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THE SMART AIRPORT APP, TRANSIT.IO:

The Travel Optimizer

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ABSTRACT

Jacqueline Andrews, Devin Burke, Uvika Chaturvedi, Jake Collins, Pranav Gupta, Vikrant Neb, Harsh Somani, and Alyssa Williams were all seniors in industrial engineering in the spring semester of 2016. They were members of Team 3 in the course titled Human Factors and Work Analysis (IE 486). This course explores the application of engineering, computer sciences, information sciences, and psychological principles and methods to the analysis and design of human work systems. In this article, the students describe their development of an application prototype to improve the airport travel experience.

INTRODUCTION

Transit.io, the Travel Optimizer, is a smart service application used to enhance the airport travel experience. It provides real-time data, information, and analytics on airline departure times, in addition to other nuggets of information, to optimize a person's travel to and from the airport. It is intended to eliminate waiting times and enhance efficiency. It is also a platform for metadata mining and understanding customer preferences and behaviors when traveling. Our team's Smart Human-Centered Service System Design solution is a smart airport application that utilizes real-time data from various sensors and data points to prevent bottlenecks at airports and enhance the traveling experience.

Our design is "smart" because we utilized machine-learning and eye-tracking technologies to provide constant updates during flight delays or long security checklines, allowing the user to adjust travel plans accordingly. Machine learning is a technique that helps provide personalized outputs and decisions after every use. Eye tracking is a technique used to help track eye fixation for evaluating usability. The eye tracker and eye tracking analysis software developed by Tobii show where the user looks, for how long, and the path the eye travels. The app also utilizes certain quick-action features, which allow the user to call a cab or print a boarding pass. There is also a travel update feature, which can be shared with others. The design updates the system as the user is moving through the terminal.

There are many different systems that exist within the scope of an airport, such as individual passengers moving through the airport and encountering other systems like TSA checkpoints, restaurant and bathroom queues, and shopping stops. This massive amount of data needs to be combined with the airport company data (e.g., whether a flight is on time and the departure gate). This creates a complex system for analysis by the learning system, which must be conveyed to the app user, who reacts to the information.

Our goal was to create the prototype of an application that improves the airport travel experience by providing an alert about the time when the user should leave his or her current location in order to catch the flight. We evaluated these prototypes using different techniques.

METHODS

Data was collected from a questionnaire given to people after utilizing Tobii (software used to track eyes). Based

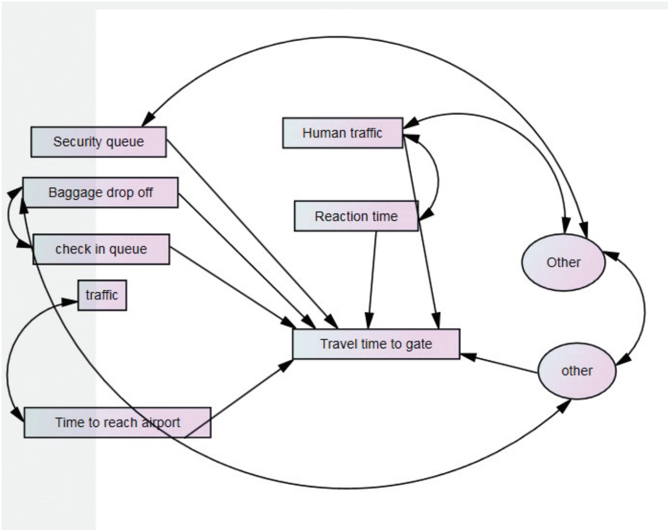

Figure 1. Structural equation model in SPSS.

on this information, we decided against any modifications to the prototype. While people suggested simpler designs, these modifications would break our overall goal of specific instructions for the user in order to reach the gate on time.

The following variables related directly to our requirement to conduct an evaluation using structural equation modeling (SEM): security queue, baggage drop-off, check-in queue, time to reach the airport, human traffic, and subsequent reaction time. Some features are interdependent, as shown in Figure 1. We used two "other" variables to account for unforeseen circumstances. Our goal was to find the variance and covariance between the defined variables based on the data obtained.

When it was time to analyze the final data from the combined subjective and objective data gathered from the testing, another SEM was created. Ultimately focusing on the functionality of the app based on different inputs, the following model was created (see Figure 2). It did not show strong correlation between the factors, even though the model was considered good, as the P-value was above .05.

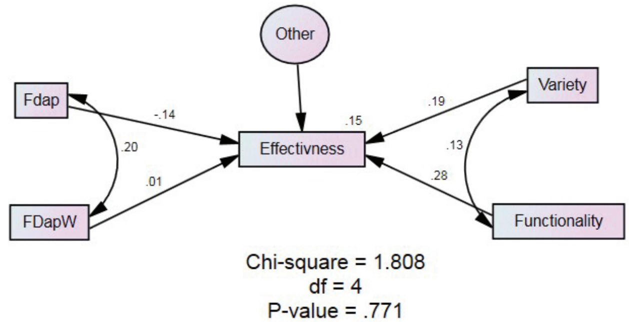

Figure 2. AMOS results in SPSS.

Overall, the results of the SPSS Analysis of Moment Structure (AMOS, a statistical software used to access models) breakdown were favorable based on the chi-squared value being larger than .05 and having a large P-value of .771. The results of the cluster analysis show that users determined that there was largely one cluster per screen, except for the second picture shown with a random two that skewed our data (see Figure 3). The results of the analytic hierarchy process (AHP) analysis concluded that our third alternative was preferred (Figure 4).

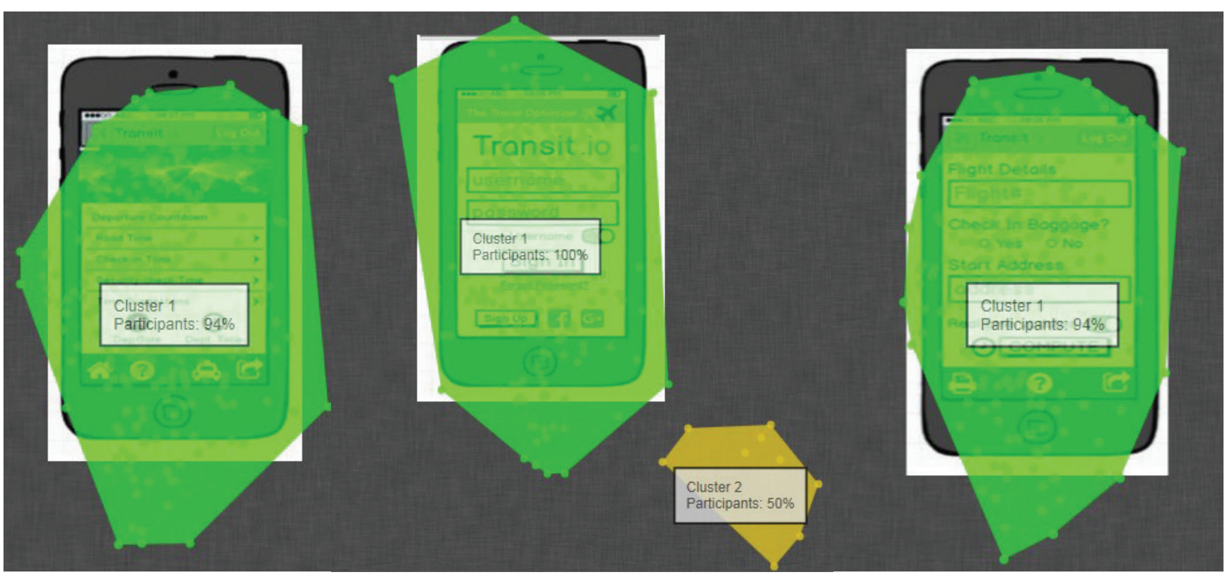

Figure 3. Cluster analysis using the Tobii eye tracking system.

		Scores for Alternatives		
Criteria	Weights	Prototype 1	Prototype 2	Prototype 3
Simplicity	0.148	0.315	0.082	0.602
Effectivness	0.494	0.158	0.187	0.655
Functionality	0.291	0.455	0.455	0.091
ime of Visualizatio	0.067	0.221	0.685	0.093
Weighted Ratings		0.272	0.283	0.445

Figure 4. Results of the analytic hierarchy process (AHP).

Cognitive Work Analysis

Cognitive work analysis (CWA), originally developed for analyzing complex systems such as nuclear power plants, provides a comprehensive framework for studying system requirements and collaborative performance (Rasmussen, 1986; Vicente, 1999). CWA offers insight into complex human-machine systems. In addition, cognitive work analysis and simulation (CWAS) provides a profound framework for simulation modeling. CWAS adds value to the CWA research methodology by providing a structured process for using system analysis as a modeling basis for cognitive behavior simulation modelers. CWAS is meant to add value one step before actual prototyping in the product and system life cycle, making it possible to examine a larger variation of design scenarios before deciding on prototyping options.

We can incorporate CWA into our airport smart app, as people trust their lives with human-machine systems such as airplanes every day, making it critical for system designers to prevent human errors and accidents. CWA is a method developed to analyze the cognitive requirements of such systems to inform the design process. On the other hand, simulation modeling has been used to provide quantitative metrics for decision-making. However, it lacks a comprehensive framework for modeling, based on a model analysis. In this research, we propose the CWAS method to bridge the gap between analysis and simulation by using the CWA results to build a dynamic representation of the system.

Although the CWAS method is widely used and well established, there are limitations in applying the analysis results in action. The product design process is an iterative process (Berente & Lyytinen, 2005) that starts with an initial idea. After evaluation, new ideas are developed. Understanding the effect of several changes in the design on the entire system's performance is a challenge when using the current CWA presentation. Therefore, there is a need for a holistic and dynamic representation of the CWA results. In addition, making decisions is easier with quantitative data, which the current CWA does not provide. The premise of this work is the suggestion that using simulation models that represent the system, based on the CWA analysis and the members' workload, would be a proper remedy to this gap.

The modeling approach in CWA is formative, meaning it defines what is needed to perform the task, regardless of the agent, the event, and the current environment of the system (Roth & Bisantz, 2013). The formative approach contrasts with the normative or prescriptive models that suggest what should be done, or the descriptive models that present what actually is done (i.e., how do workers complete the task in the existing system?). The formative approach analyzes the work by going deeper than the surface actions, at a level that is independent of the agents and the events, which reduces the reliance on expert opinion. As other methods primarily rely on eliciting the knowledge of the expert to determine how they perform their tasks and strategize their decisions, a formative CWA method seeks the intrinsic characteristics of the work that do not depend on how the work is currently accomplished. Our task scenario would include custom behavior on the app, patterns of travel, cognitive behavior of travelers, and airport personnel for smooth functioning.

Situation Awareness

Although much of situation awareness (SA) research originated within the aviation domain, SA as a construct is widely studied and exists as a basis of performance across many different domains, including air traffic control (ATC), military operations, education, driving, train dispatching, maintenance, and weather forecasting. One of the earliest and most widely applicable SA definitions describes it as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1988 p. 97). SA therefore involves perceiving critical factors in the environment (level 1 SA), understanding what those factors mean—particularly when integrated together in relation to the operator's goals (level 2), and, at the highest level, an understanding of what will happen with the system in the near future (level 3).

In context to our Smart Service System Design, (SA) can be thought of as an internalized mental model of the current state of the operator's environment. All of the incoming data from the many systems, the outside environment, fellow team members, and others (e.g., other aircraft and air traffic control) must all be brought together into an integrated whole. This integrated picture forms the central organizing feature from which all decision-making and action take place. A vast portion of the operator's job involves developing SA and keeping it up-to-date in a rapidly changing environment. This is not a simple task in light of the complexity and sheer number of factors that must be taken into account to make effective decisions. The key to coping in the information age is developing systems that support this process, yet this is where current technologies have left human operators the most vulnerable to error.

As we move into the twenty-first century, the biggest challenge within most industries is that the most likely cause of an accident receives the label of human error. In fact, in the vast majority of these accidents, the human operator is combating significant challenges. On a day-to-day basis, operators cope with demanding, complex systems. They face data overload and similar challenges that come with working in a complex system. In reality, the person is not the cause of the error, but rather the final dumping ground for the inherent problems and difficulties within the technologies. The operator is generally the one who must bring everything together and overcome whatever failures and inefficiencies exist in the system. So why do people have trouble coping with technology and data explosion?

The answer lies in understanding how people process the vast amounts of data to arrive at effective performance. If these accidents are examined in detail, it is evident that the operators generally have no difficulty in physically performing their tasks and in knowing the correct thing to do, but they are stressed by understanding what is going on in a given situation. Developing and maintaining a high level of situational awareness is one of the most critical and challenging tasks in many domains today.

Human Factors Evaluation

Application Usability: Eye tracking helps evaluate whether software guides the user to complete a routine task or to achieve a learning goal in an intuitive way. Eye tracking is used to improve human computer interaction (HCI). This technology will help us understand if the user understands and is able to do what needs to be done. We plan to add certain quick-use functionalities within the app, such as asking user preference of check-in luggage, selection of mode of transport to and from the airport, and flight tracking. The user experience design (UXD) is an important cognitive aspect of human factors within our app.

Application Design: The application should be designed so that it is user-friendly, clear, and easy to use and understand. It is easy to design a complicated system for such an app. Since many factors are integrated, the design needs to be simple, where the user inputs minimal information and gets the best possible results. The other aspect of the design is the collection of metadata and customer behavior, which can be used to study and analyze patterns. Agent-based modeling through NetLogo or similar software can be used to provide intuitive informatics to the airport personnel.

Machine Learning: Initially, the app will use general statistics, time studies such as time in the queues, and real-time stats from apps like Google Maps to calculate and suggest the time to leave for the airport. As the data keeps recording, the app self-learns based on a given situation along with trends, holiday travel, and peak hours. It will predict travel times based on a daily schedule, places visited, current location, and what is occurring in the surrounding area at a given time. The app will suggest a time frame based on these factors to prevent missing a flight. This is an exciting and upcoming field, as machine learning can be used to study peak travel times, boundary conditions and constraints, and upper bounds and capacity limits of the airport. We can use real-time analytics for efficient use of airport resources and for streamlining the process of airport travel.

RESULTS

Our team used hierarchical task analysis, human factors evaluation, and evaluation of situational awareness to analyze cognitive aspect of tasks.

Hierarchical Task Analysis

Hierarchical task analysis (HTA) describes the overall journey of the user. It is a process in which tasks are broken into subtasks until all the elementary tasks have been defined. The decomposed tasks must have a goal, conditions required to attain the goal, and criteria related to when the goal is achieved. Procedures, selection, rules, or time-sharing principles mark the relationship between a set of subtasks and a superordinate task (Hollnagel 2012, 391). This process is used in building interface design and therefore is applicable in the analysis of our design for a project prototype of the application of the Smart Airport App. We could break tasks into subtasks and then develop the wireframe of our application. Creating subtasks will help us get the user inputs required to implement our action and achieve our goal.

In our proposal, we talked about hierarchical task analysis. Figure 5 shows the hierarchical task analysis of the

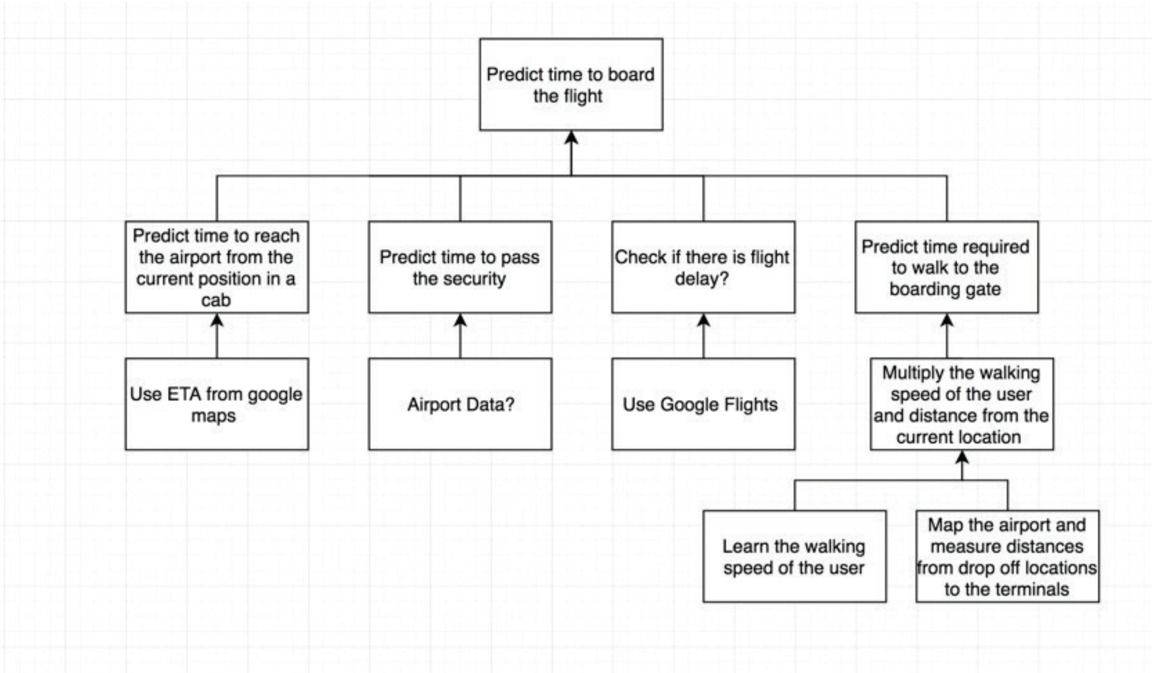

Figure 5. Hierarchical task analysis chart for the outputs shown in Google Docs.

procedure the application needs to follow to predict the time it would take to board the flight. According to the HTA, we included walking time, which could be calculated this way or by average times using time studies.

At this point, we know the tasks we would like the app to perform, and can gather information, from the user to perform the functions. The HTA chart for the inputs are given in Figure 6.

After receiving the inputs, we can provide notifications to the user as to how much time he would need to board the flight or an alert on when to leave from the current location.

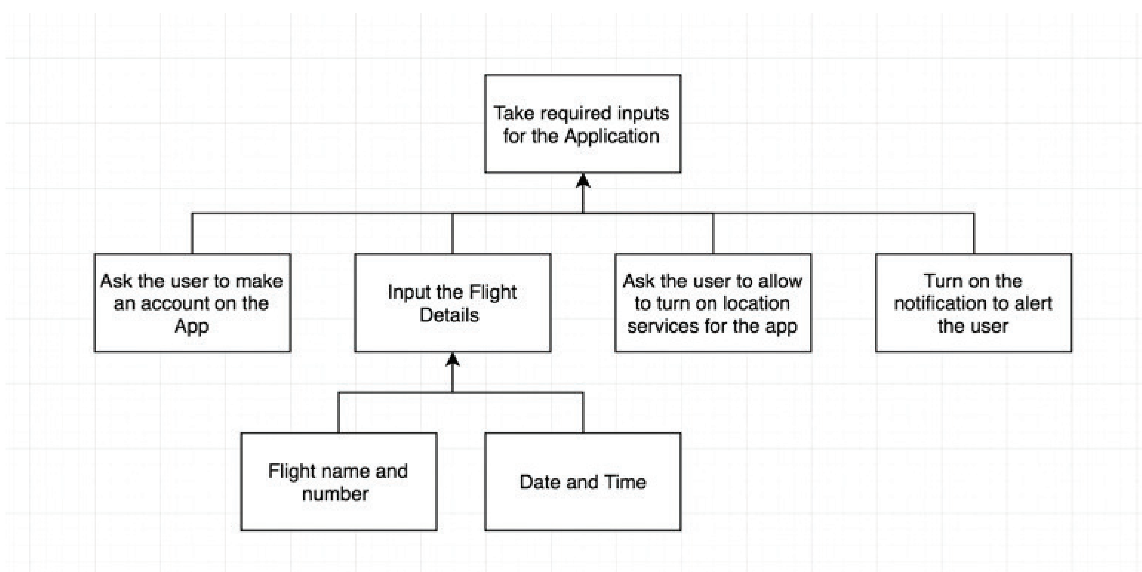

Figure 6. Hierarchical task analysis chart for the inputs shown in Google Docs.

Human factors considered in our application include information processing, selection, control of action, and, most importantly, interface design. We evaluated our model using situation awareness and considered the addition of a tutorial for first-time users.

The three different forms of our prototypes were created using Balsamiq wire framing tools and can be seen in Figures 7, 8, and 9. The final layout of the app, which was chosen after the AHP, can be seen in Figure 10.

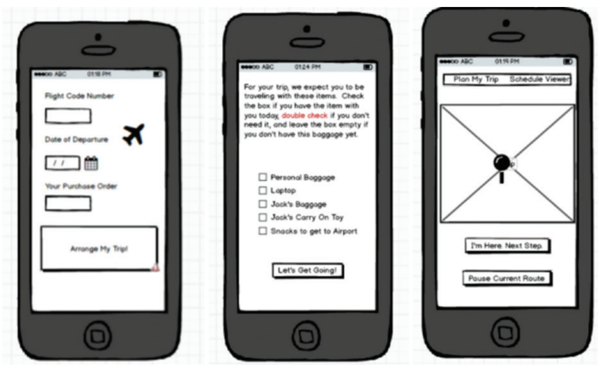

Figure 7. Prototype 1 shown in Balsamiq.

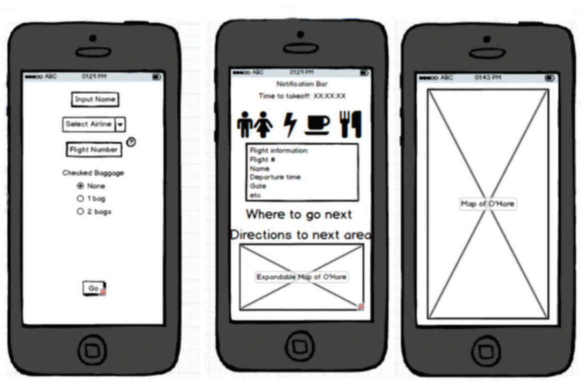

Figure 8. Prototype 2 in Balsamiq.

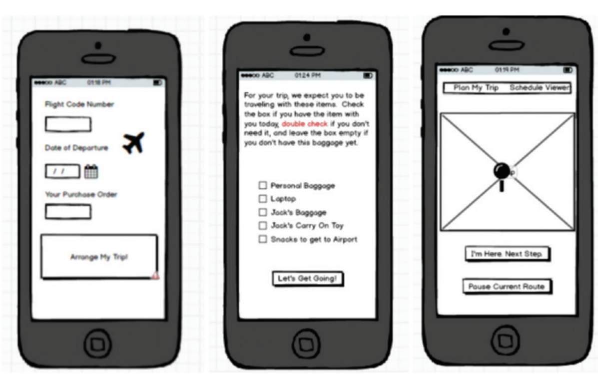

Figure 9. Prototype 3 in Balsamiq.

Figure 10. Final layout of the application in Balsamiq.

Usability Testing and Evaluation

Test subjects performed specifically designed tasks using the Tobii eye-tracking software, and data was collected and analyzed. A cluster analysis was performed using Tobii's interface ability, rather than heat maps or focal points. Areas of interest (AOI) were determined by our team and compared against the eye-tracking data to create comparative data sets. Next, questionnaire data was compiled into an Excel spreadsheet. Subjective questionnaire data and objective data collected from Tobii in lab 9 were combined into one Excel data sheet, and an AMOS SEM model was created utilizing the program software IBM SPSS AMOS. The overall goal of "effectiveness" was selected as the final output. In this lab, the criteria of simplicity, effectiveness, and functionality were chosen to signify the variables underlying the success of this app from the objective data. After obtaining data to find strong correlations through IBM SPSS AMOS, these relationships were taken into consideration when finalizing the prototype design. Analytic hierarchy process (AHP) was also applied from the survey's objective data to determine preferences.

DISCUSSION AND REFLECTION

Community/Client Impact

This app could have a large impact on the satisfaction of our client—the managers of O'Hare International Airport—and on the individuals passing through the airport's gates. In March 2016, almost 72,000 passengers passed through O'Hare, one of the busiest terminals in the world (Chicago Department of Aviation, n.d.). Patrons commonly voice frustration while navigating through this terminal. This app could reduce frustration and encourage travel from O'Hare, thus increasing sales throughout the stores within the terminal.

Student Impact

Being one of the largest teams in the class was our biggest challenge, but we learned how to work together and collaborate effectively. I (Uvika Chaturvedi) learned several things from completing this project, including how mockups are made and analyzed, how structural equation modeling is done, and how Tobii eye-tracking technology is used to determine the areas the user sees. I (Jacob Collins) learned from applying SEM to our model. It taught me how to coordinate data from different sources to create a final set of combined data—a valuable skill in this heavily data-driven world. Overall, our team learned how to develop a persuasive design proposal and low- and high-fidelity prototypes, identify a real-life human factors problem, conduct cognitive work analysis and hierarchical task analysis, evaluate a person's situation awareness, and present our results in a professional manner.

CONCLUSION

Travelers often experience flight delays and cancellations. Our app would help to minimize those delays and provide benefits to the airport and its passengers who travel through the terminal. The app is a smart service that draws on many systems that already exist within the airport. After a thorough analysis, we created an app based on AHP and SEM models. In the future, this app could be expanded for use in other airport terminals.

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