MACROSCOPIC MODELING OF A LUGGAGE STREAM IN AN AIRPORT TERMINAL

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Abstract

In the course of today's globalization, mobility becomes an increasingly important factor. To ensure this mobility, a fast and efficient traffic management is of the essence. Because of the increasing travel distances and the tight time frames, the airports are rapidly gaining customers. This contribution aims to model the dispatching of luggage at the airport, to assess possible improvements of the workflow, so as to increase efficiency of available resources and improve customer satisfaction, allowing the airport to run more profitably. The observations are intended to represent an abstract, general airport, at some points however, references to the airport Hamburg will be made. The workflows will be modeled as UML activity diagrams. Designing such traffic models is of use, when analysis in the actual environment is not possible, because of the complexity and / or disruptions in the flow of work are not permissible, like in the case of an airport. The ultimate goal of these activity diagrams is to lay the foundation for future development of executable models, in order to allow forecasts of future traffic situations affected by structural alteration, expansion measures or social changes, with different scenarios, and identify their bottlenecks to plan ahead and find possible solutions accounting for them.

Keywords: Model, Airport, Workflow, Luggage, Traffic.

Presenting Author's biography

Marc Widemann. He achieved his diploma in 2009 in computer science at the University of Hamburg, where he is now working in the department for technical informatics systems as a scientific employee and Ph. D. student. On the basis of the experience collected during his master thesis in the field of optimization and workflow management at the airport, he has done more research in this context, as seen in this article and other publications (see e.g. [1], [2] and [3]).

1 Introduction

Because of the high density of population in most European countries, the possibilities to develop and extend urban infrastructure are slim at best. Especially in reference to regulations based on those limitations, it is very hard to expand big in-plant properties like airports. The key to increase cost-effectiveness with those restricted resources, is to optimize the efficiency of capacity utilization[4]. Due to the suboptimal use of available resources, the danger exists for a lot of medium scaled airports like the Hamburg airport, to become a bottleneck in the current air traffic system. As up to date economic reports of the airlines suggest, the future growth of the air traffic will affect exactly these type of airports[5]. The airport Hamburg for example, has welcomed 2,1 millions more passengers between 2005 and 2008. The number of air connections is on the rise too: in 2008 Hamburg counted 172 000 connections, 4 000 more than in 2005[6]. To handle this kind of passenger traffic, the airport management has to grow more effective. Therefore the optimization of workflows like the departure and arrival procedures of passengers and their luggage are of the essence. To increase satisfaction of the airlines and the passengers using the airport, the luggage handling process has to happen securely and swiftly, with regard for resource consumption, which can not exceed a certain threshold, like too many luggage cars would cause traffic jams on the turnaround and cause a dent in the luggage handling companies business volume due to high fuel and personnel costs. The path to this goal can be identified by examining current and forecasting future bottlenecks in the luggage handling workflow and planning ahead to avoid them with the resources at hand. To grasp the whole functionality of the system used to handle luggage, creating models of the luggage handling processes of today's airports is necessary. The first step of this undertaking are activity diagrams, so as to lay the foundation for more sophisticated models, allowing the application of different variables like less flights or more passenger and aggregating those into scenarios, describing more global circumstances like the outburst of a volcano preventing the planes to leave and amassing passengers in the airports.

In the following, the processes of dispatching luggage during the departure and the arrival of a passenger at an airport will be described in natural language. Afterwards, the implementation of these processes in UML activity diagrams, derived from the descriptions, will be presented. After analyzing the steps in the workflow those models are describing, a summary and outlook showing the use of the information the models are providing will then conclude this article.

2 Luggage handling

2.1 Departure

A departing passenger has the possibility to hand his luggage over at the check-in counter or the luggage office. In both cases, standard and bulky luggage are differentiated. Standard luggage has to fulfill specific criteria to be safely transportable on belt conveyors; certain dimensions have been established which may vary from airport to airport[7]. Furthermore, two security concepts adopted world wide must be considered during dispatch[7]:

- Baggage Reconciliation Concept: no piece of luggage is to be found on board of a plane, when its holder is not present too.
- Hold Baggage Screening: each piece of luggage undergoes a screening to detect potential threats.

The conveyor belts usually work as follows. At the check-in counter, the passenger deposits his luggage. At first it stands on the weighing belt. The employees check if it is a standard luggage piece. Should the aforementioned dimensions match, the luggage changes to the label belt, and afterwards to the waiting belt. It resides there until a place on the discharge conveyor gets free. From there the luggage is transported to the luggage sorting. Before getting sorted, the luggage gets screened automatically by a x-ray machine for security reasons. Suspicious baggage gets separated from the safe pieces and is tested manually with the help of another x-ray machine more accurately. Should the airport employees still deem the contents of the baggage piece suspicious, it is opened and searched by hand. The manual luggage sorting works with a choice of two systems, one with container and one without. In airports where a system is in place that works without the containers, the luggage pieces are either transported over belt conveyors or chutes to the airport employees sorting and loading them according to their label onto the luggage cars. The third alternative alternative are automatic push systems. These identify the luggage with the help of their label and push them automatically onto right chute or conveyor, so the employees only need to load them onto the cars without further inspection. The luggage cars either transport the baggage loosely or with the help of special aircraft containers called unit load devices, which allows the employees to load the whole container onto the plane in one work step, as compared to the loose baggage, which needs to be dropped into the plane's cargo by hand. Before being driven to the plane, the luggage is possibly sorted according to passenger classes or transfer luggage, meaning that first class passengers and passengers on a transfer flight will usually get their luggage sooner. Bulky luggage can not be transported automatically over the belt conveyor. Usually it gets transmitted by the airport staff to a separate luggage office, where the transport to the luggage car is done manually by the employees. The luggage sorting with containers works slightly differently. Each luggage piece is put into a separate container which is conveyed independently over the belt network to the luggage cars. Labels on the containers are scanned at different key points in the belt conveyor to route the containers correctly to their extraction point, where employees load the luggage from the containers onto the luggage car. Although this system is far less prone to sorting errors, it is also more expensive for the airport who chooses to adopt this system.

2.2 Arrival

After the airplane has reached its park position, the luggage release starts. Loose baggage pieces are collected on the luggage cars and transported to the terminal. From the collecting point for all the luggage at the terminal, usually in the basement, the luggage is further processed. Standard luggage is dropped on the radial belt for the passenger to collect. The transfer luggage is identified by it's label and dropped on the belt conveyors of the airport to reach it's next flight. Bulky luggage needs to be taken care of manually as usual.

3 Model implementation

3.1 System specification

To examine this workflow, the system must be abstracted further in terms of simplicity, to create a general concept of the luggage handling workflow at an airport. The workflow of the departure starts with the arrival of the passenger at the terminal and ends with the plane dispatching. In the case of arrivals, the process starts with the plane dispatching and end with the passenger leaving the terminal. Outside influences like flight delays are not being accounted for due the time constraints of this work.

To fall back on realistic data, the airport Hamburg is used as a guideline. It is the fifth biggest airport in Germany, has a capacity of 16 million passengers a year, with 220 flights departing and arriving each day[8].

3.2 Model design

UML activity diagrams were used as a method to create the models in Fig. 2, 3 and 4. They are ideal to describe workflows and to represent time consuming activities as it is the case with luggage dispatching.

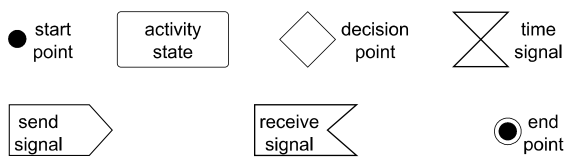

Fig. 1 Legend

An alternative would have been to use event-driven process chains, but they lack the formality of UML activity diagrams and thus make later implementations in more advanced languages difficult. Activity diagrams are used to execute sequentially several actions. To represent the interactions with other processes, the notation elements for send and receive signals are used. As soon as a signal is sent, the action described in the element counts as completed and the control flow of the process continues. The counter piece to the signal sender is the signal receiver; should the control flow reach a signal receiver, processing is paused until a signal is indeed received. These mechanisms are well suited, allowing to model the interdependencies of the processes modeled in this paper and [9]. With the help of time signals it is also possible to pause the control flow of the process. But the processing is not paused until a signal arrives or is sent, but after a certain period of time elapses.

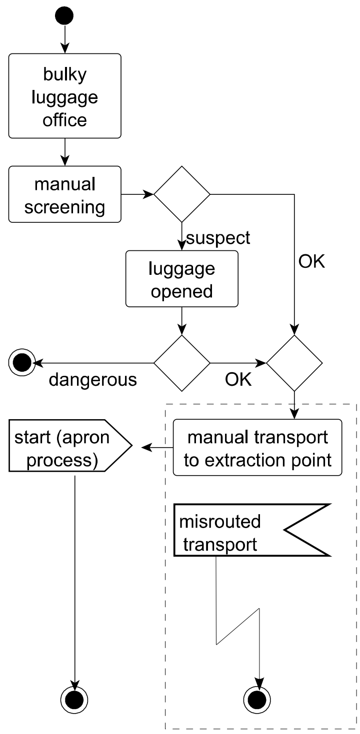

Fig. 2 Bulky luggage departure

This way time consuming activities can be modeled, like waiting for free space on the sorting belt. The symbols used in this article are all depicted in Fig. 1. Also, a detailed explanation of the UML notation can be found in [10].

Design limitations of UML activity diagrams are the lack of possibilities to define the described process more accurately, like the number of belts or luggage cars available, or how the relation of standard luggage to bulky luggage is, to predict a higher workload for the personnel. Such data can only be integrated into the models if they are implemented by a higher modeling language like Mathworks Matlab Simulink. But the models shown here represent the corner stone for those higher models.

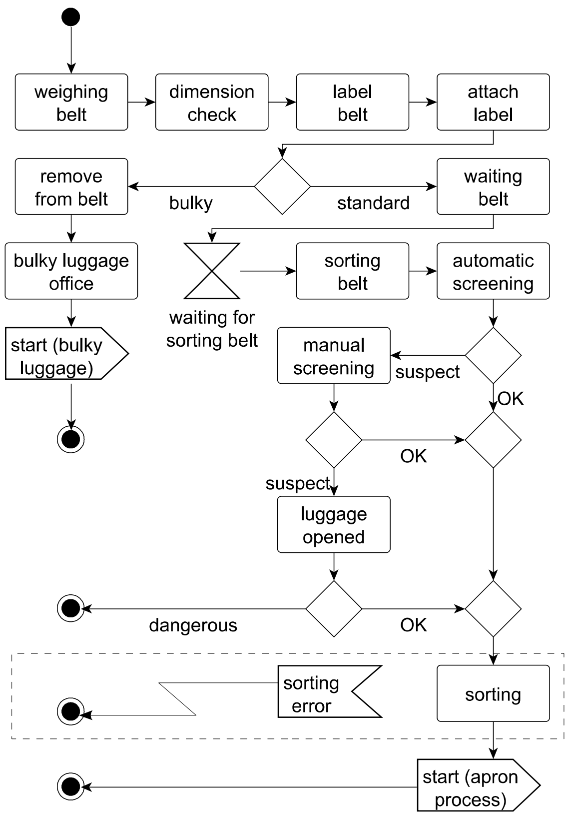

Fig. 3 Standard luggage departure

The diagrams shown here basically represent the same work flow as described in Section 2. Each model, i.e. one for the luggage departure and one for the arrival represents the process linked to a single luggage piece and has thus to be iterated for each piece. Fig. 2 represents how the bulky luggage is being handled. The process is integrated into the luggage departure process started in Fig. 3 and will be executed by the signal sender "start (bulky luggage)" until completion, except under two conditions:

1) If a luggage piece is deemed dangerous after inspection
2) Or during the interruptible activity region where the luggage is manually transported to the extraction point; should the luggage piece be misrouted, a "misrouted transport" interrupt is received and the process ends there. A complicated process to find the luggage piece's original destination is started, but was not integrated into the model to honor the original principle of simplicity and due to time constraints.

The handling of standard luggage seen in Fig. 3 has exactly four ways to complete:

1) If the luggage piece is deemed bulky, the bulky luggage process presented in Fig. 2 is started.
2) As in the bulky luggage process, should the luggage piece be deemed dangerous after it has been opened, the process ends. The airport calls the local authorities and restrains the passenger until they arrive. Again, this process was not integrated into the model to honor the original principle of simplicity and due to time constraints.
3) Here also, an interruptible activity region exists that may end the process prematurely. If the luggage piece is sorted correctly, the process continues by sending a signal to begin the apron process. Should however a "sorting error" interrupt be received, the process ends. The result is the same as in the model for bulky luggage when luggage gets misrouted.
4) Should none of the above eventualities occur, the process is executed in it's completeness.

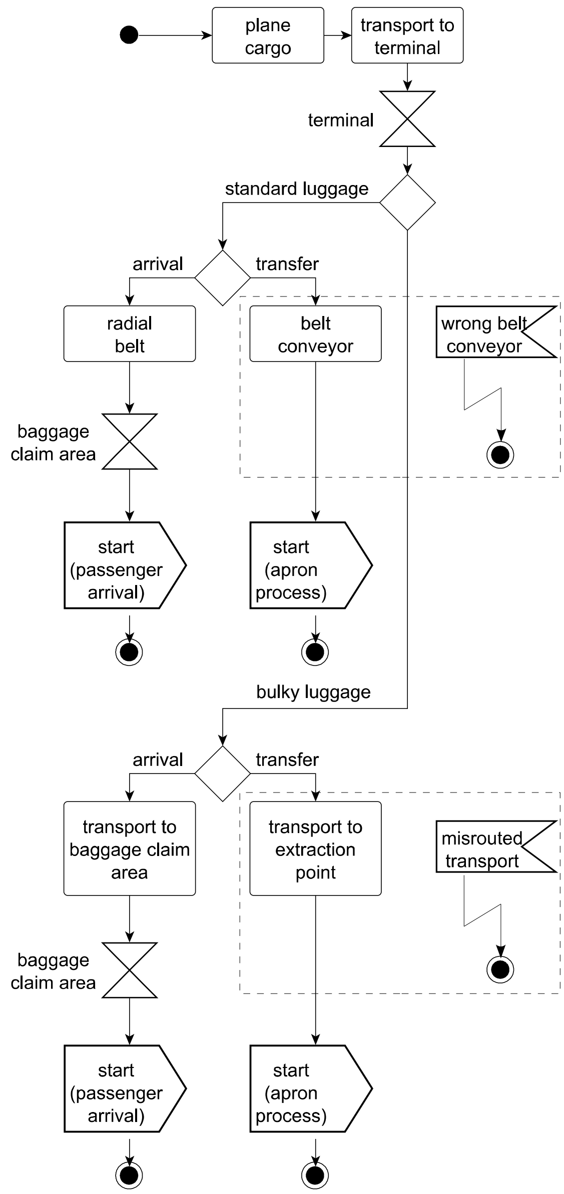

Fig. 4 Luggage arrival

Fig. 4 shows the process the arriving luggage is involved in. This process is linked with the process of arriving passengers as soon as the luggage is on the baggage claim area, which is explained further in [9]. Basically the passenger leaves the plane to enter the terminal to reach the baggage claim area either by a finger should the plane be near a gate, or by bus if the plane stops on an apron position. For transfer luggage, which is sent to connecting flights after the planes arrival, interrupt conditions similar to the luggage departure exist:

1) For standard transfer luggage, the luggage pieces are allocated by the personnel to their corresponding belt conveyors to dispatch them to the correct extraction points. The belt conveyor action is in a interruptible activity region, as the possibility subsists that some baggage pieces may be dropped on the wrong belt conveyor, dispatching them to incorrect flights, thus ending the process.
2) For bulky transfer luggage, the luggage is manually transported to the extraction point. As usual, should the luggage piece be misrouted, a “misrouted transport” interrupt is received and the process ends.

Otherwise, the process is completed after starting the apron process shown in Fig. 5. Every process presented here uses this process at the very end of their respective diagram. A signal sender was used to call the process modeled in a separate diagram to make the main processes of arriving and departing luggage more slender. It was modeled to describe the way of the luggage pieces from the extraction point to the cargo of the plane.

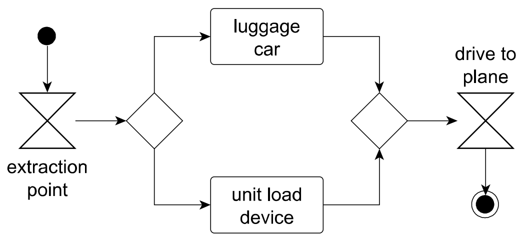

Fig. 5 Apron process

4 Performance analysis

The luggage and passenger handling are two of the most important services of an airport, besides other services like catering refueling and therefore represent a competitive factor of the airport business. The handling has to perform swiftly and dependably. Operational malfunctions often bring forth heavy economic damage in a short amount of time. In 2008, the airport London-Heathrow for example, suffered a big image loss because of non functioning luggage handling. After the opening of a new terminal, technical difficulties hit the conveyor belt. The airline company British Airways had to cancel multiple hundreds of flights and thousands of baggage pieces had to be stored for days at the airport[11]. Besides dependability and security, in all the stages of the luggage handling, the time factor is of the utmost importance. Departing passengers want to check in as late as possible, but the luggage still has to be stored in the plane early enough. The same goes for transfer passengers, who do not want to have to wait long for their connecting flight. Therefore, airports guarantee certain transfer times, like the airport Frankfurt which guarantees a delay of at most 45 minutes[12]. For arriving passengers, the baggage claim area has to be filled swiftly too; most airlines have an agreement with the airport, prompting them to deliver the first baggage pieces to the baggage claim in less then seven minutes, or else the airport has to pay the airline a punitive fee[13]. Another major factor besides the time is the reliability, the misrouting of luggage pieces should Therefore be as low as possible.

One of the contribution's goals is to propose several optimization possibilities based on the UML activity diagrams presented above. The main focus is as mentioned minimizing time consumption of the processes while maximizing reliability.

For the handling of departing standard luggage modeled in Fig. 3, the signal receiver “sorting error” is located in an interruptible activity region, and has the goal to receive a signal as rarely as possible, since it stands for the loss of luggage pieces and the premature end of the process. The time signal “waiting for sorting belt” represents the time a luggage piece has to wait before it can be dropped onto the luggage sorting belt and the process can be continued. This step in the process is actually very dependent of the technical condition of the waiting belt, and how fast it can process the luggage (an average of 1 800 luggage pieces an hour in the airport Hamburg). The number of lost baggage and the time spent waiting to be dropped on the sorting belt can be reduced with the use of luggage sorting with containers, as described in 2.1. However this method is far more costly, and it's cost effectiveness increases with the size of the airport. To define a break even point when this method becomes lucrative is however not the goal of this work.

As in Fig. 3, the handling of departing bulky luggage shown in the model in Fig. 2, has the risk of loosing baggage pieces due to false allocations. Here, the aim is that the signal receiver “misrouted transport” receives a signal as rarely as possible. Due to the constraint that the action to transport the luggage to the extraction point has to be done manually, this activity will be prone to errors. Increased shift change frequency for the employees involved could heighten their concentration and reduce errors though.

Concerning the handling of arriving luggage as seen in Fig. 4, the time of transportation to the terminal is accounted for by the time signal receiver “terminal”.

Afterwards the luggage gets distributed to the baggage claim area. As said before, according to [13] the airport operators already guarantee the airlines certain issue times for the luggage. Due to the punitive fees, the issue times usually are honored, but as can be seen in [2], this process can still be optimized regarding time and resource consumption, cutting costs for the company in charge of the luggage handling.

Finally, the apron process present in all models seen in Fig. 5 has two time signals. The time signal receiver "extraction point" represents the time spent waiting for said extraction by a luggage car. This time is solely depending on the technical factors of the belt conveyors. The second time signal receiver "drive to plane" represents the time spent on the luggage car until it arrives at the plane park position. Possibly setting up express ways on selected sections of the aprons could reduce travel times. Electronic support of this process will also prove beneficial as explained in [2].

5 Summary and Outlook

After having described the processes of handling departing and arriving luggage, this article has used this information to create three models in form of UML activity diagrams. These were used to acquire a basic understanding of the time consuming and error-prone activities within these processes. A few coarse ideas were suggested after analysis of the models, to improve the airport's efficiency and reliability in the luggage handling field. For example introducing electronic sorting of the luggage with the help of containers, or supporting the workflow of the luggage cars electronically. The focus of the analysis was notably to render the process of dispatching luggage faster. But attention should be paid to the fact that cost effectiveness or customer satisfaction are also major factors. The different goals often compete against each other. A global optimum must be found, by weighing the target functions according to the airport operators priorities. These functions and the aforementioned priorities however, are among other things the object of the conversion of these models into higher modeling languages.

To get a complete picture of the processes at an airport, the article [9] explains in the same manner as this contribution, how the workflow concerning passenger handling works, and presents adequate models allowing to achieve a better understanding of these connected processes of handling luggage and passengers. Both papers are based on the bachelor theses of Frahm[14] and Dreyer[15].

The UML activity diagrams designed and presented here to analyze the processes of the luggage handling at the airport will be of future use for the upcoming expansion of this undertaking. In [9], the concepts of the processes concerning the passenger handling were already carried over to the simulation framework of Mathworks Matlab Simulink. It represents a well known and mature commercial tool for simulation and analysis, with a wide array of interfaces to third party applications, thus leaving the door open for further processing of the models. A model is needed where for instance the number of luggage pieces currently in the system can be controlled, or how many belt conveyors and personnel is available to determine capacity utilization, and especially a way to alter those variables to find out how these numbers are linked, to find out possible workflow optimization possibilities. The interested reader may find more in-depth information about Matlab Simulink in [16].

Fig. 6 shows the current results of the conversion from the UML activity diagram of the passenger handling workflow during departures to a working simulation model. The luggage handling processes involved during those departures were integrated in a very rough manner into this conversion, yet the workflow analyzed in this contribution was not implemented in into the model by the time this article was authored and still features the following constraints. Basically, the "Check in" subsystem of the model defines a certain allocation of passengers to check in possibilities with or without luggage declaration. For each passenger who checks in with a baggage piece, the total number of luggage increases and gets carried over through the luggage path to the "Airplane dispatch – Luggage departure". All subsystems and Matlab functions on the luggage path in this model are placeholders designed to convey the above number of total baggage along the system until reaching the end point. The next step for the findings of this article is that they are to be implemented in this model and analogically in the model for arriving passengers. Like in the development of the passenger models, one problem will surely be obtaining valid data on the number of luggage usually flowing trough an airport, or how many employees are dedicated to a certain function, because of the secretive status of a lot of these numbers for the companies involved. Technically, as the conversion was already done with the passenger models, no problems should arise during the implementation of the luggage models in Matlab Simulink.

6 Acknowledgments

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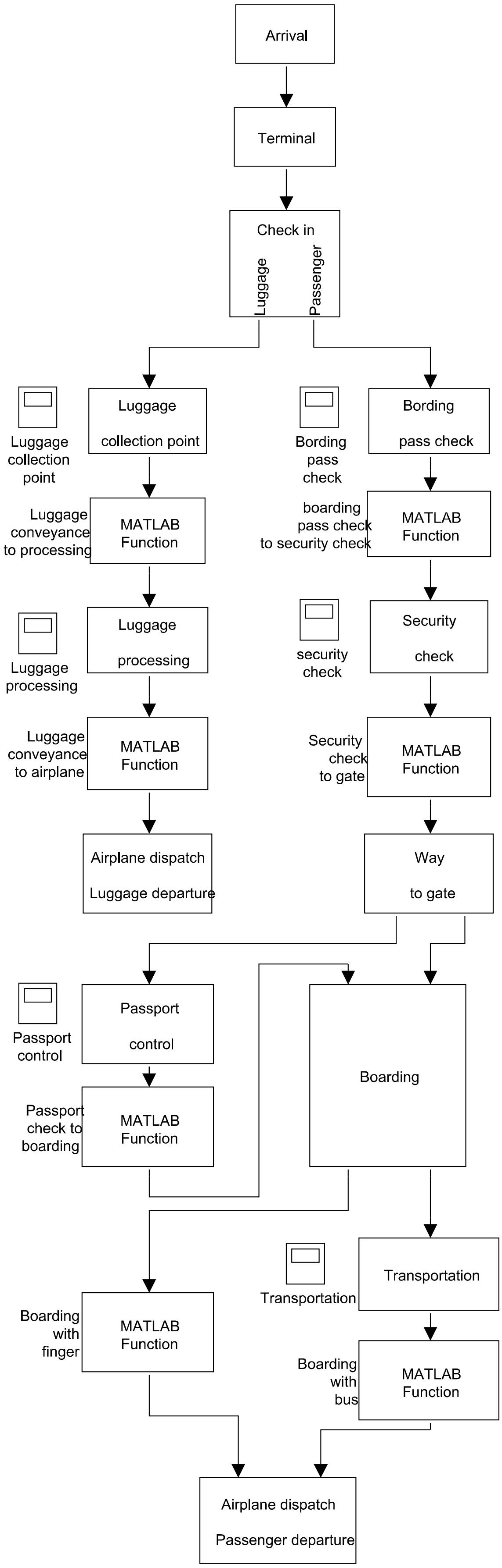

Fig. 6 Matlab Simulink model

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Fig. 6 Matlab Simulink model

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