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Luggage Management System in order to Reduce Carbon Emissions and Ensure Sustainability

Assoc. Prof. Dr. Ceren Cubukcu Cerasi*[1], Furkan Yaman[2]
MIS Department, Gebze Technical University, Gebze, Turkey, ceren.cubukcu@gmail.com
Computer Engineering, Maltepe University, Istanbul, Turkey, furkanyaman319@gmail.com

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Abstract
Air transport is a vital enabler of growth in the economy. It contributes to the economy by supporting trade and tourism. However, air transportation also affects our environment by increasing carbon emissions. Additionally, the use of private vehicles or taxis to access the airport also contributes to carbon emissions. With this study, considering that transportation to the airport has different difficulties in big cities, a mobile system will be developed that offers processes such as airport access, check-in, and luggage delivery in a single module, facilitates the person's transportation process to the airport and aims to protect the environment by directing them to public transportation. The main goal to be achieved with the luggage management software is to direct people's individual transportation to the airport to public transportation and thus, reduce carbon emissions. It is also aimed to automate the check-in process of luggage given to the plane and to reduce the time spent at the airport. Since the main aim of this study is to improve airport luggage handling, a business process improvement (BPM) approach will be adopted. Business process analysis and improvement will be used to identify, analyze, and optimize existing luggage processes. Additionally, user-centered design principles will be applied to add many user interface features to enhance user experience. The systems offering the same service are limited and there is a clear market in this field. The process will be digitized and streamlined. Time lost at the airport is going to be minimized and flight access is going to be facilitated.
Key words: *Baggage free airport, sustainability goals, software development, carbon emissions*

Introduction

Today, air transportation is considered a transportation method of great importance as it strengthens trade and tourism on a global scale (Schäfer, & Waitz, 2014). This form of transportation is highly preferred because it offers significant advantages to passengers in terms of speed, comfort, and accessibility, and therefore the total number of passengers worldwide exceeded 6.6 billion in 2022 (ACI World confirms top 20 busiest airports worldwide, 2023). The development of air transportation activities has caused this industry to contribute a lot of carbon emissions to the environment (Ma, Wang, Sun, Liu, & Li, 2018; Sgouridis, Bonnefoy, & Hansman, 2011). On the other hand, the airport has an important role in the economic growth of the country and is the driving factor of area development, especially the area around the airport (Nedeva, & Genchev, 2018; Baltaci, Sekmen, & Akbulut, 2015). The functions of the airport will be fulfilled properly if it is supported by adequate infrastructure. One of the infrastructures that must be put in place is that access to the airport must be easy and sufficient. Access to the airport must be capable of supporting the continuation of activities at the airport (Sari, Hasibuan, & Azwar, 2021). Many studies have been conducted revealing the access preferences of passengers and employees to the airport. According to these studies, private vehicles or taxis are most preferred to access the airport. This increases carbon emissions (Sari, Hasibuan, & Azwar, 2021, Chang, 2013; Chebli, & Mahmassani, 2003; Psaraki, & Abacoumkin, 2002; Gupta, Vovsha, & Donnelly, R., 2008).

While air transportation plays a crucial role in fostering economic growth through its support of trade and tourism, it presents a series of challenges that necessitate innovative solutions. One prominent issue is the environmental impact, as air transportation significantly contributes to carbon emissions, contributing to climate change. Additionally, the mode of transportation to and from airports, often reliant on private cars or taxis, further exacerbates the carbon footprint associated with air travel. Moreover, passengers routinely face the cumbersome task of managing their luggage, dealing with issues such as lost baggage, delays, and the physical strain of transporting belongings through crowded airports. Even if every other aspect of the trip was flawless, mishandled luggage upon arrival might negatively impact the overall experience of the traveler

* Kontaktinis asmuo / Corresponding author

(Singh, 2023). All of these challenges underscore the need for a comprehensive solution that not only enhances the efficiency and convenience of air travel but also addresses its environmental implications.

The aim of the innovative travel system is to redefine the travel experience, providing users with a hassle-free journey by eliminating the need to carry their own luggage so that there will be a switch from individual passenger transportation to public transportation to travel to the airport, hence lowering carbon emissions. Additionally, it aims to save travel times at the airport by automating the process of checking in bags delivered to the aircraft. Overall, the study focuses on efficient luggage management, carbon footprint reduction, streamlined airport processes, and a user-friendly interface. In the following section, literature review will be discussed. Then, methods will be explained. Afterwards, system development will be examined and finally, conclusions will be stated.

Literature Review

The quality of a passenger's travel is significantly influenced by the baggage handling system at airports. The least amount of time that can elapse between checking in baggage and the flight's departure, as well as the amount of time needed to move passengers' bags after they arrive, determine this characteristic. The baggage handling system’s capacity and dependability have an impact on each of these times (Lodewijks, Cao, Zhao, & Zhang, 2021).

There are several studies examining the baggage handling system at airports. Ekeocha and Ushe (2018) examine various baggage styles and how they are used in the baggage handling line, which is utilized by several airlines. The recommended methodology keeps total baggage handling system performance within an acceptable range while minimizing imbalances for the airlines sharing the baggage handling collection conveyor (Ekeocha, & Ushe, 2018). Frey et al. (2017) consider the organization and timing of incoming luggage that travelers retrieve from the baggage claim area. The study suggests a hybrid heuristic strategy that combines a guided rapid local search, path relinking, and a greedy randomized adaptive search procedure because the inbound baggage handling problem turns out to be NP-hard (Frey, Kiermaier, & Kolisch, 2017). In another study implemented by Hafilah et al. (2017), they use a colored petri net to handle more than 20,000 bags every day as part of a large airport's BHTS modeling and simulation (Hafilah, Radja, Rakoto-Ravalontsalama, & Lafdail, 2017). Barth et al. (2021) examines how the transfer passengers’ bags are handled at airports. Assigning each arriving aircraft's bags to an infeed area—from which a system of conveyor belts will transport them to the corresponding outgoing flight—is the transfer baggage problem. Its primary goal is to reduce the quantity of bags that are missing (Barth, Holm, Larsen, & Pisinger, 2021). A comprehensive discrete event model of the inbound luggage handling process for a sizable provincial airport in Italy is shown in the study of Malandri et al. (2018).

In the study of Johstone et al. (2015), they describe the inquiry into the design and control of conveyor-based baggage handling system merging bottlenecks, including the impact of the physical layout of the merger and the merging control algorithm. In the study of Rijsenbrij and Ottjes (2007), a prototype for a partially automated truck for loading and unloading baggage as well as an alternate scheduling and transit approach were examined using simulation. A baggage handling system microscopic simulation model that completely incorporates all baggage-related subsystems is shown in the study of Cavada et al. (2017). Arrival of passengers at check-in desks, baggage check-in, security checks, sorting, transportation to the aircraft, and loading are some of these. In order to reduce mishandled luggage and ultimately make passengers happy when their bags arrive, Singh (2023) discusses the need for a significant innovation in baggage handling. Airport baggage management systems that are contactless are important, according to Agarwal et al. (2023) The baggage handling management systems (BHMS) in use today are quite prone to errors. Using the power of computers, the study's proposed solution guarantees Covid safety and improves the current BHMS. Using its software, a ground-breaking concept aims to do away with the need for

* Kontaktinis asmuo / Corresponding author

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airport employees to assist with a passenger's check-in. The authors have created a system that generates a distinct QR code at each checkpoint, maintaining security and enabling each traveler to verify the details of their luggage four times. In order to make sure that the items are arranged effectively and optimally inside the luggage compartment, they also created the luggage sorting knapsack algorithm (Agarwal et al., 2023). Kaburagi and Aihara (2023) analyzed the influence of luggage on tourists. The findings showed that different limitations, including those related to physical limits, location, time, and transportation, can have an impact on tourists' actions when they are carrying luggage. As a result, having luggage may limit one's options for lodging and activities in addition to their range of motion. Jiang et al. (2022) emphasizes that baggage free airport terminals are the solution for the goal of sustainable airports. In their study, in order to lessen the strain on airport staff and encourage travelers to use public transport to get to airport terminals, they transfer the luggage operation out of the passenger terminals. They thus claim that it will have a substantial effect on energy and the environment, resulting in a decrease in fuel consumption and a reduction in carbon emissions. In order to create baggage-free airport terminals, this article investigates a baggage collection network design challenge utilizing augmented reality and vehicle routing algorithms (Jiang et al., 2022). This article focuses on the logistics hub and planning vehicle routes whereas our article focuses on the software development of the luggage delivery and management system to ease access to one's transportation to the airport.

Methods

This study explains the development of a luggage delivery and management system to ease access to individual's transportation to the airport. In the Level 0 Data Flowchart shown below in Figure 1, the user initiates the flight check-in process, generating a request from the system. Airport check-in and security procedures are completed, and upon successful completion, a notification is sent to the user via email or SMS to confirm the successful completion of the process.

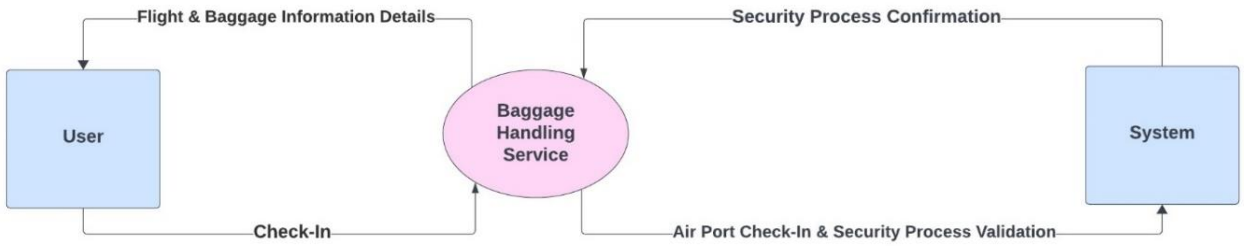

Fig. 1. *Level 0- Data Flowchart*

The mobile and web system developed offers processes such as airport access, check-in, and luggage delivery in a single module, enables the person's transportation process to the airport and aims to protect the environment by directing them to public transportation. The overview of the system is explained using Level 1 Data Flowchart which can be seen below in Figure 2.

According to Figure 2 above, the following functional (F) and non-functional (NF) features will be available in the system.

I. User Account and Profile. Sign-up and Login: Users should be able to create an account and log in securely using email, password, or social media integration. (F1)

Profile Management: Users should be able to edit their profile information including name, contact details, passport information, and travel preferences. (F2)

Flight Booking and Management: Users should be able to search, book, and manage their flights directly within the app. This includes viewing flight details, uploading booking details, changing seats, and cancelling bookings. (F3)

* Kontaktinis asmuo / Corresponding author

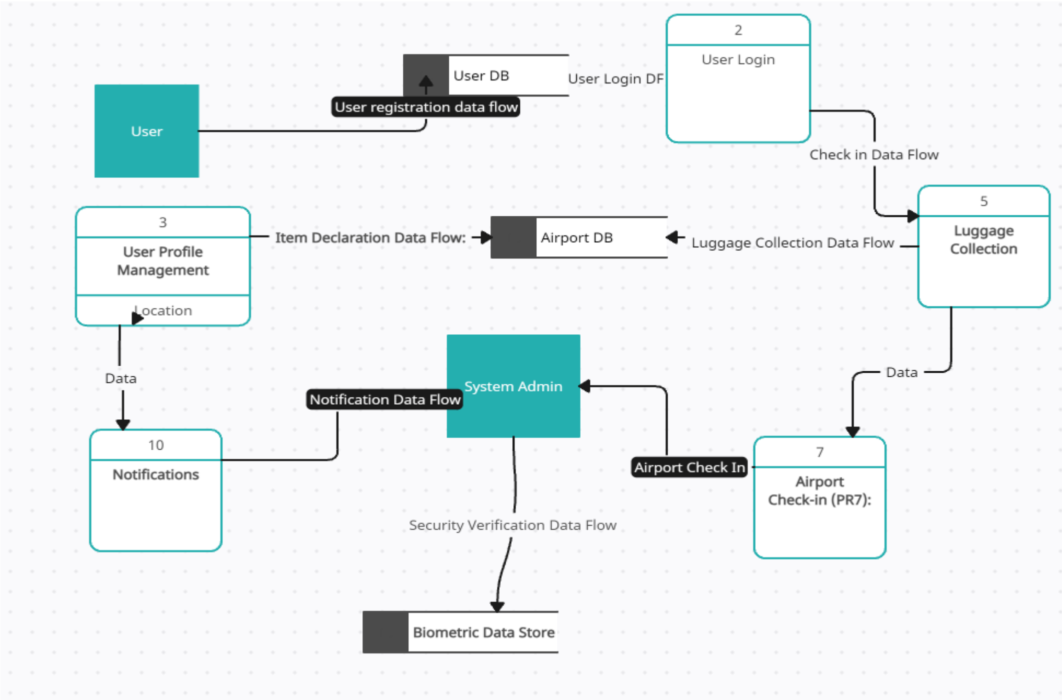

Fig. 2. *Level 1- Data Flowchart*

II. Luggage Handling and Tracking. Booking Luggage Collection: Users should be able to specify collection points and dates/times for their luggage, including options for oversized items. (F4)

Real-time Baggage Tracking: Users should be able to track the real-time location and status of their luggage throughout the journey, from collection to delivery. (F5)

Delivery Notification: Users should receive notifications when their luggage arrives at the destination airport or is delivered to their final address. (F6)

III. Airport Check-in and Security. Mobile Check-in: Users should be able to check in for their flights directly within the app, bypassing the need for traditional airport kiosks. (F7)

Passport Verification: Integrate passport scanning functionality for secure and efficient verification at the airport. (F8)

Item Declaration: Allow users to easily declare the contents of their luggage through a digital form, ensuring compliance with regulations. (F9)

IV. User Interface and Experience. Intuitive Interface: Both the back office and user-side interfaces should be user-friendly and intuitive, with clear navigation and minimal steps to complete tasks. (F10)

Multi-language Support: Support multiple languages to cater to a global audience. (NF1)

Accessibility Features: Ensure the system is accessible to users with disabilities, including screen reader compatibility and text-to-speech options. (NF2)

Push Notifications: Send timely notifications to users regarding flight updates, luggage status, and other relevant information. (F11)

V. Additional Features. Public Transportation Integration: Integrate real-time public transportation information and booking options to encourage eco-friendly travel. (NF3)

Travel Insurance: Offer optional travel insurance plans within the app for added peace of mind. (NF4)

In-app Chat Support: Provide a chat support feature within the app for users to get help quickly and easily or ask questions. (NF5)

Loyalty Program: Implement a loyalty program to reward frequent users with discounts or exclusive benefits. (NF6)

* Kontaktinis asmuo / Corresponding author

Admin Support: Make a panel for administrators. The admins can take any action they can. They can change and modify the status of every luggage. The admins can monitor and see every action a luggage can take (NF7).

Logical Data Model. The logical data model of the system is shown below in Figure 3. According to this model, there are 3 tables in the diagram: Luggages, flights and customers tables.

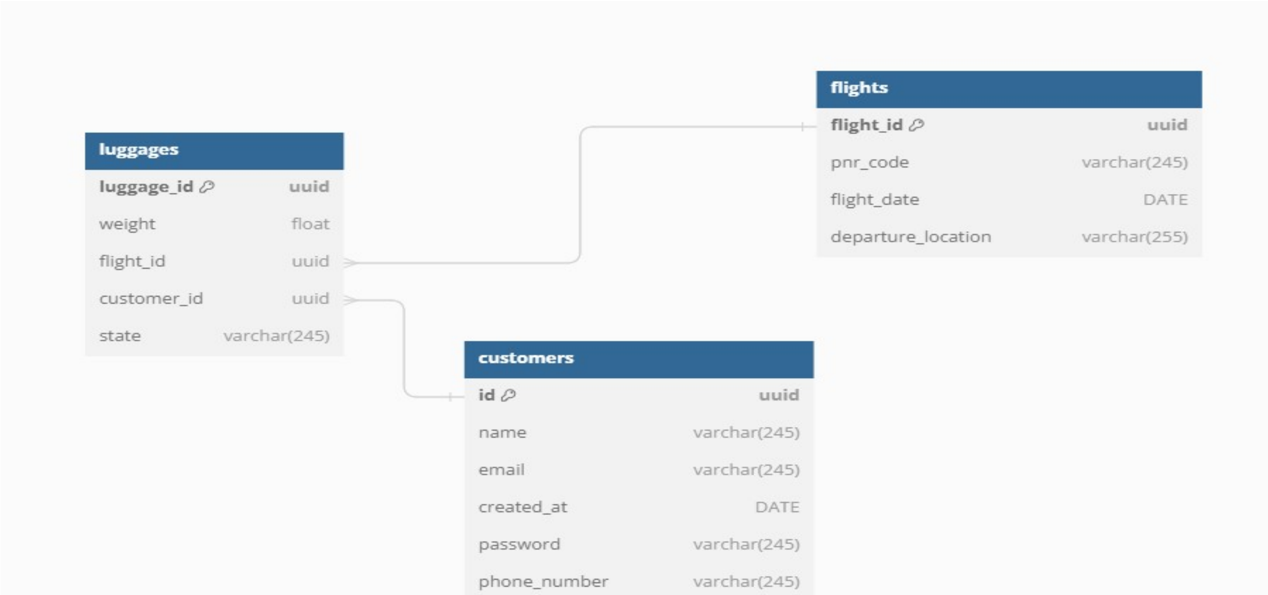

Fig. 3. *Logical Data Model*

The relationships between the tables according to Figure 3 are as follows:

- The luggages table has foreign keys referencing the flight_id and customer_id in the flights and customers tables, respectively. This means that each piece of luggage is associated with a specific flight and customer.
- The flights' table has a one-to-many relationship with the luggages table. This means that each flight can have multiple pieces of luggage associated with it.
- The customers table also has a one-to-many relationship with the luggages table. This means that each customer can have multiple pieces of luggage associated with them.

Development of the System

The backend of the system empowers customers to seamlessly manage their travel experiences through database functionality. Users can effortlessly create and view their flights, monitor the real-time status of their baggage, and complete check-in procedures with a single click. Leveraging a robust database system, customers enjoy the flexibility of instantaneously tracking the progress of their luggage.

The front end of the system has a responsive and user-friendly interface. The micro frontend system has been used in the system. It allows users to create and view their flights via card components. Furthermore, users can monitor real-time baggage status, and complete check-in procedures using the web system, or their mobile system. Users will check the status change of the luggage by e-mail. The system will be an intuitive design integration for a seamless user experience.

The study adopts a microservices architecture, enhancing modularity and flexibility in managing various aspects of luggage handling and user interactions. The user interface comprises two sides: A back office for staff managing operations and a user-side for a seamless and intuitive experience.

* Kontaktinis asmuo / Corresponding author

High Level Design.1. User Interface:

Frontend (User Side): Developed using React.js for a responsive and user-friendly interface. Allows users to create and view their flights, monitor real-time baggage status, and complete check-in procedures. Integration of intuitive design for a seamless user experience.

Frontend (Backoffice): Empowers staff to manage operations efficiently. Provides an interface for staff to oversee luggage handling, check-in procedures, and overall system status.

2. Backend:

Backend (User Side): Developed using Kotlin to ensure a robust and scalable backend. Implements database functionality to enable users to manage their travel experience. Enables real-time tracking of luggage progress and facilitates check-in procedures with a single click.

Backend (Backoffice): Supports staff in managing various aspects of luggage handling and user interactions. Interfaces with microservices to gather and display relevant operational information. Ensures data consistency and security.

3. Microservices Architecture: Microservices are employed to enhance modularity and flexibility. Different microservices handle distinct functionalities:

Luggage Collection Microservice: Manages the collection points and coordinates the collection team.

Airport Check-In Microservice: Handles PNR verification and check-in procedures at the airport.

Environmental Impact Microservice: Promotes eco-friendly travel by encouraging public transportation.

Security Microservice: Incorporates passport verification and item declaration functionalities.

Table 1 below shows the requirements of this system. React programming language is preferred to develop the frontend and Kotlin is preferred to develop the backend.

Table 1. *Project Requirements*

Backend:	Kotlin
Frontend:	React.js
Database:	Integrated with a robust database system for efficient data management using PostgreSQL,MongoDB .
Microservices:	Developed independently, communicating through APIs.

Use-Case Scenarios. Use Case 1: The actor is the user.

Use Case Description: User / Users can register for the system with the required information. Users enter their personal information which they will use in the transactions (F1). A registration error may show up if the process is unsuccessful. The system will be able to check the registered user information of each user who has been registered (F2). The user will be able to login via the login page (F1). The user will be able to upload necessary documents if they booked a flight already (F3). The PNR for the luggage will be uploaded to the system by the user. If they didn't already have booked a flight, after the log in phase, the user should book a flight in the book flight page (F3). After they book their flight, users should fill in the luggage form (F4). The user will be able to track their own luggage (F5) and receive notifications about its delivery (F6). The use-case diagram is shown below in Figure 4.

Use Case 1 ->

-> Step a -> Functional requirement F1; Functional requirement F2; Functional requirement F3.

-> Step b -> Functional requirement F4; Functional requirement F5; Functional requirement F6.

* Kontaktinis asmuo / Corresponding author

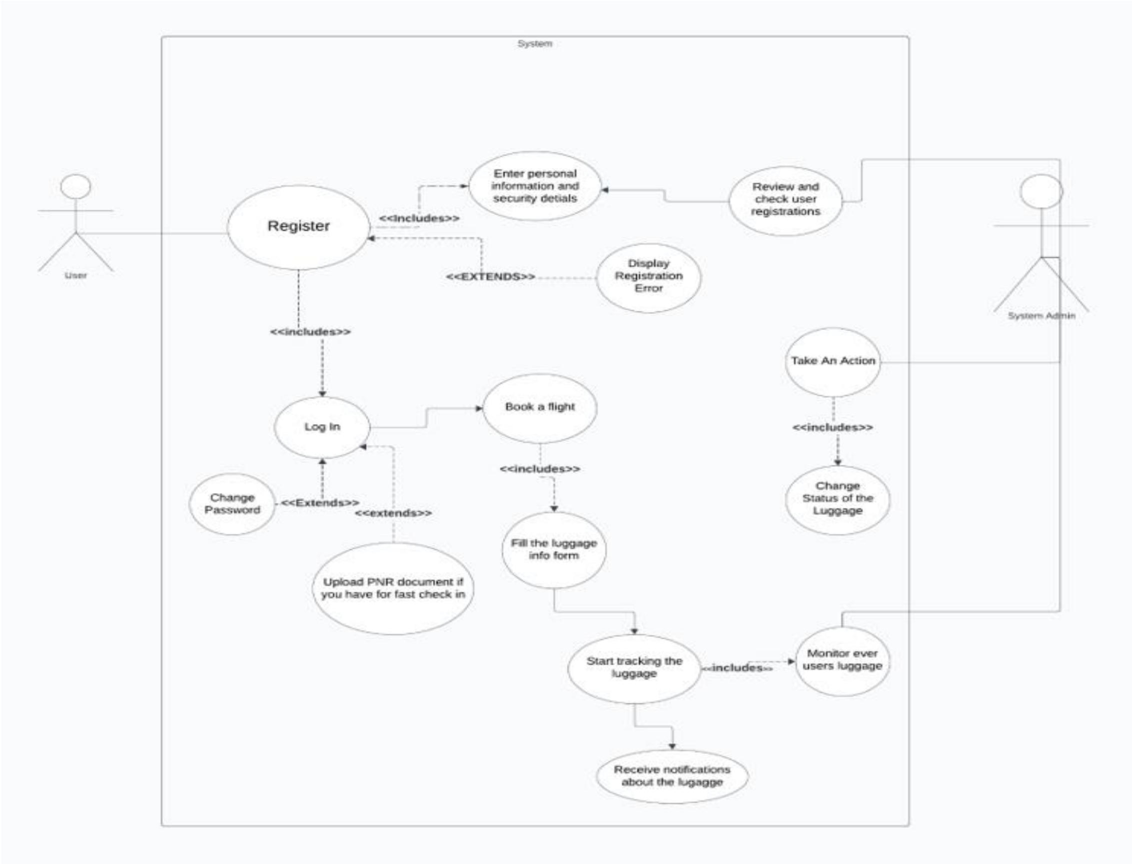

Fig. 4. *Use-Case Diagram*

Use Case 2: The actor is the admin. The admins can take any action they can. They can change and modify the status of every luggage. The admins can monitor and see every action a luggage can take (NF7). The use-case diagram is shown above in Figure 4.
Use Case 2 ->
-> Step a -> Functional requirement NF7.

Conclusions

Air travel offers a number of difficulties that call for creative solutions, even if it is vital for promoting trade and tourism and thus economic progress. The environmental impact is a major concern since air travel produces a large amount of carbon emissions, which fuels climate change. Baggage free airport terminals are the solution for the goal of sustainable airports. Therefore, this study focuses on developing a system for luggage management software to direct people's individual transportation to the airport to public transportation and thus, reduce carbon emissions.

Users initiate their travel plans through the user interface, creating and managing flights. Luggage is collected seamlessly at designated points. At the airport, staff perform PNR verification and check-in procedures. Users are encouraged to contribute to carbon footprint reduction through the environmental impact microservice. Robust security measures ensure a safe and transparent travel experience. Limitations of this study are that only the system is developed and the effects of this system on users and airports are not measured. Feature studies may measure these effects and compare the results with sustainability goals. Also, there may be security threats and violations. Airport security protocols should be reviewed regularly, and the system updated accordingly. Identity and passport control processes should be made more stringent by using artificial intelligence. Security awareness should be raised by increasing personnel training. Furthermore, there may be a lack of operational capacity. Automation and technological improvements should be

* Kontaktinis asmuo / Corresponding author

made to speed up processes. The infrastructure used should be developed and load tests should be carried out at regular intervals. Future studies may also look into these issues.

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* Kontaktinis asmuo / Corresponding author