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A hybrid discrete-event and an agent-based simulation model for assessing the performance of the check-in areas in airports

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Abstract

This manuscript presents a new hybrid microsimulation model of the check-in area based on discrete events and agent-based modelling approaches. The check-in is conceptualised as a process, hence the utilisation of the discrete events approach. The passengers' behaviouristic properties and all spatial characteristics were modelled using the principles of the agent-based modelling. The result is a model that blends the simplicity of the discrete-event approach with the customisation capabilities of the

agent based approach. The model is expected to be used as a decision support tool in the planning and development of check-in areas. The model was deployed in the Airport of Lisbon. Several scenarios, including alternative locations for the self-service check in kiosks and drop-off counters, and organisation of the check-in counters, were tested under different passenger demand conditions. Results evidenced the importance of the location of the kiosks in the terminal and the proximity with the drop-off counters.

*Keywords:*discrete event; agent based modelling; simulation; airport; check-in.

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1. Introduction

The air transport industry has recorded an average growth of above 4% in terms of Revenues Passenger Kilometres (RPK) over the last three decades (Pearce 2014). Additionally, available forecasts are also favourable predicting a growth above 4.5%, in terms of RPK, over the next couples of decades (BOEING 2016).

The rise in passenger demand brought the air transport value chain under increased pressure to maintain performance levels. Airports are no exception and, indeed, the feeling is of deterioration in the service levels (Skytraxn.d.; Travis 2012; Hetter, Katia; Pearson 2016). The check-in process is of relevancy impacting the performance of both airport and airlines (Park &Ahn 2003). By way of example, delays at the check-in may either lead to an increase of no-shows at the boarding gates or delay luggage loading and aircraft handling. It is also aninfluential parameter on passengers' perception of airport's quality of service (SevilOflac, Bengu; OzgeYumurtaci 2014). In a recent

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survey, aimed at evaluating the passengers' stress levels, SITA (2012) concluded that check -in is the third most stressful activity.

Over the recent decades, the check-in process has undergone significantdevelopments, fuelled by the technological advancements, changes in the air transport market (e.g., emergence of low cost carriers) and societal changes (e.g., hyper connected generation) (Experience 2015b; Experience 2016b; Kazda, Antonín; Mrázová 2016; Experience 2014b). On-line check -in, prior arrival at the airport, is gaining popularity and, it is already used by around 57% of passengers (SITA 2016). A trend appreciated by airlines due to inherent economic and performance benefits (Experience 2015a; Experience 2016a). Indeed, they are deploying different promotion strategies. Low-cost companies commonly opt to charge an extra fee for airport check -in. Conversely, full-service companies developed automated self- service check -in kiosks. Passengers are invited or, even, required to use this technology. New check-in concepts are also being created (Experience 2016c): family friendly check-in desks (Experience 2013). Check-in counters are increasingly relegated to drop off luggage points (Experience 2008; Experience 2014a). Furthermore, the average check-in costs per passenger through a human agent at a check-in desk is estimated in 3.02$ whereas using a self-service check-in method ranges between 0.14$ and 0.32$ (Graham, Anne; Papatheodorou, Andreas; Forsyth 2010).

The efficiency of the check-in process has attracted the attention of scholars over the years. Different methodologies and tools have been deployed, including discrete event simulation (Chun et al. 1999; Appelt et al. 2007; Bevilacqua &Ciarapica 2010; Kalakou 2012), optimisation (Yan et al. 2004; Bruno & Genovese 2010; Markovic, Nikola; Drobnjak, Zeljko; Schonfeld 2012), queueing theory (Joustra& Dijk 2001; van Dijk & van der Sluis2006), or survey analysis (Park &Ahn 2003; Chang & Yang 2008). The focus has mainlybeen on the configuration of check-in counters (e.g., location or airline allocation).(Chun et al. 1999; Markovic, Nikola; Drobnjak, Zeljko; Schonfeld 2012; Appelt et al. 2007)

The purpose of this manuscript is to describe a new microsimulation model of the check-in process based on Discrete Event Simulation (DES) and Agent Based Modelling (ABM). In a DES, system's variables change in specific points in time (Sakurada, Nelson; Miyake 2006). From a conceptual point of view, this process can be represented as a set of parallel and/or sequential activities that occur in a specific time. Every passenger must follow them, beginning at the moment he/she enters the terminal and until heading towards the security area (Figure 1.). Additionally, other activities not related with the process, such as dwelling or shopping, can also be considered as long as they can be pinpointed in time. Although this approach has been successfully applied in this context, it presents some limitations (Chun et al. 1999; Appelt et al. 2007; Esteban 2008; Bevilacqua &Ciarapica2010). Firstly, this modelling approach was not originally formulated to consider spatial properties and representations. Hence, terminals' spatial characteristics, such as layout (e.g., shape, size, or location of stairs or lifts, etc.) or location of check-in counters and other equipment (e.g., screens), are of difficult consideration. Secondly, it exhibits limitations on the customisation of individual elements' properties. Consequently, it is difficult to conveniently model passengers' behaviouristic properties, such as speed, walking paths or travelling in groups, and, inherent, relevant crowd phenomena, such as congestion, queues or walking conflicts. Thirdly, the discrete event approach is meant to estimate the effect on populations, rather than on single individuals (Caro, J. Jaime; Möller 2016).

To overcome these limitations, selected principles of agent based technology were embedded in the discrete event modelling approach, namely i) the ability to customise the agents' (i.e., passengers, visitors, staff, equipment) properties and behaviour, and ii) an environment (i.e., spatial dimension) in which agents co-exist and interact. By way of example, the model allows one to study the crowd patterns emerging from the co-existence of different types of passengers (e.g., mix of fast and slow moving passengers, or mix of knowledgeable and first-time passengers) including congestion, or conflicts of crossing passengers with queuing passengers. The outcome is a hybrid micro-simulation model that uses selected capabilities of agent-based technology to strengthen the discrete eventmodelling approach. To the best of our knowledge, no such model has been developed so far.

In 2014, the Portuguese Government decided to privatise the operations of the main national airports, in the form of a long-term concession agreement establishing minimum service levels, including the maximum waiting times and the density of passengers. The airport manager has thus all incentives to increase the efficiency of the check-in area, while maintaining the costs levels. The Lisbon Airport is the largest Portuguese airport, with a yearly passenger traffic around 20 million passengers. It shows visible signs of congestion in face of a steady increase in demand of passengers and flights (LUSA 2017; INE 2017). The model was applied to the check-in area of Terminal 1 of Lisbon Airport for the purpose of identifying alternative configurations of the layout and processes. Three scenarios were considered, including alternative locations for check-in kiosks and drop off counters, and organisation of the check-in counters.

The remaining of this manuscript is structured as follows: Chapter 2 is dedicated to a literature review. In Chapter 3, the simulation model is explained, detailing its logic, agents and environment. Chapter number 4 presents the case study and the variables inherent to it. Finally, in Chapter 5, the conclusions of the research are presented as well as new avenues for research.

2. Literature Review

Over time, scholars have been studying the check-in process (Table 1).Chun et al. (1999)created an Intelligent Resource Simulation System (IRSS) - a knowledge-based simulationsystem that uses rules and heuristics to encode knowledge on how simulation parameters vary with different types of flight - to predict, the number of check-in countersthat should be allocated to each departure flight while providing passengers with sufficient quality of service. They claim to have a more efficient system, reducing 40% of resources used, due to its capacity for considering more factors than a human can.

(van Dijk & van der Sluis 2006) took a step forward promoting the potential of a combined stochastic and deterministic approach by conjoining the queue theory/simulation approach with an integer programming (IP) method with the objective of reducing the waiting time in check-in queues, staffing hours and number of desks, which was achieved. Theauthors stated that the queue theory can provide a first order of magnitude of results that one may expect, and general insights that can be helpful. The queue theory is a mathematical analysis of systems subject to demands whose occurrence and lengths can, in general, be specified only probabilistically, with its focus on waiting lines (Cooper 1981). It is suggested that a combined approach of queueing theory and simulation should be used to capture the non-steady behaviour of the check-in process.

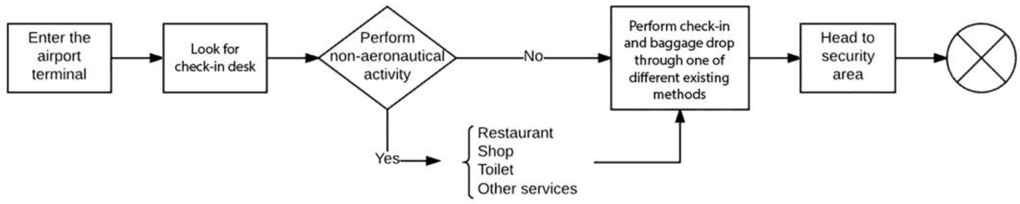

Figure 1: Check-in sequence of activities

(Bevilacqua &Ciarapica 2010) used simulation and queue theory, to determine how many check-in counters and what management strategy should be assigned to each departure flight while providing passengers with sufficient quality of service. Authors claim that although queueing theory provides a first approach to the result, these results are too restricted for a sufficiently realistic modelling and computation of the queueing features at the check-indesks. Hence, the addition of the simulation approach which gives the opportunity to consider the different behaviour of each passenger, staffing schedules and changes in passengers' volume. The authors were able to demonstrate that a considerable reduction in the average queuing times occurs using the common check-in.

Joustra& Dijk(Joustra& Dijk 2001), through a simulation model with an agent-based methodology, evaluated the performance of the check-in process under different operational rules comparing common versus dedicated check-in, dynamic vs stochastic opening and closing of counters, extension of check-in period prior to a flight, overflow for economy class passengers to business class counters, and the circumstance of bank lining. They reached the conclusion that the usage of the common check-in, the extension of check-in prior to the flight, the overflow of economy class passengers to business class counters and the circumstance of bank lining would have considerable impact on the average queuing time of economy class passengers. Also, the dynamic opening and closing of the check-in counters is essential for improving the personnel planningand offers the possibility to evaluate the effectiveness of the operational planning.

(Kalakou 2012)evaluated, through a simulation model with a discrete event methodology, the performance of passenger-related processes at the Lisbon Airport Terminal1, with the intent of improving the airport's Level of Service (LoS). The researcher conducted a survey with the intent of gathering information about passengers to further introduce in the model. The methodology of the evaluation was based on two key principles, a person-centred, attending to passengers' characteristics, their needs and requirements, and a technology- centred to draw up the rules and capabilities of the simulation model. It was noted that the check-in waiting time should be decreased. The introduction of multi-airline check-in machines was tested, allowing the conclusion that they can have a positive or a negativeinfluence, either if the airlines still have the capacity in both traditional and drop-off counters or if they are busy airlines that serve multiple flights at the same moment, accordingly.

(Appelt et al. 2007) also studied the reduction of waiting time in check-in queues, using a simulation model with a discrete event methodology. In this model, each passenger has a different behaviour according to the method of check-in he/she is going to use – check- in online, the curbside skycap or a desk or kiosk inside the building. This choice is represented by a percentage that is assigned to each one when they enter the model. Afterwards, a service time is assigned to them since all the check-in modes performed inside the building share the same queue. At the end of the process, they proceed to the securitycheck-point, exiting the model. Passengers are represented in different party sizes of 1, 2, 3 or more. Three different scenarios were created to compare different operational situations based on time in queue and average time in the system variables. The data, which was difficult to collect due to time constraints of the data collecting team, refers to peak hours from Friday to Monday. The researchers reached the conclusion that the scenario that achieved the lowest time in queue and the lowest average time in the system was the option of removing the counters as check-in points, using them for weighing bags and printing bag tags.

(Yan et al. 2004), focused on minimizing the total passenger walking distance, with an integer programming model and through the development of a heuristic method, to assign the common use check-in counters, reaching a reduction of 4.02% of the total walking distance in a week.

(Bruno & Genovese 2010) created a mathematical model to optimize the number of check-in counters to be opened for departing flights, balancing the operative costs and the passenger waiting time in such a way that balances the operative costs and the passenger waiting time at the terminal. According to the authors, the models are suitable for solving real case studies. However, the addition of practical operating constraints and more computational experience are required for further improve the research.

(Markovic, Nikola; Drobnjak, Zeljko; Schonfeld 2012) developed a model for the optimization of the number of check-in counters and their opening and closing times, optimizing the check-in process from the airline's point of view. For this, they used a non- stationary Markov chain which, according to the authors, is much more accurate than simulation analysis because it avoids the variance inherent in it, with an integer fourth order Rugen-Kutta algorithm. It is stated that no other author attempts to analyse the check-in process using non-stationary queues.

(Park &Ahn 2003), by means of a survey, developed an assignment model for the check-in counter operations, based on the passengers' airport arrival patterns. They studied that some of the major factors that are causing congestions and delays at airport passenger's terminals are the inadequate terminal capacity and the inefficient utilization of facilities alike the check-in counters. According to their survey, the total number of check-in counters and the space required depends on six factors, such as the rate of passenger arrival at the check-in counters, the airline schedules and procedures, the type of traffic, the check-in counter configuration and operation system, the standard level of service and the sender to passenger ratio.

(Chang & Yang 2008), by means of a questionnaire, aimed to explore the importance and performance of services provided by kiosks. According to IATA (International Air Transport Association) (Pearce 2014), it is known that kiosks act as a time saver for passengers, a cost saver for airlines and a space saver for airports, making airlines eager to promote their utilisation. The main conclusion was that, despite the evidences on the benefits of a widespread application of the technology-based services, they remain somewhat unperceived by passengers.

Table 1: Key properties of the check-in models of selected sources

Author	*Objectives*	*Variables used*	*Modelling tools*
(Chun et al. 1999)	No of check-in counters needed to each departure flight	Average time in queue and length of queue	Simulation
(Joustra& Dijk 2001)	Maximum possible growth in terms of the number of departing flights	Quality of service, average time in queue and length of queue	Simulation
(van Dijk & van der Sluis 2006)	Reduction of waiting time in queue	Average time in queue	Simulation
(Appelt et al. 2007)	Reduction of waiting time in queue	Average time in queue and average time in system	Simulation
(Bevilacqua &Ciarapica 2010)	Nº of check-in counters needed for each departure flight	Average time in queue	Simulation & Queue Theory
(Kalakou 2012)	Performance of the sub-processes	Average time in queue	Simulation
(Yan et al. 2004)	Minimizing the total passenger walking distance to assign check-in counters	Average distance a passenger needs to walk	Integer programming
(Bruno & Genovese 2010)	Optimize the nº of check-in counters to be opened	Average time in queue	Integer programming
(Markovic, Nikola; Drobnjak, Zeljko; Schonfeld 2012)	Optimize the nº of check-in counters to be opened	Average time in queue	Integer programming
(Park & Ahn 2003)	Optimize the check-in counter assignment	Passenger's airport arrival pattern	Survey Analysis
(Chang & Yang 2008)	Study the importance of service provided by kiosks	Questionnaire	Survey Analysis

The main ideas and insights drawn from the referred literature, with relevancy to the research published in the manuscript are:

In every reviewed study, the focus was on the check-in bay, which could improve the simulation results being a factor that could change the arrival pattern to the check-in area and passengers' behaviour.

- Simulation time never exceeded one week.
- Passengers' behaviouristic elements were often neglected.
- Non-aeronautical activities, which influence passengers' behaviour, were not considered.
- Flight delays, oversized luggage and other time-consuming events (e.g., asking information, adjusting luggage weight, etc.) were not considered either.
- Changes in the check-in layout were kept constant for the duration of the simulation
- The possibility of changing the check-in strategy in the simulation model (reallocation of airlines in check-in desks, static and dynamically, amount of importance given to kiosks, etc.) was never considered.

3. Simulation Model

3.1 Model Assumptions

Bearing in mind that the model aims at recreating the dynamics of an airport check-in process, the following assumptions were adopted:

- The model is populated by a variable number of agents (i.e., passengers), calculated according to the airports' flight schedule.

- Agents share the same behavioural elements (e.g., speed, arrival time before flight departure). Yet, they are parameterised differently to simulate different segments of passengers (e.g., leisure vs. business passenger).
- Segmentation is modelled by attributing different intervals of parametrisation to each segment. Actual values of agent's behavioural elements are randomly calculated at the beginning of the simulation according to the respective interval.
- Agents perform the same orderly set of tasks, with the exception of those not related with the check-in process (e.g., going to a restaurant) which depends on the individual behaviour.
- Agents behave rationally and have limited knowledge about the system's environment (e.g., queues work on a first-in – first-out principle, agents chose the shortest queue, or agents chose the nearest counter).
- The model recreates the typical functioning of the check-in area of a European airport (e.g., counter allocation per flight and company, or opening and closing times of the check-in).

The model was developed using the Anylogic 6[1] software.

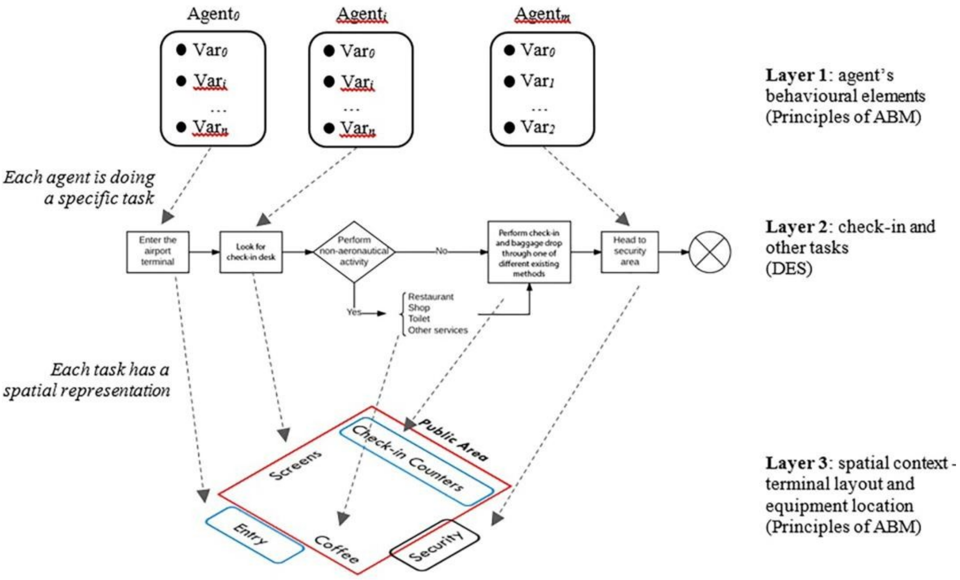

Figure 2: Overal architecture of the model

3.2 Model Architecture

The simulation model is organised in three interrelated layers (Figure 3):

- Layer 1 – Agent's behavioural elements: These passengers, represented as agents, who will perform a specific sequence of events, according to intrinsic behavioural elements (e.g., age, travelling experience or income level) and the layout. This layer borrows the principles from the agent based modelling.
- Layer 2 –Tasks: Sequential events that passengers may perform while in the system. This layer is based on the discrete events modelling approach.
- Layer 3 – Spatial Context: The geographical layer corresponding to the physical layout of the terminal and location of all relevant equipment (e.g., entry and egress doors, check-in counters or flight screens), and functions (e.g., stores, restaurants, lavatories, etc.). This layer borrows the principles from the agent based modelling.

[1]Further information available at www.xjtek.com

- The model described hereinafter follows the division between the three layers and is divided into four distinct steps:

Layer 1: Agents' Behaviouristic Properties

This layer contains the passengers' behavioural characteristics. The objective was to enable the emergence of the typical crowding phenomena (e.g., congestion, queues, etc.) visible in an airport terminal. The following characteristics were defined:

- Leisure or Business Passenger Variable – binary variable that determines which check-in counters may serve the passenger. The calculation of the variable is done according to a random uniform function, in which the user sets the probability at the beginning of the run time.
- Age Variable – discrete variable which determines the passenger's mobility (e.g., walking speed) and agility to perform tasks (e.g., reading screens or drop off baggage). The calculation of the variable is done according to a uniform random function, for different age intervals, at the beginning of the run time.
- Time Off Arrival Before Flight Variable – discrete variable that influences the passenger's level of stress and the willingness to perform a non-aeronautical activity. The calculation of the variable is done according to a triangular random function, in which the user sets the maximum, minimum and mode (van Dijk & van der Sluis 2006).
- Check-in type Variable – discrete variable that determines the passenger's mode to perform the check-in. The calculation of the variable is done according to a random uniform function, in which the user sets the probability at the beginning of the run time.
- Luggage Variable – binary variable that influences the time a passenger needs to perform the check-in. The calculation of the variable is done according to a random uniform function, in which the user sets the probability at the beginning of the run time.
- Frequent Flyers Variable – binary variable that influences the time a passenger needs to perform the check-in and the willingness to perform a non-aeronautical activity. The calculation of the variable is done according to a random uniform function, in which the user sets the probability at the beginning of the run time.
- Airline Variable – discrete variable that determines which queue should a passenger head to and influence the passenger's check-in mode and the possibility of carrying luggage. The calculation of the variable is done according to a random uniform function, in which the user sets the probability at the beginning of the run time.

Passengers have a characteristic behaviour when walking in the available space. Firstly, they always choose the shortest course possible to the destination they are heading. Second, they avoid obstacles and other passengers, crossing them at a customizable distance.

Finally, they respect queues and choose the shortest queue.

Layer 2: Check in Process

The simulation model follows four major parts, each one with several events, as detailed in Figure 2.

Step 1: The creation of a passenger

Every passenger is generated with a set of individual characteristics, mentioned in the previous section, which can be intrinsic, such as the flight information, which encompasses the airline and the number of flight, the time of flight and the time the counters open or the respective counter they should head, if performing the check-in in a counter or dispatching baggage, etc. or chosen by a probabilistic event, such as the check-in type.

The check-in type is what makes passengers opt between different check-in methods provided at the terminal. The five check-in methods considered were the following:

(1) Performing the check-in at an economic check-in desk;
(2) Performing the check-in at a business check-in desk;
(3) Performing the check-in at a kiosk;
(4) Performing the check-in at a kiosk and printing the baggage-tag; and
(5) Having performed the check-in online.

Step 2: From entrance in the model to check-in phase

To enter the physical part of the simulation, the airport terminal itself, the passengers choose, through a probabilistic event, one of the entrances. When inside, passengers look for a screen to check for the flights departure time and the check-in desk they should head to. Afterwards, and according to their check-in type, passengers' have one of two options: they wait at one of the four waiting areas that represent the non-aeronautical activities included in the model (such as coffee shops, restaurants, toilet, shops, cash withdrawal machines, etc.), or they head to their respective check-in facility.

Step 3: The check-in phase

The check-in and baggage drop counters open between 180 and 45 minutes before the departure of the respective flight whereas kiosks are operable through the beginning to the end of the model's run time.

For passengers who have either performed the check-in online or at a kiosk, after the check-in performed, if they need to drop baggage, they head to a baggage drop counter of the company they fly with. If there is no baggage drop counter, they will drop the baggage at an economic check-in counter.

Step 4: Exiting the model

With everything set and done, passengers proceed to the security area to continue their journey in the airport, exiting the model.

Layer 3: Spatial Context

The model itself can be applied to any given specific configuration. It is prepared to consider the existence of barriers such as walls and spacer boards, different levels, stairs, escalators and lifts that connect each level, moving walkways that accelerate the passenger's speed, any number of entrances and exits and even dedicated areas (ex. Airline lounges and staff only areas). The model has the capacity to support an arbitrary number of check-in counters, baggage-drop counters, kiosks and non-aeronautical services and activities.

There are four different types of check-in methods: economic check-in desks; business check-in desks; baggage-drop desks; and kiosks. The processing time of each type is defined by a triangular random function, in which the user sets the maximum, minimum and mode at the beginning of the runtime.

The non-aeronautical services (e.g., restaurants, shops, WC) are simulated as waiting areas. In these areas, the passengers wait for a given amount of time that represents the time needed to perform such activity. The waiting time is case specific and is defined by a triangular random function, in which the user sets the maximum, minimum and mode at the beginning of the runtime.

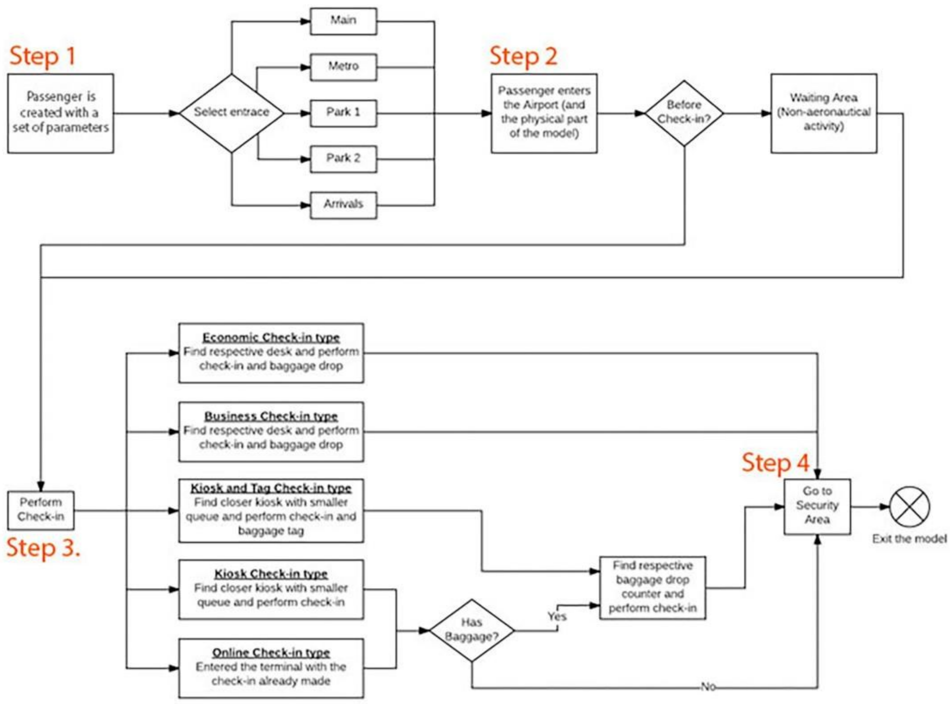

Figure 3: Detailed interpretation of check-in model

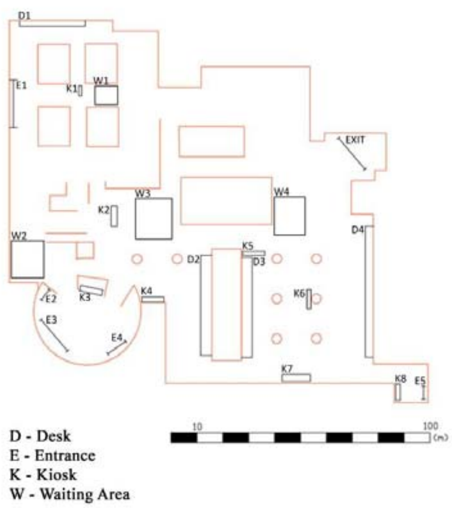

Figure 4: Plan of the Simulation Area

4. Validation and Verification of the Model

The difficulty in validating complex system models is recognised in the literature. The main problems include: complex feedback loops; the latent behaviour of the agents and random effects resulting in unexpected behaviour; and the lack of a formal equation structure that renders it difficult to trace the chain of cause and effect. With a view to increasing confidence in the model, North and Macal proposed a set of validation steps to be performed during its development, as follows (North &Macal 2007):

- Requirements Validation: the model should interpret questions and requirements of the real world.
- The objectives are presented and discussed in Section 1.
- Data Validation: the data used in the model should be accurate.
- Obtained by the authors themselves.
- Theory Validation: the assumptions of the model should be valid.
- They follow the practice of modelling as presented in Section 2 and the case study as presented in Section 4.
- Process Validation: assuring that agents, interaction structure and steps in the model correspond to real world processes.
- Thearchitecture is based on previous works as presented in Section 2 and replicates a case study's process of production as presented in Section 4[2].
- Agent Validation: agent behaviour, relationships and interactions must correspond to real world actions.

They were based on previous works as presented in Section 2 and on the case study as presented in Section 4.

5. Case Study

As a further validation step, the model was applied to Terminal 1 of the Airport of Lisbon. A few years ago, the Portuguese government privatised the national airports. The contract agreement set strict limits in terms of service levels, including maximum waiting time. In this sense, the airport manager aims at improving the service level, without changing the cost structure. The objective of the exercise was to propose enhanced configurations (layout, technology, procedures) of the check-in area (Figure I), using the existing resources (i.e., staff, automated and manual check-in counters, etc.). A total of three scenarios were analysed. The main decision variable, as defined by the airport manager, was the time in queue. The model's behaviour and results were discussed and validated with the members of the airports board.

6. Spatial Context: Check-In Area

The physical part of the model is a confined space that represents the entrance and check-in area of Terminal 1 (Figure 3). It has five different entrances (E1 to E5, see location in Figure 3) and one exit towards security gates. It includes eight different kiosk bays (K1 to K8) and four distinct areas with a set of check-in economic desks, check-in business desks and baggage drop desks (D1 to D3), with a distinct number of desks belonging to a single company or a set of companies for passengers to perform the check-in process. It also

[2]An interview with Dr.Ruas Alves, board advisory for ANA Aeroportos de Portugal, on the 24th of September 2016, served as validation step in the case study. The interview included a review of the variables, model assumptions, and input and output data.

includes four waiting areas (W1 to W4) that represent the non-aeronautical activities provided at the airport terminal, such as coffee shops, bookshops, newsagents, etc., where passengers may spend time before performing their respective aeronautical activities, such as the check- in.

The check-in facilities are divided in economic desks, business desks, baggage drop desks and kiosks. Kiosks can be used by every passenger while the desks are dedicated to companies with the following distribution:

(1) Economic and Business Check-in desks with Economic and Business Passengers

The check-in economic and business counters allow the economic and business passengers', respectively, to check-in for their flight and drop the baggage. Their service rate, being the rate at which customers are being served in a system, takes between 60 and 120 seconds per passenger for normal flights and 40 to 60 seconds for low-cost flights, for which there are no business counters.

Economic passengers flying with the air company TAP are obliged to either perform the check-in at a kiosk or online for there are no check-in economic counters for this company;

(2) Kiosk with Kiosk and Kiosk Baggage Tag Passengers

The kiosks offer two different options: only performing the check-in, where the service rate takes between 40 to 60 seconds; or also printing the baggage tag, taking between 50 to 70 seconds – in the airport's current operations, only twelve companies can perform the check-in in the kiosks and only two are allowed to also print the baggage tag – TAP and SATA.

To choose the kiosk, passengers analyse the distance from where they are to every one of the eight clusters of kiosks and the queue size every cluster has choosing the nearest kiosk with the shortest queue.

(3) Baggage Drop Counters with Kiosk, Kiosk Baggage Tag and Online Passengers

The baggage drop counters are designed to allow access to the passengers who have already performed the check-in to drop baggage. The service rate of passengers who have already printed the baggage tag (Kiosk Baggage Tag Passengers) takes between 20 and 30 seconds while the other passengers (Kiosk Passengers and Online Passengers) need 40 to 60 seconds. In the airport's current operations, only two companies have baggage drop counters, TAP and SATA. Instead of having economic check-in counters, the air company TAP has a set of 21 baggage drop counter, obliging its passengers to perform the check-in using a self- service method, as it was mentioned earlier.

Airline	*Check-in in Economic Desk*	*Check-in in Business Desk*	*Baggage Drop Desk*
United Airlines and US Airways	*5*	*1*	-
Lufthansa, Swissair and Brussels Airlines	*6*	*1*	-
Air France and KLM	*5*	*1*	-
Orbest, AirLingus and GermanWings	*4*	*1*	-
Ryanair, Air Transat and Luxair	*4*	*1*	-
Iberia nad British Airways	*4*	*1*	-
Air Europa ad Aigle Azur	*3*	-	-

TAAG and Emirates	*5*	*2*	*-*
Royal Air Maric and Air Algeria	*2*	*1*	*-*
Turkish Airlines, Euro Atlantic, Privilege Style and TACV	*4*	*1*	*-*
Vueling	*4*	*-*	*-*
TAP	*-*	*-*	*21*
SATA	*3*	*-*	*2*
TAP and SATA	-	6	-

7. Flight Information

The exercise used real data from the 7th August 2015, considered a typical day, from 12 a.m. to 10:55 p.m. The totality of flights comprised 28 companies, and 211 flights, 148 flights of which were performed by the Portuguese company TAP (approximately 70%). A total of 28180 passengers were transported.

Company	Total nº of Flights	Total nº of Passenger
Aer Lingus PLC	*1*	*160*
Aigle Azur	*1*	*167*
Air Algeria	*1*	*81*
Air Europa	*5*	*537*
Air France	*6*	*874*
Air Transat	*1*	*347*
British Airways PLC	*3*	*436*
Brussels Airlines NV/SA	*2*	*285*
Deutsche Lufthansa, AG	*5*	*893*
Emirates	*1*	*361*
Euro Atlantic Airways	*1*	*119*
Germanwings GmbH	*2*	*357*
Iberua, L.A.E. S.A. Operadora	*5*	*556*
KLM RoyalDutch Airlines	*3*	*526*
Luxair SA	*1*	*127*
Orbest, SA	*1*	*163*
PrivilegeStyle SA	*1*	*181*
RoyalAirMaroc	*1*	*114*
RyanairLtd	*2*	*360*
SataInternational Serviços e Trans. Aéreo	*6*	*1233*
SwissInternational Airlines AG	*2*	*354*
TAAG Linhas Aéreas de Angola	*2*	*340*
TACV, Transportes Aéreos de Cabo Verde	*1*	*207*

TAP Transportes Aéreos Portugueses, S.A.	*148*	*18007*
Turkish Airlines	*2*	*308*
United Airlines	*1*	*215*
US Airways, INC	*1*	*215*
Vueling Airlines S.A.	*5*	*704*

8. Passenger's Information

Passenger's information followed the logic behind the agent's behaviouristic properties, detailed in chapter 3.2.1.

Through the analysis of the data gathered it was possible to determine the appropriate distribution of each variable.

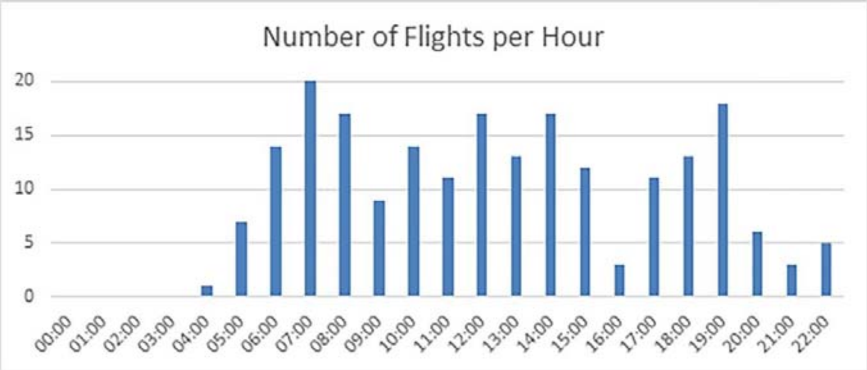

Figure 3: Number of Flights per Hour

Table 1: Agents behaviouristic properties values

	Leisure	*Business*			
Leisure or Business Passenger Variable (%)	*96*	*4*			
	Faster Pedestrians 1.37 (m/s)		*Aged over 65, Children hand-assisted & Physically disabled 1.15 (m/s)*		
Age Variable (%)	*84.5*		*15.5*		
	210min – 177.5min	*177.5min – 112.5min*	*112.5min – 80min*		
Time Off Arrival Before Flight Variable (%)	*25*	*50*	*25*		
	Check-in Economic Desk	*Check-in Business Desk*	*Check-in Kiosk*	*Check-in Kiosk and Printing Baggage-tag*	*Check-in Online*
Check-in Type Variable (%)	*48*	*4*	*4*	*25*	*19*
	Full Service Carriers		*Low-Cost Carriers*		
Luggage Variable (%)	*79*		*21*		
	Frequent Flyers		*Non-Frequent Flyers*		
Frequent Flyer Variable (%)	*4*		*96*		

Table 2: Agents behaviouristic properties values – Airline Variable

Airline Variable (%)	EI	ZI	AH	UX	AF	*TS*	*BA*	*SN*	*LH*	*EK*	*YU*	*4U*	*IB*	*KL*
	0.48	0.48	0.48	2.37	2.85	0.48	1.43	0.95	2.37	0.48	0.48	0.95	2.37	1.43
	LG	6O	P6	AT	FR	S4	LX	DT	VR	TP	TK	UA	US	VY
	0.48	0.48	0.48	0.48	0.95	2.85	0.95	0.95	0.48	70.15	0.95	0.48	0.48	2.37

9. Scenario Description

9.1 Scenario Description.

Base Case Scenario

The base case scenario corresponds to current operations, calculated from the abovementioned data.

The following figure (Figure 6) present a snapshot of runtime. It offer a visualisation of the terminal, where we may see the passenger's positioning and some emergent crowding phenomena.

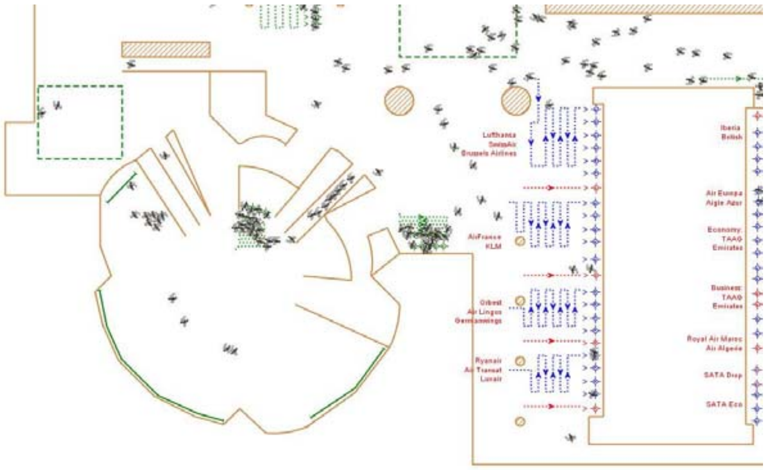

Figure 4: Base Case Scenario Simulation – Model Running – D2 to D3 Check-in Desks Area

First Scenario

The first scenario proposed the relocation of the kiosks from inner areas (K5, K6 and K7) to areas near the entrances to encourage the passengers to opt for this self-service check- in method rather than the check-in counters. Apart from the incentive to use the self-service check-in methods, this proposal was based on the fact that, at present time the inner kiosks had a lower service utilization than the kiosks near the entrances.

The kiosks are placed near each entrance according to the percentage of passengers that comes through those entrances.

Second Scenario

An important source of inefficiency is related with the current configuration of the check-in kiosks that only allows check -in in twelve out of twenty-eight airlines. Additionally, only two companies have dedicated drop off baggage counters, for passengers that use check - in kiosks or on-line check-in. All other companies require the utilisation of the business or economic check-in counters. In this scenario, check-in kiosks are replaced by dedicated check-in counters for drop off baggage.

Due to the replacement of the kiosks, the Check-in Type Variable had to be rearranged. The percentage of passengers that performed their check-in at a kiosk was transferred to the online passengers, since these passengers already have propensity to use a self-service check-in method. The Check-in Type Variable values can be seen in Table 5.

Third Scenario

This scenario entails the reduction of the number and location of the check-in economic counters and a new arrangement for the economic, business and baggage drop counters. It was assured that the time in queue of the base case scenario was not exceeded.

To that end, all the kiosks were removed and only one cluster of common baggage drop counters, with 21 counters out of 89 (approximately 24%), was created to serve all the airlines. The same aggregation was not made for the economic counters nor for the business counters.

Table 3: Input Data

Input Data	Base Case	Scenario 1	Scenario 2	Scenario 3
%Economic	48	48	48	48
%Business	4	4	4	4
%Kiosk	4	4	0	0
%Kiosk & Baggage-Tag	25	25	0	0
% Online	19	19	48	48
Nº Flights	211			
Nº Passengers	28180			

10. Results and Discussions

In the present study, there were two major decision variables: The Economic Check-in Waiting Time and the Baggage Drop Waiting Time. The results of these same variables are summarized in the following tables:

Table 4: Economic Check-in Waiting Time Results

Economic Check-in Waiting Time	25th	50th	75th	90th	95th	100
Base Case	*0.75*	*0.75*	*0.82*	*1.50*	*3.14*	*8.25*
Scenario 1	0.75	0.75	0.81	1.69	3.50	8.25
Scenario 2	0.75	0.75	0.84	1.69	2.34	5.25
Scenario 3	0.75	0.75	0.81	0.94	1.44	3.17

Table 5: Baggage Drop Waiting Time Results

Economic Check-in Waiting Time	25th	50th	75th	90th	95th	100
Base Case	*0.75*	*0.83*	*1.05*	*1.50*	*1.95*	*3.90*

Scenario 1	0.75	0.83	1.05	1.50	1.95	3.90
Scenario 2	0.75	0.75	0.75	0.87	1.33	2.92
Scenario 3	0.75	0.75	0.75	0.75	0.75	1.50

Table 14 summarises the key outcomes of the analyses, offering a brief discussion on the key advantages and disadvantages of each scenario. In summary, the key conclusions are:

- The introduction of automated baggage-drop counters brought benefits to the check-in process, reducing the waiting time for both economic check-in and baggage drop desks;
- Without exceeding the maximum and main queue times, the check-in service was improved without decreasing the passenger's quality of service.

Table 6: Comparison Chart of the Three Scenarios

	Variables at Issue	Advantages	Disadvantages
Scenario 1	*Time in queue for cluster of kiosks dropped*	*Show the importance to choose the correct placement of kiosks in the airport and the number of kiosks in each cluster*	*Does not bring many changes in the check-in counters for only 12 airlines let passengers perform the check-in in kiosks*
	Time in queue for check-in economic counters remained the same		*Static allocation of counters not being able to achieve a better service utilization*
	Service utilization of kiosks more homogenous		
Scenario 2	Time in queue for the passengers performing baggage drop and economic check-in in some airlines decreased	Show the importance for self-service check-in methods	Not enough counters in the airport to meet the perfect relation between number of counters needed for baggage drop and economic check-in
	Service utilization of every cluster of counters dropped	Shows the importance of baggage drop counters when improving self-service check-in methods	Static allocation of counters, not being able to achieve a better service utilization
		Shows online method is more viable than kiosks	
Scenario 3	Time in queue for baggage drop and economic check-in decreased in some airlines	Shows the importance of a baggage drop common facility	Static allocation of counters not being able to achieve a better service utilization
	Service utilization for every cluster was below 20%		

11. Conclusion

The air transport value chain is struggling to cope with the ever-increasing demand of passengers. Airports are no exception and efforts are being made to maintain the service level and the level of costs. In this context, the check-in area has received growing attention as it affects the efficiency of the passenger and luggage processes, and it is a relevant cause of stress for the passengers.

This manuscript presents a new hybrid simulation model of the check-in process in airport terminals, based on the discrete-event and the agent-based modelling approaches. The check-in process is conceptualised as a set of sequential tasks, hence the utilisation of the discrete-event approach. The passengers' behaviouristic properties and all spatialcharacteristics were modelled using the principles of the agent-based modelling. The result is a model that blends the simplicity of the discrete-eventapproach with the customisation capabilities of the agent-based approach. The model brings forth several contributions to the current literature:

- Incorporation of both aeronautical and non-aeronautical activities – this allows for the understanding of the mutual interference of each type of activities;
- Analysis of different check-in methods simultaneously, instead of focusing only on one check-in method;
- Ability to consider passengers' traits and behaviour.
- The model can be used as an effective decision support tool in the planning and development efforts of the terminal and check-in areas. Allowing airport managers and other decision makers to test scenarios in terms of alternative terminal area configurations, layouts or locations; technologies, equipment or human resources; or organisation of processes.
- The study of the Lisbon airport also revealed some important insights concerning the organisation of the check-in area, namely:
- The correct placement of the kiosks inside the airport greatly influences its usability;
- Common facilities for baggage drop will improve the efficiency of the check-in;
- The improvement and focus given to self-service check-in methods, especially the ones that can be performed outside the airport (such as online check-in), greatly influences the usability of check-in desks and kiosks affecting the organization of the check-in area.

As future developments, we aim at enhancing the passengers' behaviour by including advanced decision-making processes. In addition, dynamical flight schedule generation, including delays, is another improvement opportunity. Finally, deployment to other airports will help reinforce the recommendations on the check-in areas.

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