Mobile Indoor Navigation Application for Airport Transits

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Abstract

Passengers have an ultimate goal of transiting through airport terminals as efficiently and as quickly as possible while the airlines aim for a shorter turnaround time at airport terminals. However, the events of September 11 have dramatically and permanently changed air travel into a more cumbersome experience for both airlines and passengers. Not only do passengers despise long queues, they also do not like being lost in airport terminals that are new to them, especially in large international hubs. The late arrival of passengers to the boarding gates can have negative impacts on the airline companies as they wait for late passengers to arrive at the gate, sometimes causing them to find and remove already loaded checked baggage. Mobile Technology on the other hand has been growing rapidly and has provided solutions for similar problems that are faced by air travelers. Passengers have quickly adapted to the mobile revolution but the airline industry has been passive and lagging in new innovations that could simplify the travelling process of their customers while also improving their daily processes. This study focuses on the early development of a mobile indoor navigation application (app) and how the mobile application would help improve customer travel experiences within the airport while benefiting the airlines by improving their boarding processes. Analysis of the results suggested that the usage of a mobile indoor navigation application (app) provided an improvement in terms of passenger travel time within an airport.
Introduction

The main goal for passengers is to make it to their flight and safely arrive at their destination. However, to make their flight on time, there appears to be a myriad of planning that needs to be accomplished prior to boarding. Passengers also face a maze known as “the departure hall” through which the departure gate must be found. This may not be an issue if the passenger departs from a familiar airport or is an avid traveller, but to a novice in a new environment, under the stress of a time crunch, determining the appropriate departure gate may be a difficult puzzle to solve.

Financial costs are incurred when airlines have late passengers to the aircraft, necessitating a longer turnaround time. For an airline, efficient aircraft turn times at the gate can optimize airplane utilization and maximize the large capital investments (MIRZA, 2008). With the Federal Aviation Administration (FAA) predicting that airline passenger travel will nearly double in the next 20 years (FAA, 2012), it is necessary to have a solution that simplifies a passenger’s journey through an airport as it becomes increasingly populated.

One solution to help aid travelers through unfamiliar airports is to incorporate technology, specifically in the form of mobile applications (apps). The purpose of this research is to develop the logic and idea for a mobile indoor navigation application, and to study its possible benefits to air travelers. Conclusions will be drawn to see if such a development would benefit both the passengers and the airlines.

Literature Review

In an airline operation, most disruptions such as missing check-in passengers at terminals or late connecting passengers are unpredictable and stochastic in nature (Wu, 2005). There are many reasons why passengers are late for flights, primarily because of the following reasons: passengers cannot find their way to the correct gate, passengers are lost within the airport facilities, passengers forget the time of the flight, passengers cannot understand or hear the loud speakers denoting a gate change, passengers are unable to read and understand posted signs at the airport, or passengers are distracted by other factors (Bite, 2010). At the Copenhagen airport, 4% of flight delays for Scandinavian Airlines (SAS) are due to
passengers arriving late to their boarding gate (Ornellas, 2008). As a matter of fact, the Department of Transportation classified gate delays (delays around the gate area such as late passengers) as the largest cause of delays, contributing 50% of total delays in 2001 (Mueller & Chatterji, 2002).

With unpredictable delays contributing to the instability of a financially fragile industry, a mobile indoor navigation application may help resolve the factors that contribute to a passenger being late. A mobile application has the ability to provide real time information to the palm of the passengers in an instant, and it has the ability to be easily updated or easily configured to suit the individual needs of a passenger, as well as the different airline models currently in use. Moreover, as passengers are becoming increasingly technologically savvy, the biggest advantage for a mobile application solution is the volume of current and potential smart mobile device customers that can accommodate such an application.

According to Nielsen, Smartphone owners are now the majority of mobile subscribers with 50.4% of total mobile subscribers (Molina, 2010). A figure by Société Internationale de Télécommunications Aéronautiques (SITA) shows that nearly 70% of air passengers now carry a smartphone (Kanth, 2012).

Mobile indoor navigation can be beneficial due to the growth in the niche market of indoor mapping. According to Yu (2012), outdoor mapping has been thoroughly mapped, and developers see indoor mapping as the next stage that is yet to be tapped and has a lucrative future. Consequently, large companies such as Google and Meridian have begun to expand indoor mapping resources and have rolled out many trial indoor maps for large and populated indoor facilities.

**Current Technologies**

The idea of a mobile indoor navigation application is based on the current market availabilities. In addition, the airline industry has limited technological solutions to solve the problem of late and lost passengers. Listed below are a few technologies available in the market right now (or being tested):

1. **Mobile applications**

   After a delay in joining the mobile technology bandwagon, the airlines are starting to build their own mobile application or have other companies develop the mobile applications for them. A typical airline application would include the ability for passengers to purchase a flight, to
check-in ahead of time, or obtain their tickets from the mobile kiosks at the airports. However, as the competition increases between the airlines and between third party mobile application developers, some airline applications have added features that could assist with airport navigation. For example, both United Airlines and American Airlines mobile applications have airport terminal maps. Despite their attempts to increase the availability of airport maps, they are usually only of the hubs that they serve, and the maps are both static and basic. Another new feature among mobile airline application, offered by Delta Airlines, is the ability for customers to track their checked luggage (Mutzabaugh, 2011). This feature is useful to detect the location of a luggage and can be further improved for navigation purposes.

Apart from a few airlines that have managed to make their mobile applications successful, most airline applications are considered mediocre despite containing some favorable features. This is due to airline applications being created from the perspective of the airline, not the customer’s point of view and it has resulted in the creation of third party applications like “GateGuru”, “Airports”, and “Flight+”. “GateGuru” is an application that allows a user to find eateries and other services in an airport terminal with ratings and reviews from other mobile users near their gate locations. The application was created by a traveler who was frustrated by the lack of information available to passengers (Taneja, 2012). “Airports” is a mobile application that provides its users with airport gate information, detailed airport terminal maps and many other features (CNNGo, 2013). Another application available as a third party option is Flight+. In general, Flight+ combines flight tracking with a master itinerary and also information about the airports and airlines. Though the maps in Flight+ are similar to other mobile applications in that they are simple, the biggest feature of Flight+ is its ability to provide all the relevant information of a flight. Information such as actual and scheduled times, gate information, and flight location on a map. It alerts the users of changes being made to their flight (German, 2012). These are useful tools for a passenger in a hurry. One other application, developed by Apple, is known as Passbook. This is an application that uses both time and location based information. Passbook
sends alerts to the passenger based on their scheduled departure time as well as when they approach the airport, even notifying passengers of gate changes after they have checked in for their flight (Apple, 2012).

A development for airport transit navigation tested recently at the Helsinki International Airport is the usage of an RFID-enabled airport guidance display card given to transit passengers upon their arrival at the airport. The device helps them locate their gate, informs them if their departing flight has changed, and helps them navigate queues at the passport control area (Swedberg, 2011). Third party applications appear to be filling the gaps that airline applications have failed to address.

2. Indoor navigation technologies

Digital map and mapping has evolved significantly over the last two decades. Google has been at the forefront of digital mapping since the introduction of Google Maps. It has improved the basic map with new features every year (Google Maps, 2013). However most digital navigation and mapping tools have only succeeded in outdoor mapping. Most of the reason behind the success of outdoor navigation is due to the growth of Global Positioning System (GPS) and its implementation into mobile phones. Despite great success with outdoor navigation, indoor mapping and navigation has yet to be fully explored. The biggest reason behind this lack of indoor navigation is the inability to determine a person’s real location indoors due to the inability of GPS to perform indoors (Yu, 2012). Therefore many developers are finding new ways to improve indoor locating methods to develop indoor navigation. Current indoor location methods include RFID, Bluetooth, Wi-Fi access points, and QR codes (Costa-Montenegro et al., 2005). RFID generally consists of a sensing system that locates objects within the building. Bluetooth and Wi-Fi access points both work for the same purpose but these methods locate the user based on the user’s smartphone Bluetooth or Wi-Fi signals. QR codes are codes translated into a picture that is then decrypted by a smartphone and locates that user (Costa-Montenegro et al., 2011).
Along with developers trying to enhance location of users in an indoor environment, digital map providers such as Google and Meridian have provided a mapping tool for indoor navigating possibilities. For Google, they developed Google Maps indoors in addition to the already existing Google Maps by adding detailed floors plan of an airport building and including an arrow that shows a person’s orientation and location. This technology is currently being implemented in airports like Atlanta, Chicago, and Indianapolis as an initial phase (McClendon, 2011). Meridian is another mapping and navigation service similar to Google Maps. Some of the products of Meridian are currently used in places such as the Venetian Hotel in Las Vegas and the subway system in New York (Yu, 2012). Nokia is another company that is currently testing and running indoor mapping and navigation apps. They are using Bluetooth technology by adding more beacons or signal devices in the buildings (Yu, 2012). Airports or the airlines could incorporate technologies like these to be innovative and benefit themselves as well as their customers.

**Shortcomings and Issues**

There are many initiatives taken by airlines to capitalize on the trend of passengers becoming mobile and technologically savvy. However, there are many shortcomings to the initiatives taken by the airlines and also to the third party mobile applications. One such shortcoming is that the airlines are inward focused on their own operation and reducing their cost. They tend to use their legacy systems that are not as flexible to the fast-paced changes as newer systems (Taneja, 2011). Passengers have become immensely complex and extremely varied, as well, with each passenger having a different standard of satisfaction (Taneja, 2011). This makes it difficult for a single mobile application to satisfy every need of a passenger. Non-holistic approaches are also an issue, as third party applications do not work cooperatively with airline applications to improve the passenger’s experience. Each application only meets a certain need in a certain area and is lacking in others. Therefore, it is this author’s view that a holistic mobile indoor navigation application should be developed so that passengers would benefit by having a better travel experience. Aside from mobile applications having shortcomings, the technology of
indoor mapping also has its issues. The technology is still in its infancy and it may not be fully ready for large-scale usage (Yu, 2012). On the other hand because of its development stage, rapid growth is a side effect that will benefit the users. However, issues of high costs and accuracy can be factors that keep prospective customers from investing in the new technology (Yu, 2012). High costs occur because of the implementation of the technology such as more Wi-Fi or Bluetooth access points, which helps determines the accuracy of the users. Keeping cost low on the other hand may cause the location accuracy of the user to be degraded and could lead to a bad customer user experience. The goal of this study is to incorporate current available indoor navigation technologies and develop the logic for a mobile application that helps the journey of a passenger and simulate it to determine if it has an advantage over the current airport navigation method.

Methodology

Mobile Application (App) Development

Measures

Basic knowledge of mobile app development was obtained through research and instructional guides available in print and online.

Procedures

Knowledge of mobile app development obtained from sources was applied to determine a simple logic and working for a mobile indoor navigation app. The result from this basic development is the general idea of how the mobile app would work and function as an indoor navigation tool. Once the logic was determined, a paper simulation was completed to test its usability and to compare it to the static map method by doing a simulation study.

Simulation Study

Participants

Participants for this study included students who were attending Purdue University and members of the general public of the city. All voluntary participants responded to the flyers or by word of mouth from other participants. Sixty-five voluntary participants took part in this study.
Measures

Two different paper maps were used to conduct the simulation study. One paper map simulated a typical static map located at airport terminals consisting of diagrams of all facilities and floors on one large paper (Appendix A). The second paper map was sized to fit the palms of the participants and these palm-sized maps provided turn-by-turn directions to their destination (Appendix B). A stopwatch was used to time each participant as they made their way to the designated destination.

Procedures

To determine if using a mobile indoor navigation app would make for a better experience and a faster travel time, a simulation study was done to compare the current method of a static map to the mobile app method.

The simulation study was conducted at the student union of Purdue University to simulate an airport terminal. Participants navigated through the student union to a specific destination, similar to what passengers would do in airport terminals to locate gates or services. This simulation study consisted of two methods: a static map method (Reference Test), and a mobile app map method (Application Test). Participants were assigned one method of either Reference or Application to reach their destination. The assignment of the method for the tests were alternated among the participants based on the random number table obtained from the National Institute of Standards and Technology (NIST) (2005), as a counter balancing technique.

In the Reference Test, participants were orally told of the destination and they were shown a map with their current location marked out. The participants then proceeded to the destination. For the Application Test, the participants were also orally told of the destination. However, in this test, the participants were given a set of turn-by-turn directions to their destination on a palm-sized paper to simulate the usage of a mobile app. The participants then made their way to the destination. The researcher recorded the elapsed time each participant took to reach his or her destination. The dependent variable was the time elapsed for the participants to reach their destination, while the independent variable was the method of navigation that was assigned.
Results

Due to the two-tiered approach of this study, the results are presented in two corresponding categories as shown below:

Mobile App Development

In the development of the mobile app, the logic and workings of the mobile app were created. The result is a general idea of how the mobile app would work and function as an indoor navigation tool. For this study, the results and logic behind the mobile app were created in a two-process flowchart format as shown in figure 1 and figure 2 of Appendix C. Figure 1 represents Process 1 of the mobile app in which it requires the user (passenger) to input his or her flight information (either flight numbers or origin and destination airports with specific dates and times) and the application will gather the necessary information of the selected airports and store an offline version for the user. Process 2 of the mobile app is the navigation assistance portion of the program. This process provides the latest flight information and uses the location data of the user to provide turn-by-turn directions for the user to reach their gate as shown in figure 2.

Simulation Study

After the simulation study was completed, the elapsed time data for both tests were recorded for analysis and comparison. Because both tests were given the same destination, a direct comparison between the two tests was possible. The hypothesis for the simulation study that determines if mobile app was a better solution to the current map method was listed as follows:

- \( H_0: \mu_{\text{app}} = \mu_{\text{map}} \)
- \( H_A: \mu_{\text{app}} < \mu_{\text{map}} \)

For the reference test (map method), the minimum elapsed time was 98.10 seconds and the maximum elapsed time was 359.10 seconds with an average of 224.40 seconds. In the application test (app method), the minimum, maximum and average time were 99.50 seconds, 196.60 seconds and 142 seconds.
respectively. The summarized data and comparison can be seen in Appendix D. Standard deviation for the reference test (map method) was 76.98 seconds and 22.81 seconds for the application test (app method).

**Statistical Analysis**

Once the data were obtained, statistical analysis was done to draw conclusions of the simulation study. Using statistical software, the data obtained were put through an Anderson-Darling normality test to determine if the data obtained could be considered a normal distribution. To do so, p-value was calculated from the data of the simulation and a p-value of 0.05 was set as the limit. If the p-value for the actual data was less than this limit, a conclusion may be drawn that the data do not follow a normal distribution. However, if it is higher than the set limit, there is not enough evidence to conclude that the data do not follow a normal distribution (Anderson & Darling, 1954). P-value from both the reference test and application test were 0.098 and 0.507 respectively. Therefore there is not enough evidence to conclude that both tests did not follow a normal distribution.

Because normality can be assumed, a two-sample t statistic was done to test the hypothesis of this study. Results from the two-sample t statistic obtained from using statistical software were as shown in Appendix D. From the values in table 1 of Appendix D, H₀: μ_app = μ_map is rejected. Therefore, it can be shown at α = 0.05, that the time to navigate inside the student union is less for the application test (app method) than the reference test (map method).

**Discussion**

The notion that using a mobile app as an indoor navigation tool would provide not only a better experience but also a faster way to navigate through new environments led to the hypothesis that was created for this study. To test that, a simulation was created to study the effects of using a mobile application as a navigation tool. About 60 participants were used in order to obtain accurate and statistically testable results. Also, the null hypothesis, H₀: μ_app = μ_map was rejected based on the data obtained from the simulation. By rejecting the null hypothesis, it may be concluded that the application test (app method) was a faster option to navigate through an airport as can be seen in Appendix D.
While the app method was faster on average, some participants using the reference test (map method) had faster or equal times to those who took the Application test (app method). Reasons for this could be that some participants are better at analyzing maps and are generally better with directions than others. In fact, the existence of such participants in the data allows it to simulate a real world airport travel where some passengers who are frequent fliers know their way around airports better than others. Another noteworthy observation is the standard deviation. With a smaller standard deviation in the application test (app method) of just 22.81 seconds as compared to 76.98 seconds for the reference test (map method), the data showed that even though there may be a faster time in the reference test (map method), the application test (app method) is a more consistent method and also faster on average than the large varying times of the reference test (map method).

**Conclusion and Recommendations**

This study was based on the idea that incorporating the fast evolving world of mobile technology and indoor mapping into the current state of airport travel can provide a better experience for not only the passengers, but also the airlines and the airports. By running a simulation study to test the effectiveness of the mobile indoor navigation app, it showed that the application test (app method) was a faster and more consistent way around a student union. An observation by the author during the simulation is that the mobile indoor navigation app also provided the participants of the simulation study a better overall experience, as they were less likely to become confused while navigating the simulation. In summary, the findings from this study show that the implementation of mobile technology into the aviation industry is mutually beneficial to the passengers and the airlines.

There are a few recommendations that can be applied from the outcome of this study. The airline and aviation industry should be aware of emerging technologies that could help improve their daily operations and the satisfaction of their customers. The airline industry should also adapt to new trends that are rapidly growing in the world such as mobile technologies. A better experience would help retain more customers and also possibly bring in new customers as these features make the airline or airport stand out among the competition.
For future research, a few areas could be improved on to obtain more reliable data and feedback. One of which is working with people knowledgeable in mobile app development to create such an application. Also a larger sample size would provide a better and more normalized data to analyze with. Because mobile apps are flexible to changes, various ideas can be implemented and studied for their effects on airport travel. There may be a necessity for the inclusion of a map route that assists passengers who are disabled. In conclusion, due to the agility and rapid growth of mobile technology, the mobile app is a possible solution to improving air travel.
References


Molina, B. (2012, May 8). Nielsen: Smartphone owners now the majority, *USA TODAY.*


Appendix A

Sample of a portion of the static map
Appendix B

Sample of palm-sized paper maps that provided turn-by-turn directions
Appendix C

**Figure 1.** Mobile application (app) Process 1 flow chart

1. **Start Screen**
   - Accept user Agreement
   - Proceed to Process 2
   - 1st activation?
   - Have previous data?

   - Yes
   - No

2. **Gather map from server of all airports in itinerary**

3. **Save Decision**
   - User picks one
   - Display results
   - Send input to server

4. **Request User if wants to save offline map**
   - Yes
   - No

5. **Save offline map**
   - End Process 1

**Figure 2.** Mobile application (app) Process 2 flow chart

1. **Process 2**
   - When 2 hours before flight or near airport
   - Gather latest info from server
   - Send push notification with:
     1) Departure Time
     2) Boarding Time
     3) Gate Location

2. **User open app?**
   - Yes

3. **Begin Navigation**
   - User picks one
   - Calculate route options:
     1) Fastest Route
     2) Handicapped route

4. **Gather map data from indoor map client server**

5. **Detect Current user location and send to server**

6. **End Navigation once at gate**
   - Does user have connecting flight?
   - Yes
   - No
   - End Process 2
Appendix D

Histogram of time for reference test (map method) and application test (app method)

Table 1. Two-sample t-statistic results between reference test and application test

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