Analysis of Passenger Group Behaviour and Its Impact on Passenger Flow using an Agent-based Model

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Abstract: Group interaction within crowds is a common phenomenon and has great influence on pedestrian behaviour. This paper investigates the impact of passenger group dynamics using an agent-based simulation method for the outbound passenger process at airports. Unlike most passenger-flow models that treat passengers as individual agents, the proposed model additionally incorporates their group dynamics as well. The simulation compares passenger behaviour at airport processes and discretionary services under different group formations. Results from experiments (both qualitative and quantitative) show that incorporating group attributes, in particular, the interactions with fellow travellers and wavers can have significant influence on passenger's activity preference as well as the performance and utilisation of services in airport terminals. The model also provides a convenient way to investigate the effectiveness of airport space design and service allocations, which can contribute to positive passenger experiences. The model was created using AnyLogic software and its parameters were initialised using recent research data published in the literature.

1 INTRODUCTION

Revenue of airports nowadays is gradually transferring from aviation related sectors to non-aviation sectors (retail revenues) and also from traditional airline sources (lease arrangements) to passengers (fees collected from ticket sales) (Harrison et al., 2012, Schultz et al., 2010a). A positive passenger experience is likely to result in repeat visits, which not only helps further generate airport's financial profit, but also satisfies the needs of other stakeholders such as operating airlines, retailers, passengers and visitors (Popovic et al., 2010). Hence, the passenger experience has become a major factor that influences the success of an airport.

In this context, passenger flow simulation has become a significant approach in designing and managing airports (Schultz et al., 2007, Kleinschmidt et al., 2011). Although it has been proven that social interactions greatly influence crowd behaviours and decision making, far too little attention has been paid to group behaviour when developing passenger flow models (Qiu and Hu, 2010, Singh et al., 2009, Ma et al., 2012). This paper aims to evaluate the impact of group dynamics on passenger flow in an international departure terminal using an agent-based model for the check-in process. The remainder of the paper is organised as follows. Section 2 reviews previous work related to airport design and simulation techniques. Section 3 demonstrates the construction and configuration of the agent-based model in the context of an international airport. Section 4 provides the simulation results and analysis and Section 5 summarises the major findings.

2 RELATED WORK

In recent years, there has been an increasing amount of literature on airport passenger terminal design, analysis and modelling. Tosic (1992) offered a comprehensive review about global airport terminal models. The review introduced the features and proposed applications of the models, along with their strengths and weaknesses. Generally, model inputs are the physical layouts of the building, flight schedules, arrival time of passengers and processing rates. The evaluations of the model usually consist of the queue length, utilities and waiting times at all

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facilities. Although some literature had considered passengers as groups of people, how the group dynamic influences group behaviour at each activity and the overall system performance were not illustrated nor analysed. In spite of this, those models provided valuable references for future model designs.

Schultz et al. (2010b) investigated passenger dynamics in the airport terminal by analysing field data from Dresden International Airport. The research pointed out that approximately 50% of passengers were travelling in groups and the group size has significant influence on passenger speed. Other factors that influence passenger speed are gender, travel purpose (business/ leisure) and the amount of carry-on baggage.

Popovic et al. (2009) presented an observation technique that investigated how passenger activities mediate people's experience in the airport. In the study, detailed passenger behaviour in the airport was recorded. It was found that passengers travelling in groups had a considerable waiting time at the security process. The video showed that after the security screening point, people wait for their group members in the middle of the walkway to passport control. The findings of the study provide valuable information for modelling passenger behaviour and group dynamics in this paper. Using the same observation technique, Livingstone et al. (2012) reported results of passenger landside retail experience in airports. Through the data collection from 40 passengers, researchers found that the existence of passenger's travel companions can influence passenger's landside dwell time and shopping behaviour in discretionary activities. The limitation of the observation technique is that passengers who participated in the research were aware that they were being recorded. Furthermore, the low efficiency of video recording and data processing restricted the technique to only a small number of people.

Ma, et al. (2011, 2012) introduced an individual agent decision model to simulate stochastic passenger behaviour in airport departure terminals. Using Bayesian networks, the conditional probabilities of passengers' advanced traits (shopping preference, hunger level, technology preference, etc) were calculated through the basic traits (age, gender, nationality, flight class, etc.). By considering the restriction factors (such as remaining time and walking distance) passengers in the simulation can behave autonomously based on the results of Bayesian network inferences. However, the simulation did not explain how the group dynamics influence the passengers' decision making process and what will happen if passengers were in a group where group members have very different behaviour in their advanced traits.

Cheng et al. (2014) conducted a case study to demonstrate how the agent-based passenger flow model can be used to examine the efficiency of an airport evacuation strategy. By comparing evacuation time of individual passengers and passengers in groups, the impact of group dynamics during an airport evacuation process was analysed. The simulation results shows that group dynamics can significantly impact passenger behaviour during airport evacuation processes and consequently affects the total evacuation time.

3 MODEL REALISATION

3.1 Airport Environment

In agent-based modelling, three key elements need to be identified and modelled: agents, their environment, and their interactions with other agents and the environment (Macal and North, 2010). The model environment is an airport departure terminal, which is divided into landside and airside.

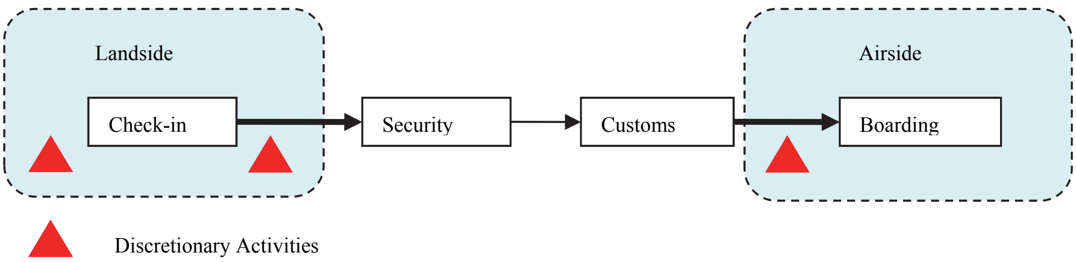


Figure 1: The International airport departure processes.

The landside of the terminal is open to the public, while the airside of the terminal is only accessible for passengers.

Figure 1 illustrates a high-level description of the passenger departure processes in the model. Passenger activities are categorised into processing and discretionary activities (Kraal et al., 2009). Processing activities are mandatory for passengers before boarding the plane. On the landside of the terminal, passengers check-in for their flights, and pass through security screening and border processing before entering airside and boarding. Discretionary activities are considered as any other activities undertaken by passengers during non-processing time (Kraal et al., 2009, Livingstone et al., 2012). Discretionary activities can happen between two sequential mandatory activities as shown in Figure 1. Examples of discretionary activities in the proposed model include random walking, store browsing, having food and using other airport services. Retail shops and airport services are located at both landside and airside to emulate the real-world scenario.

In order to guarantee there is ample time left for security measures, passengers are often advised to arrive at the airport three hours before the standard flight departure time. In the model, the flight check-in process starts at 2.5 hours prior to flight departures and closes on 25 minutes before the departure time. A row of check-in service counters (eight counters per row) are assigned to the check-in process of each flight. Among the eight counters, there are two counters for business class passengers and six counters for economy passengers.

3.2 Pedestrian Configuration

Pedestrians in the model are categorised into passengers and wavers. Passengers are those who will board on the plane, while wavers are fellow companions who accompany the passengers to the airport but do not board the flight. Age, gender, residential status and travel purpose are four basic characteristics of passengers in the model. These four factors can influence advanced passenger characteristics such as mobility and shopping preference.

Table 1 summarises the distribution of airport passengers' age and gender provided by the global passenger survey conducted by IATA (2013). According to the country of residence, passengers in the model are divided into Australian resident and overseas visitors. The Australian Bureau of Statistics (ABS) provided the information of departure passengers' country of residence and passengers' main reasons for their journey in 2012-2013 financial year (ABS, 2013). These four basic characteristic factors: age, gender, country of residence and travel purpose will be initialised to each agent according to the percentage rate showed in the Table 1. The age and gender are assigned to each agent when the agent enters the system. Since passenger groups usually share common features of country of residence and travel purpose, these two factors are initialised to each agent after the pedestrian group has finished assembling and will assume passengers in the same group have a common country of residence and travel purpose. Based on these four basic characteristic factors, passenger groups in the model are initialised with different speeds and activity preferences, which enable agents to act autonomously in the simulation.

Table 1: Basic passenger characteristics in the airport.

Passenger characteristics	Source	Detailed factors	Percentage in total passengers
Age range	IATA global passenger survey (IATA, 2013)	< 25	10%
		25 - 34	31%
		35 - 44	23%
		45 - 54	18%
		55 - 64	11%
		>65	7%
Gender	IATA global passenger survey (IATA, 2013)	Male	59%
		Female	41%
Country of residence	Australian Bureau of Statistics (ABS, 2013)	Australian resident	58%
		Overseas visitor	42%
Travel purposes	Australian Bureau of Statistics (ABS, 2013)	Business	15%
		Leisure	85%

3.3 Pedestrian Group Interaction

Pedestrians in the airport are predominantly driven by specific goals: passengers want to finish airport processes and board their flights; and wavers accompany passengers in the airport and send them off. In this paper we focus explicitly on the interactions within pedestrian groups. There are some basic rules that govern the relationship and interactions of a group:

- During movement, pedestrians in the same group generally move toward the same destination.
- All group members will try to keep a uniform speed, except during situations such as avoiding obstacles and collision with other pedestrians.
- If group members fall behind due to any reason, other group members will slow down until the stalled group member catches up.
- At mandatory processes such as check-in, passengers who finish the process faster need to wait for all other group members to complete the process before moving on.
- If time is allowed for discretionary activities, pedestrians in the same group will generally undertake the same activity together once the activity is chosen.

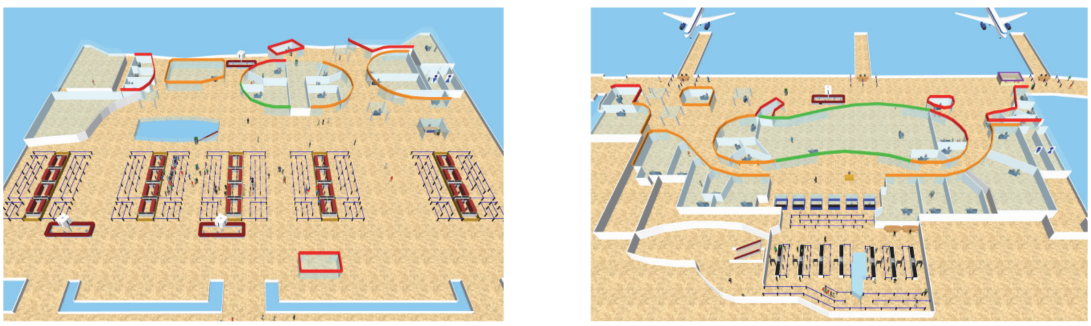
The model takes the departure flight schedule and passenger numbers for each flight as input. The attributes of the agents such as group size, speed, flight schedule and class, and shopping preference are initialised. The interactions between the agents and the environment are defined. Based on the flight schedule, the agents are appropriately introduced in the environment. Detailed micro-activities in each process, for instance, the passenger behaviour at check-in process is modelled based on observational data collected by the Human System team of the Airports of the Future project (Kraal et al., 2009).

4 RESULTS AND ANALYSIS

The 3D simulation environment of an international airport departure terminal is shown in Figure 2. The model is built within the AnyLogic 6.8 platform to simulate the daily operation of the airport. Activities of each agent in the system were updated successively according to preset characteristics within a discrete-event structure of the AnyLogic simulation software.

To evaluate the effect of group dynamics on facilitation and overall congestion at the check-in area, we ran simulations under three different scenarios. These are passengers travelling: (a) alone; (b) in groups of varying size; (c) in groups of varying size with wavers. Figure 3 illustrates the screenshots taken for the same flight and timeline of the simulation. From the model observation, it was noted that passengers who travel in groups will wait for group members in the pathway after finishing the check-in process. This waiting behaviour of passenger groups can cause congestion in the pathway behind the check-in area and slow down the passenger flow. More severe congestion can be seen in the scenario where passenger groups are accompanied by wavers [Figure 3 (c)].

Data collected from three different simulations at the check-in process show that passenger group dynamics influence the check-in queue time and dwell time (Figure 4). The check-in dwell time is the average time elapsed between passengers entering the check-in area and leaving it with their companions (if there are any), while check-in queue time is the average time elapsed between passengers entering the queuing area and getting served by the check-in staff. From the table in Figure 4, we note passengers travelling in groups or with wavers spend approximately 3 minutes to regroup after the process. This leads to a longer dwell time in the check-in process.

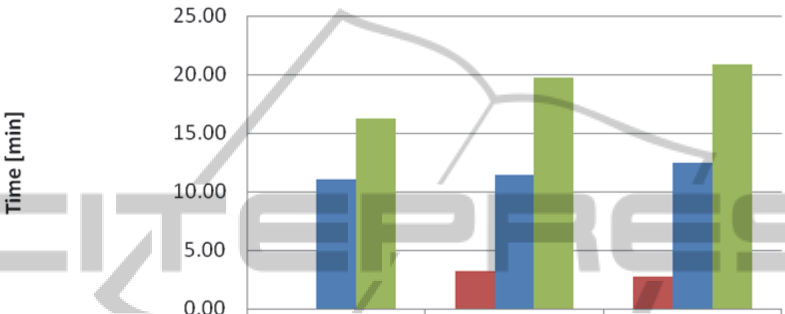


(a) (b)

Figure 2: Airport departure terminal simulation environment (a) landside of the terminal; (b) airside of the terminal.

(a) (b) (c)

Figure 3: Facilitation and overall congestion at check-in for three different scenarios. Passenger travelling: (a) alone; (b) in groups; (c) in groups with wavers.



	Alone	In groups	In groups with wavers
Regroup time [min]	0.00	3.22	2.71
Queue time [min]	11.05	11.45	12.46
Total dwell time [min]	16.25	19.71	20.91

Figure 4: Regroup, queue and dwell times at the check-in process for the three different scenarios.

The model results also suggest that the time passengers spend in queuing can be influenced by group structure. It can be seen that passengers travelling alone spend approximately 2 minutes less in the queue when compared to passengers travelling in groups. A possible explanation for witnessing such a trend could be the congestion caused by people waiting to regroup with their fellow travellers around the queuing area. In essence, ignoring group dynamics in agent based modelling may yield results that may not accurately represent the real-world observations.

5 CONCLUSIONS

Through the simulation of the check-in process, it is shown that agent-based modelling can be used to analyse group dynamics of pedestrians in a complex environment. The results in this study suggest that the group dynamics can potentially lead to congestion and longer check-in dwell times. Such scenarios can lead to potential flight delays and thus contribute to a lower level of service (LOS) and poor passenger experience. Furthermore, they may also leave the passengers with less time for discretionary activities which may not be favourable for airport retail operators. Therefore, from the airport management perspective, it would be beneficial if terminal operators could run the simulation beforehand by inputting flight schedules and passenger quantity details into the model. The simulation results will provide valuable information for airport operators to respond proactively to any potential congestion. Furthermore, the advanced modelling incorporating group dynamics provides a more powerful long-term planning tool and airport design analysis tool.

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