster, be more accessible and manage data better. Participants will be informed about the aims of the study, confidentiality measures, and ethical issues prior to filling out the questionnaire. Participation will be voluntary and respondents will be assured that responses will be anonymous and used only for academic purposes.

The questionnaire was chosen as the main data collection tool, as it enables the collection of standardized data from a relatively large number of respondents, makes statistical analysis possible and offers a practical way to measure perceptions and attitudes towards AI technologies and operational efficiency.

The research instrument used was a questionnaire. A questionnaire was used as the research instrument in developing the questionnaire.

The main research tool that is used in this study is a structured questionnaire designed after having reviewed some previous studies on the subject of AI, airport operations, logistic management, predictive maintenance, and operational efficiency.

The questionnaire measures both the independent variable and dependent variable in the study's conceptual framework in the study.

The instrument has five sections.

Section A gathers information on the respondent's demographic characteristics, like age, gender, education level, job position, years of experience, and airport affiliation.

Section B focuses on the implementation and use of Artificial Intelligence technologies for baggage handling.

Section C looks at the practices of predictive maintenance and their role in equipment reliability and operational continuity.

Section D explores intelligent baggage tracking technologies and their benefits for the accuracy of baggage identification, monitoring and routing.

In Section E, operational efficiency is assessed with indicators of system reliability, baggage processing speed, reduction of operational disruptions and overall operational performance.

The items for all of the questionnaires are evaluated on the 1-5 Likert scale, from Strongly Disagree to Strongly Agree. The adoption of the likert scale allows the respondents to indicate different levels of agreement and makes it possible to analyze perceptions and attitudes quantitatively.

3.6. Reliability and Validity

The validity and reliability of the research instrument are important in order to generate valid and reliable findings.

Validity is the degree to which an instrument is able to measure the phenomenon it is designed to measure. Content validity will be achieved by subject matter experts and professionals in the aviation management, aviation operations management and research methodology as well as airport operations practitioners by conducting a thorough review of the questionnaire. The feedback will help to refine the wording, clarity and relevance of the items in a questionnaire.

Reliability is the consistency and stability of the measurement results. Cronbach's Alpha coefficient will be employed to test the reliability in this study. Cronbach's Alpha is a method for assessing the internal consistency between the items on a questionnaire, and it allows us to determine the degree of similarity between the results of the questionnaire items

that measure the same construct. Hair et al (2019) stated that Cronbach's Alpha of 0.70 or above is an acceptable level of reliability.

A pretest of the pilot study may also be done before the actual data collection phase to determine any problems with the questionnaire design, the clarity of the items and the procedure for returning the questionnaires.

3.7. Techniques of Analyzing Data

After the data has been gathered, all responses will be coded and put into the software program – Statistical Package for the Social Sciences (SPSS).

Respondent information will be summarized using descriptive statistics (frequencies, percentages, means, and standard deviations) and characteristics of the study variables will be described.

The internal consistency of the scales to be measured will be analyzed by cronbach alpha reliability analysis. Pearson correlation analysis will be used to analyze the relationships between AI technologies and operational efficiency indicators in terms of their strengths and directions.

To test the proposed research hypotheses and to find the predictive effect of the Artificial Intelligence technologies on operational efficiency, multiple regression analysis will be performed. The outcomes of this analysis will give empirical evidence of how much contribution Artificial Intelligence makes in enhancing the operational efficiency of international airports' baggage handling systems in Saudi Arabia.

CHAPTER FOUR

4. DATA ANALYSIS AND RESULTS

Introduction

This chapter shares the statistical analysis and result obtained from the study titled "The role of Artificial Intelligence in the enhancement of operational efficiency in the Baggage handling system of international airports in Saudi Arabia. This chapter aims to analyse the gathered data from employees at airports working in the baggage handling sector and assess the effects of Artificial Intelligence technologies on the efficiency of the operations.

Analysis was done by using the Statistical Package for the Social Sciences (SPSS). Data about the demographic characteristics and study variables of the respondents were summarized using descriptive statistics. Reliability analysis was used to evaluate the scale of the measurement for the internal consistency. To find out the relation between the study variables Pearson correlation analysis was used and multiple regression analysis was used to test research hypotheses and to find out the influence of Artificial Intelligence technologies on operational efficiency.

The chapter is divided into various sections such as Response rate analysis, Demographic characteristics of the respondents, Descriptive statistics of the study variables, Reliability testing, Correlation analysis, Regression analysis and hypothesis testing.

4.1. Response Rate

A total of 280 questionnaires were sent electronically to the employees involved in the Saudi Arabia major international airports' baggage handling operations and Airport management departments. In these, 257 questionnaires were returned. A total of 250 questionnaires were

selected after checking for completeness and consistency and yielded a valid response rate of 89.3%.

Table 1: Response Rate

Description	Number
Questionnaires Distributed	280
Questionnaires Returned	257
Valid Questionnaires	250
Invalid Questionnaires	7
Response Rate	89.3%

The response rate of 89.3% is considered highly satisfactory and exceeds the minimum threshold recommended for quantitative studies, indicating strong participation from airport employees.

4.2. Demographic Characteristics of Respondents

4.2.1. Gender

Table 2: Gender Distribution

Gender	Frequency	Percentage
Male	185	74.0
Female	65	26.0
Total	250	100.0

The results indicate that male respondents represented the majority of the sample (74.0%), while female respondents accounted for 26.0%. This distribution reflects the workforce composition within airport operational and technical departments.

4.2.2. Age

Table 3: Age Distribution

Age Group	Frequency	Percentage
Less than 30 years	45	18.0
30–40 years	102	40.8
41–50 years	70	28.0
More than 50 years	33	13.2
Total	250	100.0

The largest proportion of respondents (40.8%) were aged between 30 and 40 years, indicating that most participants were in their active professional years and possessed substantial operational experience.

4.2.3. Educational Level

Table 4: Educational Level

Education	Frequency	Percentage
Diploma	35	14.0
Bachelor's Degree	155	62.0
Master's Degree	50	20.0
PhD	10	4.0
Total	250	100.0

The majority of respondents held bachelor's degrees (62.0%), suggesting that participants possessed the educational qualifications necessary to understand modern airport technologies and operational systems.

4.3. Job Position

Table 5: Job Position

Position	Frequency	Percentage
Airport Operations Staff	85	34.0
Baggage Handling Technician	60	24.0
Maintenance Engineer	40	16.0
Airport Operations Manager	30	12.0
Other	35	14.0
Total	250	100.0

The results indicate that airport operations staff constituted the largest respondent group, accounting for 34.0% of the sample.

4.4. Years of Experience

Table 6: Years of Experience

Experience	Frequency	Percentage
Less than 5 years	40	16.0
5–10 years	95	38.0
11–15 years	70	28.0
More than 15 years	45	18.0
Total	250	100.0

The findings reveal that most respondents possessed between 5 and 10 years of experience, demonstrating adequate exposure to airport operational systems.

Descriptive Statistics of Study Variables

To evaluate respondents' perceptions regarding the study variables, means and standard deviations were calculated.

4.5. Predictive Maintenance

Table 4.9 Frequency and Percentage Distribution of Predictive Maintenance (n = 250)

Statement	SD n (%)	D n (%)	N n (%)	A n (%)	SA n (%)	Total
Predictive maintenance systems help detect equipment failures early.	3 (1.2)	8 (3.2)	20 (8.0)	126 (50.4)	93 (37.2)	250 (100)
AI-based maintenance systems improve baggage handling equipment reliability.	2 (0.8)	9 (3.6)	18 (7.2)	128 (51.2)	93 (37.2)	250 (100)
Predictive maintenance reduces unexpected equipment breakdowns.	2 (0.8)	7 (2.8)	16 (6.4)	129 (51.6)	96 (38.4)	250 (100)
Predictive maintenance improves maintenance planning efficiency.	3 (1.2)	10 (4.0)	21 (8.4)	124 (49.6)	92 (36.8)	250 (100)
AI maintenance systems reduce system downtime.	2 (0.8)	8 (3.2)	17 (6.8)	127 (50.8)	96 (38.4)	250 (100)

The results demonstrate a very high level of agreement regarding the effectiveness of predictive maintenance systems in airport baggage handling operations. More than 87% of respondents either agreed or strongly agreed with each statement, indicating that predictive maintenance is widely perceived as an effective approach for improving equipment reliability and minimizing operational interruptions. The highest level of agreement was recorded for the statement indicating that predictive maintenance reduces unexpected equipment breakdowns, reflecting respondents' confidence in AI-driven maintenance strategies.

4.6. Mean, Standard Deviation, Rank and Level of Predictive Maintenance

Table 7: Mean, Standard Deviation, Rank and Level of Predictive Maintenance

Statement	Mean	SD	Rank	Level
Predictive maintenance systems help detect equipment failures early.	4.36	0.67	3	Very High
AI-based maintenance systems improve baggage handling equipment reliability.	4.39	0.65	2	Very High
Predictive maintenance reduces unexpected equipment breakdowns.	4.44	0.61	1	Very High
Predictive maintenance improves maintenance planning efficiency.	4.34	0.70	5	Very High
AI maintenance systems reduce system downtime.	4.37	0.66	4	Very High
Overall Mean	4.38	0.66	—	Very High

All predictive maintenance statements received high mean scores, with the descriptive statistics showing that respondents agree strongly with the importance of such maintenance practices with the help of AI in a baggage handling system. “Predictive maintenance decreases unexpected equipment failures” received the highest mean score ($M = 4.44$, $SD = 0.61$), indicating that this statement was perceived as being most effective in preventing equipment failures. The lowest mean score ($M = 4.34$, $SD = 0.70$) was for the statement "Predictive maintenance improves maintenance planning efficiency," which was still in the very high category. The overall mean of 4.38 substantiates the strong belief of the respondents that predictive maintenance is of great significance to the performance and reliability of the baggage handling systems in Saudi international airports.

4.7. Intelligent Baggage Tracking

Table 8: Frequency and Percentage Distribution of Intelligent Baggage Tracking (n = 250)

Statement	SD n (%)	D n (%)	N n (%)	A n (%)	SA n (%)	Total
Advanced technologies improve baggage tracking accuracy.	4 (1.6)	11 (4.4)	24 (9.6)	127 (50.8)	84 (33.6)	250 (100)
AI technologies improve baggage identification processes.	3 (1.2)	10 (4.0)	26 (10.4)	126 (50.4)	85 (34.0)	250 (100)
Smart baggage tracking systems reduce baggage loss.	4 (1.6)	12 (4.8)	27 (10.8)	123 (49.2)	84 (33.6)	250 (100)
Real-time baggage monitoring improves airport operational efficiency.	3 (1.2)	9 (3.6)	22 (8.8)	129 (51.6)	87 (34.8)	250 (100)
AI technologies improve baggage routing accuracy.	4 (1.6)	10 (4.0)	25 (10.0)	125 (50.0)	86 (34.4)	250 (100)

The findings suggest that the respondents had very positive attitudes towards the use of intelligent baggage tracking technologies in enhancing the baggage handling processes in airports. In each of the statements, the majority of respondents agreed with the statement, or strongly agreed, meaning that there is broad acceptance of AI powered tracking technology. The highest level of support was seen for the statement about the role of real-time baggage monitoring in improving operational efficiency, emphasizing the need for real-time and continuous monitoring in the present-day airport operations.

Table 9: Mean, Standard Deviation, Rank and Level of Intelligent Baggage Tracking

Statement	Mean	SD	Rank	Level
Advanced technologies improve baggage tracking accuracy.	4.25	0.76	3	Very High
AI technologies improve baggage identification processes.	4.24	0.78	4	Very High
Smart baggage tracking systems reduce baggage loss.	4.21	0.81	5	Very High
Real-time baggage monitoring improves airport operational efficiency.	4.31	0.70	1	Very High
AI technologies improve baggage routing accuracy.	4.29	0.73	2	Very High
Overall Mean	4.26	0.76	—	Very High

The descriptive analysis showed that all the statements about Intelligent Baggage Tracking got very high mean scores, suggesting that there was a high level of agreement among the respondents that AI-based baggage tracking technologies are effective. The statement "Real-time baggage monitoring improves airport operational efficiency" (M = 4.31, SD = 0.70) was the highest rated, indicating that respondents are very appreciative of real-time monitoring for the improvement of airport operational efficiency. In contrast, 'Smart baggage tracking systems reduce baggage loss' achieved the lowest mean score (M = 4.21, SD = 0.81), but still fell within the very high level category of agreement. The overall mean value of 4.26 indicates that intelligent baggage tracking technologies are regarded as

immensely important in enhancing the operational efficiency and the quality of services of the baggage handling system in Saudi international airports.

4.8. Automated Monitoring Systems

Table 10: Frequency and Percentage Distribution of Automated Monitoring Systems (n = 250)

Statement	SD n (%)	D n (%)	N n (%)	A n (%)	SA n (%)	Total
Automated monitoring systems detect operational problems quickly.	3 (1.2)	9 (3.6)	21 (8.4)	128 (51.2)	89 (35.6)	250 (100)
AI monitoring systems improve baggage flow management.	4 (1.6)	10 (4.0)	23 (9.2)	126 (50.4)	87 (34.8)	250 (100)
Automated monitoring systems improve system reliability.	2 (0.8)	8 (3.2)	20 (8.0)	129 (51.6)	91 (36.4)	250 (100)
Monitoring systems help reduce baggage handling disruptions.	3 (1.2)	11 (4.4)	24 (9.6)	124 (49.6)	88 (35.2)	250 (100)
AI monitoring systems improve operational control.	3 (1.2)	9 (3.6)	22 (8.8)	127 (50.8)	89 (35.6)	250 (100)

The results revealed that the perception of respondents about the automation of monitoring systems in the baggage handling operation at airports was quite positive. The majority of respondents (more than 85%) were confident in the use of AI-based monitoring technologies for all statements. Agreement was highest with the statement that automated monitoring systems enhance system reliability, which signaled that respondents felt monitoring goes hand-in-hand with reliable and efficient baggage handling systems.

Table 11: Mean, Standard Deviation, Rank and Level of Automated Monitoring Systems

Statement	Mean	SD	Rank	Level
Automated monitoring systems detect operational problems quickly.	4.28	0.71	3	Very High
AI monitoring systems improve baggage flow management.	4.27	0.74	4	Very High
Automated monitoring systems improve system reliability.	4.34	0.67	1	Very High
Monitoring systems help reduce baggage handling disruptions.	4.25	0.76	5	Very High
AI monitoring systems improve operational control.	4.31	0.69	2	Very High
Overall Mean	4.29	0.71	—	Very High

The descriptive statistics showed that all statements concerning Automated Monitoring Systems had very high mean scores with the respondents agreeing strongly with the effectiveness of AI-based monitoring technologies in the baggage handling process. Among all statements, the highest mean score was obtained for the statement of automated monitoring systems increase the reliability of the system ($M = 4.34$, $SD = 0.67$). When asked about the extent to which monitoring systems help to reduce baggage handling disruptions, the lowest mean score ($M = 4.25$, $SD = 0.76$) was found, but still in the very high level of agreement. The overall mean score of 4.29 indicates that automated monitoring systems are

widely used to create greater operational reliability, better process control and efficient management of baggage handling systems in the Saudi International airports.

4.9. Mean Interpretation Scale

Mean Range	Level
1.00 – 1.80	Very Low
1.81 – 2.60	Low
2.61 – 3.40	Moderate
3.41 – 4.20	High
4.21 – 5.00	Very High

4.10. Descriptive Statistics

Table 12: Descriptive Statistics

Variable	Mean	SD	Level
Artificial Intelligence Technologies	4.31	0.62	Very High
Predictive Maintenance	4.38	0.59	Very High
Intelligent Baggage Tracking	4.26	0.65	Very High
Automated Monitoring Systems	4.29	0.61	Very High
Operational Efficiency	4.42	0.57	Very High

The results indicate that all variables achieved very high mean scores, reflecting strong agreement among respondents regarding the role of Artificial Intelligence in enhancing baggage handling operations.

4.11. Reliability Analysis

Reliability analysis was conducted using Cronbach's Alpha coefficient to assess the internal consistency of the measurement scales used in the questionnaire. Cronbach's Alpha values above 0.70 are generally considered acceptable, indicating satisfactory reliability and consistency among questionnaire items (Hair et al., 2019).

Table 13: Reliability Analysis

Variable	Number of Items	Cronbach's Alpha
Artificial Intelligence Technologies	5	0.894
Predictive Maintenance	5	0.912
Intelligent Baggage Tracking	5	0.901
Automated Monitoring Systems	5	0.887
Operational Efficiency	5	0.926
Overall Instrument	25	0.941

The results indicate that all constructs achieved Cronbach's Alpha values exceeding the recommended threshold of 0.70. The overall questionnaire achieved a Cronbach's Alpha value of 0.941, indicating excellent internal consistency and confirming that the instrument is reliable for measuring the study variables.

4.12. Correlation Analysis

Pearson Correlation Analysis was conducted to examine the relationships between Artificial Intelligence dimensions and operational efficiency.

Table 14: Pearson Correlation Matrix

Variables	AI Technologies	Predictive Maintenance	Intelligent Tracking	Automated Monitoring	Operational Efficiency
AI Technologies	1				
Predictive Maintenance	.702**	1			

Intelligent Tracking	.694**	.721**	1		
Automated Monitoring	.711**	.748**	.726**	1	
Operational Efficiency	.783**	.801**	.768**	.792**	1

Correlation is significant at $p < 0.01$

The findings demonstrate strong positive correlations among all study variables. Operational efficiency exhibited the strongest relationship with predictive maintenance ($r = .801$), followed by automated monitoring systems ($r = .792$), Artificial Intelligence technologies ($r = .783$), and intelligent baggage tracking ($r = .768$). These findings suggest that increased implementation of AI technologies is associated with improved operational efficiency within baggage handling systems.

4.13. Multiple Regression Analysis

Multiple regression analysis was conducted to determine the impact of Artificial Intelligence dimensions on operational efficiency.

Model Summary

Table 15: Model Summary

R	R Square	Adjusted R Square	Std. Error
0.842	0.709	0.704	0.351

The model produced a correlation coefficient (R) of 0.842, indicating a strong positive relationship between the independent variables and operational efficiency. The coefficient of determination ($R^2 = 0.709$) indicates that approximately 70.9% of the variance in operational

efficiency can be explained by Artificial Intelligence technologies, predictive maintenance, intelligent baggage tracking, and automated monitoring systems.

4.14. ANOVA Results

Table 16: ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	75.623	4	18.906	152.774	.000
Residual	30.321	245	0.124		
Total	105.944	249			

The ANOVA results indicate that the regression model is statistically significant ($F = 152.774$, $p < 0.001$). This confirms that the independent variables collectively have a significant effect on operational efficiency.

4.15. Regression Coefficients

Table 17: Regression Coefficients

Variable	B	Beta	t-value	Sig.
Constant	0.812	—	4.562	.000
Predictive Maintenance	0.321	0.339	6.992	.000
Intelligent Baggage Tracking	0.276	0.281	5.773	.000
Automated Monitoring Systems	0.241	0.256	5.012	.000
AI Technologies	0.198	0.207	4.146	.000

The results reveal that all independent variables significantly influence operational efficiency. Predictive maintenance emerged as the strongest predictor ($\beta = 0.339$), followed by intelligent baggage tracking ($\beta = 0.281$), automated monitoring systems ($\beta = 0.256$), and overall Artificial Intelligence technologies ($\beta = 0.207$).

These findings indicate that predictive maintenance contributes most significantly to improving baggage handling system performance.

4.16. Hypothesis Testing

The hypotheses were tested based on the results of the regression analysis.

Table 18: Hypothesis Testing Results

Hypothesis	Statement	Result
H1	Artificial Intelligence positively influences operational efficiency.	Supported
H2	Predictive maintenance positively influences operational efficiency.	Supported
H3	Intelligent baggage tracking positively influences operational efficiency.	Supported
H4	Automated monitoring systems positively influence operational efficiency.	Supported

The statistical results confirm that all proposed hypotheses were supported. The findings provide strong empirical evidence that Artificial Intelligence technologies significantly enhance the operational efficiency of baggage handling systems in Saudi Arabian international airports.

4.17. Discussion of Key Findings

The findings indicate that respondents perceive Artificial Intelligence technologies as highly important in improving baggage handling operations. The high mean scores obtained for all study variables demonstrate a positive attitude toward the adoption of AI-enabled systems in airport operations.

The strong relationship between predictive maintenance and operational efficiency suggests that proactive maintenance strategies contribute substantially to reducing

unexpected equipment failures and improving system reliability. This finding aligns with previous studies emphasizing the role of AI-driven predictive maintenance in enhancing operational continuity and reducing downtime.

Similarly, intelligent baggage tracking technologies were found to significantly improve operational efficiency by increasing tracking accuracy and reducing baggage mishandling incidents. Automated monitoring systems also demonstrated a significant contribution to operational performance through real-time monitoring and anomaly detection capabilities.

Overall, the findings indicate that Artificial Intelligence technologies represent a critical enabler of operational excellence in airport baggage handling systems and support the ongoing digital transformation initiatives within Saudi Arabia's aviation sector.

Chapter Summary

This chapter presents the results of the statistical analysis conducted using SPSS. The findings showed that all study variables achieved very high mean scores, indicating strong agreement regarding the importance of Artificial Intelligence technologies in airport baggage handling operations. Reliability analysis confirmed the consistency of the measurement scales, while correlation and regression analyses demonstrated significant positive relationships between Artificial Intelligence technologies and operational efficiency. All research hypotheses were supported, indicating that predictive maintenance, intelligent baggage tracking, and automated monitoring systems contribute significantly to enhancing the operational efficiency of baggage handling systems in Saudi Arabian international airports.

The next chapter discusses these findings in relation to the existing literature and theoretical framework and explores their practical and theoretical implications.

CHAPTER FIVE

5. DISCUSSION

Introduction

This chapter explores the results of the present study in light of the research objectives, research hypotheses and literature reviewed in Chapter Two. The discussion is intended to give the statistical results an in-depth interpretation, by comparing the current results with previous empirical studies on the use of Artificial Intelligence (AI) in airport operations and baggage handling systems. The chapter also provides information about the similarities and differences between the current results and the previous studies with reference to the operational context of the international airports in Saudi Arabia.

This study focused on the use of Artificial Intelligence (AI) technologies to increase the operational efficiency of the Baggage Handling System (BHS) in international airports in Saudi Arabia. Four main areas of Artificial Intelligence were investigated and their effects on operational efficiency analysed, these being: Artificial Intelligence technologies, predictive maintenance, intelligent baggage tracking and automated monitoring systems. The statistical results revealed that all of the independent variables had very high mean scores and statistically significant positive effect on operational efficiency. In addition, all the research hypotheses were confirmed, which shows that, AI technologies are a critical part in enhancing airport baggage handling operations in the Kingdom of Saudi Arabia.

This chapter is divided into different sections. The first part of the paper covers the perception of respondents about the technologies of Artificial Intelligence. This paper compares the current results with a previous study on predictive maintenance, intelligent baggage tracking, automated monitoring system and operational efficiency in the following sections. The hypothesis tested, the theory implications, the practical implications and a summary of the key findings are also discussed.

5.1. The concept of Artificial Intelligence Technologies.

The result of the present study showed that the overall mean score for the Artificial Intelligence technologies was very high ($M = 4.31$) which means employees from Saudi Arabian international airports have high levels of confidence in the contribution of Artificial Intelligence to the improvement of the baggage handling process. Respondents have confirmed that AI technologies contribute to the efficiency of operational monitoring, better decision making, coordination of operational systems and overall effectiveness of the baggage handling process. The results indicate that airport staff members have gained a fair degree of confidence in the applications of AIs and understand the critical role they play in promoting airport operational excellence.

The results are in line with Tafur (2025), who performed a systematic review of the applications of Artificial Intelligence in aviation, finding that AI has emerged as one of the main technologies that is revolutionizing the operation and management of airports, with the potential of intelligent automation, predictive analysis, machine learning, and real-time decision-making. Tafur stressed that AI technologies can optimize airports' flexibility in operations and minimize congestion and delays while boosting service quality. Likewise, Wild et al. (2025) highlighted that the adoption of Artificial Intelligence in airport environments is no longer an option, given its ability to enhance operational integration, speed up decision-making processes, and optimize passenger services through intelligent digital systems.

The results also confirm the study by Geske (2024) that the application of Artificial Intelligence can significantly improve the operational efficiency of air transport by allowing for the analysis of large amounts of operational data and quick response to operational changes in the airport. According to Geske, the implementation of Artificial Intelligence

technologies gives airports operational performance because it helps optimize the use of resources, eliminates unnecessary activities and increases the responsiveness of the system. Similarly, Brynjolfsson and McAfee (2017) noted that Artificial Intelligence augments organizational productivity by aiding in evidence-based decision making, and automation to improve operational processes. They concluded that the organizations that adopted the AI technologies are more capable of addressing the operational challenges and mitigate the inefficiencies which align with the current study.

The agreement between the present study and the previous studies can be explained by the rapid technological change in the aviation sector around the world. Digital technologies are now more crucial than ever to the effective operation of the airport, processing vast quantities of information in real time. Artificial Intelligence allows the operators of airports to access operational information on the spot, which contributes to faster response times for operational incidents and more precise management of baggage handling systems.

The findings are significant in the context of Saudi Arabia where Saudi Vision 2030 is set to make the Kingdom one of the world's foremost aviation and logistics hubs. Major international airports like King Abdulaziz International Airport, King Khalid International Airport, and King Fahd International Airport are still seeing significant increase in the number of passengers, demanding advanced technological solutions that will enable them to maintain high operational efficiency. This, in turn, highlighted the positive perception shown by the respondents with the growing implementation of Artificial Intelligence technologies across the Saudi airports, validating the fact that AI has become an essential part of the Saudi airports' digital transformation.

In general, the results show that the use of Artificial Intelligence (AI) technologies in airports is acceptable for the operational personnel, and they believe that AI is essential in the

airports for operational efficiency, which aligns with the previous empirical evidence and the strategic goals of Saudi Arabia in aviation modernization efforts.

5.2. Predictive Maintenance

The results of the current study showed that predictive maintenance had the highest overall mean score of all the dimensions of Artificial Intelligence ($M = 4.38$), reflecting the fact that respondents had strong confidence that the predictive maintenance application is one of the best applications of Artificial Intelligence for improving operations in the baggage handling sector. In addition, the multiple regression analysis showed that predictive maintenance had the highest coefficient ($\beta = 0.339$), indicating that the enhancement of predictive maintenance practices has the highest impact on operational efficiency compared with other Artificial Intelligence dimensions that were studied in this paper.

The findings presented in the present study are very well aligned with the research work of Gupta et al. (2023) on the application of Internet of Things (IoT) sensors coupled with machine learning algorithms to study predictive maintenance for bagging handling conveyors in airports. In their study, they found that predictive maintenance was an effective way to minimize unexpected equipment failures, better schedule maintenance, and enhance equipment availability. Continuous monitoring of a conveyor system also allowed maintenance workers to detect problems with the equipment before they could cause operational failures, Gupta et al. reported. The results of this study corroborate the current findings with very high levels of agreement from the respondents that predictive maintenance decreases unexpected equipment failures and increases system reliability.

Likewise, Haldar (2025) discovered that using AI-driven predictive analytics significantly improved baggage handling processes by predicting equipment failures before they affect airport operations. Haldar says predictive maintenance cut down operational disruptions, maintenance expenses and baggage processing reliability. This is very similar to

the results of the present study, with a high degree of agreement among respondents about the benefits of predictive maintenance in minimizing system downtime and improving operational continuity.

The present results are also in agreement with Lee et al. (2015) who claimed that predictive maintenance is one of the major applications of Artificial Intelligence in industrial systems. Their research showed they could continuously monitor equipment operating data using machine learning algorithms to foresee failure. Predictive maintenance allows maintenance teams to take proactive measures instead of reactive measures because it can detect abnormal operating patterns before equipment breaks down. Therefore, there are fewer downtimes and increased equipment reliability for organizations.

Similarly, Fay et al. (2022) highlighted the need to incorporate operational simulation with maintenance planning to enhance the efficiency of airport baggage handling systems in the context of predictive maintenance. Their study revealed that predictive maintenance using simulation can reduce unnecessary maintenance costs, maximize equipment use, and minimize operation interruptions. The results found in this study corroborate with the present study and indicate predictive maintenance is the most pertinent aspect impacting operational efficiency.

There were several reasons for this agreement between the present study and previous studies, related to the nature of the baggage handling systems themselves. Today's baggage handling technology is very complex and made up of many digital and mechanical parts such as conveyor belts, motors, scanners, sensors and baggage sorting machines. When one component fails unexpectedly, it could cause other components to go down and impact the airport's operations. Predictive maintenance, powered by AI, is a continuous monitoring system that analyzes real-time data from equipment to identify potential problems before they arise, enabling airport staff to proactively address them. This preventative maintenance

approach reduces downtime, increases equipment availability and maximizes the overall efficiency of an airport.

The results of these are of great practical significance for the aviation industry in Saudi Arabia. Saudi Vision 2030 will seek to dramatically increase the capacity of passengers transported with the Kingdom to become a global aviation and logistics hub. This growth demands baggage handling systems that can run around the clock with minimal interruptions. Predictive maintenance offers airport operators an effective technological solution to support high levels of operational reliability even with growing passenger traffic. Hence, this high level of support is because of the respondents' operating experience along with the increasing need for sophisticated maintenance technologies at Saudi airports.

Based on the results of the current study, it can be concluded that overall, predictive maintenance is the most influential application of Artificial Intelligence (AI) in enhancing the performance of a baggage handling system (BHS) in international airports in Saudi Arabia. The results are coherent with the previous international research and extend the knowledge of the effectiveness of predictive maintenance in the application context of Saudi airports.

5.3. Intelligent Baggage Tracking

The overall mean score for intelligent baggage tracking technologies was very high ($M = 4.26$) suggesting that participants were very satisfied of the usefulness of AI-supported baggage tracking systems for the baggage handling operations at airports. There was a positive correlation between the individual statements and the mean scores, with real-time baggage monitoring scoring the highest mean score, indicating that the airport staff believe that real-time baggage monitoring is one of the most valuable functions of intelligent baggage tracking technologies. Also, the results presented in multiple regression analysis indicated that intelligent baggage tracking was statistically significantly positively affecting the

operational efficiency ($\beta = 0.281$), which means that baggage tracking technology improvements positively affect the performance of the baggage handling directly.

The results of the current research are coherent with the results of the Baggage IT Insights Report by SITA (2023), which found that airports that have introduced Artificial Intelligence, RFID technologies and real-time Baggage Monitoring systems experienced significant decreases in the proportion of baggage mishandled and increases in the visibility of baggage along the entire airport journey. The report found that airports implementing intelligent tracking technologies had higher baggage delivery accuracy, lower baggage loss rates, and higher levels of passenger satisfaction. The results of these findings greatly support the current study, which found that 89% of respondents were confident that Artificial Intelligence bolsters baggage identification, routing accuracy and operational efficiency.

Likewise, Nounou (2025) conducted a study on machine learning applications in baggage handling systems and found that AI can greatly improve the accuracy of baggage identification and routing by continuously analyzing operational data. According to the researcher, AI-powered tracking systems can reduce routing mistakes and enhance coordination between different airport departments. These findings align well with the results of the present research, especially the respondents' responses that intelligent baggage tracking helps to increase the accuracy of baggage routing and decreases baggage loss.

The current results also align with those presented by Vidhate et al. (2025), who also constructed a computer vision-based framework for proactively detecting anomalies in a baggage handling system. Their study has shown that Artificial Intelligence can monitor the movement of bags continuously and detect the mis-location of bags, congestion of conveyors and operational anomalies in real-time. When such capabilities are available, airport operators can act quickly, before operational issues impact upon airport performance. The results of this

study are corroborated by the findings of these studies, as they all point out the need to use real-time Baggage Monitoring for operational efficiency.

Similarly, International Airport Review (2025) noted that in the current airport environment, intelligent baggage tracking technology is essential to the airport system because as the number of passengers grows, continuous baggage visibility in the airport system is required. The report found that the air hubs that use Artificial Intelligence-powered baggage tracking technology have higher operational reliability and customer confidence in airport services.

The results are also in agreement with Hassan et al. (2019) who concluded that using deep learning and computer vision techniques significantly raises the baggage identification accuracy in the context of airport screening and baggage handling. They showed that the use of Artificial Intelligence cuts down on manual work, improves the accuracy of operations, and decreases baggage handling mistakes, all of which contribute to a more efficient operation.

The results from the present study are in good agreement with those from the literature, which may be attributed to the properties of baggage handling systems. Thousands of bags are moved through airports on a daily basis and the identification and routing of these bags need to be highly accurate. While effective, conventional barcode systems are susceptible to damage of the label, misread codes by scanners, and routing mistakes. Machine learning algorithms, computer vision systems, and predictive analytics are some of the technologies that AI brings to bear on the airport's operations, helping to overcome these challenges by continuously tracking the movement of bags and responding swiftly to any disruptions.

The results are of great importance within the Kingdom of Saudi Arabia and will have a significant impact since the airport passenger traffic is still growing rapidly as it aligns with

Saudi Vision 2030. International airports like King Abdulaziz International Airport, King Khalid International Airport and King Fahd International Airport are preparing to handle millions more passengers annually as they expand their operating capacity. In such cases, smart baggage management solutions are vital to keeping the service running, minimizing the risk of lost bags, and maintaining continuity, especially when operating in more complex environments.

The results of the present study are in close agreement to the previous studies conducted in other countries internationally, but it introduces empirical evidence from the Saudi Arabian International Airports as limited research has been conducted in the operational effects of Artificial Intelligence in the Baggage Handling Systems. Therefore, the present study addresses an important research gap mentioned in Chapter Two and validates that one of the most important operational efficiency drivers for Saudi airports is intelligent baggage tracking.

The results confirm the positiveness of the impact of implementing intelligent baggage tracking technology on the performance of baggage handling systems in general: with the help of intelligent baggage tracking technology, the visibility of baggage is enhanced, the accuracy of the baggage tracking is raised, the mishandling of the baggage is decreased, the coordination of the operation is strengthened, and the decision making time is shortened. The research results reinforce the importance of intelligent baggage tracking as a strategic investment for airport operators aiming to enhance their operational efficiency and passenger experience in the fast-growing aviation industry in Saudi Arabia.

5.4. Automated Monitoring Systems

The results of the present study showed that the automated monitoring system had an overall mean score of $M = 4.29$, which is regarded as a very high score, showing that the respondents strongly agreed that the monitoring systems based on Artificial Intelligence were

effective in improving the baggage handling operations. The highest mean score was given to the individual statement, "Automated monitoring systems improve system reliability" with $M = 4.34$, meaning airport employees believe that one of the most important elements that contributes to a reliable baggage handling operation is continuous operational monitoring. Moreover, the regression analysis results showed that automated monitoring system had a statistically significant positive coefficient ($\beta = 0.256$) for operational efficiency, indicating that AI-based monitoring technologies contribute to improving operational efficiency at airports.

The present results are similar to the study done by Oukacha et al. (2025) who designed a computational real-time baggage handling monitoring system using Artificial Intelligence (AI) technologies. Through their research, they have been able to show that intelligent monitoring systems constantly monitor and analyses operational data from the baggage handling equipment and detect operational anomalies before they become serious system failures, thereby reducing the need for manual monitoring and enabling systems to react to detected anomalies. The researchers found that real-time monitoring plays a crucial role in enhancing the operational reliability and reducing the baggage handling interruptions. The comments made in this study were in keeping with the earlier findings: respondents were very positive about the use of automated monitoring systems in enhancing operational control and minimizing operational disruptions.

Likewise, Vidhate et al. (2025) demonstrated that using AI-driven computer vision systems can significantly enhance baggage handling processes by keeping a constant eye on baggage movement and automatically identifying any abnormal patterns in the process. Their study shows that intelligent monitoring technologies can identify the congestion of conveyors, accumulation of bags, the malfunction of airport equipment or routing error as soon as it happens, giving the airport operator the time needed to take corrective action before

operational performance becomes degraded. Both findings are very similar to the current results as respondents believe that automated monitoring systems quickly identify issues in the operation and the flow of baggage is better managed.

The current results also corroborate Schwarz (2021), who highlighted the need of modern airport logistics to rely more on automated monitoring technologies that can offer continuous operational visibility. Schwarz claimed that the intelligent monitoring system helps airport decision making by giving managers on-site monitoring information about the operational situation, such as the condition of equipment, the flow of baggage, and potential bottlenecks in the system. These functions can help airport management to streamline its resource utilization and reduce delays and inefficiencies in operations. The similarity between Schwarz's results and the findings presented here again demonstrate the value of the automated monitoring systems in the baggage handling operations of an airport.

Similarly, International Airport Review (2024) claimed that AI and machine learning tools have revolutionized airport operational monitoring through predictive supervision of airport facilities. The report said intelligent monitoring systems enhance operational resilience by detecting system anomalies prior to their disruption of airport operations. This means that airports with AI-driven monitoring systems have a more stable operation, lower equipment downtime, and better passenger experience. The results of this study are greatly supported by these findings.

The consistency of the current study with previous studies can be attributed to the characteristics of BHS airport operations. They are working continuously around the clock and are engaged in the simultaneous movement of thousands of pieces of baggage, having to pass through a multitude of conveyor networks, scanners, sorters and transportation equipment, all interconnected. Manual monitoring becomes more difficult and inadequate under these complex operating conditions. Artificial Intelligence can monitor all operational

parts at once and can detect abnormalities, equipment problems, congestion points and workflow interruptions in real-time. This ability significantly enhances the agility of operations and the risk of significant operational failures.

In Saudi Arabia, automated monitoring systems will play a crucial role in the near future in the aviation industry. Saudi Vision 2030 seeks to build new airports, boost the carrying capacity to over 330 million passengers per year and make the Kingdom a hub for aviation and logistics services for the world. These are lofty goals that can only be met by airport systems that can operate seamlessly as complexity grows in their operations. This allows airport authorities to effectively monitor the operations continuously by means of automated monitoring technologies, and simultaneously to enable data-driven operational decision making.

Another noteworthy finding from this current study is that on each of the automated monitoring systems statements, the respondents had a high degree of agreement. This indicates that airport workers are aware not just of the technical potential of AI but also its value in affecting their day-to-day operations. Operational staff's acceptance of the study could help to implement higher level Artificial Intelligence (AI) applications in Saudi airports in the future.

While the significance of automated monitoring systems is frequently found in the literature, most of the studies were performed in an environment of European, North American or international airports. In contrast, the current research study gives empirical evidence from Saudi Arabian international airports, which extends the existing literature and fills a gap in the literature highlighted in Chapter Two concerning the scarcity of studies that focus on Artificial Intelligence applications in Baggage Handling Systems (BHS) in the aviation sector of Saudi Arabia.

In conclusion, the present results validate the use of automated monitoring systems as one of the basic technological pillars of the operational efficiency in an airport BHS.

Artificial Intelligence-based monitoring technologies are a key component of achieving safer, faster, and more efficient baggage handling operations in Saudi Arabia's international airports through continuous monitoring, rapid detection of anomalies, and better operational control and system reliability.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATIONS

Introduction

The conclusion of the study *The Role of Artificial Intelligence in Improving the Operational Efficiency of Baggage Handling Systems in International Airports in Saudi Arabia* is presented in this chapter. It briefly outlines the key results of the statistical analysis and provides an interpretation of the results for airport management, policy makers and researchers. The chapter also emphasizes the theoretical and practical value of the study, suggestions for the improvement of the baggage handling operations by Artificial Intelligence technologies, the limitations of the study and directions of future studies.

The aim of this study was to explore how Artificial Intelligence (AI) can enhance the efficiency of baggage handling systems in Saudi Arabia's international airports. In particular, the study focused on four Artificial Intelligence dimensions: Artificial Intelligence technologies, predictive maintenance, intelligent baggage tracking and automated monitoring systems, and their influence on the operational efficiency.

In order to attain the goals of the research, a quantitative research approach was used. The data was gathered by a structured questionnaire that was sent to the employees of 3 major Saudi international airports, which includes the airport operations, baggage handling, maintenance and logistics departments. The Statistical Package for the Social Sciences (SPSS) was used to analyze a total of 250 questionnaires that were received and found to be valid. The collected data were analyzed with descriptive statistics, Cronbach's Alpha reliability analysis, Pearson correlation analysis and multiple regression analysis.

The conceptual framework suggested that the use of Artificial Intelligence technologies had a positive impact on operational efficiency through predictive maintenance, intelligent baggage tracking and automatic monitoring systems. Four research hypotheses were developed and statistically tested.

6.1. Key findings of study.

The results showed that the respondents were quite agreeable about all dimensions of Artificial Intelligence introduced into the baggage handling system. The mean scores were extremely high for technologies such as Artificial Intelligence technologies, predictive maintenance, intelligent baggage tracking, automated monitoring systems and operational efficiency, reflecting high levels of confidence amongst airport staff of the effectiveness of application of AI.

The reliability analysis showed that the Cronbach's alpha values for all measurement scales were good ($r > 0.70$). The overall questionnaire gave a reliability coefficient of 0.941, which indicates that the research instrument was very reliable.

The results of the Pearson correlation analysis indicated positive relationships between all the operating efficiency dimensions and the dimensions of AI. The most highly correlated operational efficiencies were seen as predictive maintenance, automated monitoring systems, Artificial Intelligence technologies, and intelligent baggage tracking.

Additionally, the multiple regression analysis showed that all of the independent variables were significant in affecting operational efficiency. AI technologies came in second best predictive maintenance, intelligent baggage tracking, automated monitoring systems and artificial intelligence technologies were the other indicators of operational efficiency. All the above-mentioned variables accounted for about 70.9% of the variation in the operational efficiency, which means that the development of Artificial Intelligence is a significant factor affecting the performance of baggage handling at Saudi international airports.

Finally, all the hypotheses that were proposed were supported by the hypothesis testing. Such results offer compelling empirical evidence for the effectiveness of using Artificial Intelligence in enhancing the efficiency of baggage-handling systems.

6.2. Conclusion

AI is a critical technology to enhance the baggage handling processes and workflows within Saudi Arabian international airports. The potential of Artificial Intelligence technologies to boost operational reliability, decision making, minimize operational disruptions, and maximize system performance is well understood among the employees in the airport operational environment.

Second, predictive maintenance is the most impactful Artificial Intelligence application on the efficiency of baggage handling operations. By anticipating equipment failures before they happen, Artificial Intelligence can help airport maintenance teams to minimize unexpected equipment failures, lower maintenance costs, increase equipment availability, and keep the airport running smoothly.

Thirdly, intelligent baggage tracking systems allow for greater baggage identification, routing accuracy and real-time monitoring, which significantly improve the performance of baggage handling. These technologies are directly responsible for the reduction of mishandled bags and enhance passenger satisfaction and the efficiency of airport operations.

Fourth, automated monitoring systems have an important role in reinforcing the operational control of airports. By leveraging Artificial Intelligence, continuous monitoring of the baggage handling equipment and its operational processes can also detect anomalies quickly, minimize operational interruptions, and enhance the overall reliability of the system, benefiting the airport staff.

Fifth, the synergy of the application of Artificial Intelligence technologies can greatly improve the efficiency of airport operation by establishing a unified operational system integrating predictive maintenance, intelligent monitoring, data analysis and automated decision making. The results align with the AI's potential as a strategic asset that can aid Saudi Arabia's aviation industry in achieving its digital transformation.

The study ultimately suggests that Artificial Intelligence should no longer be considered as a technological tool that can be optioned for use in airports, but rather as a strategic solution to enhance the efficiency of airport operations and support the Saudi Vision 2030's long-term goals.

6.3. Implications

6.3.1. Theoretical Implications

This research is important for its contribution to prior work in a number of important respects. On the one hand, it expands existing knowledge on the use of Artificial Intelligence in the context of an airport's baggage handling system, which has been studied less empirically than other aspects of aviation, like processing passengers or air traffic management. On the other hand, it introduces novel concepts that enhance the Airport baggage handling system by allowing for more dynamic and efficient operations. Secondly, it validates empirically the conceptual link between Artificial Intelligence technologies and operational efficiency in the context of international airports in Saudi Arabia.

Third, the study shows that predictive maintenance, intelligent baggage tracking, and automated monitoring systems are three distinct but complementary aspects of the use of Artificial Intelligence to improve airport operational performance. Lastly, the study joins the ever-expanding research concerning digital transformation in airport management and offers empirical findings from an emerging aviation market.

6.3.2. Practical Implications

The applications of the findings of this study are important for airport authorities, airport operators, aviation policy makers and technology providers. Airport management should keep on growing the use of Artificial Intelligence in all the baggage handling systems to make the process more efficient.

Predictive maintenance solutions that can predict equipment failures before disruption can occur should be considered a top priority for the maintenance department at the airport. Airport authorities need to invest more in the intelligent baggage tracking technologies that incorporate AI, RFID technologies, computer vision, and machine learning to enhance the visibility of baggage and lessen baggage mishandling.

Airport companies should increase the use of automated monitoring systems that can continuously monitor the operation of the baggage equipment and alert the operators to any anomalies in the operation.

Operational employees should be given training to enhance their Artificial Intelligence knowledge and ensure maximum utilization of the intelligent airport technologies.

The government should keep promoting Digital transformation in the airport sector in line with Saudi Vision 2030 through investments in the infrastructure of Artificial Intelligence (AI) and integrated airport technologies.

6.4. Recommendations

Airport management should also increase the use of Artificial Intelligence (AI) technologies in all areas of airport baggage handling to increase efficiency and service quality.

Comprehensive predictive maintenance systems integrating Artificial Intelligence and IoT sensors should be considered by airport operators in order to minimize unexpected equipment failures and better plan maintenance operations.

To minimize the loss of bags and enhance the accuracy of the baggage identification, intelligent baggage tracking technologies combining RFID, machine learning, and computer vision should be deployed in the entire baggage handling system at the airport.

Airports should be equipped with integrated Artificial Intelligence monitoring centers capable of constantly monitoring the dynamics of the baggage handling operations and make real-time operational decisions.

It is necessary to set up continuous training courses for airport staff to improve their technical skills in the application of Artificial Intelligence and digitalization of airports. Airport management should make it easier to foster cooperation with Artificial Intelligence (AI) technology vendors and research centers to boost innovation in airport operational systems.

The aviation sector needs to have national policies that promote the safe and secure use of AI technologies in Saudi airports.

Recommendations for future studies

The current research could be continued in future studies by incorporating other Artificial Intelligence technologies that impact airport operations.

A longitudinal study should be performed to assess the impact of the use of Artificial Intelligence in the long term in the operation of the baggage handling system.

The study can be replicated at other airports in the Gulf Cooperation Council (GCC) region to compare the implementation of Artificial Intelligence in other international airports.

A possible mediating relationship between organizational readiness and employee digital competence to innovation capability and technology acceptance could be explored. The betweenness of employee digital competence, organizational readiness and innovation capability, and technology acceptance could be examined.

Qualitative research methods could be combined with quantitative to gain deeper understanding of operational challenges related to the implementation of Artificial Intelligence in future studies.

The economic impact and payback of the use of Artificial Intelligence in airport baggage handling systems can also be analysed.

6.5. Limitations.

The study used a cross-sectional research design and thus causal relationships over time were not explored.

The study was conducted only in three main airports of Saudi Arabia; thus the results of the study are limited to the smaller regional airports or airports in other countries.

The study was self-reported questionnaire-based and thus could be impacted by the perception of the respondents.

While there were four dimensions of AI looked at, there are other technological enablers that could affect the performance of baggage handling, such as robotics, digital twin, autonomous vehicles, blockchain technologies, cybersecurity and cloud computing.

Chapter Summary

The study closed by summarizing the research, giving the main findings, discussing the theoretical and practical implications, making recommendations for airport management and policy makers, pointing to the limitations of the study, and outlining directions for future research. Results showed that Artificial Intelligence technologies substantially enhance the efficiency of international airports' Baggage Handling Systems in Saudi Arabia.

The most impactful Artificial Intelligence applications that helped in achieving operational excellence were predictive maintenance, intelligent baggage tracking, and automated monitoring systems. Together, these results underline the vital role of AI in streamlining the Kingdom's aviation sector, fostering safer, more reliable, and more efficient airport operations, and advancing Saudi Arabia's Vision 2030 and ongoing digital transformation.

7. References

Alketbi, M. A., Dweiri, F., & Dalalah, D. (2025). The role of artificial intelligence in aviation construction projects in the United Arab Emirates: Insights from construction professionals. *Applied Sciences*, 15(1), 110.

<https://doi.org/10.3390/app15010110>

Geske, A. M. (2024). Artificial intelligence as a driver of efficiency in air transport operations. *Journal of Air Transport and Regional Studies*.

<https://doi.org/10.1016/j.jatrs.2024.100030>

Tafur, C. L. (2025). Applications of artificial intelligence in air operations: A systematic review. *Results in Engineering*.

<https://doi.org/10.1016/j.rineng.2024.103742>

Oukacha, O., et al. (2025). Computational ergo-design for a real-time baggage handling monitoring system. *Sustainability*, 17(9).

<https://doi.org/10.3390/su17093794>

Halдар, P. (2025). Airline baggage handling using predictive analytics and machine learning models. *Journal of Computer Science and Technology Studies*.

<https://al-kindipublisher.com/index.php/jcsts/article/view/11709>

Vidhate, K., et al. (2025). Computer vision framework for proactive anomaly detection in baggage handling systems. *Scientific Reports*.

<https://pmc.ncbi.nlm.nih.gov/articles/PMC12575755/>

Nounou, R. S. A. (2025). Machine learning applications in baggage handling efficiency. *Transportation Research*.

<https://www.sciencedirect.com/science/article/pii/S2941198X25000338>

Gupta, S., Mitra, A., Koenig, S., Kumar, R., & Tiwari, P. (2023). Predictive maintenance of baggage handling conveyors using IoT sensors.

https://www.researchgate.net/publication/367395480_Predictive_maintenance_of_baggage_handling_conveyors_using_IoT

Fay, B., et al. (2022). Using process simulation platforms for reviewing baggage handling processes. *Procedia CIRP*.

<https://doi.org/10.1016/j.procir.2022.09.069>

Thums, J., et al. (2023). Future air transportation and digital work at airports. *Transportation Research Interdisciplinary Perspectives*.

<https://doi.org/10.1016/j.trip.2023.100808>

Ryczyński, J., et al. (2024). Air cargo handling system assessment model using fuzzy logic and reliability theory. *Sustainability*.

<https://doi.org/10.3390/su162310469>

Wild, G., et al. (2025). Artificial intelligence and immersive technologies in aviation: Current applications and future trends.

<https://pmc.ncbi.nlm.nih.gov/articles/PMC12408884/>

Satyanarayana, N. (2025). *How artificial intelligence will transform airports and customer experience*. Airports Council International.

<https://www.aci->

[asiapac.aero/f/library/8949/How%20Artificial%20Intelligence%20Will%20Transform%20Airports%20and%20Customer%20Experience%20-%20Naga%20Satyanarayana%20-%20BLR.pdf](https://www.aci-asiapac.aero/f/library/8949/How%20Artificial%20Intelligence%20Will%20Transform%20Airports%20and%20Customer%20Experience%20-%20Naga%20Satyanarayana%20-%20BLR.pdf)

International Airport Review. (2025). Baggage trends shaping the aviation industry.

<https://www.internationalairportreview.com/article/224182/baggage-trends-shaping-the-aviation-industry/>

International Airport Review. (2024). The power of AI and machine learning for airport operations.

<https://www.internationalairportreview.com/article/222537/the-power-of-ai-and-machine-learning-for-airport-operations/>

Straits Research. (2024). Airport automation and operational efficiency improvements.

<https://straitsresearch.com/article/airport-automation-is-improving-security-and-passenger-flow>

8. Appendix A

8.1. Questionnaire

Demographic Information

1. Gender

Male

Female

2. Age

Less than 30

30–40

41–50

More than 50

3. Educational Level

Diploma

Bachelor's Degree

Master's Degree

PhD

4. Job Position

Airport Operations Staff

Baggage Handling Technician

Maintenance Engineer

Airport Operations Manager

Other

5. Years of Experience

Less than 5 years

5–10 years

11–15 years

More than 15 years

6. Airport

King Abdulaziz International Airport (Jeddah)

King Khalid International Airport (Riyadh)

King Fahd International Airport (Dammam)

Variables and Measurement

Variable	Type	Number of Items
Artificial Intelligence Technologies	Independent Variable	5
Predictive Maintenance	Independent Variable	5
Intelligent Baggage Tracking	Independent Variable	5
Automated Monitoring Systems	Independent Variable	5
Operational Efficiency	Dependent Variable	5

Likert Scale

1 = Strongly Disagree

2 = Disagree

3 = Neutral

4 = Agree

5 = Strongly Agree

Artificial Intelligence Technologies

No	Statement	1	2	3	4	5
1	Artificial intelligence technologies are used in airport baggage handling systems.					
2	AI technologies improve operational monitoring in baggage handling systems.					
3	AI systems help detect operational problems quickly.					
4	AI technologies improve decision-making in airport operations.					
5	AI technologies improve coordination between airport operational systems.					

Predictive Maintenance

No	Statement	1	2	3	4	5
6	Predictive maintenance systems help detect equipment failures early.					
7	AI-based maintenance systems improve baggage handling equipment reliability.					
8	Predictive maintenance reduces unexpected equipment breakdowns.					
9	Predictive maintenance improves maintenance planning efficiency.					
10	AI maintenance systems reduce system downtime.					

Intelligent Baggage Tracking

No	Statement	1	2	3	4	5
11	Advanced technologies improve baggage tracking accuracy.					
12	AI technologies improve baggage identification processes.					

13	Smart baggage tracking systems reduce baggage loss.					
14	Real-time baggage monitoring improves airport operational efficiency.					
15	AI technologies improve baggage routing accuracy.					

Automated Monitoring Systems

No	Statement	1	2	3	4	5
16	Automated monitoring systems detect operational problems quickly.					
17	AI monitoring systems improve baggage flow management.					
18	Automated monitoring systems improve system reliability.					
19	Monitoring systems help reduce baggage handling disruptions.					
20	AI monitoring systems improve operational control.					

Operational Efficiency of Baggage Handling Systems

No	Statement	1	2	3	4	5
21	AI technologies improve baggage processing speed.					
22	AI technologies improve system reliability.					
23	AI technologies reduce baggage handling errors.					
24	AI technologies reduce operational delays.					
25	AI technologies improve overall airport operational efficiency.					