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Enterprise Architecture for Enterprise Innovation

Autonomous Check-In Luggage System

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1 Introduction

The aviation industry is undergoing a profound transformation, driven by rapid technological innovation and increasing passenger expectations of seamless travel experiences. To meet these evolving demands, our airline is launching an Autonomous Luggage Check-In System aimed at transforming the check-in process and greatly improving airport operational efficiency. This system leverages advanced technologies like Radio Frequency Identification (RFID) tracking and self-service kiosks to automate the entire check-in process, reducing the need for human intervention. By optimizing workflows, minimizing wait times, and improving the overall passenger experience, this innovation sets a new benchmark for efficiency and convenience in the aviation sector. We believe that this system represents a pivotal step forward and invite other industry players to explore how it can redefine luggage handling and operational excellence across the board.

1.1 Case Description

The Autonomous Luggage Check-In System is designed to transform the traditional luggage check-in experience through the integration of self-service kiosks, RFID technology, and centralized data management. By automating the check-in process, the system minimizes the need for human intervention, thereby streamlining operations and enhancing passenger convenience.

Upon arrival at the airport, passengers are greeted by user-friendly self-service kiosks that allow them to check-in their luggage with ease. The kiosks allow real-time verification of flight details and passenger identity, either by manual entry or by scanning boarding passes. This immediate verification process reduces delays and empowers passengers to take control of their check-in experience.

The system includes advanced weighing mechanisms that accurately assess the weight of the luggage while notifying passengers of any excess luggage fees. Once the luggage is validated, the kiosks print securely embedded luggage tags, which are affixed to the luggage. These tags contain vital flight information and are automatically scanned as the bags enter the sophisticated airport luggage handling system.

This seamless process not only minimizes the risk of human error but also enhances security through better tracking capabilities. Passengers can enjoy real-time visibility of their luggage status throughout their journey, fostering a greater sense of confidence in the operational integrity of the airline.

1.2 Case Processes

The Autonomous Luggage Check-In System implements a range of efficient, automated processes that greatly enhance the airport experience for both passengers and airline staff. This system streamlines operations by automating key steps in the check-in process, resulting in faster service, reduced wait times, and smoother workflows, ultimately improving overall efficiency and customer satisfaction.

Passenger Check-In Initiation

The process begins when a passenger approaches the self-service kiosk, greeted by an intuitive interface. Passengers can either manually enter their flight details or scan their boarding pass for instant validation. This quick verification helps reduce congestion during peak hours, allowing passengers to check-in swiftly and without hassle.

Luggage Weighing and Fee Calculation

After flight verification, passengers are instructed to place their luggage on the integrated weighing scale. The system automatically checks the weight against the airline's luggage allowance. If the luggage exceeds the permitted weight, passengers are immediately notified of any excess luggage fees. This upfront transparency allows passengers to make informed decisions, helping to streamline the check-in process and reduce surprises during boarding.

Luggage Tagging

Once the luggage is weighed and any fees settled, the kiosk prints a uniquely encoded luggage tag. Passengers are guided through a simple step-by-step process to securely attach the tag to their luggage. This step is essential for ensuring accurate tracking and identification as the bags move through the airport's system, reducing the chance of errors or misplaced luggage.

Automated Luggage Routing

After tagging, the system scans the luggage and seamlessly integrates it into the airport's automated transport network. Using advanced RFID and barcode scanning technologies, the luggage is directed to the correct luggage handling area according to its flight details. This automation ensures efficient and accurate routing, minimizing delays and greatly reducing the risk of lost luggage.

Real-Time Luggage Tracking

The system offers real-time tracking capabilities, allowing passengers and airline personnel to monitor the status of the luggage throughout its journey. This feature provides transparency and peace of mind, enabling passengers to stay informed about their luggage's location. The enhanced visibility improves customer confidence in airline operations, contributing to a smoother and more reassuring travel experience.

1.3 Purpose

The primary purpose of this report is to provide an in-depth analysis of the Autonomous Luggage Check-In System from the perspective of a Norwegian airline. By utilizing enterprise modeling frameworks such as 4EM and ArchiMate, the report seeks to elucidate the system's objectives, processes, and technological components in detail.

The report aims to demonstrate how the implementation of this system can yield significant benefits, including reduced waiting times, enhanced operational efficiency, and increased passenger satisfaction. By adopting these frameworks, we will explore how the system aligns with the airline's strategic goals, fostering a culture of innovation and efficiency in the face of evolving industry demands.

Moreover, this report will advocate for the broader adoption of the Autonomous Luggage Check-In System across airports, showcasing its potential to modernize and enhance airport operations in a fast-paced aviation landscape. By highlighting both the practical implications and strategic advantages of the system, this analysis serves as a compelling case for investing in automation technologies that prioritize passenger experience while ensuring operational excellence.

2 Enterprise Modeling

2.1 Design of the Model

The design and analysis of the Autonomous Luggage Check-In System rely on two established frameworks: 4EM (For Enterprise Modeling) and ArchiMate. These frameworks provide complementary perspectives that enable a thorough understanding of the system's goals, processes, and technological components while ensuring alignment with the broader operational objectives of the airport and airline. By using 4EM for detailed goal modeling and process analysis, and ArchiMate for architectural visualization, the model presents a holistic representation of the system's integration within the airport's infrastructure. This dual-framework approach ensures that every aspect of the system is geared toward operational efficiency and passenger satisfaction.

2.2 4EM

2.2.1 Goal Sub-Model

The goal sub-model identifies the primary objectives of the system, which include automating the luggage check-in process, reducing passenger wait times, and improving operational security and accuracy. To achieve this, the following sub-goals have been defined:

- **Automate Check-In Processes**
  Replace manual luggage check-in with automated systems to reduce human error and operational costs.
- **Enhance Passenger Experience**
  Minimize wait times and offer real-time tracking for greater convenience and confidence.
- **Ensure Security and Accuracy**
  Use RFID technology to improve tracking and prevent misplaced luggage.
- **Support Operational Scalability**
  Design the system to handle increased passenger volumes during peak travel times.

These sub-goals provide a clear roadmap for evaluating the system's success. The fulfillment of the purpose will be measured through key performance indicators (KPIs) such as reduced average check-in times, improved passenger satisfaction scores, and lower incidence of lost or misplaced luggage.

Challenges and Opportunities
The system faces challenges such as ensuring uptime during peak hours, managing cybersecurity risks, and addressing spatial constraints for installing kiosks and conveyor systems. However, it also offers significant opportunities for innovation, such as integrating mobile applications to enhance passenger engagement and providing on-site assistance for passengers less comfortable with technology. These aspects will be crucial in realizing the full potential of the system.

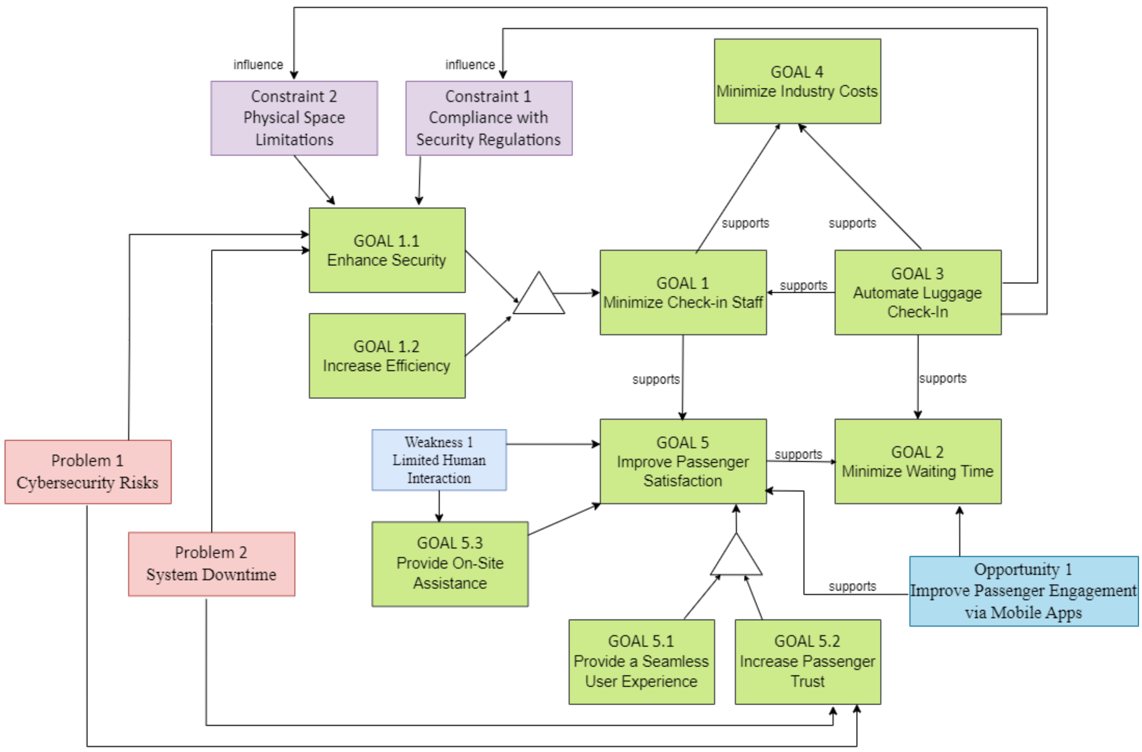

Figure 1: 4EM - Sub-Model Goal

2.2.2 Business Process Sub-Model

The check-in process begins when a passenger approaches the kiosk and selects the check-in option. The kiosk prompts the passenger to input their flight details or scan their boarding pass. Upon verification of the flight information, the kiosk guides the passenger through the luggage check-in process. This involves weighing each piece of luggage, comparing the weight to the allowed limit, and printing luggage tags. Finally, the luggage is scanned and transferred to the conveyor belt for automatic routing to the correct flight.

Passenger Interaction and Information Verification
Initially, the passenger approaches the kiosk and initiates the check-in procedure. The kiosk requests the passenger's flight details, which are verified against an external system. If verification fails, the kiosk displays an error message, prompting the passenger to retry or seek assistance.

Luggage Check-in and Tagging
Once the passenger's flight information is confirmed, the kiosk guides them through the luggage check-in process. The passenger places their luggage on the weighing scale and the kiosk compares the weight to the allowed limit. If the luggage exceeds this limit, the passenger is notified and given the option to pay for excess luggage. The kiosk then prints luggage tags and instructs the passenger to attach them to their luggage.

Luggage Handling and Routing
After tagging, the luggage is scanned and transferred to the conveyor belt. The conveyor system automatically directs the luggage to the appropriate flight's luggage handling area. Any discrepancies or issues are flagged for manual inspection by a luggage handler or security personnel.

External Processes
The diagram also highlights the involvement of external systems in the process. An external system is utilized to verify the passenger's flight information, while the luggage conveyor system routes the luggage to the appropriate flight based on the tagging information.

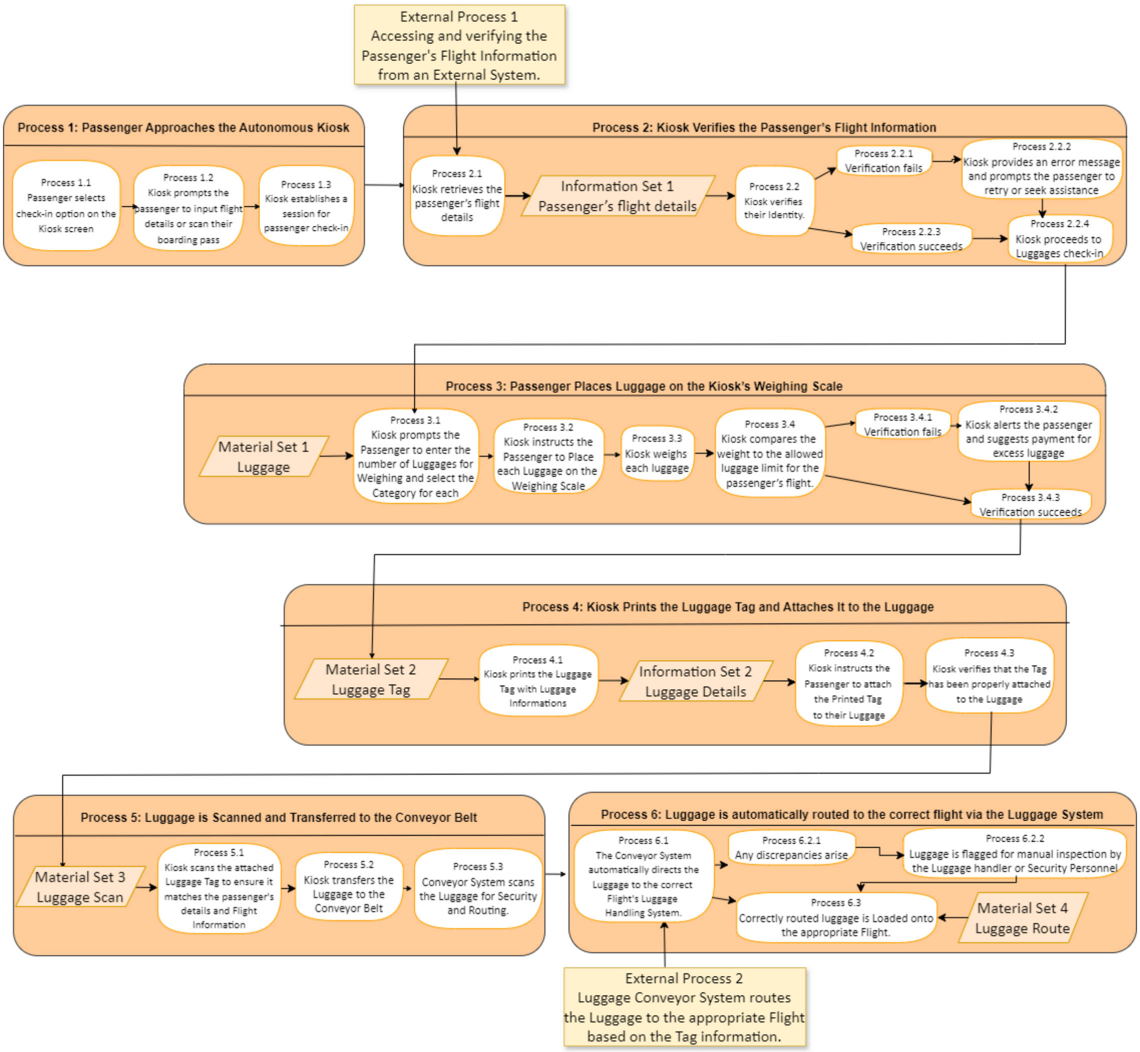

Figure 2: 4EM - Sub-Model Process

2.2.3 Technological Components Sub-Model

This section illustrates an autonomous check-in and luggage handling system designed to streamline airport operations. It comprises four main technical components, each contributing to overall system efficiency.

Autonomous Kiosk System
Serves as the primary user interface, allowing passengers to interact through a touchscreen interface, QR/barcode scanners, and integration with airline databases. This enables real-time retrieval of flight and passenger information and real-time data processing after completing the procedure that notifies the passenger.

Weighing Mechanism
Automates luggage weighing and integrates with payment systems to handle excess luggage fees seamlessly. This component ensures accurate luggage weight recording, allowing passengers to pay for excess fees directly through the system and minimizing the need for manual interventions.

Luggage Handling System
Manages luggage once checked in, featuring a tag printer for labeling, a conveyor belt system for transporting bags, and RFID/barcode scanners to ensure error-free tracking and routing. This system reduces manual handling and improves luggage routing accuracy.

These components are designed to meet key requirements such as real-time information management, automated weighing and payment processing, error-free luggage routing, and high system availability during peak hours. The integration of these systems ensures a seamless, automated experience for both passengers and airport staff, minimizing errors and improving efficiency throughout the check-in and luggage handling process.

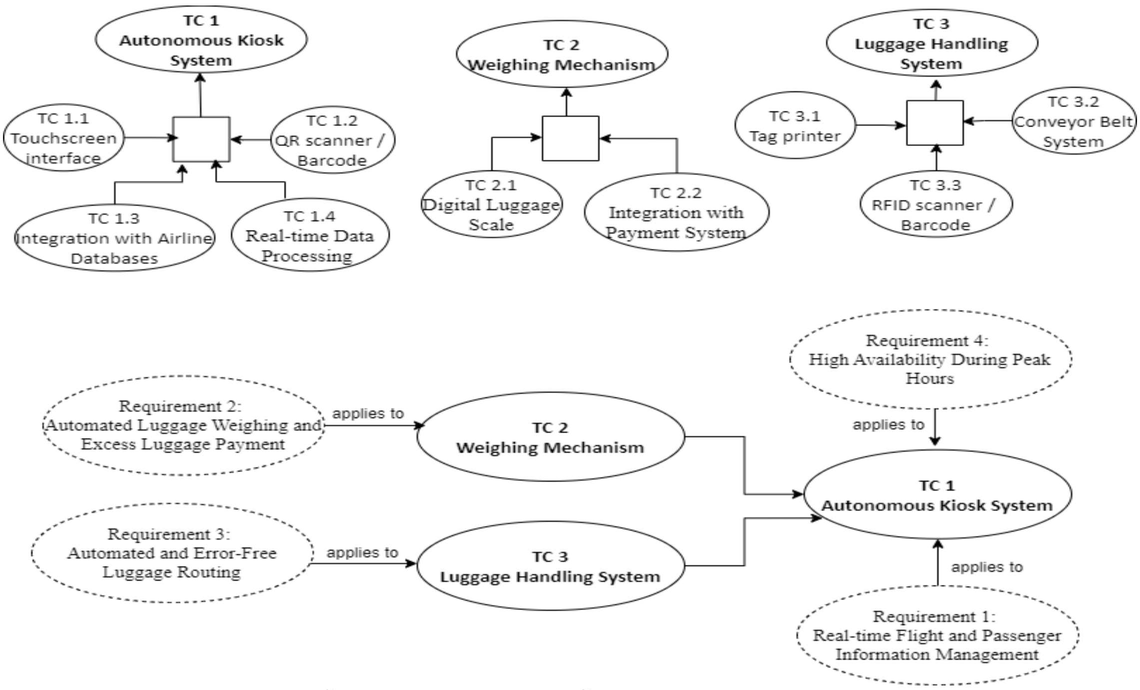

Figure 3: 4EM - Sub-Model Technical Components and Requirements Model

2.2.4 4EM - Enterprise Model

This enterprise model outlines goals, processes, and technical components for an autonomous check-in and luggage handling system. Key objectives include enhanced security, reduced staff involvement, improved efficiency, and shorter wait times. It links these goals to processes like kiosk-based passenger check-ins, luggage weighing, and automatic routing, ensuring regulatory compliance and addressing downtime and cybersecurity risks. Mobile app integration is also explored to boost passenger engagement.

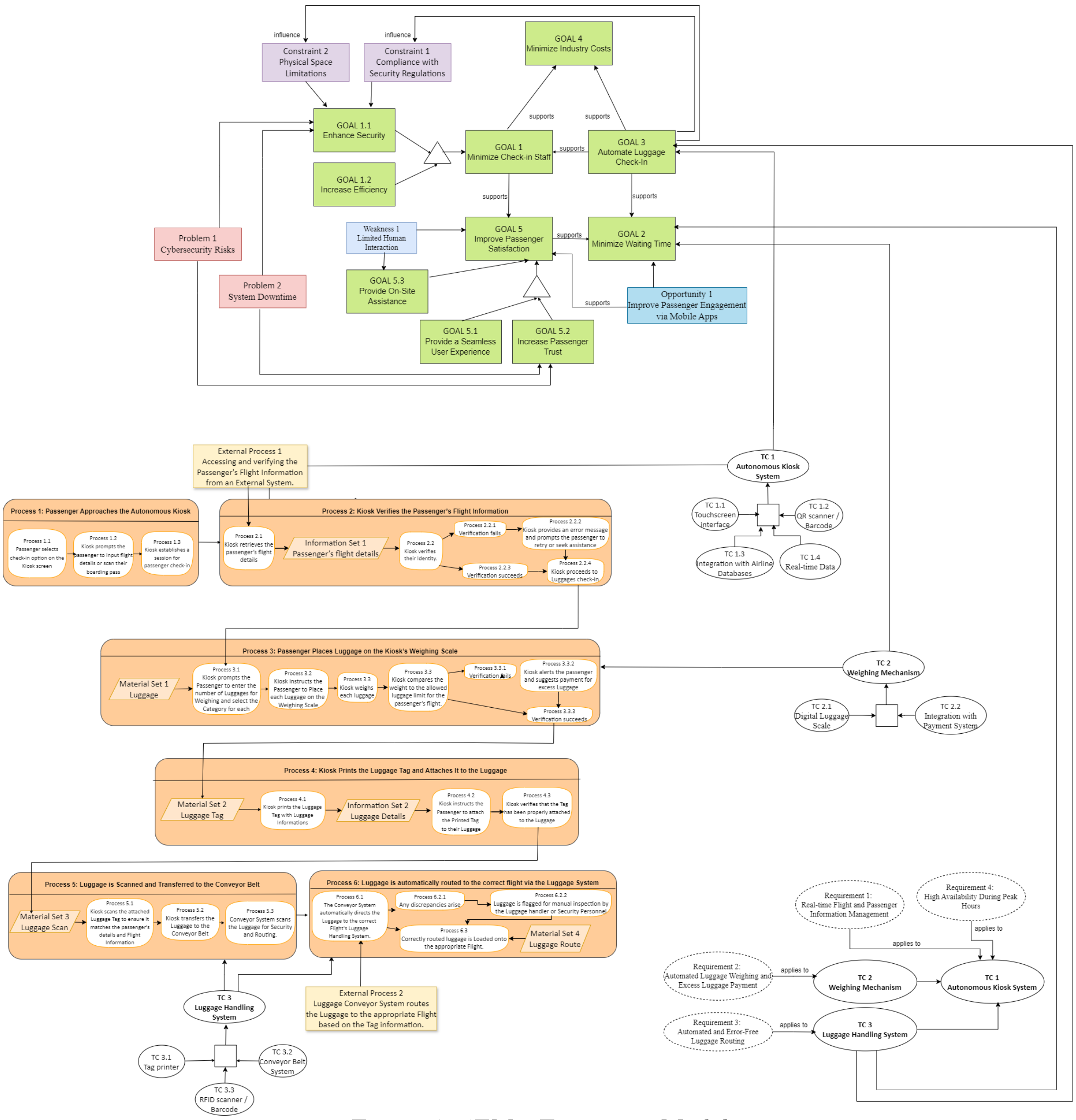

Figure 4: 4EM - Enterprise Model

2.3 ArchiMate

ArchiMate provides a standardized language for describing the structure and functioning of business processes, organizational setups, information flows, IT systems, and technical infrastructures, organized into distinct layers. One of the core principles of ArchiMate is that model structures across these layers are designed to be similar (Lankhorst 2017, p.77). This allows for easy alignment between models from different layers. Like the 4EM framework, the key perspectives in this approach include the motivation view, business process view, and organizational view, which can later be integrated to form a comprehensive enterprise view.

2.3.1 Motivation Layer

The motivation layer emphasizes the driving forces behind the system's development and deployment. The primary motivation lies in automating luggage check-in to enhance operational efficiency, minimize staffing requirements, and reduce passenger waiting times. These goals align with the broader objectives of improving passenger satisfaction and reducing operational costs, both of which are essential in today's competitive aviation industry.

The layer also incorporates strategies to address challenges like physical space constraints and stringent security regulations. Additionally, it underscores the importance of engaging passengers through mobile applications. This innovation fosters real-time interaction, allowing passengers to track their luggage, receive updates, and reduce their perceived waiting time, contributing to an enhanced overall travel experience.

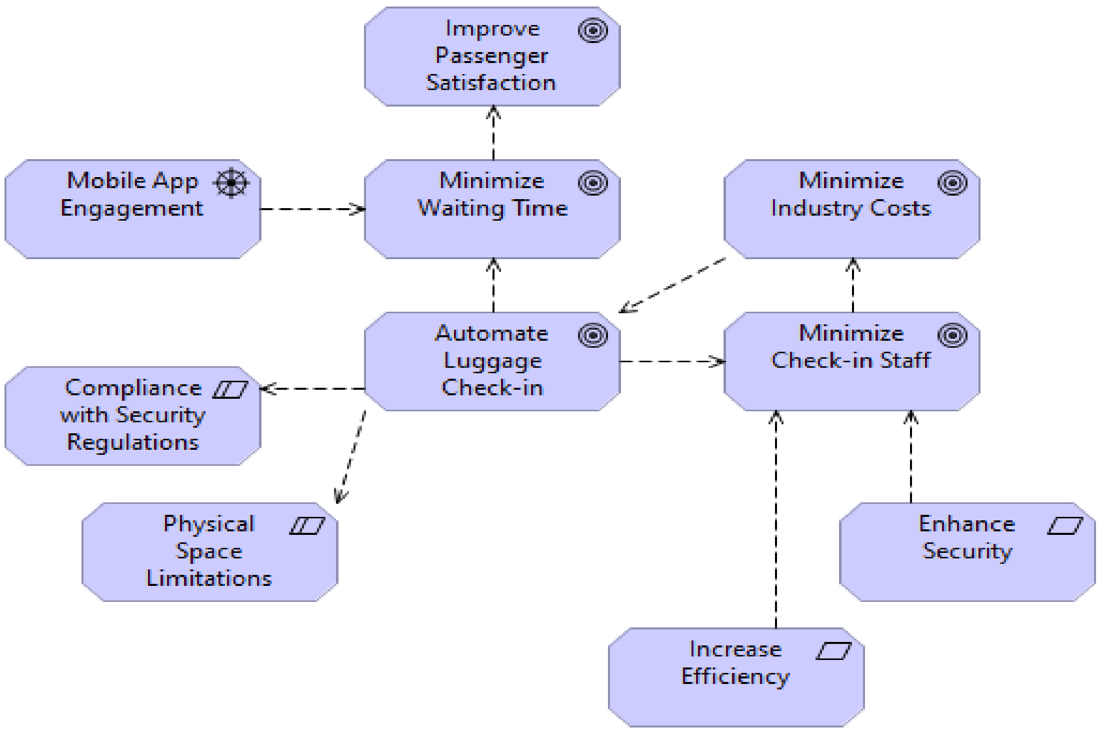

Figure 5: ArchiMate - Sub-Model Motivation Layer

2.3.2 Business Process Layer

The business process layer for the luggage check-in process demonstrates how automation enhances traditional workflows, streamlining efficiency and accuracy.

The process begins with passengers using self-service kiosks to verify their flight details. Passengers can either scan their boarding passes or manually input their flight information. Once the details are validated, the kiosk instructs passengers to place their luggage on an integrated weighing scale. The system calculates the luggage weight and compares it with the airline's allowance, immediately notifying passengers of any excess fees and facilitating payment directly through the kiosk.

After weight verification, the system generates luggage tags equipped with RFID or barcode technology. Passengers attach these tags to their luggage, which is then scanned and directed to the airport's conveyor system. The automated system ensures accurate routing of the luggage to the appropriate flight handling area. If any irregularities are detected, the system flags the luggage for manual inspection by security personnel.

This process showcases the transformative role of automation in reducing manual intervention, minimizing errors, and optimizing the overall check-in experience for passengers and airport staff alike.

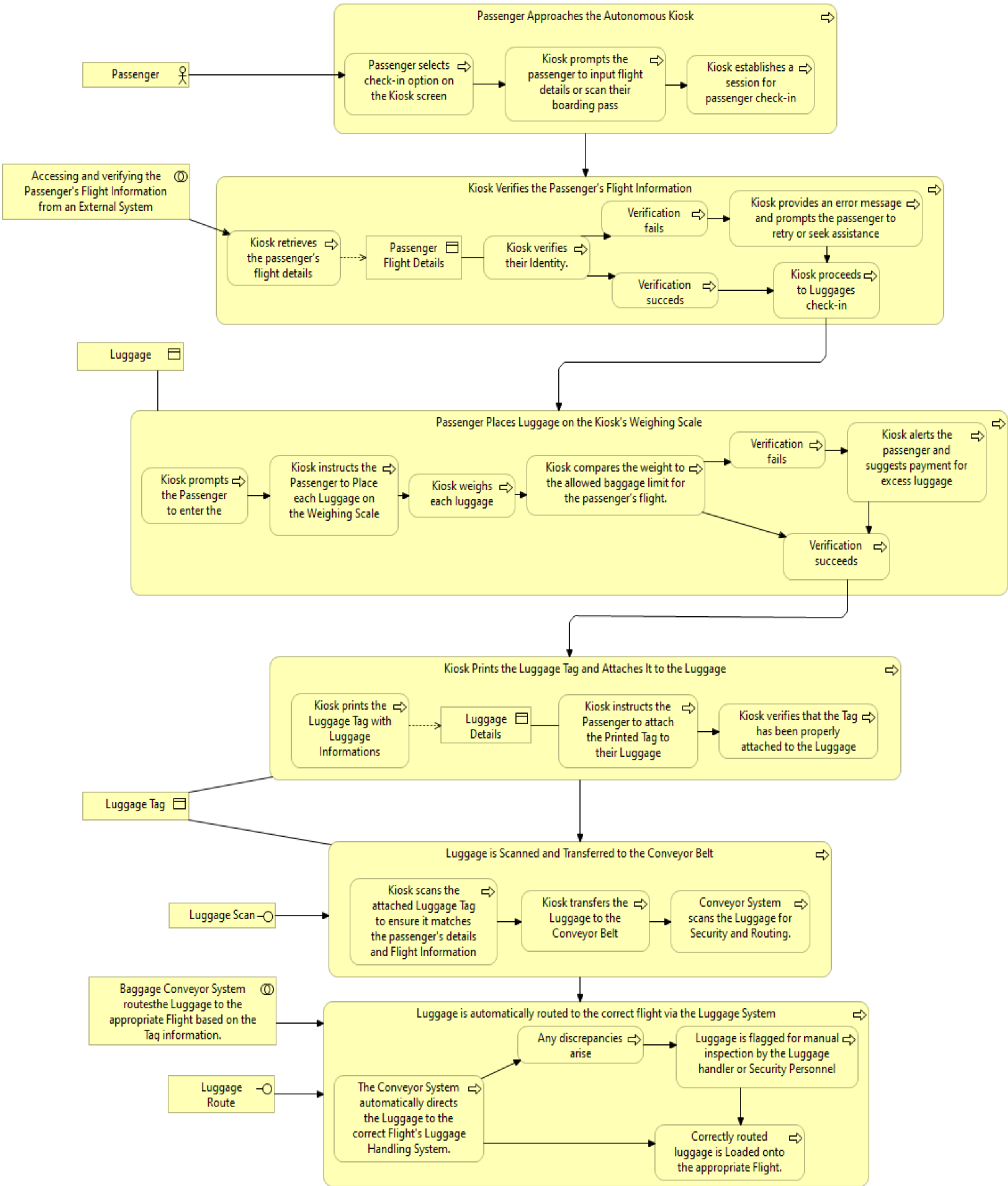

Figure 6: ArchiMate - Sub-Model Business Process Layer

2.3.3 Technology Layer

The technology layer illustrates the architectural foundation of the Autonomous Luggage Check-In System. It details the interconnected components that enable seamless luggage processing, ensuring real-time communication and efficient operations.

At the heart of the system is the Autonomous Kiosk System, which serves as the interface between passengers and the luggage handling infrastructure. The kiosk retrieves passenger and flight data by connecting to airline databases and verification services. It interacts with the Weighing Mechanism, which automates luggage weight assessment, and the RFID/QR Code Scanner, which scans and tracks luggage tags.

Once the luggage is tagged, the Luggage Tagging Service ensures that each tag is encoded with accurate routing data. The tagged luggage is then routed through the Luggage Handling System, which uses advanced conveyor belts and scanning technologies to direct luggage to the correct flight. This process is governed by the Luggage Route Service, which coordinates the movement of luggage in real-time.

The system's decentralized architecture ensures robust and efficient operations, minimizing reliance on a central server. This approach not only enhances scalability and fault tolerance but also supports data-driven decision-making across all components.

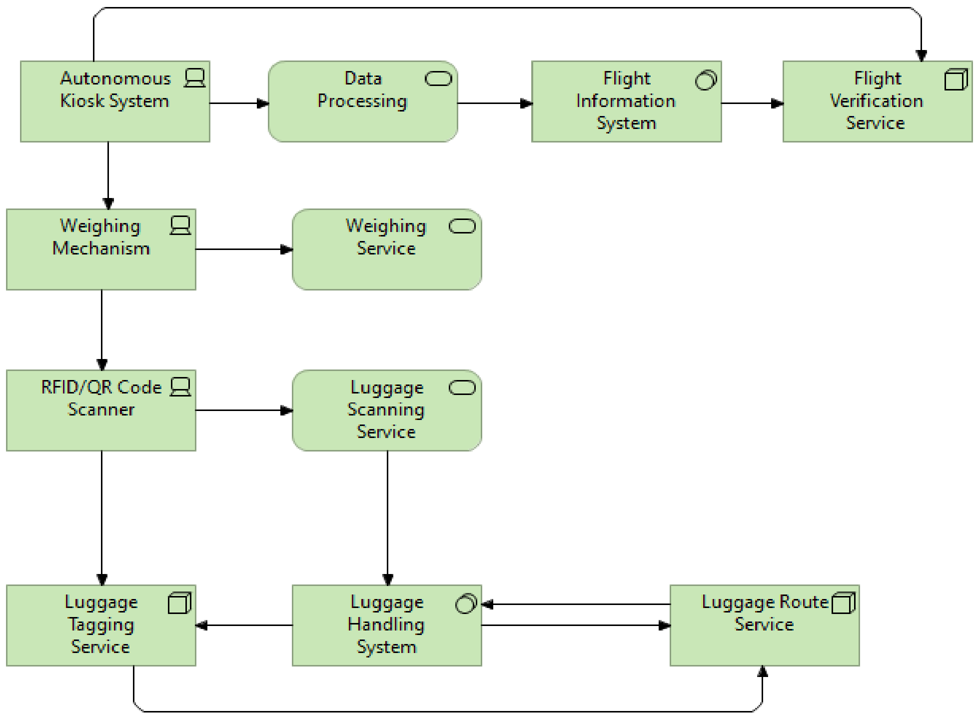

Figure 7: ArchiMate - Sub-Model Technology Layer

2.3.4 ArchiMate - Enterprise Model Layer

The ArchiMate enterprise model provides a layered representation of the Autonomous Luggage Check-In System, encompassing its business, application, technology, and data aspects. Each layer is meticulously crafted to highlight the integration of automated processes, cutting-edge technologies, and passenger-focused solutions.

In the business layer, key processes like check-in, weighing, tagging, and routing are visualized, demonstrating how automation reduces staff involvement while maintaining compliance with security protocols. The application layer emphasizes the role of software systems in facilitating real-time data exchange and decision-making. In the technology layer, the model showcases the infrastructure components, such as kiosks, conveyor belts, and scanning devices, that ensure smooth operations.

The data layer integrates all components by visualizing the flow of information across the system, from passenger inputs at the kiosk to the final routing of luggage. This interconnected structure highlights the system's reliance on data-driven automation, ensuring accuracy and efficiency without the need for centralized control.

By combining these layers, the ArchiMate enterprise model demonstrates the Autonomous Luggage Check-In System's potential to revolutionize luggage handling in the aviation industry. It provides a clear roadmap for integrating automation and IoT technologies, ensuring scalability, resilience, and passenger satisfaction.

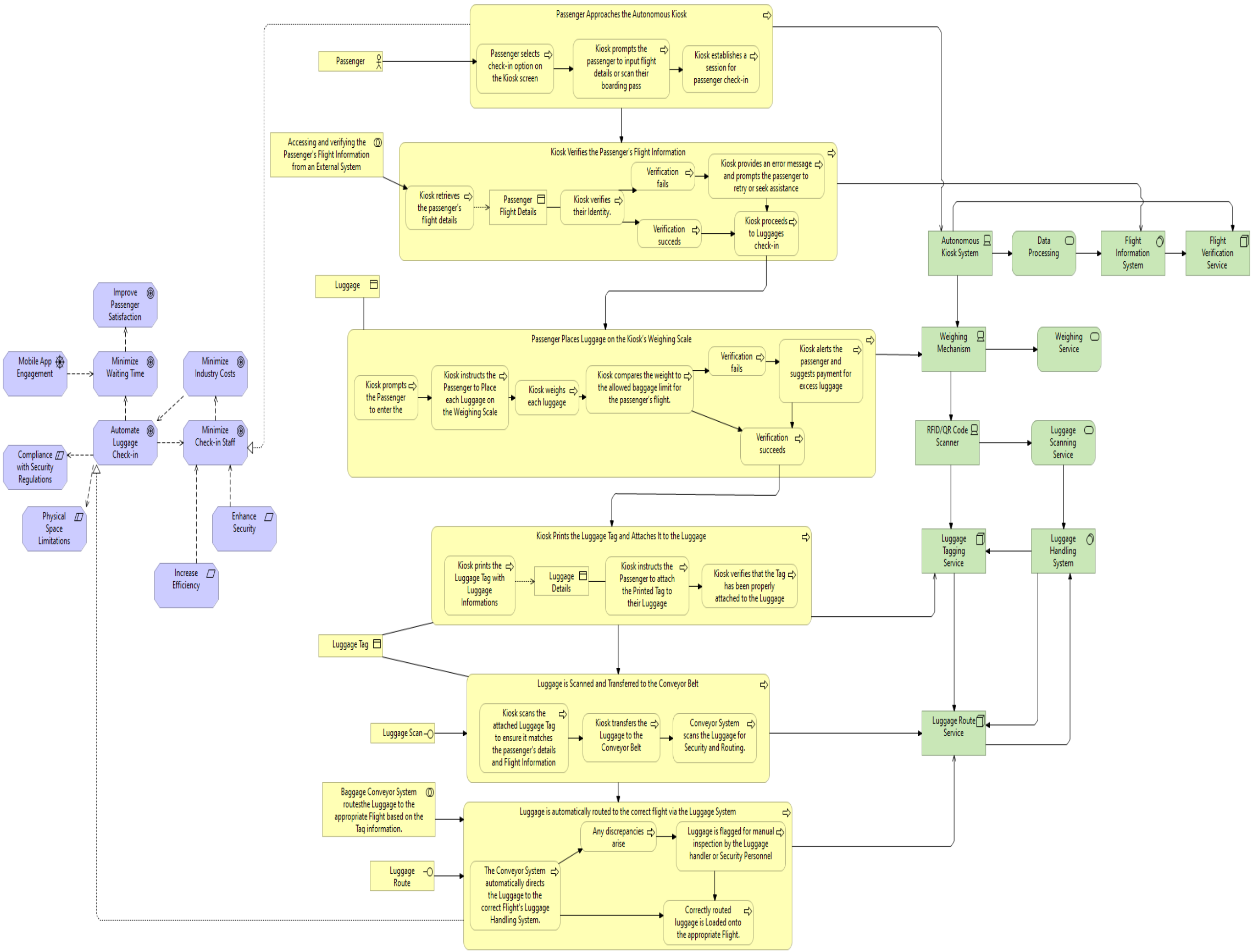

Figure 8: ArchiMate - Model

2.4 Choice of Modeling Tool

For the Autonomous Luggage Check-In System, the 4EM framework emerges as a more appropriate choice due to its ability to align strategic objectives with operational processes and technological elements. Unlike ArchiMate, which focuses heavily on IT infrastructure and its interdependencies, 4EM takes a broader view, integrating both high-level business goals and detailed system functionalities.

4EM excels in linking strategic objectives, processes, and technology through its Goal Sub-Model, which directly aligns with the airline's aims of improving efficiency, reducing wait times, and enhancing customer satisfaction. Its Business Process and Technological Components Sub-Models provide deep insights into how specific operations, like luggage weighing and RFID tracking, interact with the system's underlying technology. This enables a comprehensive understanding of how the system supports both operational efficiency and sustainability goals, such as reducing energy consumption and minimizing waste.

On the other hand, ArchiMate is highly effective at visualizing the technical architecture and the integration of IT components, like kiosks and RFID systems, within the enterprise. However, its layer-based structure can make it difficult to directly link strategic business goals with technology. While ArchiMate excels at managing technical complexity, it lacks the flexibility needed to integrate broader objectives such as innovation and sustainability into the business processes.

In contrast, 4EM offers the flexibility to seamlessly model both business strategy and technology integration, making it the ideal framework for innovations like the Autonomous Luggage Check-In System. In this case, operational efficiency, customer experience, and sustainability are key drivers. Although 4EM may lack some standardization in IT modeling, its comprehensive approach ensures that both the enterprise's strategic goals and technological infrastructure are well-aligned, making it the better choice for driving innovation and sustainability.

2.5 Using the Model

The effectiveness and growth of the Autonomous Luggage Check-In System depend on the collaboration and efforts of several important stakeholder groups. Each group has specific roles and responsibilities that are vital for the system's successful implementation, scalability, and overall efficiency.

Primary Stakeholders

Passengers

Passengers are the primary users and the focal point of the system's design and functionality. To ensure an intuitive and user-friendly experience, they require clear and simple instructions at every step of the process. This ease of use minimizes confusion, enhances their overall journey, and fosters higher satisfaction with the system.

Airline Employees

Airline staff play a key role in supporting passengers during the check-in process. They assist by providing guidance, resolving kiosk-related issues, and helping with any unforeseen technical difficulties. Proper training for these employees is essential to ensuring passengers, especially first-time users, have a smooth and professional experience.

Operational Support Stakeholders

Kiosk Operators and Maintenance Teams

These teams form the crucial link between the system's technology and its users. They offer real-time assistance to passengers encountering issues and ensure the equipment functions properly.

Their expertise in troubleshooting and maintenance is particularly valuable during busy travel periods when demand is highest.

Aviation Companies
Airlines and airport operators are instrumental in scaling the system for widespread use. By promoting the adoption of the check-in system at various airports, they help streamline processes, reduce waiting times, and enhance passenger flow. Their collaboration plays a key role in improving the overall travel experience.

Technical and Development Stakeholders
IT Providers and Technology Vendors
These stakeholders are responsible for providing and maintaining the technological components of the system, such as RFID tags, kiosks, weighing mechanisms, and conveyor belts. They also handle system updates and resolve technical challenges, ensuring the system integrates seamlessly into airport infrastructure. Their work is critical to the reliability and efficiency of the system.

Stakeholder Interactions Through the Model
To support scalability and adaptability, the system relies on a detailed goal model. This model identifies strengths, weaknesses, and challenges, proactively addressing issues such as infrastructure integration or technical difficulties during large-scale rollouts. Partnerships with IT providers further help refine the system's performance and capabilities.

The process model focuses on the entire passenger journey, pinpointing areas where airport staff provide value and identifying potential bottlenecks. External support, like database management and software updates, ensures kiosks continue to function smoothly and efficiently.

From a technological perspective, the components model evaluates key infrastructure requirements, including costs, maintenance needs, and system dependencies. By addressing risks such as server downtime or equipment failures, and by incorporating critical elements like RFID tags and tracking apps, the model ensures reliable and uninterrupted operations.

Conclusion
In conclusion, the success of the Autonomous Luggage Check-In System relies on the collective efforts of its stakeholders. Clearly defined roles and strong collaboration are essential to achieving the system's full potential. Together, these contributions improve efficiency, reduce congestion, and enhance the travel experience for passengers at airports worldwide.

2.6 Evaluate the Model

2.6.1 Evaluate the Model - Theoretical Concepts

Information Quality Concepts

Accessible
Information should be easily accessible by authorized users in the right format and at the right time. Delays or barriers in accessibility can cause missed opportunities or incorrect decisions. For example, a sales rep without timely access to inventory data may miss out on closing a deal.

Accurate
Information must be free from errors. Inaccurate data due to incorrect inputs can lead to flawed decisions. For instance, feeding erroneous data into a business intelligence system will produce

inaccurate insights, risking poor decisions.

Complete
Information should include all relevant facts and details. Incomplete information can lead to misinformed decisions. For example, omitting key financial details in a report might paint a misleading picture of a project's profitability.

Economical
Information should be cost-effective to produce. The benefits of the information must outweigh its cost. For example, gathering extensive data may be expensive, but if it improves efficiency, it is worth the cost.

Flexible
Information must be adaptable for multiple purposes. If a system is too rigid, it may limit its use across various areas, leading to inefficiencies. For example, inventory data can support sales, production, and financial analysis if the system is flexible.

Relevant
Information must meet the specific needs of the decision-maker. Irrelevant data wastes resources and time. For example, lumber price data is irrelevant to a semiconductor manufacturer.

Reliable
Information must come from trusted sources to be useful. Unreliable data leads to bad decisions. For example, information from unverified sources like rumors may mislead decision-makers.

Secure
Information must be protected from unauthorized access. Sensitive data, like customer information, must be safeguarded to maintain confidentiality and integrity.

Simple
Information should be straightforward and avoid overcomplexity. Complex data can cause overload, making it difficult to focus on key insights. For instance, too many metrics in a financial report can confuse rather than help decision-makers.

Timely
Information should be provided when it's needed. Outdated data can render decisions irrelevant. For example, weather data from last week won't help with today's planning.

Verifiable
Information should be cross-checked against other sources to ensure its accuracy. Verifiable data enhances trust and ensures that decisions are based on facts, especially in critical domains like finance or law.

Modeling Process Concepts

G The Goals of the Modeling
The Goals represent the primary objectives of the modeling process. They define what the model aims to achieve and guide the modeling decisions, such as what data to include and what the end result should accomplish.

L What Can Be Expressed in the Modeling Language
The Modeling Language refers to the specific set of symbols, notation, or syntax used to represent the model. It can include mathematical formulas, diagrams, flowcharts, or programming languages that help structure and communicate the model.

M What Is Expressed in the Model
The Model refers to the actual content or artifact created through the modeling process. It represents the system, process, or phenomenon being studied, including the relationships, variables, and relevant data needed to understand the subject of the model.

A What Actors That Develop or Have to Relate to the Model Have Access To
Actor Access defines the levels of access that different stakeholders or actors have to the model. This includes who can view, modify, or interact with different parts of the model, depending on their roles and needs.

D What Can Be Expressed About the Domain (Area of Interest)
The Domain refers to the specific area of interest or subject that the model represents. This could be a business process, technical system, or scientific phenomenon, and it defines the scope of what the model covers.

K The Explicit Knowledge of the Participating Persons About the Domain D
Explicit Knowledge refers to the factual, documented knowledge that participants (actors) bring to the modeling process. It includes their understanding of the domain and the specific details needed to accurately represent the system or process in the model.

I What the Participating Persons Interpret the Model to Express
Interpretation refers to how the participants (both social and technical actors) understand and interpret the model. Their interpretation is shaped by their knowledge, perspectives, and roles, and it influences how they use and apply the model.

T What Relevant Tools Interpret the Model to Express
Tools refer to the software, methodologies, or technologies used to analyze, interpret, or manipulate the model. These tools help the actors work with the model and extract meaningful insights, making the modeling process more effective and efficient.

2.6.2 Evaluate the Case Model

G The Goals of the Modeling

The goals of the Autonomous Luggage Check-In System are well-defined to address the challenges faced by airports, with a focus on efficiency, security, and cost reduction. These goals are measurable, with clear indicators like throughput, security measures, and reduced staffing needs. They are flexible, allowing for adjustments as priorities shift, such as improving customer satisfaction or implementing new technologies. The goals are simple, ensuring they align with stakeholder needs, and are regularly updated to reflect the project's progress. Performance metrics are in place to evaluate whether the system is meeting its objectives.

L What Can Be Expressed in the Modeling Language

The modeling language, including tools like 4EM and ArchiMate, is effective in capturing the system's design. It translates high-level goals such as security and efficiency into concrete operational processes and technological components. Elements like kiosks, RFID scanners, and automated luggage handling are clearly mapped out. The language also allows for the representation of interactions between various actors like passengers, staff, and IT teams, specifying their roles and responsibilities. Additionally, it illustrates business processes such as check-in procedures and luggage movement, ensuring that every part of the system is visually represented and understood by all stakeholders.

M What Is Expressed in the Model

Through tools like 4EM and ArchiMate, the model provides a clear visual representation of the system's architecture and processes. Strategic goals, like security and efficiency, are reflected in detailed workflows, ensuring alignment throughout the system. The model also shows how physical components like kiosks and scanners interact with human actors such as passengers and airport staff. This approach is cost-effective, removing the need for expensive prototypes or extensive documentation. The model is adaptable to changing requirements, like new technologies, and is based on solid design principles that guarantee reliability. It is secure to protect sensitive data and can be verified against real-world data to ensure accuracy.

A What Actors That Develop or Have to Relate to the Model Have Access To

Stakeholders have access to a well-structured and intuitive model that helps them easily understand the system's design. This model gives an accurate representation of how components like kiosks and RFID scanners interact during the check-in process. It is comprehensive, covering all processes from check-in to luggage handling. The model is flexible, so it can be modified as needed to address new challenges like regulatory changes. Security is ensured through access controls to prevent unauthorized modifications. The model is designed to be understandable to stakeholders with different technical backgrounds and is regularly updated to reflect the project's progress. Its real-world applicability ensures that stakeholders can verify that the model aligns with operational needs and objectives.

D What Can Be Expressed About the Domain (Area of Interest)

The model captures all the relevant knowledge about the domain, especially in areas like check-in and luggage handling processes. It reflects the complexity of real-world operations, covering aspects like security, regulatory compliance, and technological integration. The model is comprehensive, addressing everything from passenger interactions with kiosks to automated luggage handling. It is flexible, able to incorporate new domain-specific requirements like evolving security regulations. Based on industry standards, it ensures reliability and follows best practices. Sensitive information, such as passenger data and security protocols, is securely handled. The model is updated regularly to stay aligned with current domain knowledge and regulatory changes.

K The Explicit Knowledge of the Participating Persons About the Domain D
Stakeholders, including airport staff, IT professionals, and airline employees, have access to explicit domain knowledge communicated through training, documentation, and the model itself. This ensures everyone involved in the design and implementation understands key aspects of airport and airline operations, including check-in, luggage handling, and security. The knowledge is comprehensive, eliminating the need for external consultants. It is flexible and adaptable to changes like new technologies or regulations. Each participant's role-specific knowledge is clear—airport staff focus on operations, IT professionals on system integration, and airline employees on customer service. This knowledge is up-to-date, reliable, and protected to maintain confidentiality. It is also simple to access and verify against industry standards and real-world data.

I What the Participating Persons Interpret the Model to Express
Stakeholders interpret the model as a clear and accurate representation of the system, providing valuable insights into how it functions and its intended goals. Regardless of their technical expertise, all participants can understand the system's objectives, operations, and processes. The model is seen as a comprehensive tool that eliminates costly revisions during implementation. It is flexible enough to adapt to new requirements, such as regulatory changes, and remains highly relevant to the system's goals of efficiency, security, and customer satisfaction. Stakeholders trust the model for informed decision-making, recognizing its reliability, which is built on sound design principles. Security is a key focus, ensuring sensitive data is protected. The model is simple, breaking down complex systems into understandable components, and is updated regularly to stay timely. It can also be verified through real-world data to ensure the design meets its objectives.

T What Relevant Tools Interpret the Model to Express
The tools used to interpret the model, like ArchiMate and 4EM, ensure stakeholders can understand the system's design and make informed decisions. These tools help visualize the system's architecture, goals, and processes, making them an effective means to interpret and analyze the model. They are cost-effective, allowing for rapid updates without the need for physical prototypes or extensive documentation. The tools are flexible and reliable, accommodating changes in system requirements and ensuring accurate interpretation across disciplines. Security is prioritized with access controls to protect sensitive data. The tools are user-friendly, making it easy for stakeholders with varying technical expertise to engage with the model. They provide real-time updates, ensuring stakeholders always have the most current information. These tools also support verification, allowing stakeholders to validate the system's design and performance against real-world data, ensuring alignment with the project's goals.

3 Open Service Innovation and Service Design

3.1 Customer Journey

The customer journey for check-in and luggage handling at airports can differ significantly based on whether a traditional check-in system or an autonomous check-in system is in place. This section examines the distinctions between these two approaches, beginning with the conventional check-in process and transitioning to a more efficient and technology-driven autonomous system. The accompanying diagram provides a comprehensive overview of the customer journey under both systems, detailing key stages from flight booking to luggage collection at the destination airport.

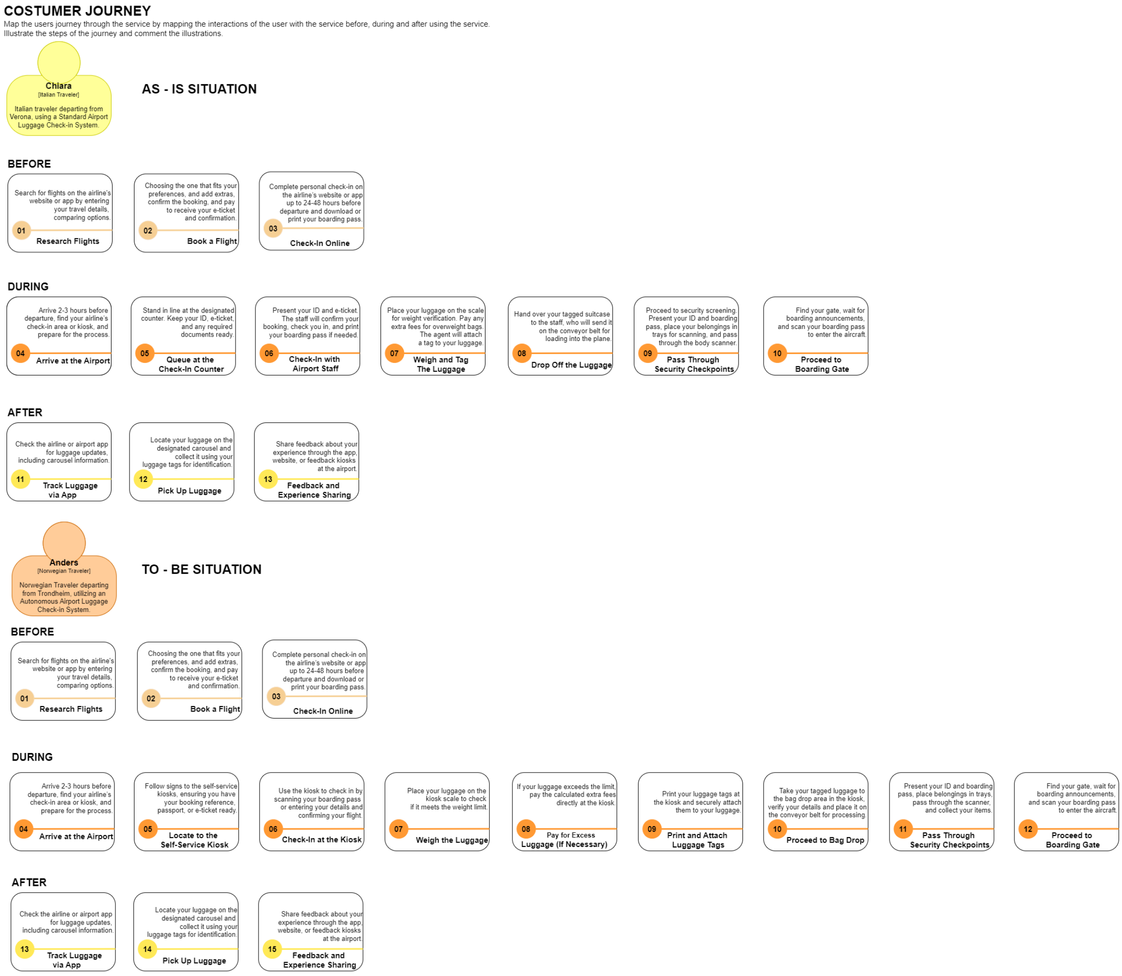

Figure 9: Customer Journey

3.1.1 AS - IS Situation: Traditional Check-in Luggage System

Before the Flight

Search for Flights Online
Passengers start their journey by researching flight options online. They look for flights based on various criteria like price, flight schedule, and airline. They often use websites, apps, or third-party aggregators to compare flight offers across multiple airlines and platforms. This step generally takes place in the comfort of the customer's home or office.

Compare Prices and Airlines
Customers compare the different airlines, flight schedules, and prices. Many travelers may also check for promotions or discounts that can influence their decision. The goal is to find the best deal within their preferred travel time frame and budget.

Book the Flight
After selecting the flight, customers proceed to book the tickets. Booking can be done directly through the airline's website, a travel agent, or a third-party booking service. Once booked, the customer receives a confirmation email, which includes essential travel information, a booking reference, and sometimes a digital or physical ticket.

During the Flight

Arrive at the Airport
On the day of travel, passengers arrive at the airport with adequate time to go through the check-in process. Depending on the airport's size, passenger volume, and the time of day, this can involve navigating through various terminals or security areas.

Queue at the Check-in Counter
In the traditional check-in process, passengers must stand in line at the airline's check-in counter. These counters are typically staffed by airline personnel who assist passengers with ticketing, luggage handling, and checking identification. This part of the process can be time-consuming, especially during peak travel seasons or at busy airports.

Check-in with Airport Staff
When it's the passenger's turn at the counter, they present their identification (e.g., passport or ID) and their flight details. The airline staff checks the travel documents, verifies the flight reservation, and confirms seat preferences. If the passenger has checked luggage, it is weighed, tagged, and processed by the airline personnel.

Weigh and Tag the Luggage
The staff manually weighs each checked piece of luggage to ensure it complies with the airline's weight restrictions. If the luggage exceeds the allowed weight, the passenger is charged for excess luggage. The staff then attaches a luggage tag that includes important information like the destination airport and flight number. This process involves handling the luggage directly.
Drop Off the Luggage
Once tagged, the checked luggage is handed over to the airline personnel. The staff then sends the luggage to be scanned and transported to the correct aircraft for loading. This step involves significant staff interaction and takes time for each passenger.

Pass Through Security Checkpoints
Once the check-in process is complete, passengers move to the security checkpoint. Passengers

present their travel documents and proceed through security checks, which include walking through metal detectors and having their carry-on luggage scanned by X-ray machines. The duration of the security process varies depending on factors such as the airport's operational efficiency, passenger volume, and the time of day, with potential waiting times in queues.

Proceed to the Boarding Gate
Once through security, passengers can proceed to the designated boarding gate. Depending on the size of the airport and the availability of seating, this part of the journey may involve additional walking, waiting, and sometimes more checks before being allowed to board the flight.

After the Flight

Board the Flight
Once at the gate, passengers present their boarding passes for scanning and pass through the boarding process. Flight attendants assist passengers in locating their seats on the plane.

Arrive at the Destination Airport
Upon landing, passengers disembark the aircraft and head to luggage claim. In international airports, this may include going through customs and passport control before heading to the luggage area.

Collect Luggage from the Luggage Carousel
After passing through customs (if applicable), passengers collect their checked luggage from the luggage carousel. This process can sometimes take a while, as bags are unloaded and transported to the carousel in batches. Passengers must identify their bags among the many others on the carousel.

Exit the Airport
Finally, once their bags are collected, passengers exit the airport. This marks the end of the check-in process. At this point, travelers can either continue their journey or head home.

3.1.2 TO - BE Situation: Autonomous Check-in Luggage System

Before the Flight

Search for Flights Online
The initial steps of searching for flights, comparing airlines, and booking remain largely the same. Customers continue to make their decisions based on similar criteria like price, schedule, and personal preferences.

Compare Prices and Airlines
Passengers still compare available flights across multiple platforms to find the best option before booking.

Book the Flight
Customers proceed to book their flight through the airline's website or a third-party service, just like in the traditional process. After booking, they receive an e-ticket or confirmation with the booking details.

During the Flight

Arrive at the Airport
Passengers arrive at the airport and are ready to check-in. While the process is largely the same,

passengers will now have additional options for self-service check-in.

Locate the Self-Service Kiosk
Instead of proceeding to a staffed counter, passengers locate a self-service kiosk. These kiosks are strategically placed in airports to ensure that travelers can quickly find them. Some airports offer kiosks throughout the terminal, reducing congestion at check-in counters.

Check-in at the Kiosk
At the kiosk, passengers input their details (e.g., booking reference, passport number) to verify their identity. The system confirms seat availability, processes the check-in, and updates the passenger's flight status. This eliminates the need for a customer service agent in most cases.

Weigh the Luggage
The kiosk includes a built-in luggage scale. The passenger places their checked luggage on the scale to determine if it meets the airline's weight allowance. If the luggage exceeds the limit, the kiosk will prompt the passenger to pay for excess luggage directly through the system.

Pay for Excess Luggage (if Necessary)
If the luggage exceeds the weight limit, the passenger is prompted to pay the additional charges via the kiosk's payment system. This step is handled autonomously, meaning no interaction with airline staff is required.

Print and Attach Luggage Tags
Once the luggage is weighed and excess fees are paid (if applicable), the kiosk prints luggage tags. Passengers must attach these tags to their checked luggage themselves, reducing reliance on staff assistance. The tag includes crucial information such as the destination airport and flight number.

Proceed to Bag Drop
After tagging the luggage, passengers proceed to the automated bag drop area. These self-service stations automatically verify the luggage tag, scan the bag, and confirm that it is ready for transport. The luggage is then sent to be screened and transferred to the correct aircraft, all without requiring staff assistance.

Pass Through Security Checkpoints
After completing the autonomous check-in process, passengers proceed through security, just like in the traditional process. Depending on the airport, security may be more streamlined, as more passengers may have already completed their check-in through kiosks, reducing wait times.

Proceed to the Boarding Gate
Once cleared through security, passengers head to the boarding gate. With the self-check-in process having sped up their earlier steps, they may have more time to relax before boarding.

After the Flight

Board the Flight
After presenting their boarding pass at the gate, passengers board the flight in the usual manner.

Arrive at the Destination Airport
Upon arrival, passengers head to luggage claim as usual. There is no major change here, as the autonomous check-in process only affects the pre-flight and boarding phases.

Collect Luggage from the Luggage Carousel
Passengers collect their checked luggage from the carousel in the same way as with the traditional process. However, the luggage handling on the airline's side may be more automated and efficient, allowing for quicker delivery to the carousel.

Exit the Airport
After retrieving their luggage, passengers exit the airport, having experienced a more efficient check-in and luggage drop process than with traditional methods.

Future Innovation: Internal Central System Server

The airline industry can significantly benefit from creating an internal central system server that integrates key functions like check-in, luggage handling, and security into one platform. This system would streamline operations, enhance communication across departments, and improve the passenger experience.

Cost Reduction
By automating processes and reducing manual tasks, airlines can lower labor costs and optimize resource allocation, making operations more cost-efficient.

Improved Customer Satisfaction
The system would provide real-time updates, faster check-ins, and smoother luggage handling, reducing wait times and offering personalized services, improving the overall travel experience.

Optimized Staff Operations
The system can automate routine tasks and dynamically adjust staffing based on real-time data, ensuring optimal coverage during peak travel times.

Data Security
A centralized system allows airlines to quickly adopt the latest security measures, protecting customer data from cyber threats and ensuring compliance with regulations, maintaining trust in a digital world.

3.2 Blueprint

Lines of Differentiation
The service blueprint employs key lines of differentiation to distinguish between various components and interactions in the service process. These lines provide clarity on the roles of customers, frontstage operations, backstage processes, and support systems, ensuring seamless and efficient service delivery. Below is an explanation of the three primary lines of differentiation

Line of Interaction
The Line of Interaction separates the actions taken by customers from visible service interactions. This line highlights the points where passengers engage directly with the service, such as interacting with self-service kiosks. While passengers may experience the outcomes of certain processes (e.g., paying excess luggage fees), they do not directly engage with back-end systems or algorithms handling these operations.

Line of Visibility
The Line of Visibility differentiates visible, customer-facing operations from the backstage processes that support them. For example, passengers can observe and interact with the self-service kiosks and assistance counters but remain unaware of invisible systems like weight-check algorithms or tag-printing mechanisms that enable these interactions.

Line of Internal Interaction
The Line of Internal Interaction delineates backstage interactions from support processes that ensure the service's operational reliability. While backstage interactions involve processes such as RFID tracking and luggage tagging, support processes include system monitoring, kiosk maintenance, and error resolution, which remain entirely hidden from passengers.

These are divided into 5 lanes as below
Physical/Online Evidence
This lane represents all visible elements of the system that passengers interact with or observe during their journey. These touch-points guide passengers through the service process, such as the airline website/app, boarding passes, airport signage, self-service kiosks, real-time luggage tracking apps, and feedback portals.

Customer Actions
This lane maps every step passengers take throughout their journey, from researching flights and booking tickets to providing post-experience feedback. These actions are central to the passenger's experience, including locating kiosks, checking in, weighing luggage, and boarding the flight.

Frontstage Interactions
This lane highlights visible interactions passengers have with service personnel or technology. It includes interactions with self-service kiosks, assistance counters, and security scanning procedures.

Backstage Interactions
This lane focuses on the essential processes and systems that passengers do not see but which are crucial to service delivery. These include weight check algorithms, kiosk fee systems, RFID/barcode systems, and tag printing mechanisms.

Support Processes and Systems
This lane ensures the smooth operation of all other components. It includes system monitoring, maintenance of kiosks and scales, error handling, real-time data integration, and lost/delayed luggage processes that keep the service running efficiently and seamlessly.

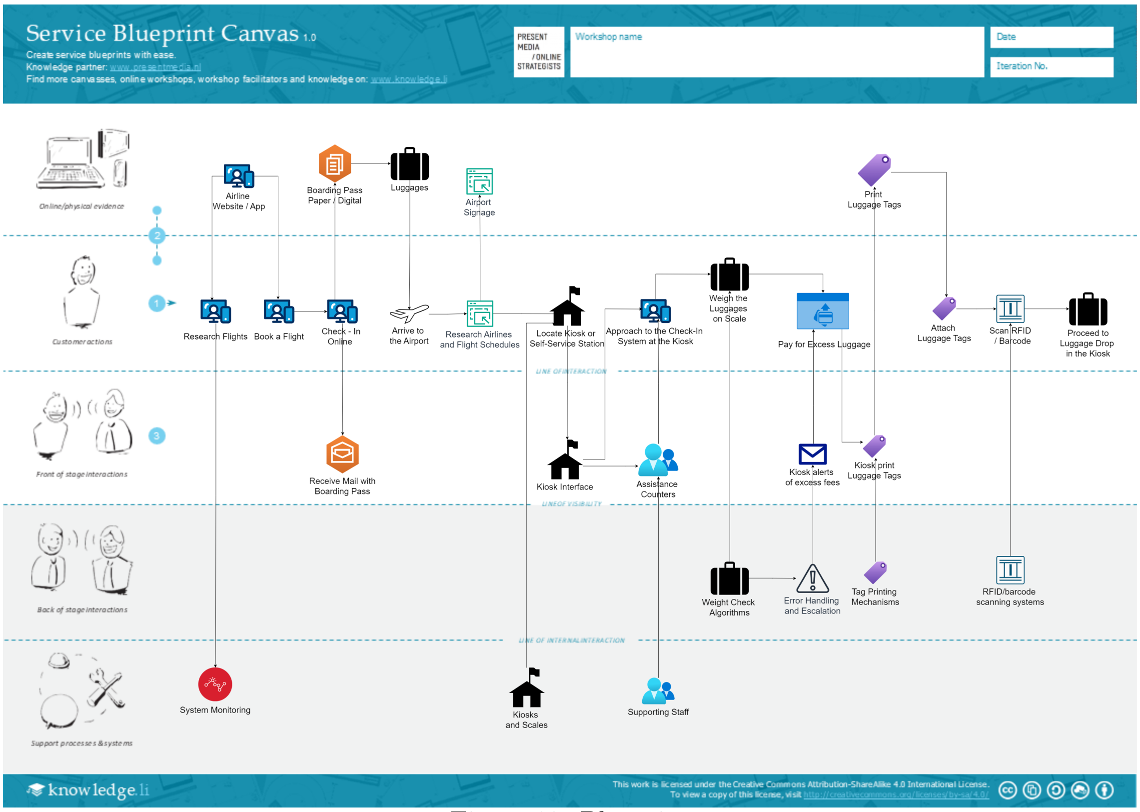

Figure 10: Blueprint

The service process involves multiple steps that guide passengers from pre-travel preparations to post-experience feedback. Each stage is designed to enhance efficiency, minimize effort, and ensure a seamless travel experience. The process is divided into various lanes, each representing a specific category of actions, interactions, and systems that contribute to the overall experience. Below is a detailed explanation of each step and how it relates to the lanes.

Pre-Travel Activities

Research Flights

Customer Actions Passengers compare airlines, routes, and pricing on airline websites or apps, helping them make informed decisions.
Physical/Online Evidence Passengers interact with the airline website or app to gather information about flight options. This platform serves as the starting point for research, offering digital resources for comparisons.

Book Flights

Customer Actions Once a flight is chosen, passengers confirm their bookings and receive tickets electronically. This may include adding optional services like additional luggage or preferred seating.
Physical/Online Evidence The airline website/app generates the booking confirmation and electronic tickets, which are delivered via email or within the app.

Check-In Online

Customer Actions If available, passengers complete online check-in, providing their travel details and receiving a digital boarding pass via email or app.
Physical/Online Evidence The digital boarding pass sent through the airline's website or app serves as key evidence of the passenger's check-in, which they carry with them to the airport.

Airport Arrival and Check-In

Arrival at Airport
Customer Actions Upon arrival at the airport, passengers use signage or digital tools to locate the check-in area or self-service kiosks.
Physical/Online Evidence Airport signage, both physical and digital, directs passengers to check-in areas, kiosks, or customer service desks.

Locate Kiosk

Customer Actions Passengers find the self-service kiosks, which help them complete the check-in process.
Physical/Online Evidence Self-service kiosks are clearly visible and are located near the entrance or check-in zones, allowing passengers to independently manage their check-in.

Use Kiosk

Customer Actions Passengers interact with the self-service kiosk interface to check-in, verify personal details, and make any additional selections.
Frontstage Interactions Passengers interact with the kiosk's digital screens to complete their check-in, print luggage tags, and pay for excess luggage.
Backstage Interactions The kiosk system verifies the passenger's information, integrates with flight databases, and ensures the details are accurate.

Weigh Luggage and Pay Fees

Customer Actions Passengers place their luggage on the connected scales for automated weight measurement. If the luggage exceeds the allowed weight, they make an excess luggage payment.
Frontstage Interactions The kiosk displays luggage weight and prompts the passenger to pay any excess luggage fees.
Backstage Interactions Weight check algorithms calculate the excess luggage fees based on the weight of the luggage and integrate with payment systems to facilitate payment.

Tag Luggage

Customer Actions After paying any necessary fees, passengers print luggage tags, which they then attach to their bags.
Frontstage Interactions Passengers use the kiosk to print tags with their flight details, which they then attach to their checked luggage.
Backstage Interactions The tag printing mechanism retrieves flight and luggage data, ensuring that the correct tags are printed with accurate information.

Luggage Processing and Security

RFID/Barcode Registration
Customer Actions Tagged luggage is scanned at drop-off points, allowing the system to register the luggage and initiate tracking.
Frontstage Interactions Passengers observe as their tagged luggage is scanned by the system at the drop-off area.
Backstage Interactions RFID and barcode systems track the luggage as it moves through the airport, allowing the system to update its location in real-time.

3.3 Reflections

The transition to autonomous check-in and luggage handling systems represents a transformative leap in the airline industry, with notable benefits in customer experience, operational efficiency, and technological innovation. This section reflects on the impact and implications of these changes, offering insights into their advantages and challenges.

Enhanced Customer Experience and Empowerment
Autonomous systems empower passengers by introducing self-service kiosks for tasks such as check-in, luggage tagging, and payment for excess luggage. These systems significantly reduce waiting times and provide travelers with greater control over their journey, fostering a sense of independence and convenience. The integration of real-time luggage tracking further enhances the passenger experience by offering peace of mind and transparency about the status of their belongings. These advancements collectively create a smoother, faster, and more satisfying travel experience, especially during peak travel periods.

Improved Operational Efficiency
From an operational perspective, automation streamlines key processes, such as luggage weighing, tag printing, and luggage drop-off, reducing reliance on manual interventions. This allows staff to focus on complex or high-touch tasks, such as assisting travelers with special needs or resolving issues. Additionally, automated systems minimize errors in luggage handling and accelerate passenger processing, resulting in reduced labor costs and improved resource allocation. Technologies such as RFID tracking and automated bag drop systems further enhance speed, accuracy, and overall efficiency in luggage logistics.

Seamless Technology Integration and Scalability
The autonomous system exemplifies the successful integration of various technologies, including self-service kiosks, real-time data analytics, and automated luggage handling. This interconnected approach ensures smooth operations and scalability, enabling airlines and airports to adapt to increased passenger volumes or accommodate future innovations. The system's modular design allows it to be expanded or upgraded with minimal disruption, making it a sustainable solution for the evolving needs of the airline industry.

Challenges and Human-Centered Considerations
While the benefits of automation are clear, certain challenges must be addressed. System malfunctions or technical failures could lead to delays, creating potential bottlenecks during high-traffic periods. Additionally, some passengers—such as those unfamiliar with the technology, elderly travelers, or those with disabilities—may prefer or require human assistance. Striking the right balance between automation and human support is crucial to ensuring inclusivity and maintaining service quality. Providing adequate on-site assistance and clear instructions can help bridge the gap for passengers who may struggle with autonomous processes.

Strengthened Security and Data Protection
As digital systems handle sensitive passenger information, robust cybersecurity measures are paramount. Protecting data through advanced encryption, secure server infrastructure, and compliance with global data protection regulations is essential to maintaining trust. A focus on proactive security measures not only safeguards personal and financial information but also ensures the long-term viability of these systems in an increasingly connected world.

4 Business Model

The autonomous luggage check-in system marks a transformative step toward enhancing airport efficiency and improving passenger convenience. By automating the check-in process, it allows travelers to bypass traditional counter queues, streamlining their journey while minimizing human errors. This report outlines the business model for implementing such a solution, emphasizing its strategic partnerships, resources, activities, and revenue streams. The following sections explore the essential components that enable the system to provide value to travelers and airport stakeholders while ensuring sustainable growth.

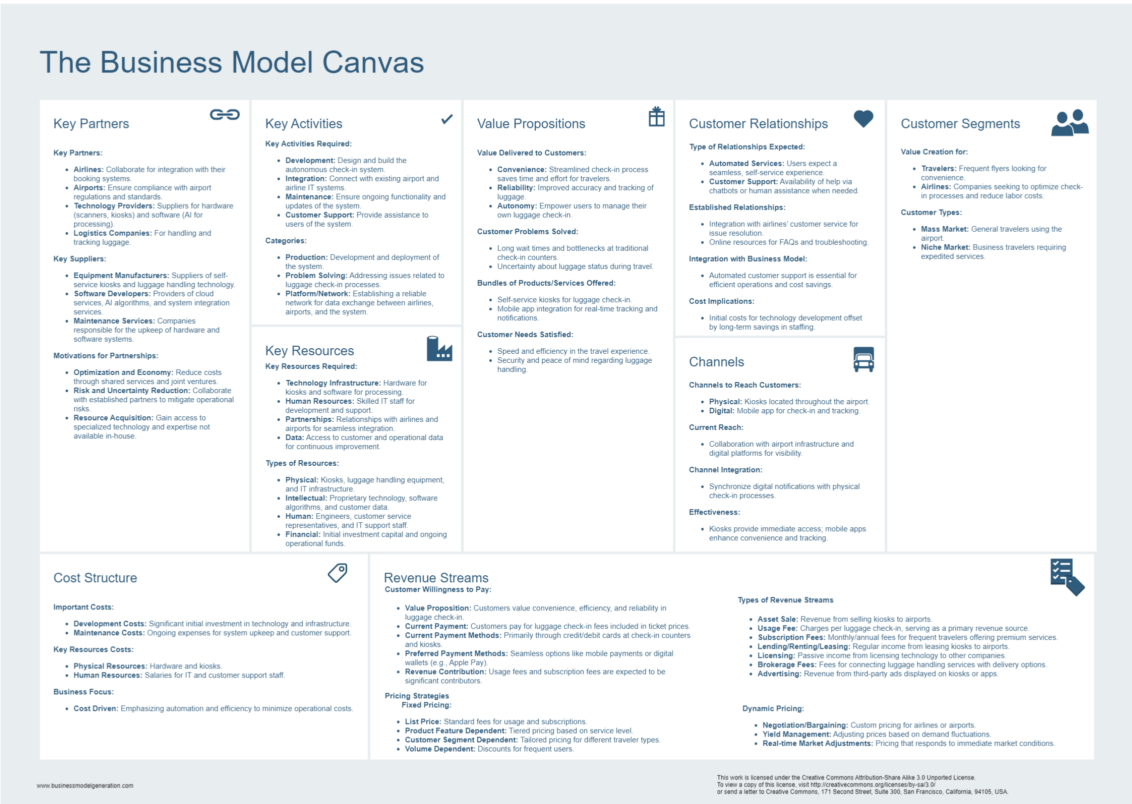

Figure 11: Business Model Canva

4.1 Key Activities

To operate the autonomous check-in system successfully, several critical activities must be undertaken:
System Development
This involves the design and development of the autonomous luggage check-in technology, encompassing both hardware (kiosks, scanning devices) and software (user interfaces, AI-driven processing systems). Continuous improvement and innovation in this area are necessary to enhance user experience.

Integration
A key activity is ensuring seamless connectivity between the autonomous check-in system and existing IT frameworks at airports and airlines. This integration facilitates data exchange and operational efficiency, allowing for real-time monitoring and updates.

Ongoing Maintenance
Regular maintenance and updates of the system are vital for ensuring its functionality and reliability. This includes software updates, hardware checks, and troubleshooting issues that may arise, thus minimizing downtime and ensuring a smooth user experience.

Customer Support
Providing robust customer support is essential for assisting users and addressing any issues during the check-in process. This includes training staff to help passengers, as well as offering online resources such as FAQs and troubleshooting guides to enhance user satisfaction.

4.2 Key Resources

The operation of the autonomous check-in system relies on various critical resources:
Technological Infrastructure
This includes all hardware and software components necessary for processing check-ins and managing luggage. High-quality kiosks, scanning devices, and a reliable software platform are essential for system functionality.

Human Capital
Skilled personnel are necessary for IT development, system maintenance, and customer support. Having a team of qualified engineers and customer service representatives ensures that the system operates smoothly and that users receive timely assistance.

Strategic Partnerships
Collaborations with airlines and airports are crucial for successful system integration. These partnerships enhance operational capabilities and ensure compliance with industry standards.

Data Assets
Access to customer data and operational insights is vital for continuous improvement of the service. Analyzing this data allows the company to identify areas for enhancement and adapt services to meet customer needs more effectively.

4.3 Value Propositions

The autonomous luggage check-in system delivers several key benefits to users, which are critical for attracting and retaining customers:
Enhanced Convenience

By enabling quick and efficient luggage check-in without the need for lengthy queues, the system significantly improves the overall travel experience for passengers. This convenience is particularly appealing to frequent travelers who prioritize speed and efficiency.

Increased Reliability
The system reduces the potential for human error in the check-in process, offering travelers accurate luggage tracking. This reliability builds trust among users, as they can monitor the status of their luggage throughout their journey.

User Autonomy
Passengers gain more control over their luggage check-in process, allowing them to manage it independently and reducing their reliance on airport staff. This autonomy enhances the overall experience by empowering travelers to take charge of their check-in activities.

4.4 Customer Relationships

Building and maintaining positive customer relationships is crucial for the system's success:
Automated Self-Service
Users expect a smooth, self-service experience that minimizes friction and enables independent check-in. The design of the system should facilitate this by providing intuitive interfaces and clear instructions.

Accessible Support Services
Offering multiple support channels, including chatbots and live agents, ensures that travelers can receive help whenever needed. Responsive customer support can significantly enhance user satisfaction and loyalty.

4.5 Channels

The system utilizes a mix of physical and digital channels to effectively reach customers:
Physical Kiosks
These kiosks are strategically placed throughout airports, providing travelers with immediate access to check-in services. The physical presence of these kiosks is essential for maximizing user interaction and convenience.

Digital Platforms
A complementary mobile app enhances the user experience by offering real-time luggage tracking and notifications. This digital channel allows users to stay informed and engaged throughout their travel experience.

4.6 Customer Segments

The autonomous luggage check-in system targets various customer segments, including:
General Travelers
This segment includes individuals utilizing airport services who seek efficient and convenient check-in options. These customers value time-saving solutions and ease of use.

Business Travelers
Frequent travelers, such as business travelers, require expedited services and premium handling for their luggage. Catering to this segment can result in higher revenue through tailored service offerings and subscription models.

4.7 Cost Structure

Understanding the cost structure is crucial for sustainable operations:

Development Costs

Significant initial investments are necessary for technology development, infrastructure, and deployment. Budgeting for these costs is essential to ensuring the project is adequately financed.

Maintenance Costs

Ongoing expenses related to system upkeep, software updates, and customer support must be carefully managed to ensure long-term sustainability. Establishing a budget for maintenance helps to avoid unexpected costs and ensures consistent service quality.

4.8 Revenue Streams

The autonomous luggage check-in system has multiple potential revenue streams, which can enhance its financial viability:

User Fees

Revenue generated from charges per luggage check-in represents a primary source of income. This fee structure can be designed to incentivize users while covering operational costs.

Subscription Services

Offering monthly or annual subscription plans for frequent travelers seeking premium services can generate consistent revenue. This model appeals to business travelers who prioritize efficiency and convenience.

Leasing Agreements

Regular income from leasing kiosks to airports adds a steady revenue stream. This arrangement can provide airports with modern technology while generating revenue for the system operator.

Licensing Revenue

Passive income through licensing technology to other entities interested in implementing similar systems can expand revenue without significant additional investment.

Brokerage Fees

Revenue derived from connecting luggage handling services with delivery options for travelers creates additional income streams. This service can enhance the travel experience by offering convenience in luggage transport.

Advertising Revenue

Income from third-party advertisements displayed on kiosks and within mobile applications can supplement earnings. By partnering with relevant brands, the system can monetize user engagement effectively.

5 Flourishing Business Model

In the fast-paced travel landscape, the integration of advanced technology within airport operations is vital to meeting evolving passenger expectations. This business model canvas presents a comprehensive framework for an autonomous luggage check-in system aimed at simplifying the check-in process, increasing operational efficiency, and elevating passenger satisfaction. By focusing on sustainability, effective resource utilization, and user-centric solutions, this model caters to the varied needs of travelers, airlines, and airport authorities. The accompanying diagram encapsulates the core components of this innovative approach, illustrating its strategic alignment with industry objectives.

Flourishing Business Canvas v2.0

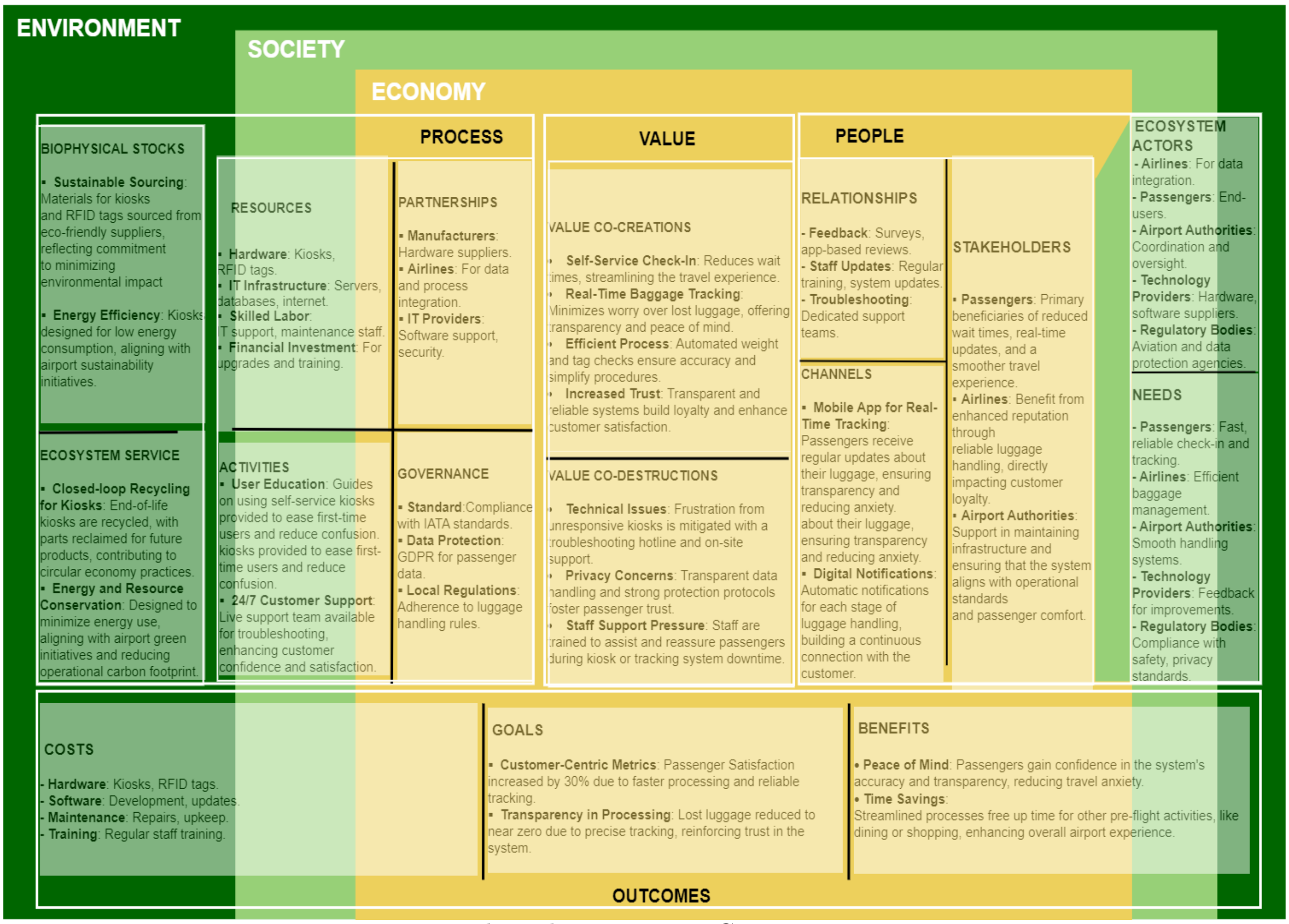

Figure 12: Flourishing Business Canvas

5.1 Environment Layer

5.1.1 Biophysical Stocks

The environmental sustainability of the autonomous check-in luggage system is supported through various initiatives:

Sustainable Sourcing

Materials used for kiosks and RFID tags are sourced from environmentally responsible suppliers. This practice not only aims to minimize environmental impact but also ensures that the materials are sustainable and ethically produced. This approach contributes to the Un Sustainable Development Goal (SDG) 12: Responsible Consumption and Production by encouraging sustainable resource management.

Energy Efficiency

The kiosks are engineered for low energy consumption, aligning with broader airport sustainability initiatives. This reduces operational costs and contributes to the airport's commitment to minimizing its carbon footprint, directly supporting SDG 7: Affordable and Clean Energy.

Closed-Loop Recycling

At the end of their life cycle, kiosks will be recycled, allowing for the reclamation of parts for future products. This closed-loop recycling approach supports a circular economy by reducing waste and encouraging the reuse of materials, in line with SDG 12: Responsible Consumption and Production.

Energy and Resource Conservation

The entire system is designed to minimize energy use, further supporting green airport initiatives and contributing to an overall reduction in the airport's carbon footprint, reinforcing the principles of SDG 13: Climate Action.

5.1.2 Costs

A comprehensive understanding of the costs associated with the autonomous check-in luggage system is critical for its viability:

Hardware Costs

These include the procurement and installation of kiosks and RFID tags, which are essential for the functioning of the self-service check-in process.

Software Costs

Ongoing expenses will be incurred for system development, updates, and necessary security enhancements to ensure the system remains robust and secure against potential threats.

Maintenance Costs

Periodic repairs and upgrades will be required to maintain system reliability and performance, ensuring a consistent user experience.

Training Costs

Regular training sessions will be necessary for staff members to effectively operate and troubleshoot the system, ensuring that they are well-equipped to assist passengers.

5.2 Society Layer

5.2.1 Resources

The successful implementation of the autonomous check-in luggage system relies on several key resources:
Hardware
The system's infrastructure consists of kiosks and RFID tags that facilitate passenger check-in and luggage tracking, enhancing operational efficiency.

IT Infrastructure
A robust IT infrastructure, including servers, databases, and internet resources, is necessary for real-time tracking and data management, ensuring that the system operates seamlessly.

Skilled Labor
Qualified personnel will be essential for system support, maintenance, and training, providing the expertise needed to keep the system functioning optimally.

Financial Investment
Adequate funds must be allocated for infrastructure development, ongoing updates, and continuous staff training, ensuring the system's long-term sustainability and effectiveness.

5.2.2 Activities

Key activities are vital for the successful operation and acceptance of the system:
User Education
Providing clear guides and instructions will help passengers navigate self-service kiosks more effectively, reducing confusion and enhancing their overall experience.

24/7 Customer Support
A dedicated support team will be available around the clock to troubleshoot and assist passengers with any issues they may encounter, ensuring prompt resolution of concerns.

5.2.3 Governance

Effective governance is essential for maintaining the integrity and functionality of the system:
Standard Compliance
The system will adhere to IATA (International Air Transport Association) standards to ensure safety and reliability in operations, fostering trust among users. **IATA** is a global trade association that represents over 290 airlines worldwide and sets the standards for air travel, ensuring that the system's processes align with international norms.

Data Protection
Implementing robust protocols to protect passenger data is critical. These measures will ensure privacy and build confidence in the system's handling of sensitive information

Local Regulations
The system will comply with local luggage handling regulations, ensuring that all operational practices are aligned with existing legal frameworks.

5.3 Economy Layer

5.3.1 Process

Successful partnerships are crucial for the operation of the autonomous check-in luggage system:
Manufacturers
Hardware suppliers play a vital role in providing the essential equipment necessary for the system's deployment.

Airlines
Partner airlines will contribute to data integration efforts, enabling seamless operational processes and enhancing the overall travel experience for passengers.

IT Providers
Technology partners will support software development, security enhancements, and ongoing maintenance, ensuring that the system remains up-to-date and secure.

5.3.2 Value

Creating value through the system involves co-creating positive experiences while addressing potential challenges:
Value Co-creations
Self-Service Check-In
This feature significantly reduces wait times, streamlining the passenger experience and allowing for more efficient airport operations.

Real-Time Luggage Tracking
Passengers benefit from transparency regarding their luggage, which minimizes stress and anxiety about lost items.

Efficient Processes
Automated weight and tag checks ensure accuracy and reliability during the check-in process, enhancing operational efficiency.

Increased Trust
A dependable system fosters customer loyalty and enhances the reputation of both airlines and airports.

Value Co-destructions
Technical Issues Frustration from unresponsive kiosks can be mitigated through a dedicated troubleshooting hotline and on-site support to assist passengers promptly.

Privacy Concerns
By adopting transparent data handling practices, the system builds passenger trust and alleviates privacy worries.

Staff Support Pressure
Staff will receive comprehensive training to assist passengers effectively, particularly in cases of kiosk or system downtime.

5.3.3 People

Understanding the perspectives of various stakeholders is essential for continuous improvement:
Feedback
Collecting insights through surveys and app-based reviews will provide valuable information for ongoing enhancements to the system.

5.3.4 Relationships

Building strong relationships among stakeholders is key to achieving operational success:
Passengers
Travelers benefit from a more efficient and streamlined travel experience characterized by reduced wait times and timely real-time updates on their luggage.

Airlines
Partner airlines gain customer loyalty and enhanced reputation due to reliable and efficient luggage handling, leading to positive passenger experiences.

Airport Authorities
Authorities maintain critical infrastructure to ensure the system meets operational standards and supports passenger comfort, ultimately leading to increased airport efficiency.

5.3.5 Channels

Effective communication channels are essential for engaging with passengers:
Mobile App for Real-Time Tracking
Passengers can receive regular updates about their luggage status, helping to alleviate anxiety during their travel experience.

Digital Notifications
Automatic notifications throughout the luggage handling process enhance passenger connection and keep them informed every step of the way.

5.3.6 Stakeholders

Identifying and engaging with key stakeholders is vital for the system's success:
Passengers
They are the primary beneficiaries of the enhanced travel convenience and reduced stress that the system provides.

Airlines
Airlines benefit from improved reputations due to efficient luggage handling and increased customer satisfaction.

Airport Authorities
Authorities ensure that the infrastructure aligns with operational standards and meets passenger needs effectively.

5.4 Ecosystem Actors

5.4.1 Actors

Several key actors play integral roles within the ecosystem of the autonomous check-in luggage system:
Airlines
These are key players in data integration and operational processes, facilitating seamless interactions within the system.

Passengers
As end users, passengers directly benefit from the system, enjoying improved convenience and efficiency during their travels.

Airport Authorities
These authorities oversee the infrastructure and ensure compliance with relevant standards and regulations.

Technology Providers
They supply the necessary hardware and software, playing a critical role in the system's functionality.

Regulatory Bodies
These organizations ensure compliance with aviation and data protection standards, safeguarding passenger interests.

5.4.2 Needs

Understanding the needs of each actor is crucial for the system's success:
Passengers
They demand fast, reliable check-in and tracking services to enhance their travel experience.

Airlines
Airlines seek efficient luggage management solutions to improve customer satisfaction and streamline operations.

Airport Authorities
These authorities require smooth handling systems to ensure operational efficiency and passenger comfort.

Technology Providers
Feedback from users is essential for ongoing system improvements and refinements.

Regulatory Bodies
These entities ensure compliance with safety and privacy standards, reinforcing trust in the system.

5.5 Outcomes

5.5.1 Goals

The implementation of the autonomous check-in luggage system aims to achieve the following key goals:

Customer-Centric Metrics
Increase passenger satisfaction by 30% as a result of faster processing times and reliable tracking of luggage.

Transparency in Processing
Strive to reduce lost luggage incidents to near zero, reinforcing passenger trust in the system's efficiency and reliability.

5.5.2 Benefits

The benefits of the autonomous check-in luggage system are numerous and impactful:
Peace of Mind
Passengers will gain confidence in the system's accuracy and transparency, significantly reducing travel-related anxiety.

Time Savings
A streamlined process will free up valuable time for passengers, allowing them to engage in other activities and enhancing their overall travel experience.

6 Redesigned Enterprise Model

The evolution of airport operations hinges on adopting technologies that streamline processes, enhance security, and improve passenger experiences. With growing passenger numbers, there is an urgent need for solutions that balance efficiency, security, and cost-effectiveness.

A key innovation in this context is the *Internal Central System Server*, which integrates all technological components into a unified infrastructure. This system reduces reliance on external companies for storing and processing sensitive passenger data, cutting costs while improving privacy. By keeping data within the airport's control, the server ensures compliance with privacy standards and reduces outsourcing expenses.

The Internal Central System Server enables real-time synchronization of passenger and luggage data, minimizes errors, and remains operational during peak periods. Its scalable design supports growing demand, facilitates automated decision-making, and seamlessly integrates with airline and regulatory systems. This innovation represents a significant step towards cost efficiency and enhanced data security, forming the foundation of more efficient airport operations.

6.1 4EM - Models

6.1.1 4EM - Technological Components Sub-Model

This sub-model demonstrates an autonomous check-in and luggage handling system, supported by advanced technological components that enhance performance and improve the user experience.

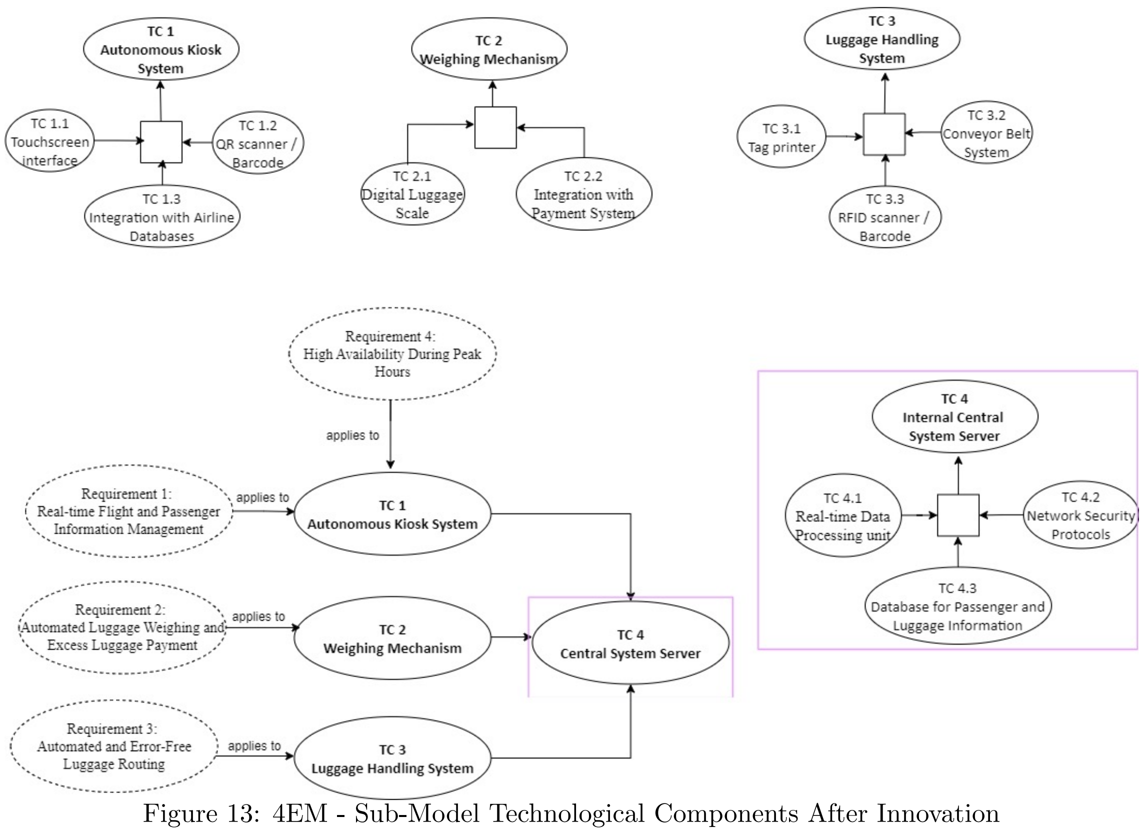

Figure 13: 4EM - Sub-Model Technological Components After Innovation

Autonomous Kiosk System
These kiosks act as the primary interface for passengers, providing intuitive touchscreen displays, QR and barcode scanning, and real-time integration with airline databases. By automating the check-in process, they reduce the need for manual intervention and deliver a seamless passenger experience.

Weighing Mechanism
An automated system that accurately measures luggage weight and integrates with secure payment platforms for handling excess luggage fees. This ensures quick, accurate processing, reduces delays, and improves customer satisfaction.

Luggage Handling System
Featuring automated conveyor systems with RFID and barcode technologies, this system handles luggage tagging, routing, and tracking with minimal errors. It ensures that every bag reaches the correct destination efficiently.

Internal Central System Server
Serving as the system's backbone, this server integrates and manages all components. It provides robust real-time data processing, scalable storage, and advanced network security, ensuring seamless operation even during peak traffic. The server safeguards sensitive data while optimizing workflows for greater efficiency and security.

The combined functionality of these components supports real-time data synchronization, high system reliability, and error-free operations. The Internal Central System Server acts as a central hub, enabling a fully connected, secure ecosystem for passengers and airport staff.

6.1.2 4EM - Enterprise Model

This model outlines the alignment of objectives, processes, and technological advancements to create a fully autonomous, streamlined system. At its core is the Internal Central System Server, which integrates all components, driving efficiency and seamless functionality.

The model enhances security by implementing centralized data management and encrypted data flows to protect sensitive passenger information. Automating processes like check-in, luggage handling, and payment transactions reduces manual involvement, cuts costs, and improves reliability.

Efficiency is further enhanced by eliminating manual bottlenecks through automation and real-time coordination. This results in smoother operations, fewer errors, and significantly reduced passenger wait times, providing a frictionless experience from check-in to luggage drop-off.

Core processes such as kiosk-based check-ins, automated luggage weighing, and intelligent routing are powered by the Internal Central System Server. Its scalable design supports future enhancements, including mobile app integration, which allows passengers to receive real-time updates and access self-service features for an engaging and convenient travel experience.

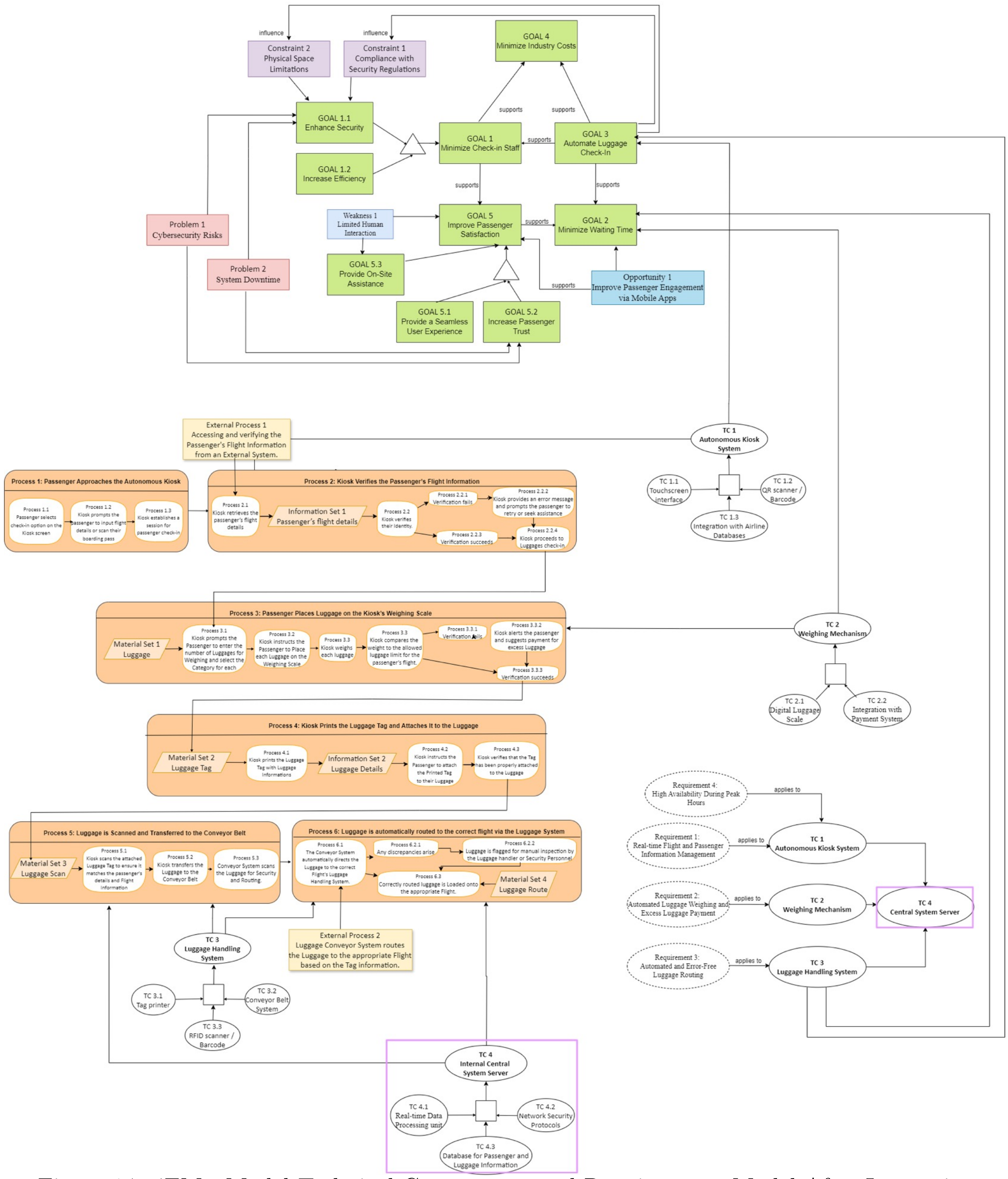

Figure 14: 4EM - Model Technical Components and Requirements Model After Innovation

6.2 ArchiMate - Models

ArchiMate - Technology Layer

This model visualizes the architecture of the autonomous luggage check-in system.
The *Autonomous Kiosk System* collects passenger data, connects to flight information systems, and integrates with other system components.
Luggage details are processed through the *Weighing Mechanism* and *RFID/QR Code Scanner*.
Bags are tagged using the *Luggage Tagging Service* and routed to their respective flights via the *Luggage Handling System* and *Luggage Route Service*.

The decentralized interaction between components ensures efficient luggage processing, even without a central server, while maintaining high reliability.

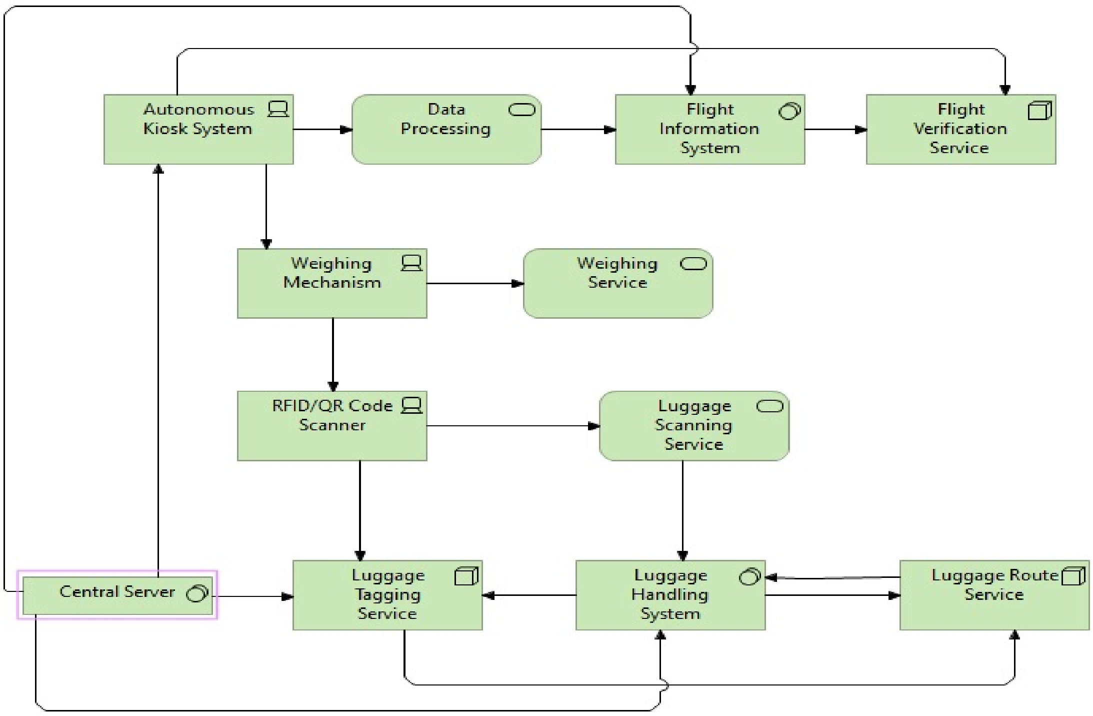

Figure 15: ArchiMate - Sub-Model Technology Layer After Innovation

6.2.1 ArchiMate - Enterprise Model Layer

The ArchiMate model represents a sophisticated enterprise system for logistics or manufacturing, with four layers:
Business Layer
Highlights critical processes such as production, logistics, and quality control, alongside key roles and physical assets.
Application Layer
Facilitates processes with integrated applications, ensuring smooth functionality.
Technology Layer
Showcases the required infrastructure and devices, emphasizing automation and IoT integration.
Data Layer

Depicts data flows and their interactions, focusing on real-time, decentralized operations without dependence on a central server.

This model showcases the integration of data-driven operations and seamless interactions. The forthcoming report will provide detailed insights into the system's components, interactions, technology infrastructure, benefits, and challenges.

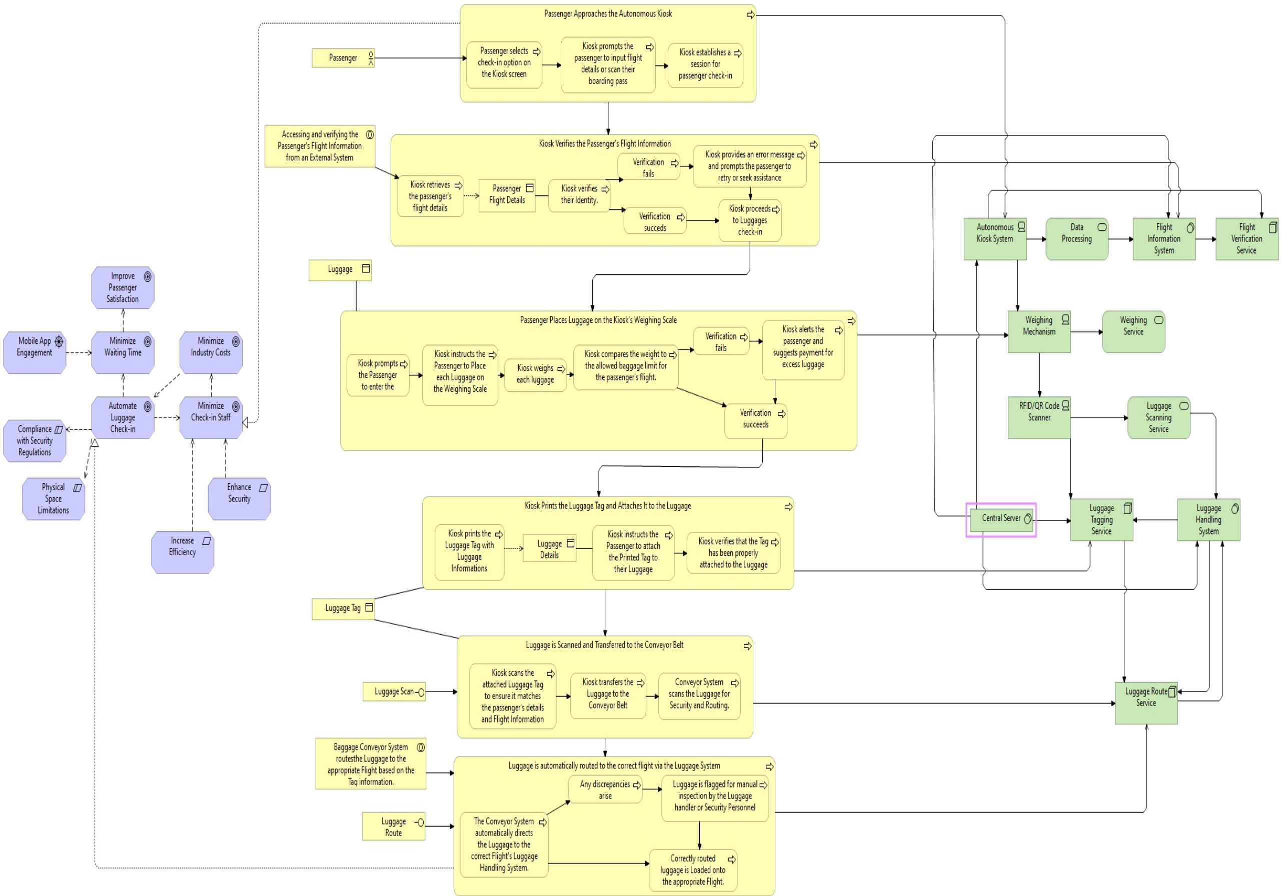

Figure 16: ArchiMate - Model After Innovation

6.3 Relate the Enterprise Model to Enterprise Architecture

Integrating Enterprise Architecture (EA) with the Autonomous Airport Operations model ensures that business processes, technology, and infrastructure function cohesively and effectively. EA provides a structured framework to align business goals with the technology used to achieve them.

Key Parts of the Model in Enterprise Architecture

Business Layer
The business layer in EA represents the organization's goals and processes. In this model, processes such as automated check-in, luggage handling, and payment operations belong to this layer. These aim to improve efficiency, reduce costs, and enhance the passenger experience. For example, automating check-in and luggage handling aligns with the airport's goals of reducing operational costs and increasing passenger satisfaction.

Application Layer
This layer includes the software and systems that support business processes. Components such as the Autonomous Kiosk System, Weighing Mechanism, and Luggage Handling System fit into this layer. These systems work together to automate tasks and ensure coordination. The Internal Central System Server is the core of the application layer, enabling real-time data exchange and smooth operation.

Technology Layer
The technology layer focuses on the physical infrastructure—hardware, networks, and servers—that supports applications. For this model, devices like kiosks, RFID scanners, and servers are key components. This layer ensures efficient data processing and scalability during peak periods. Edge computing enhances performance by processing large data volumes closer to the source, improving speed and reliability.

Data Layer
This layer manages the storage, sharing, and security of data. For the airport model, it involves handling sensitive passenger information, luggage details, and operational data. Security and privacy are critical, with data encrypted and securely stored. Real-time data tracking via RFID ensures smooth operations and minimizes luggage-handling errors.

Connection Between Enterprise Modeling and Enterprise Architecture

Enterprise Modeling (EM) visualizes how business processes and technologies interact, while Enterprise Architecture (EA) provides a structural blueprint to organize and align these elements. The Internal Central System Server serves as a bridge between the business and technology layers, facilitating real-time coordination and smooth data flow.

This model adopts modern EA principles, such as decentralized data processing and cloud computing, to enhance system flexibility and scalability. By automating processes, the model aligns with EA's goal of creating efficient, secure, and adaptive systems.

6.4 Re-evaluate the Model

G: Modeling Goals
The model must holistically address immediate operational needs such as improving efficiency, bolstering security, and enhancing passenger satisfaction. Beyond these immediate goals, it should

prioritize scalability, flexibility, and future-proofing. By incorporating metrics for emerging challenges like sustainability and predictive maintenance, the system ensures alignment with long-term objectives. Goals should actively integrate advancements in AI, IoT, and machine learning to prevent obsolescence. Key performance indicators (KPIs) should be periodically re-evaluated to measure progress and adaptability to future airport operational demands. Failure to plan for technological or regulatory shifts could compromise the system's viability over time.

L: Expressing in the Modeling Language
The modeling language must enable a dual focus on current efficiency and the seamless incorporation of future technologies, such as cloud-based infrastructure, blockchain for luggage tracking, and real-time data analytics. Rigid, overly specific modeling languages risk constraining innovation, whereas flexible tools like ArchiMate and BPMN can offer adaptable frameworks for expressing changes in workflows or system interactions. Additionally, modeling languages should facilitate cross-disciplinary collaboration by using visual elements and simplified interfaces that align with the understanding of diverse stakeholders, including non-technical participants.

M: Model Content
The model should not only detail the current system's architecture but also proactively document potential future-state scenarios. Elements such as autonomous systems for AI-powered security checks and predictive analytics for congestion management should be represented. By anticipating industry trends like green aviation technologies and 5G connectivity, the model can remain relevant over time. Furthermore, ensuring the model captures interoperability standards for integrating third-party systems reduces the risk of lock-in to outdated technologies, improving longevity and adaptability.

A: Actors with Access to the Model
Access should extend beyond current operators to include policy-makers, innovation strategists, and third-party service providers. Broadening stakeholder involvement fosters diverse insights and fosters innovative contributions. Tiered access controls should be implemented to safeguard sensitive data while allowing relevant actors to interact with the model according to their roles. Stakeholders like customer experience managers and cybersecurity experts should be explicitly included to address user-centric and security-focused design aspects, ensuring comprehensive feedback.

D: Domain Representation
The model must encapsulate both the current domain and anticipated technological disruptions. Incorporating trends like edge computing for real-time decision-making and big data analytics for passenger flow optimization ensures its longevity. Additionally, the model should reflect emerging user behaviors, such as contactless interactions and personalized passenger services, which have gained prominence post-pandemic. This dual focus ensures the system remains operationally effective while being adaptable to future innovations or regulatory environments.

K: Domain Knowledge of Participants
Participants must have comprehensive knowledge of both current infrastructure and future-oriented innovations. Regular training and cross-disciplinary workshops ensure all participants are aligned with technological and operational advancements. For instance, staff should understand how to leverage AI-driven insights or IoT sensor data for improved decision-making. Knowledge-sharing practices, such as digital repositories or collaborative platforms, can address any knowledge gaps and keep documentation consistent with best practices and industry standards.

I: Interpretation of the Model by Participants

Participants must interpret the model in a way that aligns with both immediate objectives and long-term strategic goals. Regular stakeholder reviews and simulation exercises help bridge gaps in understanding. Misinterpretations should be addressed through iterative feedback loops and frequent updates to the model's visualization and documentation. The incorporation of real-time dashboards and scenario-testing modules enables participants to see the impact of potential changes, fostering alignment and reducing risks of flawed decision-making.

T: Tools for Model Interpretation

The tools for interpreting the model must support real-time updates, seamless scalability, and integration of predictive capabilities. Advanced platforms like cloud-based modeling suites should enable remote collaboration and instantaneous feedback. Tools should also allow for the incorporation of digital twins to simulating system behavior under different conditions, which is critical for understanding the impact of changes before implementation. AI-powered analytics embedded in the tools can automate the detection of inefficiencies and suggest improvements, ensuring the system remains efficient and secure over time.

7 Reflections

The experience gained in the TDT4252 course is reflected upon, along with consideration of potential alternative approaches to the case study.
Working on the autonomous luggage check-in system was both enriching and challenging. As a newcomer to advanced modeling, I faced a steep learning curve that felt overwhelming at times. Using two modeling languages, 4EM and ArchiMate, added complexity. I found 4EM more intuitive for mapping goals and processes, while ArchiMate provided a structured framework for technical layers. In hindsight, a more balanced use of both could have yielded a clearer and more comprehensive system representation. One consistent challenge was determining the "correctness" of the models, which often felt subjective. Greater proficiency with ArchiMate might have mitigated this uncertainty.

Exploring customer interactions through tools like customer journeys and service blueprints was another steep learning curve. These methods were unfamiliar, and understanding their role in capturing passenger experiences required substantial effort. Limited detail in the course materials on these topics further complicated this process. Despite this, working with these tools enhanced my understanding of the system's functionality from a user-centric perspective. It revealed opportunities for operational improvements while aligning with passenger convenience.

The business modeling phase brought much-needed structure and clarity. Tools like the Business Model Canvas and the flourishing business model provided a broader perspective on how the system could deliver value to stakeholders. While I had some experience with the Business Model Canvas, the flourishing approach's emphasis on sustainability and interconnected systems offered a novel and valuable dimension. This phase required in-depth discussions with the project lead and careful analysis of organizational aspects, which, while challenging, underscored the strategic potential of business modeling in decision-making.

By the time I reached the final model redesign, the process felt far smoother. The earlier phases had built a strong foundation, allowing for seamless integration of enterprise modeling, customer experience design, and business modeling. This final stage demonstrated how the autonomous luggage system could achieve both operational efficiency and enhanced passenger satisfaction, culminating in a cohesive and practical solution.

A recurring challenge throughout the course was synthesizing the extensive syllabus into actionable models. The wide range of materials and concepts demanded significant effort to integrate, but this also deepened my understanding of enterprise architecture frameworks. Applying these frameworks to a real-world problem, such as the autonomous luggage system, highlighted their practical relevance and adaptability.

Reflecting on the case study, I appreciated its focus on innovation and automation in the aviation industry. However, I occasionally considered whether a case study addressing organizational challenges within Start NTNU could have been equally compelling. Such a study might have provided valuable insights into managing complex stakeholder environments and navigating structural challenges. Nevertheless, the autonomous luggage system case offered a focused exploration of technological and operational challenges, and the skills I gained will undoubtedly be useful in addressing broader organizational issues in the future.

Overall, the course was a transformative experience. It equipped me with invaluable tools and perspectives that I am eager to apply to future projects.

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