Proceedings of the 2018 Winter Simulation Conference
M. Rabe, A.A. Juan, N. Mustafee, A. Skoogh, S. Jain, and B. Johansson, eds.

SIMULATING PASSENGER'S SHOPPING BEHAVIOR AT AIRPORT WITH A CONCEPTUAL AGENT-BASED MODEL

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ABSTRACT

Airport retail revenue has long been recognized as a critical revenue stream to ensure an airport's financial sustainability and stability. However, there is a lack of simulation model on how airport terminal could be better designed to facilitate this vital revenue stream. This paper presents a conceptual agent-based simulation model on passengers shopping behavior in the airport context. This model attempts to investigate the relationship between terminal design and retail performance through different scenarios studies. Results show that finger pier terminal shape can have a negative impact on retail revenue if shops are decentralized. Terminal with centralized shopping areas also performed better than a terminal with decentralized shopping area. Future research directions were proposed at the end to improve the existing simulation model with the aim of making it an essential evaluation tool for future terminal design.

1 INTRODUCTION

Air transport industry has greatly benefited from the increase in travel demand over the last few decades. While airlines and airports' aeronautical functions are continuously under the limelight with the ever-increasing travel demand, this paper focuses on the airports' retail revenue, a crucial part of the non-aeronautical functions of the airport which is often neglected despite its importance. According to Airport Council International (ACI 2017), airport retail (including food & beverage (F&B)) is contributing to 32.6% of the total non-aeronautical revenue and it increased by 11% compared to the result in 2015. Airport generated an estimated $19.5 Billion on retail alone in 2016 based on the ACI report (ACI 2016). In fact, some even label airport retail as the Formula 1 of retail because airport generates 36% of its revenue from 16% of the space used on retail (Thompson 2007).

There is some degree of similarity between airport retail and retail in a shopping mall. However, airport retail has far more restrictions than retail in a shopping mall. The primary objective of passengers is flying, and shopping is not the primary goal in the airport context. As a result, airport terminals are usually designed for its aeronautical functions, even though the design of airport terminal has a significant impact on airport retail which contributes to almost 14% of the overall airport revenue as shown in Figure 1 (ACI 2017). Some airlines view airports as "bus stops" to process passengers (Nikolaeva 2012), resulting in the lack of focus on other non-aeronautical functions such as retail activities. Terminal design without consideration of retail functions has created a lot challenges for airport retailers, especially in the older airport terminal designs (ACRP et al. 2011). Hence, retail revenue is usually adversely affected due to the poor terminal design.

Terminal construction is capital intensive, and any mistake will be costly to recover. One feasible way to test out the terminal design without a high cost is through the means of simulation. Current airport simulation models in the literature tend to be discrete-event driven and focus on the process-driven activities such as check-in. Queueing and routine processes are critical elements in discrete event simulation. Meanwhile, airport retail usually does not involve fixed procedures and passengers have their own threads of control. Thus, Agent-Based Model (ABM) could be a more suitable alternative (Siebers et al. 2010). Agents in the model should be given the full autonomy in making their own micro decisions. However, such an ABM is currently rare among existing airport simulation studies.

This paper aims to demonstrate the potential of ABM in investigating the impact of terminal design on retail revenue through the simulation of passenger's shopping behavior in different scenarios of terminal design. Such an ABM can contribute to the simulation research in several ways. It is a novel approach to test the relationship between airport retail performance against terminal designs. More importantly, the model demonstrates that realistic agents, who behave like real passengers and interact with the airport retail environment, is possible. The model also provides additional insights into how people could be modeled under an enclosed environment. The implementation of such ABM suggests its potential that can be applied in a broader context, such as shopping mall, stadium or museum. This model serves as a cornerstone for future model expansions.

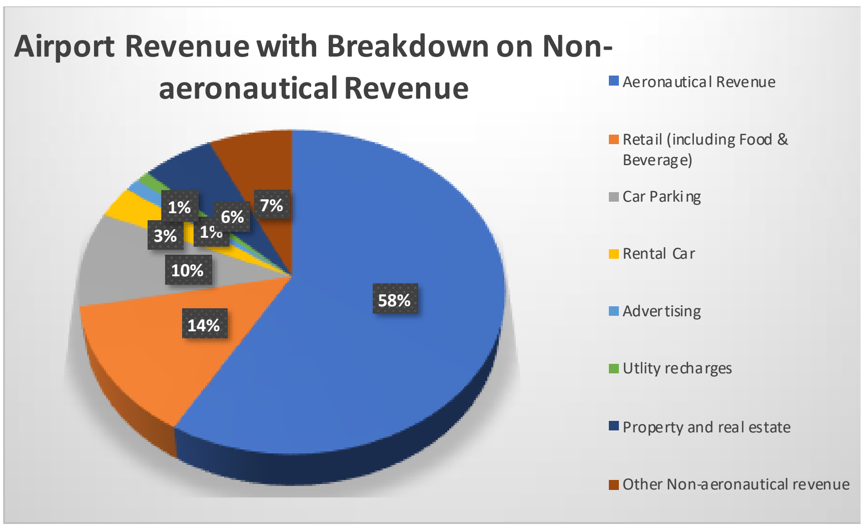

Figure 1: Airport revenue with a detailed breakdown on non-aeronautical revenue.

The paper is organized as follows. Section 2 provides a literature review on airport retail, focusing on the crucial factors that have been included in our ABM. Section 3 explains the conceptual design. Section 4 describes the simulation model set-up. Section 5 presents some selected analysis and results. Section 6 concludes the paper and provides directions for future research.

2 LITERATURE REVIEW

2.1 Factors Impacting Retail Performance

To design a reasonably realistic airport retail environment and agents in the proposed model, a literature review on two critical elements of airport retailing – passenger characteristics and terminal design –is performed. Passenger characteristics are one of the deciding factors in the retail performance and, therefore, five of those characteristics are studied in this model. On the other hand, terminal design (i.e., terminal shape and retail layout), which is the focus of this paper, are also reviewed.

Age

Age is not only a significant factor in influencing purchasing decisions, but various age groups also exhibit different shopping behavior and preference under the airport environment. For example, Liu et al. (2014) pointed out that young travelers are more likely to undertake shopping activities than middle age group, while the middle age group (aged 50 and above) spend more money on shopping at the airport (Jansen-Verbeke 1998; Lehto et al. 2004). Recent studies have demonstrated that senior travelers have stronger purchasing power than the young passengers and the middle age group (Perng et al. 2010; Han et al. 2015). Age also affects the passenger's movement speed in the airport (Schultz et al. 2010).

Gender

Gender is identified as one of the most significant factors in passenger's purchasing decision in retail (Baron and Wass 1996; Pan and Zinkhan 2006; Reimers and Clulow 2009; Lu 2014). Females have a higher possibility to be a more frequent shopper and spend more time on shopping (Freathy and O'Connell 1999; Hobson 2000; Freathy and O'Connell 2012). Females are also more likely to shop compared to their male counterparts. Airport retail has demonstrated this, whereby women are more apt to browse and make a purchase than men (Perng et al. 2010). For example, Freathy and O'Connell (2012) found that for those passengers who spent more than one hour in the airport shopping area, only 37% were men, and 63% were women.

Travel Purpose

Travel purposes can be broadly classified into two categories: business or leisure. Research has established a relationship between travel purposes and airport expenditure. The traditional view was that business passengers spend less at airport compared to leisure travelers. This is also partly due to the view that the use of business lounge will reduce passenger's dwell time and the possibility to shop in the airport's airside area. Recent literature increasingly challenges this viewpoint and suggests that business travelers could devote more money than leisure travelers under certain conditions. Torres et al. (2005) argued that business travelers tend to spend more than leisure travelers if the boarding time is less than 45 minutes. Del Chiappa et al. (2016) pointed out that business travelers prefer quick service for food and beverages whereas leisure travelers concern about restaurant location.

Income

Airline passengers typically earn three to five times more than the national average. The higher income level of these passengers has led to major airports' retail sales per square foot to be six times greater than shopping malls and downtown shops (Kasarda 2008). The difference in income level among travelers has a significant impact on airport retail performance. For example, Castillo-Manzano (2010) suggested that income-related factors help to explain the likelihood of purchase by passengers. Higher income passengers are more willing to spend more money to make the trip comfortable and convenient. However, there is a reverse relationship between income level and spending when there are bargains at the airport (Lehto et al. 2004). Lower income travelers tend to spend more money when there are bargains.

Dwelling Time

Dwell time is one of the most influencing factors in passenger's shopping behaviors. Dwell time is the time between a passenger's arrival at a check-in lounge and the scheduled departure time of the flight that the passenger checks in for (Wu 2012). Baron and Wass (1996) pointed out that the primary reason for passenger browsing and shopping at the airport is to fill the dwell time. The consensus is that longer free dwell time of passenger in the airport will induce a higher chance of browsing and shopping. According to Castillo-Manzano (2010), the free dwelling time has a significance level of 99% in explaining both the decision to consume food or beverages and making a purchase.

Terminal Shape

Airport terminal can be categorized into five basic configurations: Finger pier, Midfield Concourses, Linear, Transporter, and Satellite. Terminal configurations directly impact passenger flows in the terminal. The various shapes can have different advantages and disadvantages towards airport retail. The best terminal configuration highly depends on the importance of airport stakeholders at any location and over time (De Neufville 2016).

Retail Layout

An airport's retail layout is critical to successful airport retail. Two of the most common forms of retail designs are centralized shopping area and decentralized shopping area. A centralized retail layout creates the visual appeal of a shopping mall, which leads to a synergy between shops and increases the likelihood of passenger purchases. Meanwhile, a decentralized retail layout provides travelers more opportunities to purchase as it spreads shops across departure gates (Freathy and O'Connell 1999).

2.2 Simulation Approach to Airport Studies

Despite the ever-increasing importance of the airport retail, there is little research on the relationship between the airport terminal design, passenger characteristics and airport retail (Brown 1991; Moon et al. 2016). As a result, the current terminal design process is still dominated by "intuitions" (Harrison et al. 2012). With the rapid advancement of computer technology, simulation can provide a compelling way to make good use of the data through modeling passenger shopping behaviors in airports (Miwa and Takakuwa 2008). However, as illustrated in Table 1, previous airport simulation studies focused on check-in and other process-driven activities, airport retail received little attention. Airport retail is not part of the early simulation model's objective. As a result, it received very limited attention. As airport retail revenue develops, recent airport simulation models have started to include airport retail in their objective. However, airport retail received only partial coverage as these models' primary goal was not airport retail. This paper aims to develop a simulation model that emphasizes airport retail to fill the existing literature gap and provide means to evaluate future retail design performance.

Table 1: Summary of past airport simulation model (Kleinschmidt et al. (2011) and author's literature review).

Author	Check-in	Security	Immigration	Boarding	Retail
Gatersleben and Van der Weij (1999)	Yes	Yes	Yes	Yes	Limited
Kiran et al. (2000)	Yes	Yes	Yes	Yes	Limited
Kleinschmidt et al. (2011)	Yes	Yes	Yes	Yes	Partial
Ma et al. (2012)	Yes	Yes	Yes	Yes	Partial
Cheng et al. (2014)	Yes	Yes	Yes	Yes	Partial

3 CONCEPTUAL DESIGN

3.1 Conceptual Model

As suggested by Mota and De La Mota (2018), a conceptual model was constructed before the simulation model was implemented. As demonstrated in Figure 2, the conceptual model emulates passenger' thought process through three stages – observation, decision and execution in the airport retail area. The iteration process of the three phases starts after each passenger enter the airside of the terminal and lasts until the passenger arrives at the boarding gate, which is the end point of all passengers. Furthermore, the literature suggests that once a passenger arrives at boarding gate or lounge area, it is challenging to encourage them to return to the main section of the airport terminal and re-enter the retail environment (Livingstone 2014).

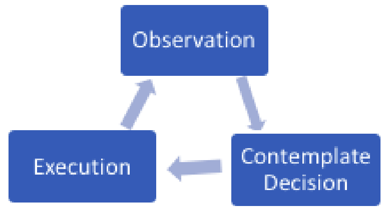

Figure 2: Passenger's thought process.

3.2 Passenger's Behavior in the Airside of the Terminal

In the model, the passengers' shopping preferences and behaviors are determined by factors highlighted in Section 2. Each passenger is assumed to go through their thought process on the go, so that passenger is always thinking and planning the next move while executing the last one. The passenger's behavior is profoundly influenced by the impact of dwell time as highlighted by (Lin and Chen 2013). Thus, the passenger behavior is designed based on dwell time. During the thought process, the dwell time is continuously evaluated. Once the remaining dwell time is less than thirty minutes after considering the distance between their current location and the boarding area, the passengers will head straight to the gate.

At the observation stage, each passenger observes the surrounding against their profiles as well as their personal status including the dwell time. Then, the passenger's profile exerts an impact on its decision making. For example, they will identify their favorite shops and check if these shops are close to them. The passenger will have a higher chance to visit its preferred type of shops when the shops are close to them.

At contemplate decision stage, passenger evaluates its options of six main type of activates: shopping, dining and drinking, wandering, resting, going to toilet and advance to gate/lounge early. The final decisions depend on a range of factors including passenger characteristics, remaining time, location, shop layouts, budget and capacity of shops.

In the execution stage, passengers move to the location according to their decision made in the previous stage and spend time and money in the corresponding area. Besides the time constraint, each passenger also has a limited budget to spend depending on the income level. If a passenger has executed a particular decision previously, this will lead to a reduced chance of passenger making the same decision.

4 SIMULATION SET-UP

The simulation was implemented in AnyLogic 8 based on the conceptual model described in Section 3. Agent-based modeling is found to be particularly applicable to our context. As an airport comprises multiple stakeholders and social interaction (Wu and Mengersen 2013), ABM enables passenger behaviors simulation in such environment. ABM also allows the simulated passengers to behave naturally and autonomously, with designed thinking 'logic' that mimics the behaviors of actual passengers. This unique characteristic makes agent-based modeling especially appropriate for the study of passenger behavior in an airport environment. Compared to some other types of modeling such as the discrete event where the passengers are being told what to do, the agents in this ABM can make their own judgment and decisions. In this way, we can examine and compare the impacts of different terminal shapes and shop layouts on the passenger behaviors and retail revenue, keeping 'passenger logic' the same in all scenarios.

Passenger profile

The passenger profile is designed according to literature based on Section 2.1, which is summarized as in Table 2. More factors could influence passenger's shopping decisions, but we limit our model to those factors listed in Table 2 for demonstration purpose. More elements would be included in the future model expansion.

Table 2: Passenger profile.

Passenger Characteristics	Impact on Model Design
Age	Movement speed and type of shop preference
Gender	Type of shop preference and the likelihood of purchase
Travel Purpose	Likelihood of purchase and early arrival at the gate
Dwell time	Purchasing decision and likelihood to move to the gate
Income	Available budget to spend

Facility Profile

The facility profile is designed based on the type of activities that are available in the airport airside area. The facility profile is summarized in Table 3 below.

Table 3: Facility profile.

Facility	Impact on Model Design
Food and Beverage	Limited capacity, amount of money and time spent varies
Resting Area	Limited capacity, amount of time spent varies
Duty-Free Shops	Limited capacity, amount of money and time spent varies
Luxury-Shops	Limited capacity, amount of money and time spent varies
Toilet	Limited capacity, amount of time spent varies
Gate	No further activities once passengers reach the gate
Other Areas of the Terminal	Allow passengers to wander around, no limited capacity

Terminal Profiles

The terminal is designed based on two of the five most common terminal shapes. Most of the condition has been kept the same to show a clear comparison of the performance of the different type of terminal designs. Table 4 below shows the terminal profiles.

Table 4: Terminal profile.

Type of Terminal	No. of facilities	Space (m^2)
Linear	7	490,000
Finger	7	490,000

Decision-making Logic: example Agent A

While 20,000 agents were modeled in a simulation run, we here use a sample agent – agent A to explain how the simulation logic works. Assuming agent A is a male, 30 years old, earns $100,000 per year, business traveler and has 1.5 hours of dwell time to be spent in the terminal. These parameters have an impact on agent A's preference for facilities, available time, budget, browsing and purchasing probabilities. Agent A will move towards his pre-assigned gate. He can choose to go to any of the seven facilities or even wander around. If his preferred facility is located within 15 meters to his current location, he has a higher chance to go into that facility. As agent A moves in the terminal, he is continuously observing and making decisions. If he decides to use any facilities, he will have a much-reduced chance of revisit or repeat consumption at the same facility again. The spending of each agent is recorded at each shop, the total expenditure of the 20,000 agents is calculated as the sum of all recorded spending across all shops. Once Agent A's budget is reduced to a certain level, agent A will stop all shopping activities. In this model, we assume agent A can estimate the time required to move from his current location to the gate by calculating their speed against distance. At any point of the simulation, if agent A estimates that the boarding time is within 30 minutes, the agent starts to move towards gate immediately.

5 SELECTED RESULTS AND ANALYSIS

5.1 Base model

To facilitate comparison, a centralized shopping area, as shown in Figure 3, is presented as the comparison benchmark for different simulation scenarios defined in later sections. Figure 4 shows the partially decentralized retail layout designs. Figure 5 shows the complete decentralized shopping layout design. While the centralized and decentralized design is the most common layout in airport retail, we added the partially decentralized design for a more interesting comparison across these three layouts.

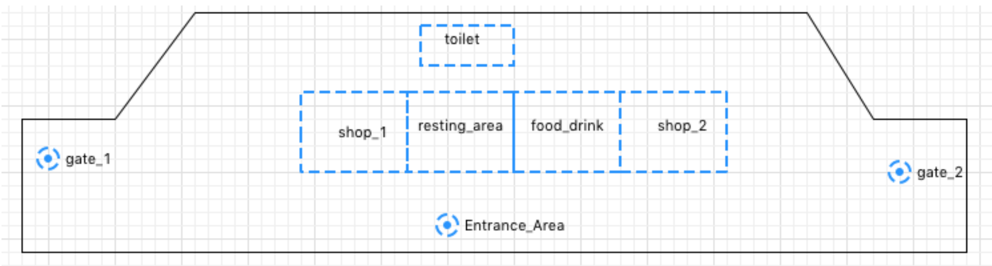

Figure 3: Centralized layout (base case: linear).

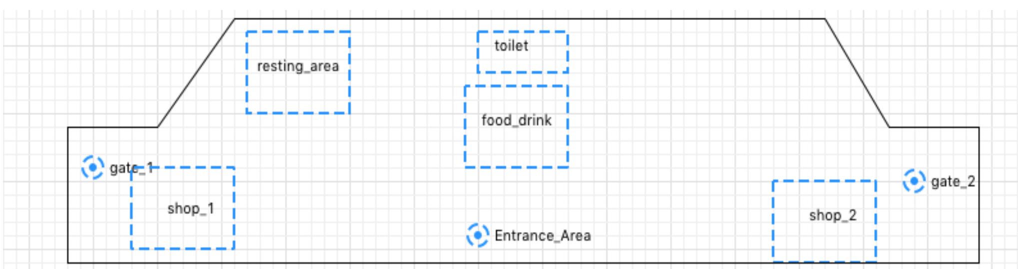

Figure 4: Partially decentralized layout.

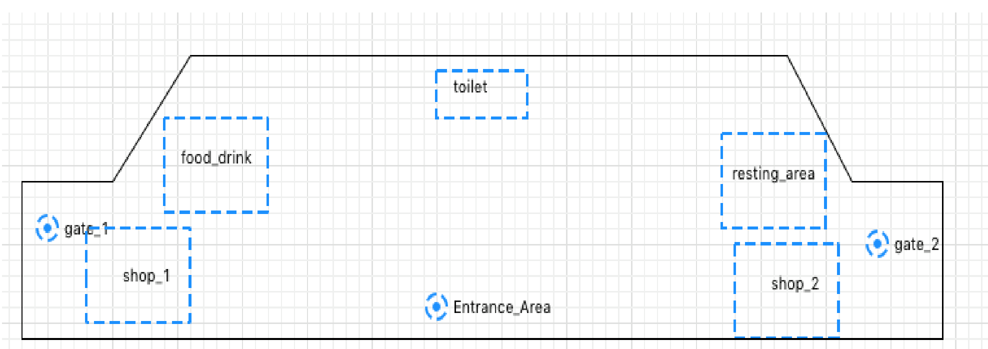

Figure 5: Decentralized layout.

5.2 Case Study A – Terminal layout

The impact on airport retail for the three terminal layouts – (1) centralized, (2) partially decentralized and (3) completely decentralized were simulated. With scenario (1) as our base case, (2) and (3) were compared to observe the effect of terminal layout on overall retail revenue.

Figure 6 showcases the revenue change as the layout was changed in different scenarios. The results show that the centralized shopping design produces the highest retail outcome. The difference in retail revenue could be due to several reasons. First of all, all shops in the centralized shops are in the direct line of passenger flow, and passengers are "forced" to pass through these shops on their way to their departure gate. Secondly, the clustering of shops together could have an indirect positive impact on sales in the current model setup. Passengers are more likely to go to the preferred facility if the facility is located within 15 meters from the passenger. Clustered shops could lead to a higher possibility that the passenger's preferred facility is within 15 meters upon their exit from the previous facility. The partially or completely decentralized layout means that passengers have to walk a longer distance to get into shops. This has a negative impact on their dwell time. Given dwell time has a direct impact on the shopping rate in existing literature and this model design, the partially or completely decentralized layout will likely reduce passenger's likelihood of browsing and shopping. This result highlights the importance of terminal layout on airport retail. With all other condition remains the same but different terminal layouts, the result is drastically different across three scenarios.

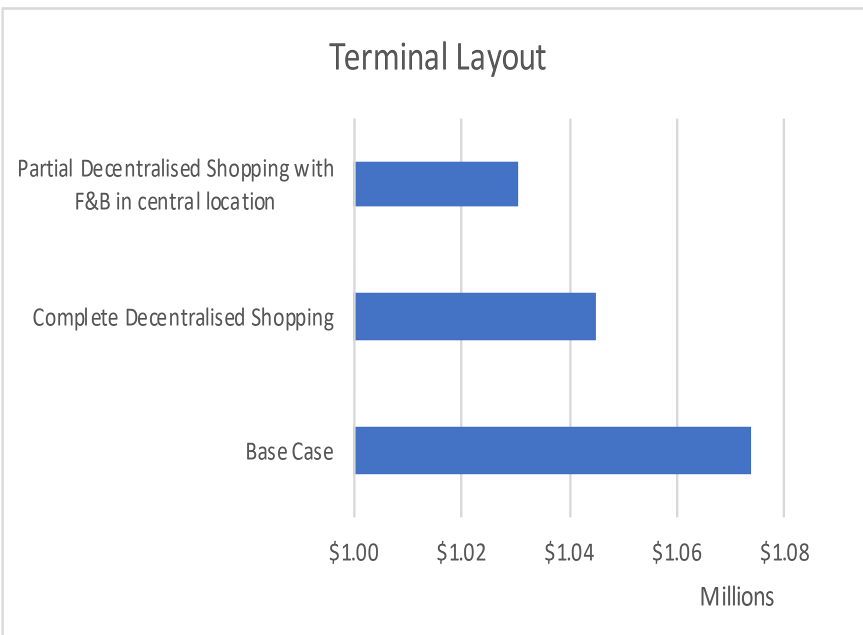

Figure 6: Terminal layout comparison.

5.3 Case Study B – Terminal Shape

The impact of terminal shape has long been argued to have a significant effect on the airport retail revenue. However, to the best of the author's knowledge, no existing simulation model in the literature demonstrates the impact of terminal shape on airport retail. In this section, we used two of the five most common terminal configurations to illustrate the capability of this exploratory model. The finger shaped terminal is shown in Figure 7. The only change in this scenario is the change of terminal configuration, and all other conditions remained the same.

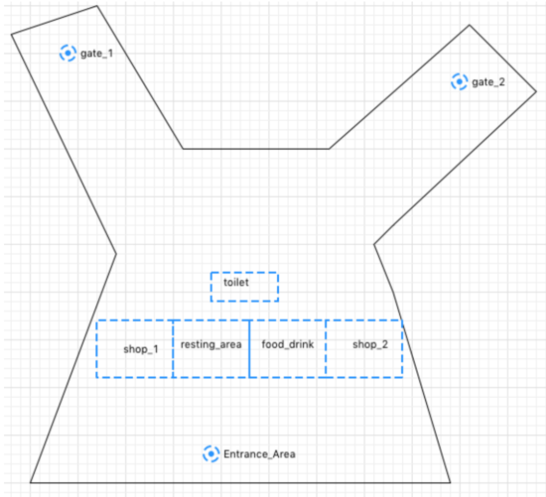

Figure 7: Terminal shape: finger.

Figure 8 shows the result comparing finger-shaped terminal and linear-shaped terminal. While both terminals produced very similar retail revenue when the shops are centralized, the result is vastly different when the shop is partially or completely decentralized in our model. This means that airport might need to duplicate its shops in each ‘finger' to offer more retail opportunities in a finger-pier shaped terminal. However, in the airport context, it is a challenge to duplicate each type of shops on each finger due to the space constraint. This result also contradicts Doganis (2005)’s statement that retail offers should be spread out across the whole terminal as centralized layout generated the most revenue among the three layouts. In the current model design, it could be argued that the partially or completely decentralized layout splits the passenger flow and thus reduces passenger’s penetration ratio to shops. This will reduce passenger’s chances of browsing and shopping. On the other hand, centralized shopping helps to improve penetration ratio and increase the propensity of passengers to spend.

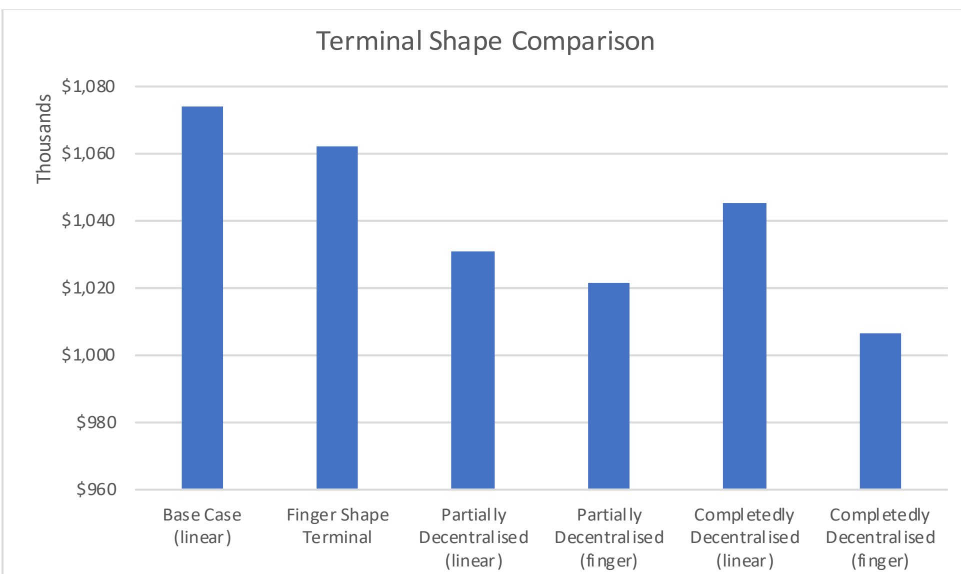

Figure 8: Linear vs. finger.

6 CONCLUSION AND FUTURE RESEARCH

This paper presented a conceptual Agent-Based Model that can simulate passengers' shopping behavior under various scenarios. It is the critical first step in moving towards a better and more holistic airport passenger shopping simulation. The model was intentionally designed to be simple but robust for future expansion. The model allows the potential for the agent (passengers) to behave like a human being by calibrating the agents' logic. The agents interact with the airport facilities based on their characteristics and personal status. Despite the interesting results presented in this paper, the model should be further improved in several ways. First of all, real passenger shopping data should be collected in an airport environment for the calibration purpose. Secondly, passenger's shopping behavior model should be enhanced and validated. With the availability of passenger data and a validated shopping behavior model, our model could deliver future revenue prediction and many other possibilities. Furthermore, the conceptual model should be expanded to include more factors and elements that impact airport retail revenue. Future research could also incorporate the aeronautical needs of the airport, so it can present a more balanced view of how terminal could be better designed to facilitate airport retail. The model can be an invaluable tool to airport retail operator in evaluating how terminal could be better developed in the future.

ACKNOWLEDGMENTS

This project is supported by the Australian Government Research Training Program Scholarship.

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