FlyKey

Arjun Nair

Syed Ali Abbas

Anna Wojdecka

Advisor: Deborah S. Carstens, Ph.D.

Florida Institute of Technology

14th April 2021

Table of Contents

1. Executive Summary

In this proposal, a multidisciplinary, multicultural team of three Graduate students from the Florida Institute of Technology set out to address the issue of how to mitigate the risk of infectious diseases at airports while improving passenger and personnel safety. The proposal targets the ACRP Design Challenge- Airport Environmental Interaction: Innovative approaches to help contain and control the spread of disease at airports. Additionally, our integrative design solution addresses Airport Management and Planning: Strategies for mitigating potential cybersecurity challenges at airports.

We propose a digital solution that enhances safety for passengers as well as staff and enhances passenger efficiency. This will be accomplished by using smart scheduling and eliminating infection risk touchpoints within the journey blueprint. This approach fuses human-centered design research methods with emerging technological innovations.

FlyKey is a revolutionary platform that optimizes travel experience, provides a comprehensive contactless approach, and provides three layers of functionality:

A passenger-processing FlyKey App, which facilitates the whole contactless airport experience, from check-in to arrival and provides a secure digital ID certification.

A tablet FlyKey-Personnel App, which enables smooth contactless staff-passenger interactions with airport personnel.

A central FlyKey-Analytics platform, which integrates passenger information and provides real-time analytics of passenger flow through the airport. Using trend and activity prediction algorithms, FlyKey radically changes the way we optimize passenger time-space allocation.

The loss of a single life is valued at $9.2 million, while the social and psychological costs cannot be quantified. Within a year, COVID-19 has taken over 500,000 lives in the U.S alone. FlyKey aims at protecting travelers from potential sources of infection in the travel experience. FlyKey is a scalable solution for airports that is easy to implement, and the benefits exponentially outweigh the implementation costs.

2. Problem Statement and Background

Since the Coronavirus pandemic spread, international air passenger traffic has dropped approximately 60 percent (ICAO, 2020). The drastic decrease in demand was never predicted and has created an unprecedented challenge for the aviation industry. The International Air Transport Association (IATA) forecasts that the demand for air travel is not expected to recover to the levels of 2019 until the year 2023; however, the recovery levels will be influenced by the progression of the COVID-19 pandemic (IATA, 2020). Similarly, Oliver Wyman, a global advisory firm, forecasts the recovery to the 2019 passenger levels in late 2022 (Stalnaker & Murray, 2020). COVID-19 is expected to change the way we travel forever. As lockdowns are lifted, an increasing number of people want to travel, either for family or business. With the resumption of non-essential travel, passenger willingness is an integral component of successfully operating airports and airlines.

As airports are a common area of the congregation for travelers, it can be inferred that the coronavirus' risk of spread is significant if the appropriate measures are not put in place. Our project aims to examine the opportunity to implement various technological and health measures at airports, which have the possibility of becoming a viral hotspot, on-demand for air travel. Airline and airport executives believe that the challenge of reducing passenger concerns about health and safety measures is integral to overcome the decline in consumer demand for air travel, provide safety and security for staff and travelers, and establish new operations (Bouwer, Krishnan, & Saxon, 2020).

Design Purpose:

The design and implementation of new touchless interfaces for airport procedures will play a crucial role in the future of air travel. This includes gesture-based sensing, touchless fingerprint detection, and voice activation. Those solutions require a high-quality UX design to be accessible, intuitive, and need robust built-in security measures (Iqbal, 2020).

The emerging opportunities in using Artificial Intelligence (AI) and Machine Learning (ML) systems to improve digital contact tracking and data sharing present many ethical concerns. New guidance systems and frameworks for developing transparent, ethical, responsible AI systems are being developed (Leslie, 2020).

The design solution aims at combating the issues related to the transmission of COVID-19 in the airport environment. Since no particular screening method is fully effective, The FlyKey group has developed a wholesome solution to address both airports and passengers' concerns, where airports do not have to worry about effective implementation of health and safety measures. Our design focuses on the implementation of technology to ease the passenger traveler experience by making the airport experience convenient.

The design has twofold benefits: allowing passengers to travel efficiently at their convenience, by flexibility, and for airports to receive real-time analytical data about the airport's operational status. Lastly, FlyKey allows the airport to strategically ease the peak travel bank congestion at hub airports by staggering passengers at the different waypoints.

3. Literature Review

3.1 COVID-19 as an example

What started in a wet market in Wuhan, China, in late November of 2019 as an infectious pneumonia-like disease has emerged to be the biggest disrupter of global peace and harmony. Officially declared as a pandemic on March 11, 2020, the Coronavirus (COVID-19) pandemic has changed the way humans' function worldwide - starting with working from home, quarantine, and lockdown measures in cities around the world. As of April 2021, the COVID-19 pandemic has caused over 2.92 million deaths and infected over 135.1 million individuals (JHU, 2021). The U.S. is currently leading with the highest infection rate globally, with over 31.16 million infections and over 561,780 fatalities due to COVID-19 (JHU, 2021).

COVID-19 is caused by the SARS-CoV-2 pathogen, which causes a variety of symptoms with a varying level of seriousness, including high-grade fevers, lack of taste, acute pneumonia, shortness of breath, cough, muscle and body aches, cramps, loss of taste/smell, headaches, sore throat, nasal congestion, nausea or vomiting, and diarrhea. Patients infected by COVID-19 experience various symptoms that may be unique from other individuals. (CDC, 2020)

The aviation industry is the global economy's lifeblood and is the arteries of interconnected worldwide economic activity. Since the aviation industry is a global connector and an enabler of connectivity for both passengers and cargo, the worldwide effects of the COVID-19 pandemic on commercial aviation have been significant. COVID-19 has led to a disruption in passenger connectivity, airlines' bankruptcy, forcing airlines to change their strategies, and early fleet retirement. Due to pandemics' inevitable nature, preparation against white swan events needs to be executed and planned, as the effects of pandemics are global due to the interconnectedness and dependence on international trade economies. Due to a rapid decrease in the peak commercial passenger traffic by approximately 60.5%, airlines worldwide were forced to reduce the capacity offered by 66% (IATA, 2020). Additionally, passenger confidence to travel plummeted, triggering a ripple effect on several industries that rely heavily on aviation: hospitality and tourism, manufacturing, and logistics. The industry supports over 65 million employments worldwide, both directly and indirectly through the supporting industries (IATA, 2020). Airports act as the facilitator of commerce and trade in the local community. Airports largely depend on airlines for revenues, particularly through aeronautical revenues and non-aeronautical revenues. Given the reduction in passenger demand, commercial service airports are forecasted to have a 56.7% reduction in revenue due to the Coronavirus pandemic (ACI, 2020). As passenger traffic returns to a new level of normalcy, it is integral for airports to proactively mitigate transmission of the virus through health, safety and technological measures.

3.2 Screening Measures and their Effectiveness in Air Travel

Gaber et al (2009) analyzed the screening for infectious diseases at international airports, namely the *Frankfurt Model*, which predicts that there is a more significant chance for the transmission of the SARS family coronavirus at airports in comparison to onboard the aircraft due to reduced levels of ventilation. Due to the lack of specific and standardized procedures, the Frankfurt model designed by the researchers aimed to introduce a new "pragmatic approach" to screen passengers during entry and exit at airports. The Frankfurt Model is a detailed model that meets all the requirements of the World Health Organization's (WHO) International Health Regulations (IHR). Additionally, the model also introduces a new contact tracing and classification technique to be used onboard the aircraft to classify passengers at likely risk.

The researchers acknowledged the role of aviation in the transmission and travel of infectious diseases worldwide and made specific recommendations for airports. The study identified several aspects of the travel experience that are potential sources for transmitting the virus. The researchers identified the possible routes of infection into two categories – before boarding the aircraft and after leaving the aircraft. The possible routes of infection before boarding the aircraft include the check-in counter lines, the gate holding area, the jet bridge, which are highly congested with poor ventilation, and other confined spaces in the airport.

Possible routes of infection after disembarking, as highlighted by the researchers, are passport control and customs queues, baggage claim areas, and traveler's transportation to and from the airport. All of the areas flagged as a potential risk by the researchers were areas with poor ventilation and the possibility of the congregation of passengers.

Gostic et al. (2020) analyzed the effectiveness of traveler screening programs at airports in identifying infected passengers using a mathematical model analyzing the effectiveness of the COVID-19 screening measures. The study recognized that current screening measures are an ineffective barrier to the spread of the virus. Some of the reasons for the ineffectiveness of the screening programs are the absence of visible/detectability of the symptoms during the incubation period of the SARS CoV-2 virus, which may vary from two to 14 days, the variability in the severity of the symptoms caused by the SARS CoV-2 virus, and the inaccuracy of the screening tools and inability of personnel.

An earlier study conducted by the researchers estimated that screening programs would miss detecting 50 to 75% of symptomatic travelers (Gostic et al., 2015). This research study incorporated both departure and arrival traveler screening into the mathematical considerations for screening effectiveness. The researchers estimated the probability of detecting an infected traveler using the mean incubation time and the fraction of subclinical (minimally recognizable clinical diagnostic) cases (Gostic et al., 2020).

The results from the 2015 study found that undetected cases by the screening programs were primarily due to the lack of detectability and the lack of symptoms of the SARS CoV-2 virus. The study also determined that variability in the pathogen's incubation period increases the likelihood of the screening protocol not flagging an infected passenger. The study recommended effective traveler **contact tracing for potentially infected passengers** undetected during the screening process. Gostic et al. (2015) suggest that the effectiveness of each screening program's screening components significantly depends on the time between the travel and the time of exposure.

Temperature screening is an effective mitigation strategy to identify symptomatic patients within the airport terminal since 78% of symptomatic, infected individuals experienced fever as a symptom (Gostic et al., 2020). A similar research study conducted by Bitar et al. (2009) highlights that the thermal screening cameras were unable to identify individuals with a recent onset of fever (i.e., in the early stages of the infection progression). Chan et al. (2004) conducted a research study that made recommendations on the optimal distance and screening procedure, stating that the face with the mouth open at a distance of 1.5 meters from the infrared thermal camera was the optimal method of accurate temperature collection.

Huizer et al. (2014) also studied the efficacy and applicability of control measures employed by airports, airlines, and governmental health agencies in mitigating the transmission of diseases through air travel. The study acknowledged the impact of air travel on the transmission of pathogens in creating health risks (Huizer et al., 2014). The control measures identified include entry and exit screening of travelers and crew, traveler information declaration, quarantine regulations, hygiene-related regulations, and contact tracing measures (Huizer et al., 2014).

Huizer et al. (2014) provided a comprehensive overview of the control measures' effectiveness, comparing each of the mitigation strategies by reviewing previous research studies conducted between 1990 and 2013. The researchers conducted a literature review of studies using PubMed as the source using keywords such as "air travel term" and "intervention term" as the source of extracting the relevant studies. Additionally, the study utilized the European Centre for Disease Prevention and Control (ECDC) public guidelines on disease transmission onboard aircraft to retrieve studies on transmission data. The study found that mitigation measures such as patient isolation, health monitoring, information provision about the disease to passengers, and increased health measures effectively prevented disease spread. Additionally, the researchers recommended contact tracing as an effective support measure in transmission control, depending on the disease's nature. Unlike other research studies, Huizer et al. (2014) stated the unlikeliness of effective transmission prevention using border screenings, quarantine measures, and travel restrictions. These measures involve complex planning and resources and can effectuate significant travel implications for travelers.

3.3 Health and Safety Measures

Chu et al. (2020) aimed to investigate and analyze the effects of pandemic mitigation strategies, including social physical distancing, face coverings, and eye protection equipment on the transmission of COVID-19 in the general community setting in hospital settings. Healthcare agencies and governments across the world have recommended these measures in an effort to curb the spread of the pathogen and minimize community transmission. The results from this study were aimed at providing clarification on the effectiveness of various safekeeping measures advised by different agencies.

The researchers conducted a metadata analysis of existing research studies to determine the optimal distance to be maintained to ensure the prevention of transmission of the pathogen. The study utilized 21 WHO specific sources to acquire the necessary data on the source SARS CoV-2 and Beta-Coronaviruses. The findings of the research study incorporated results from a total of 44 identified comparative studies in both non-health care and hospital settings with a total number of 25,697 patients. The results from this meta data analysis demonstrate that the probability of transmission is significantly reduced with a physical distancing of 1 meter or more, in comparison to physical distancing of less than 1 meter (Chu et al., 2020). The protection against transmission increased with the increase in the distance. The use of face masks significantly reduced the transmission risk between individuals. The results from unadjusted studies and sensitivity analysis studies obtained by the researchers corroborated the trend in the results.

3.4 Efficacy of Face Masks in Stopping COVID-19 Transmissions

Several research studies conducted by Zhang et al. (2009), Chu et al. (2020), Hendrix et al. (2020), and Seidelman et al. (2020) have shown the effectiveness of masks in preventing the human-to-human transmission of the SARS-CoV-2 pathogen. Due to the effectiveness demonstrated by the aforementioned research studies, it is to be assumed throughout the course of this study that the Health Measure referred to in this study is the use of face masks. The mandating of face masks has become prevalent in the U.S, and as of September 2, 2020, over 34 states mandate the use of face coverings in public. (Markowitz, 2020), while other states have varying degrees of face-covering requirements at the city or county level.

Two hairstylists working at a salon in Springfield, Missouri, were exposed to the novel coronavirus. Stylist A exposed stylist B to the virus, and both individuals developed respiratory symptoms. The stylists attended to a total of 139 customers from the onset of clinical symptoms to the time they were isolated (Hendrix et al., 2020) Both stylists and all of the salon's 139 customers attended by the stylists adhered to state masking recommendations. The Green County Health Department of Springfield, Missouri conducted contact tracing of all the individuals who were in contact with the infected stylist. The Health department offered nasopharyngeal swabs to all exposed individuals. 48.2% of the exposed customers at the salon agreed to be COVID tested. All results were confirmed negative (Hendrix et al., 2020).

The Green County Health Department contacted all of the customers 90 days after their salon appointment with the infected stylist to inquire whether they experienced any respiratory symptoms post their appointment at the salon. 83.7% of the 139 exposed customers reported not experiencing respiratory symptoms (Hendrix et al., 2020). This supports the concept that the usage of masks reduces the transmission of infection between individuals. The effectiveness of masks in reducing the transmission and surface spread of the SARS-CoV-2 is also supported by research conducted by Konda et al. (2020), in which the usage of face masks significantly increased the protection against the transmission of viruses.

3.5 Passenger Demand for Air Travel

Lamb et al. (2020) aimed to construct two statistical models capable of identifying the factors connected to the type of people willing to fly during the COVID-19 pandemic. The researchers divided 23 predictors into five sections, namely: personality, demographic, emotional, health, and air travel predictors were explored by Lamb et al. (2020).

A total of 632 participants from the USA were randomly separated into two samples for the study. Both the groups were tasked with completing an electronic survey. The researchers questioned the participants regarding their air travel history and then a situational question to test their views on flying during the current pandemic. The researchers found through their research that the five factors that most affected the decision of business travelers to fly were the perceived threat to the virus, risk-taking propensity, agreeableness, fear, and affect. Meanwhile, for leisure travelers, the five significant factors were primarily the purpose of travel, perceived threat, agreeableness, fear, and affect. The most common factors were perceived threat, agreeableness, fear, and affect. Lamb et al. (2020) predicted that a person with perceived threats could turn out to have negative emotions about flying out, of which fear could be one, explaining the results.

The purpose of the study conducted by Lamb et al. (2020) was to assess the type of person most likely to fly during the pandemic. The authors of the study believe governments could utilize the results of the study. A possible application could be to maintain policies on wearing masks or even disinfecting people and infrastructure to reduce the fear, thereby making people more likely to want to travel again.

Graham, Kremarik, and Kruse (2020) studied the changes in attitudes of elderly passengers to travel since the COVID-19 pandemic. The researchers focused on the 65+ age group as there is no specific data that suggests a shift in attitudes of elderly passengers. Additionally, elderly passengers are at a significantly higher risk and are the most vulnerable age group affected by the SARS-CoV-2 pathogen. (CDC, 2020).

3.6 Summary and Study Implications

The Frankfurt model (Gaber et al., 2020) also recommended introducing a "back-up medical station" in the airport terminal for travelers who are flagged by the screening methods during entry or exit screening for further examination or quarantine measures. This system is being applied globally during the COVID-19 pandemic as a recommendation by the researchers.

Grant et al. (2020) highlighted the asymptomatic behavior of the COVID-19 virus, making it challenging to effectively screen for infected travelers at airports and checkpoints. Due to the lack of understanding of the virologic behavior, identification of asymptomatic transmission is difficult. The effectiveness of temperature-based screening to screen for infected travelers also needs to be considered, as the study noted that only 78 percent of patients experienced fever. This implies that the infrared thermal screening measures could be ineffective in identifying infected passengers.

Gostic et al. (2020) reiterates that no screening program by itself is effective, and that a significant number of infected passengers would be undetected during the traveler screening. The researchers also suggest the application of traveler tracing measures to detect the cases missed by the screening process or in the incubation period of the pathogen. When implementing additional health measures, it is important to know that they may be ineffective, as it is integral to understand the nature of the virus.

The results from Chu et al.'s (2020) meta data analysis study supports an optimum physical distancing between individuals of at least 1 meter. In addition to the physical distancing measures, the use of protective equipment, including face masks and eye protection, is also recommended. The data from this meta data analysis study is integral to implement safe travel measures at airports and onboard aircraft. The implementation of a 2-meter physical distancing will ensure there is no transmission of infection amongst travelers at airports. Since it is not economically feasible to maintain a physical separation of 1 meter or above onboard aircraft, the mandating of masks is essential to curb viral transmission.

Until a safe majority of the population has been fully vaccinated, health and safety measures need to be kept in place to curb community transmission. In order to keep passengers and crew safe onboard aircraft and in the airport setting, facial coverings are the best-known measure that is also cost-effective. The overall risk of COVID-19 infection during travel has been reported to be minimal when the appropriate measures are put in place. Additionally, the research implicates the integral nature of implementing extensive testing and contact tracing measures as an effective strategy to mitigate community transmission. Authorities and airports should implement more effective detection technology to scan and trace travelers.

3.7 Technology as a tool against COVID-19

Airports and airlines saw a catastrophic collapse in passenger demand for air travel during the COVID-19 pandemic. The industry needs to be proactive and investigate technological advancements to react to future pandemics that do not include the closure of passenger flights and airports. In addition to implementing robust health monitoring technologies, digital solutions can assist the industry in physical adaptation to this new environment.

Most commercial airlines require passengers to be present at the airport premises, 3 hours before international flights and 2 hours before domestic flights, to complete pre-departure formalities. Utilizing apps such as FlyKey can significantly enhance the overall customer experience as it enables customers to explore and finish their travel procedures at their convenience. It allows customers to check-in, get their boarding passes, obtain luggage tags, and save customers' time. Furthermore, usage of the app helps disseminate information faster to customers. At mega airports, where there is a remote possibility that passengers miss their flight notifications, FlyKey provides regular personalized notifications for flight updates, which is greatly beneficial for the customer. The application is tailored to our customers' individual needs, and by utilizing the app, they have easy access to information; they can be clarified on their FAQs, whether it be about flight details or concessions.

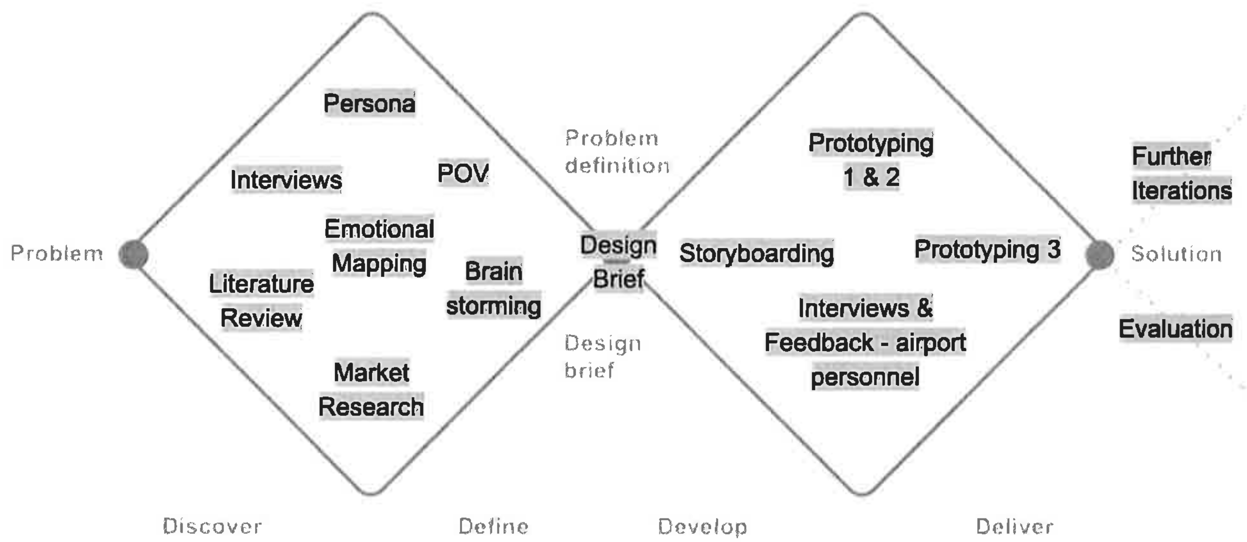
The aviation industry is very data-driven; however, due to COVID-19, the historical data collected by airlines and airports alike become redundant. FlyKey aims to rebuild customer confidence by enhancing the overall customer experience and to help airports and airlines acquire analytical data through real-time strategic reports. The data gathered is the driving force, as it enables the industry to take dynamic business decisions, greatly impacting the effectiveness and efficiency of asset management, route planning, facilities planning, and future airport development. This application is a comprehensive solution for all entities involved in the travel experience. i.e., the passenger, the airport, the airlines, third-party concession providers. Although several airports have implemented health and safety measures to curb the transmission of COVID-19 like enhanced sanitization, mandating masks, trying to implement touchless experiences, these measures do not guarantee to curb transmission. (Gostic et al., 2015). In addition to the implementation of FlyKey, the measures would allow airports to jointly combat COVID-19 alongside the other stakeholders.

4. Design Research Methodology

In the design research process, the team has followed a Double Diamond design methodology (Design Council, 2015). Figure 1 below illustrates diagrammatically methods and tools utilized at each stage of the project. Yellow highlights demonstrate the steps already completed; the blue ones show the teams' planned further development path.

Figure 1

Double Diamond design research methodology illustrating methods and tools utilized within the project.



In the first, divergent 'Discover' phase, our secondary research consisted of literature review and market research. As a part of primary research, the team conducted user interviews and emotional journey mapping (Design Council, 2015). Based on the gathered insights, we have developed a persona in the convergent 'Define' phase and constructed a problem statement. We selected a design direction from the concepts generated during the brainstorming and reformulated a design brief.

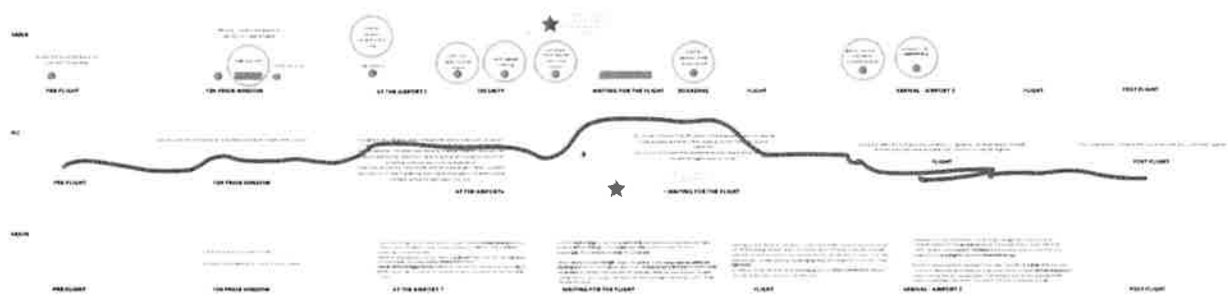
The second part of the diamond focused on the development and the execution of the selected concept. In the 'Develop' phase, the Storyboard of the ideal user journey through the airport has been constructed, and its main touch-points analyzed. Based on that, the first two iterations of the prototype have been developed. Those assets have been utilized during the conducted interviews with airport personnel to gather their feedback. As a next step, a platform concept and a third prototype was developed. After the submission, the team will conduct further usability testing evaluation of the third prototype and work on further development.

4.1 Task Analysis - User journey mapping

To understand the customer pathway for a long-haul flight and empathize with the customer, each of the researchers has performed an immersive journey blueprint mapping (Plattner, 2012). User journey mapping has been delivered using the Miro.com platform and illustrates the task from flight booking through Covid-19 testing, airport check-in, and flight to the arrival at the final destination

Figure 2

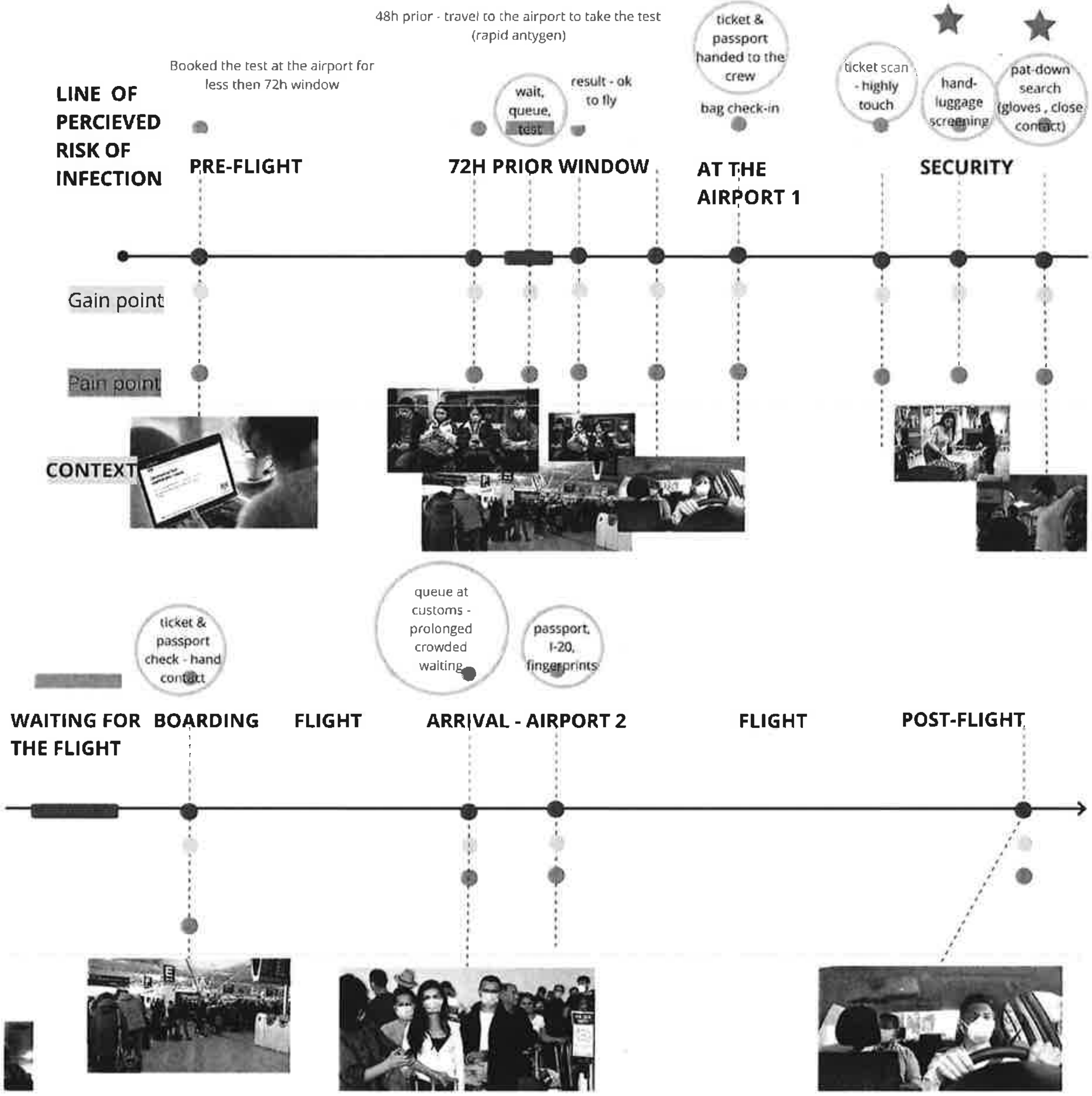
Journey empathy blueprint for three international connecting flights, completed by each of the researchers



The figure below illustrates a detailed user journey with analyzed touchpoints (Figure 3). The plotted grey line illustrates the perceived risk of infection, and potential intervention points linked to the peak points have been highlighted as yellow circles.

Figure 3

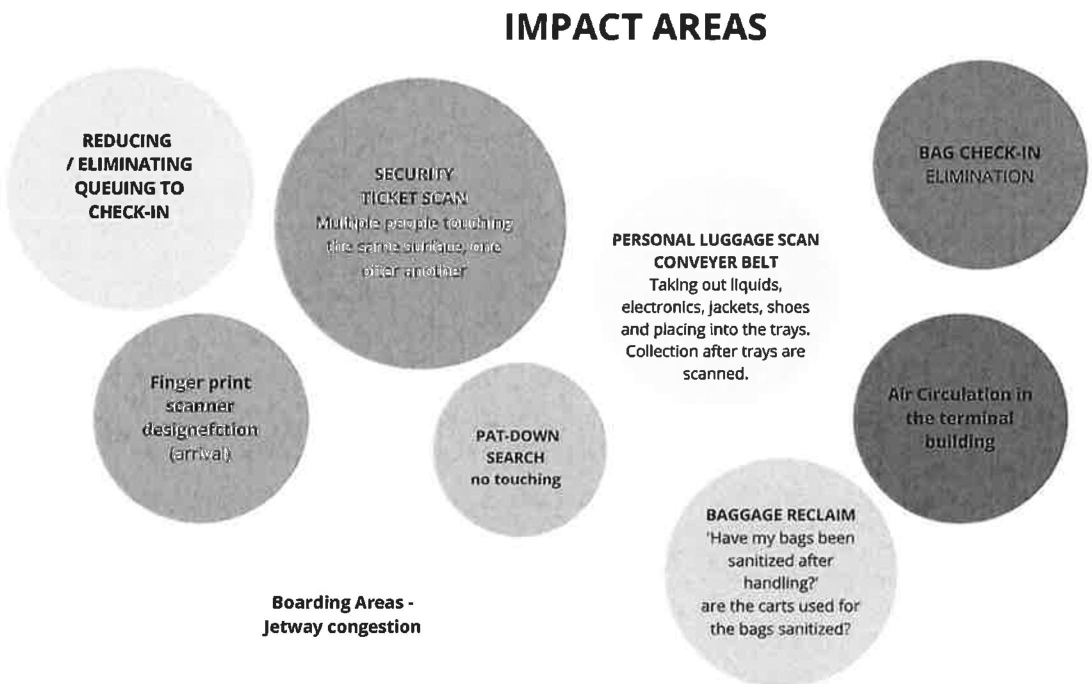
A detailed emotional map analysis.



4.2 Design Opportunity Areas and User Persona

Based on the primary and secondary research, the team mapped the potential opportunity areas where design can have an impact (Figure 4).

Figure 4
Identified Design Opportunity Areas.



Based on the research insights, the team developed a persona of the customer (Plattner, 2012), illustrated in Figure 5.

The Design Opportunity areas and the Persona have served as a basis for the concept generation and selection (Sharp, 2019).

Figure 5

The developed Persona of the customer.

Alex

AGE: 45

LOCATION: Orlando, FL

RELATIONSHIPS

Alex is married to Sarah and they have two young kids, a seven year old and a 2 year old toddler. His parents live in London and Sarah's family lives in California. His wife works as a creative writer. Sarah is immunocompromised and they both had a vaccination already.

LIFESTYLE

Alex used to travel very frequently, both work, visiting family and holidays with his wife and kids. His work tripos would be usually not longer than a couple of days.

The pandemic has had a huge impact on their family lifestyle. They haven't been able to see their parents for over 10 months now, and is hoping they can all travel safely again soon.

OCCUPATION

Alex works as a mechanical engineer for a medical company. Before the pandemic, his worked included frequent travel. He is passionate about new technology and opportunities and is thinking of having his own startup.

Yearly income: $160k

VALUES & ASPIRATIONS

Alex loves new technology and the convenience it can offer. He is a people person, known for his sense of humor and 'glass half full' outlook.

Family is at the core of his life and providing stability and security to the loved ones is his key motivator.

NEEDS

An easy way to travel, which would allow him and his family to feel safe.

PAINS: He also hates long time wasted waiting at the airport. He recently applied for a TSA Pre-Check scheme.

Overwhelmed by thoughts of multiple C19 tests pre and post travel, despite the vaccination. When he thinks of the logistics of travelling with his wife and little kids he feels like giving up, especially ad each country has different regulations.

SCENARIO: When Alex can travel again, the airport check-in is much smoother. The touchless journey limits the exposure to potential infections. The overall time of the pre and post journey hassle has been significantly reduced.

Figure 6

Design Brief

DESIGN BRIEF

FlyKey App

WHO

CONTEXT

Frequent international traveller, 18-65

CUSTOMER NEEDS: less queuing, less document handling, reducing contacts and touch-based interfaces to minimise the infection risk, a single simplified process for multiple airlines and destinations (integration of multiple services in one place)

VIABILITY: Significant cost reduction for the airport and airlines - reducing time and passenger congestion, staffing and the increased demand for air travel.

FUNCTION

FlyKey makes air travel simpler and safer. It allows the customer to provide all the documents required to travel and enables a completely contactless airport experience.

EXPRESSION

An application with simple, minimal aesthetic, evoking trust, and known for reliability.

WHY

STRATEGY

PHILOSOPHY: **The end of the compromise between safety and convenience.**

The identity of the holder and the authenticity of each document are verified using state-of-the-art technologies, providing stronger safety guarantees for everyone (e.g., it would be impossible to forge the result of the covid test) while facilitating the process. Allowing the customer to perform a significant portion of the security checks at home means simplifying the check-in process at the airport and reducing contacts at the airport, which in turn reduces the risk of spreading diseases: touchless interfaces and timely planned interactions to reduce the passenger queuing clusters and improve travel safety.

STRUCTURE: We will partner with airports, airlines, and COVID-19 testing medical centers. The roll-out will be introduced gradually, beginning with a trial testing on selected flight routes within selected airports.

INNOVATION & UNIQUE OFFERING: A universal platform incorporating every step of the travel experience from Check-In to Security, to the Boarding processes. Integrating identity verification, vaccination passports & airline partners.

WHEN & HOW

PROCESS

BUDGET: Initial investment: $300K

MATERIALS & RESOURCES: Cloud computing resources for the information system supporting the service. Terminals equipped with NFC/QR code readers and contactless biometric identification (based on cameras) to be installed in the airport, interfacing with the existing infrastructure (e.g. turnstiles). Partnership with COVID-testing services. Airport staff training.

WHEN: Initial launch in December 2021 for a limited number of airports and airlines. Extension to more airports and airlines in 2022.

TIMELINE

March - April 21 - customer needs and experts interviews, establishing

April - May 21 - physical and software prototyping & technology development, agile approach, sprints, user testing & feedback

June - July 21 - coding & initial testing

July - August 21 - partnership with BA and recruiting participants for the pilot study.

The first prototype would be piloted with one airline (BA), on a route Orlando-London.

Sept 21 - pilot testing begins.

Oct 21 - Collected insights for next design iterations

4.3 Design Brief and Establishing Requirements

The team has selected a concept of a digital solution from the generated concepts, which focused on creating an ecosystem of touchless interfaces, improving passenger flow through the airport through efficient and planned passenger time slot allocation. The design brief for the application is illustrated in Figure 6 above. The key requirements for the application included:

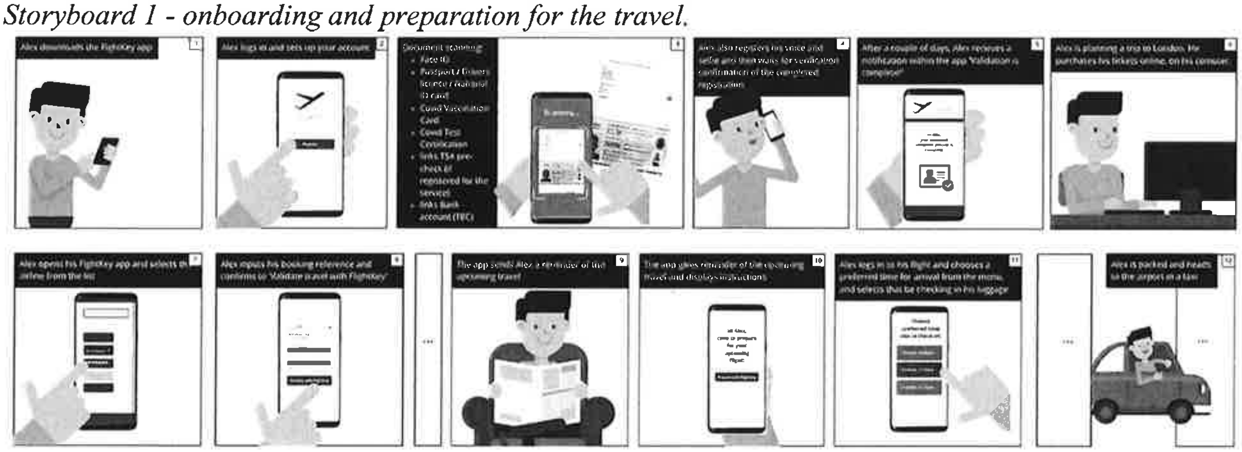
- A digital ID, to allow for less real document 'handling'; this would integrate encrypted ID documents, visas, as well as Covid-19 test results, or vaccinations.
- Touchless ID verification, check-in & baggage drop-off.
- Easy check-in time slot booking.
- Alerts integration, such as 'go to the gate X,' and time slots for boarding.

4.4 Storyboarding

The following storyboard illustrates the application onboarding and document verification process and preparation for a flight (Figure 7).

Figure 7

Storyboard 1 - onboarding and preparation for the travel.



After arriving at the airport, the customer uses the mobile application to use touchless self-check-in, luggage drop-off, security check, and boarding the plane. Should the user need help at any stage, the app allows for touchless information sharing with airport personnel (Figure 8).

Figure 8:
Storyboard 2 - at the airport and the air travel

4.5 Iterative Prototyping, Interviews & Evaluation

As a next step, we developed two rounds of prototypes illustrated in Figure 10 and Figure 11. The first prototype has a rapid prototyping character and encompasses the key onboarding andalert screens (Figure 9). The second prototype integrates all the key app functionality and has been developed as a click-through prototype using the Balsamiq.cloud platform (Figure 10).

Figure 9:
The first iteration of the prototype - onboarding.

Both Storyboards and the Prototype (Figure 10) have been used as a research tool to obtain feedback from the airport personnel. The qualitative semi-structured interviews were conducted with three experts from the aviation industry, delivered via Zoom. The interviews confirmed the importance of focusing on the selected design direction, and the collated insights were grouped using thematic analysis and informed the next round of concept iteration.

Figure 10

The second iteration of the prototype - onboarding and the detailed functionality.

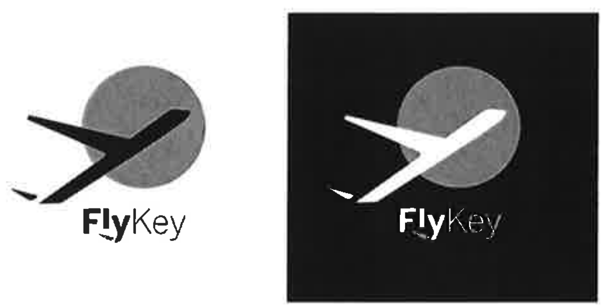
In the final prototyping phase, the application flow and main functionality were refined, and an interactive click-through prototype was developed using AdobeXD software (Figure 11). The color scheme for the app and the app logo have also been refined (Figure 12).

Figure 11

The FlyKey app final prototyping phase

Figure 12

FlyKey logo and the color scheme.



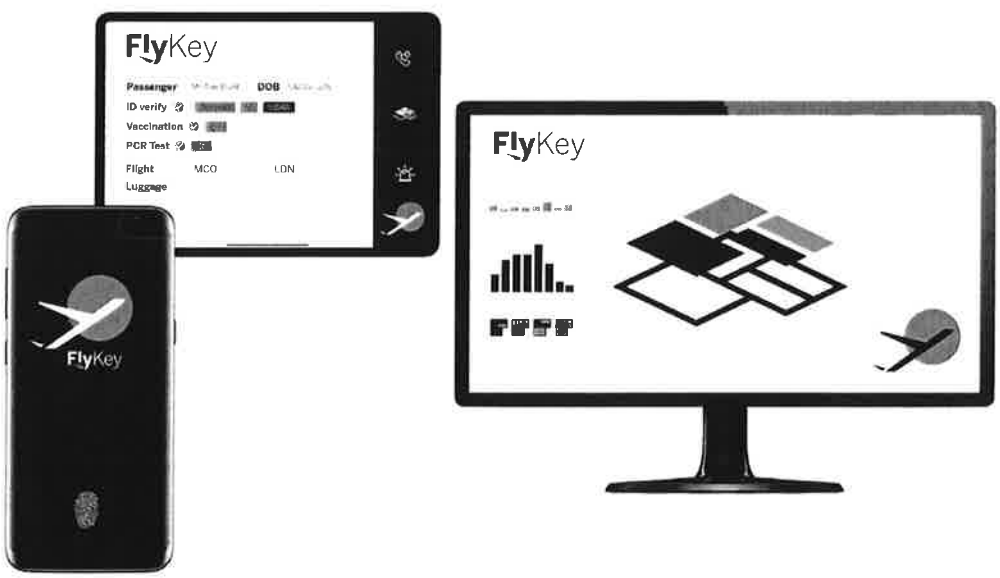
5. Design Solution

5.1 The FlyKey Platform

The FlyKey solution is a digital platform that is designed to provide a safe and efficient travel experience, integrates three layers of functionality (Figure 13):

1. A passenger FlyKey App, which holds passenger digital ID and facilitates the contactless airport experience, from check-in to arrival.
2. An airport personnel tablet FlyKey application, which allows for contactless interactions with passengers and other airport personnel.
3. A central FlyKey platform, which integrates all the passenger information and provides a real time analytics of passenger flow through the airport, as well as allows smart passenger allocation using trend prediction algorithms.

Figure 13
The FlyKey platform.



The main screen allows to toggle between: flight and airport details, alerts, and check-in information (Figure 14).

Figure 14
FlyKey main screen

The ID verification - user opens the app and taps on a floating button 'VERIFY ME'. The app guides the user through the NFC verification process, analogous to ApplePay (Figure 15).

Figure 15
FlyKey ID verification.

The FlyKey App provides alerts, assists, and guides the user though the airport procedures (Figure 16).

Figure 16
FlyKey alerts and luggage self-check-in.

The application onboarding process contains multiple steps to provide maximum safety and is analogous to registration for an online bank, such as Monzo (Figure 17).

Figure 17
FlyKey onboarding - document verification.

The user provides multiple documents for verification, such as a passport, driving license, biometric face identification, and unique voice ID (Figure 18).

There is an option of integrating within the application encrypted country-specific vaccination cards required for the visit, such as Covid-19 or yellow fever vaccine, or encrypted QR code with PCR testing results.

Figure 18
FlyKey onboarding - document verification continued.

5.2 Safety Risk Assessment

Due to exponential growth in the aviation industry, airports have been at the forefront of technological innovation. As new challenges evolve, the aviation industry has to adapt to deal with them. Cyber security is now paramount for aviation safety, and this is one of the key focus areas of flight key as our primary concern is the protection of customer data and data privacy. The FlyKey team has identified points of concern as a threat to the application's safety and security, which are described below:

One of the major potential concerns for the passengers is storing their personal information on a third-party application. The trust factor needs to be addressed in order for passengers to use the application without worrying about data theft or phishing concerns. In order to effectively provide and safeguard the passenger's personal information, FlyKey aims to partner with one of the best cyber security firms in the United States - Cybriant. Cybriant is an award-winning cybersecurity service provider, providing continuous threat detection with remediation. The company provides enterprise-grade cybersecurity services and solutions, covering fundamental cybersecurity needs in a comprehensive, all-in-one service.

In order to prevent impersonation of personal information, airport personnel will have the ability to verify individual passenger identities through the verified documentation and IDs submitted to the FlyKey application. Airport Personnel will also have Face recognition and voice and biometric verification in case of phone thefts, as that is the primary point of contact between airport personnel and passengers.

5.3 Response to Cyber attacks

According to the ACRP guidebook of best practices, a cybersecurity program should have a process to quickly and effectively respond to cybersecurity attacks while minimizing the duration of their impact. This is accomplished through a series of objectives; the first is to identify the targeted data and systems and the vector used to circumvent countermeasures. The next objective is to communicate and collaborate with relevant stakeholders, passing on the information and carrying out an effective response, containing the attack to the data and systems already affected to the extent possible, and then close the actor's vector to limit further infiltration. Responding to cyber threats requires immediate attention, especially in sensitive environments such as airports. The challenge posed is the appropriate allocation of resources because if too much attention is focused on the attack, it could lead to the likelihood of another, possibly more harmful attack (Murphy et al., 2015). The need to maintain countermeasures stands as the decision-making factor in FlyKey's decision to partner with a third-party cyber-security provider Cybriant.

5.4 Benefit Analysis

The implementation of FlyKey comes with several benefits, which are listed in table 1 below.

Table 1: *Benefits of FlyKey*

Benefit	Description	Estimates	
COVID-19 Compliance	**1)** FlyKey staggers passenger traffic by strategically implementing time slots for boarding, check-in and security. **2)** Implementation of a touchless experience throughout the airport for passengers and staff alike by reducing touchpoints. **3)** Effective contact tracing of passengers and employees to minimize exposure to COVID-19. **4)** Platform for passengers to upload all necessary documents regarding COVID-19.	**Cost of Hospitalization[1]** **Avg. number of hospitalizations[2]** **Value of injury[3]** **Cost of death[4]**	**$38,221** **2% of travelers** **$6.15 million/per day** **$9.1 million/per pax**
Operational Benefits	**1)** Minimizes congestion at high traffic stages of the travel experience i.e., security, check-in, boarding, jet bridge. **2)** Allows airports to operate efficiently during peak operational traffic by supporting current facility requirements.	**Cost of Delay** **Cost of congestion - expedited requirement for**	**Total cost is estimated at $2.6 billion/day for all airports in the US**

	3) Provides passengers a higher level of convenience throughout travel experience. Personalized notifications to assist passengers. **4)** Provides the airport and airline management with highly valuable analytical data, which enhances operational efficiency and Improves Level of Service (LOS) **5)** Reduces operational costs by increasing operational efficiency- Reducing delays, cancellations, and inconvenience to passengers. **6)** Scalable, cost-effective solution for airports to easily implement in a short term	**facility development** **Cost of cancellations** **Cost of lost expectations** **Fuel costs due to additional delays resulted by late pax**	
	Total cost for implementation of FlyKey for MCO/day - 300,000 initialization + 4760 per year in service cost.	**Total cost if FlyKey is not implemented at MCO is $790,030/day**	
In this case, the benefits of implementing FlyKey far outweigh the astronomical costs.			

Note: The following assumptions have been made in order to estimate the cost of not implementing FlyKey at airports.

[1]The average cost of hospitalization has been adapted from www.fairhealth.org and estimates the cost of COVID-19 hospitalizations for insured patients.

[2]The average number of hospitalizations has been estimated by assuming a 5.5% positivity rate (CDC, 2021). Additionally, the percentage of COVID-19 positive patients requiring hospitalization is estimated by using the 7-Day Average of hospitalizations at 36,257 cases and positive cases at 67,530 as reported to the U.S. CDC. (CDC, 2021). An average of 80,744 travelers/day has been estimated for Orlando International Airport.

[5]Delay costs have been estimated using the data provided by Airlines4America.

Table 2: *Intangible customer and airport personnel benefits considerations.*

The table below lists the potential benefits of implementing FlyKey at airports.

	POTENTIAL BENEFITS	customer	airport personnel

1	Limiting points of contact for all personnel at the airport - touchless interfaces		
2	Decreasing transit time for passengers		
3	Optimizing customer service by time-slot scheduling and reducing airport congestion		
4	Less requirement for having physical copies of sensitive documents - environmentally friendly and sustainable		
5	Potential for a real-time view of passenger flow, numbers, and behavior analysis/prediction.		
6	From an analytical perspective, this application can provide customer data. This impacts planning and operations and gives us a chance to enhance operational efficiency		

5.5 Cost Assessment

A Cost and Benefit Analysis is integral to successfully implement the proposed product at any airport. For the course of this case study, Orlando International Airport has been chosen as the model airport to provide a numerical estimation of the development and implementation at the airports are described below in each stage of the process.

Stage 1: Alpha

The Alpha stage of the project involves the research and development and initial prototype development of the application. This process took a total of 04 months and was done entirely by Graduate Students at the College of Aeronautics at Florida Institute of Technology, under the advice of Dr. Deborah Carstens. The initial stage involves labor costs for the Student Researchers and the Faculty Advisor, as listed below. The total cost for the initial research and development phase is estimated at $5,100.

Table 3: *Initial Stage Costs – Research and Development Phase*

Initial Stage Costs: Alpha Phase

ITEM	RATE	QUANTITY	SUBTOTAL	REMARK
LABOR				
Student	$20/hr	150 hrs	$3,000	3 GRA's- 50hrs each
Faculty	$70/hr	30 hrs	$2,100	1 Faculty Advisor
Subtotal			$5,100	

Note: The duration of this phase is planned at four months for the research and development of FlyKey.

Stage 2: Beta Testing

Table 4: *Stage 2 Costs – Beta Phase including application development.*

Stage 2 Costs: Beta Phase

ITEM	RATE	QUANTITY	SUBTOTAL	REMARK
LABOR				
Software Developer	$50/hr	1000 hrs	$50,000	3 Software Developers 300 hrs each
Legal Compliance Attorney	$80/hr	50 hrs	$4,000	1 compliance attorney 50 hrs
Subtotal			$54,000	

Note: The duration of this phase is planned for six months for the Beta development of the application by our software developers. The full-stack development of FlyKey will be completed entirely in house by our software development team.

The Beta testing and development of the FlyKey application will be done by FlyKey's software development team, and the beta phase of the project is expected to take a period of six months. This stage will include the full stack development of the application, analyzing the UI/UX aspects of the application, and ensuring regulatory compliance per U.S Department of Justice guidelines. The beta phase is expected to cost approximately $54,000.

Hence, the **total costs associated with the final development of FlyKey is $59,100,** and the entire development process will be completed in a period of 10 months. Following the development phase, FlyKey will be ready for implementation at airports and will be customized as per the requirements of the airport.

Stage 3: System Implementation and Onboarding

For this project, Orlando International Airport (KMCO) was the airport selected for the initial implementation of the application. In the implementation phase, costs include setup costs of purchasing tablets and NFC readers for the check-in stations, security checkpoints, and boarding gates. Additional costs include the initialization of the application and onboarding training for airport employees. Labor costs for the implementation phase include the installation of hardware, all of which are to be incurred by the airport. The tables below list the projected costs and the duration of each phase of implementation of FlyKey at our model airport, KMCO. A cost-benefit analysis is conducted to evaluate the impact of our proposed design, as illustrated in table 1.

Table 5: *Cost Analysis of System Installation and Onboarding at Orlando International Airport.*

COST ANALYSIS OF SYSTEM INSTALLATION AND ONBOARDING

ITEM	RATE	QUANTITY	SUBTOTAL	REMARK
LABOR				
Electrician	$30/hr	10 hrs	$300	One Worker
IT Technician	$40/hr	10 hrs	$400	One Worker
Trainer	$40/hr	5 hrs	$200	One Worker
Materials				
NFC reader	$300 each	200	$60,000	For check-in, security, boarding gates, and concessions
iPad Tablet	$800 each	100	$8,000	For employees
Retina Scanner	$150 each	25	$3,750	For boarding gates
Biometric Scanner	$200 each	25	$5,000	For security checkpoints
Subtotal			$76,750	

Note: This cost is to be borne entirely by the airport and other relevant stakeholders and is not included in the cost for the implementation of FlyKey. Since this is an example of FlyKey being implemented at KMCO, the costs that are incurred by the stakeholders are demonstrated above.

The cost of initial licensing for FlyKey at a large hub airport is set at $300,000, where the product is licensed for the airport and initialized. This includes any setup costs associated with implementation. Following the initial implementation, the table below displays the system operation costs for a period of one year. The operational costs are designed to be minimum and are directly contingent upon any potential abnormalities in system operation. The costs below are a rough estimation and in no way imply that there would be unforeseen breakdowns.

Table 6: *Operational Cost Estimation – 1 year period for Orlando International Airport.*

COST ANALYSIS OF SYSTEM OPERATION - ONE YEAR AT MCO

ITEM	RATE	QUANTITY	SUBTOTAL	REMARK
Service				
Technical Support	$40/Day	15 Days	$600	Network Maintenance and Troubleshooting
Labor				
Technical Support Advisors	$80/Day	52 Days	$4160	Routine maintenance of equipment
SUBTOTAL			$4760	

Note: System operation cost is directly dependent on the occurrence and need for troubleshooting and routine preventive maintenance

5.6 Future Developments

The pandemic has induced a rapid implementation of digital solutions in areas of tele-health and tele-working. We expect this will also be applied to the digitalization of identity and implementation of touchless interfaces within travel. The next step is to incorporate a secure digital identity to limit document handling. FlyKey's next step is going to be to conduct usability testing. Based on the feedback, we will further iterate the solution. The application is a breakthrough for numerous concerns for the aviation industry, especially enhancing the customer experience while also increasing customer cooperation in adhering to the stringent health and safety measures due to the pandemic. FlyKey's machine learning algorithms based on the data gathered are effectively going to enable greater accuracy in forecasting. Our digital ID will only reveal relevant information to the pertinent users. Our solution hence enhances overall security for the sensitive airport environments while also providing a globally integrated platform to the aviation community. Although no solution can effectively prevent the transmission of infectious diseases in a public setting, FlyKey, combined with the other implemented health and safety measures, aims to effectively minimize the transmission by reducing touchpoints and congestion.

6. Appendices

Appendix A.

List of complete contact information

Team Member	Email
Team Member Arjun Nair	anair2014@my.fit.edu
Team Member Syed Ali Abbas	sabbas2017@my.fit.edu
Team Member Anna Wojdecka	awojdecka@my.fit.edu
Advisor Debbie Carstens	carstens@fit.edu

Appendix B.

Description of Florida Institute of Technology

With our focus on student success, Florida Institute of Technology's mission is to provide high-quality educational experiences to a culturally diverse student body in order to prepare them for entering the global workforce, seeking higher-education opportunities and serving within their communities. The university also seeks to further knowledge through basic and applied research and to serve the diverse economic, cultural and societal needs of our local, state, national and international constituencies. In support of this mission, we are committed to:

- Fostering and sustaining a productive institutional culture of assessment leading to the continuous improvement of academic and administrative programs in order to promote student development;
-Developing an organizational culture that values and encourages intellectual curiosity, a sense of belonging and shared purpose among faculty, students and staff, and pursuit of excellence in all endeavors;
-Recruiting and developing faculty who are internationally recognized as educators, scholars and researchers;
-Achieving recognition as an effective, innovative, technology-focused educational and research institution;
-Recruiting and retaining an excellent, highly selective and culturally diverse student body;
-Continually improving the quality of campus life for members of the university community;
-Providing personal and career growth opportunities for both traditional and nontraditional students and members of the faculty and staff, including those who avail themselves of Florida Tech University Online;
-Securing and maintaining professional accreditation for all appropriate programs.

The mission statement of the College of Aeronautics is:

The College of Aeronautics mission is to prepare students for success and advancement in the aviation professions; advance aviation knowledge through faculty and student research, scholarly activity and projects; and encourage and enable student and faculty service to the university, community and aviation professions.

Appendix C.

Description of airport operators and industry experts who provided advice and feedback for your design process. These are people that your team interviewed.

Dr. William B Rankin, AAE is an Aviation Management Expert and has over 40 years of experience in the aviation industry. Dr. Rankin has successfully managed several large hub airports, and is an expert in the field of aviation security and airport management. Dr. Rankin is a Professor of Aviation Management at Florida Institute of Technology and provided feedback on the security and feasibility aspect of FlyKey through a semi-structured interview. In the interview with Dr. Rankin, he suggested to the team to interact with real-world practitioners for ideas for prototyping and other challenges we would face in the project. Dr. Rankin suggested that for future development of FlyKey, we should potentially partner with industry organizations like American Association for Airport Executives (AAAE), Airports Council International (ACI-NA), and Airlines 4 America (A4A).

Dr. Patricia Ryan, AAE is a seasoned aviation consultant who has over 40 years of aviation experience and has been the Director of Business Development for major hub airports around the USA. Dr. Ryan provided practical feedback about the implementation of FlyKey, and the potential challenges that the FlyKey team would face. Dr. Ryan highlighted the importance of such applications in the future of air travel. Her expertise

Dr. Deborah Carstens, PMP is a Professor of Human Factors at Florida Institute of Technology and has an extensive background in Human Factors in Aviation. Dr. Carstens' experience significantly helped with the shaping of the prototype in terms of the User Experience and provided advice on the development of FlyKey. Dr. Carstens also serves as our Faculty Advisor for the project.

Dr. Farhat Abbas is a Nephrologist in Pakistan. The team consulted with Dr. Abbas on the Epidemiological approach to fighting COVID-19 in the airport environment. Although Dr. Abbas is a Nephrologist, his extensive experience in healthcare helped shape our approach towards FlyKey. Dr. Abbas suggested that we develop a wholesome approach to tackle the risks associated with traveling during COVID-19.

Mehnaz Hassan is an Airport Development Analyst at Skymantics, a consulting firm advising airports and airport organizations. She has been working on blockchain implementation in airports for the last year.

Appendix D.

Sign-off form for faculty advisor(s) and department chair(s). Sign-off form is available at the Competition website, https://vsgc.odu.edu/acrpdesigncompetition/wp-content/uploads/sites/3/2018/03/Appendix_D_design_competition.pdf.

Appendix E.

Evaluation of the educational experience provided by the project. Evaluation questions for both student and faculty are provided on the Competition website.

Appendix E questions are on the competition site at https://vsgc.odu.edu/acrpdesigncompetition/wp-content/uploads/sites/3/2018/03/Appendix-E_design-competition.pdf for students, please be sure to answer these questions in your paper. The faculty portion from me are addressed below and also need to be included in your paper:

Faculty

Faculty Questions	**Answer**
1. Describe the value of the educational experience for your student(s) participating in this competition submission.	The Airport Cooperative Research Program University Design Competition for addressing airport needs provided students with the ability to apply learned research and product development methodologies to a real-world problem and design solution opportunity. Learning is far too often theoretical for students so this project provides students a means to apply learned classroom concepts to the real-world.
2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?	A graduate Human Performance 1 course in the College of Aeronautics was the environment for the learning experience. The course level and context is appropriate.
3. What challenges did the students face and overcome?	The dynamic student team embraced the project components and encountered very limited challenges. Specifically, the only challenge faced was initially in obtaining access to airport personnel due to COVID-19. However, students were able to identify contact with appropriate airport personnel.
4. Would you use this competition as an educational vehicle in the future? Why or why not?	I will have students continue to submit to this competition for all future graduate Human Performance 1 courses.
5. Are there changes to the competition that you would suggest for future years?	I appreciate the video on "Guidance for Preparing Benefit/Cost Analyses." This was extremely helpful especially for teams with tangible costs and benefits. The only additional challenge for some team submissions is in identifying costs and benefits for intangible items such as people's

	time and increased efficiency. It would be helpful if the competition website can also recommend resources for how to quantify intangible costs and benefits.

Students

1. Did the Airport Cooperative Research Program (ACRP) University Design Competition for Addressing Airports Needs provide a meaningful learning experience for you? Why or why not?	The ACRP Competition provided a unique opportunity for us to apply the learning to a real-life context, allowing us to expand our knowledge in designing a holistic, multi-layered solution, and validate design decisions with industry experts at each step of the way.
2. What challenges did you and/or your team encounter in undertaking the competition? How did you overcome them?	The biggest challenges were around the complexity, and multi-dimensional character of the area we focused on. The final solution addressed the challenge in a three-way manner: through a passenger-facing application, airport personnel system, and the central prediction/analysis system.
3. Describe the process you or your team used for developing your hypothesis.	We have followed a Double-Diamond method for designing services (Design Council, 2015), described in detail in Section 4 of our report.
4. Was participation by industry in the project appropriate, meaningful and useful? Why or why not?	Participation in the industry project was a truly meaningful opportunity to learn and grow. Designing for a real context made the effort really worthwhile. We intend to work on the proposed solution beyond the competition.
5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?	This project had a tremendous impact on the way we will approach problem-solving. It allowed us to work as a part of a multidisciplinary multicultural team, which was an exceptional experience.

Appendix F: References

Bielecki, M., Patel, D., Hinkelbein, J., Komorowski, M., Kester, J., Ebrahim, S., ... & Schlagenhauf, P. (2020). Reprint of: Air travel and COVID-19 prevention in the pandemic and peri-pandemic period: A narrative review. Travel medicine and infectious disease, 38, 101939.

Bouwer, J., Krishnan, V., & Saxon, S. (2020, November 10). Will airline HUBS recover FROM COVID-19? Retrieved February 07, 2021, from https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/will-airline-hubs-recover-from-covid-19#

Centers for Disease Control and Prevention. (2020). Older Adults and COVID-19. Retrieved from https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/older-adults.html

Chu et. al. (2020) "Physical Distancing, Face Masks, and Eye Protection, To Prevent Person-to-Person Transmission of SARS-Cov-2 and COVID-19: A Systematic Review and Meta-Analysis, *The Lancet,* 395(10242), pp. 1973-1987, June 27, 2020 Council, D., (2015). Design methods for developing services. *Keeping Connected Business Challenge*. https://www.designcouncil.org.uk/sites/default/files/asset/document/Design%20methods%20for%20developing%20services.pdf

Gaber, W., Goetsch, U., Diel, R., Doerr, H. W., & Gottschalk, R. (2009). Screening for infectious diseases at international airports: the Frankfurt model. *Aviation, space, and environmental medicine*, *80*(7), 595–600. https://doi.org/10.3357/asem.2360.2009

Gostic, K., Gomez, A. C., Mummah, R. O., Kucharski, A. J., & Lloyd-Smith, J. O. (2020). Estimated effectiveness of symptom and risk screening to prevent the spread of COVID-19. *eLife*, 2020*(9)*, e55570. https://doi.org/10.7554/eLife.55570

Graham, A., Kremarik, F., & Kruse, W. (2020). Attitudes of ageing passengers to air travel since the coronavirus pandemic. *Journal of Air Transport Management*, 87, 101865. https://doi.org/10.1016/j.jairtraman.2020.101865

Grant, M. C., Geoghegan, L., Arbyn, M., Mohammed, Z., McGuinness, L., Clarke, E. L., & Wade, R. G. (2020). The prevalence of symptoms in 24,410 adults infected by the novel coronavirus (SARS-CoV-2; COVID-19): A systematic review and meta-analysis of 148 studies from 9 countries. *PLOS ONE*, 15(6), e0234765. https://doi.org/10.1371/journal.pone.0234765

Hendrix, M. J., Walde, C., Findley, K., & Trotman, R. (2020). Absence of Apparent Transmission of SARS-CoV-2 from Two Stylists After Exposure at a Hair Salon with a Universal Face Covering Policy — Springfield, Missouri, May 2020. *MMWR. Morbidity and Mortality Weekly Report, 69*(28), 930-932. https://doi:10.15585/mmwr.mm6928e2

IATA. (2020, November). Deep losses continue into 2021. Retrieved February, 2021, from https://www.iata.org/en/pressroom/pr/2020-11-24-01/

IDEO.org, (2015). *The Field Guide to Human-Centered Design*. IDEO https://www.designkit.org/resources/1

Iqbal, M. Z., & Campbell, A. (2020). The emerging need for touchless interaction technologies. Interactions, 27(4), 51-52.

Johns Hopkins School of Medicine - Coronavirus Research Center. (2020). Retrieved September 26, 2020, from https://coronavirus.jhu.edu/

Konda, A., Prakash, A., Moss, G. A., Schmoldt, M., Grant, G. D., & Guha, S. (2020). Aerosol Filtration Efficiency of Common Fabrics Used in Respiratory Cloth Masks. *American Chemical Society nano*, 14(5), 6339–6347. https://doi.org/10.1021/acsnano.0c03252

Lamb, T. L., Winter, S. R., Rice, S., Ruskin, K. J., & Vaughn, A. (2020). Factors that predict passengers willingness to fly during and after the COVID-19 pandemic. *Journal of Air Transport Management*. 89. https://doi-org.portal.lib.fit.edu/10.1016/j.jairtraman.2020.101897

Leslie, D. (2020). Tackling COVID-19 through responsible AI innovation: Five steps in the right direction. Harvard Data Science Review (2020).

Lund, A. M. (2001). Measuring usability with the use questionnaire. Usability Interface, 8(2), 3-6. https://garyperlman.com/quest/quest.cgi?form=U

Murphy, R., Sukkarieh, M., Haass, J., & Hriljac, P. (2015). Guidebook on Best Practices for Airport Cybersecurity. Retrieved from file:///C:/Users/salia/Downloads/22116%20(1).pdf

Sharp, H., Rogers, Y., & Preece, J. (2019). *Interaction Design*. John Wiley & Sons, Inc.

Stalnaker, T., & Murray, G. (2020, August 13). COVID-19 Will Challenge Airlines for Years. Retrieved November 10, 2020, from https://www.oliverwyman.com/our-expertise/insights/2020/aug/covid-19-will-challenge-airlines-for-years.html

Štimac, I., Pivac, J., Bračić, M. and Drljača, M., (2021). The Impact of COVID-19 Pandemic on the Future Airport Passenger Terminals Design. International Journal for Traffic and Transport Engineering, 11(1).

United Nations. International Civil Aviation Organization, Air Transport Bureau. (2020, October 8). *Effects of Novel Coronavirus (COVID-19) on Civil Aviation: Economic Impact Analysis*. Retrieved October 9, 2020, from https://www.icao.int/sustainability/Documents/COVID-19/ICAO_Coronavirus_Econ_Impact.pdf

Wang X, Ferro EG, Zhou G, Hashimoto D, Bhatt DL. Association Between Universal Masking in a Health Care System and SARS-CoV-2 Positivity Among Health Care Workers. *Journal of American Medical Association*. 2020; 324(7):703–704. doi:10.1001/jama.2020.12897

WHO. (2020, March). Coronavirus disease (covid-19): Similarities and differences with influenza. Retrieved from https://www.who.int/news-room/q-a-detail/coronavirus-disease-covid-19-similarities-and-differences-with-influenza

Zhang, L., Peng, Z., Ou, J., Zeng, G., Fontaine, R. E., Liu, M., Cui, F., Hong, R., Zhou, H., Huai, Y., Chuang, S. K., Leung, Y. H., Feng, Y., Luo, Y., Shen, T., Zhu, B. P., Widdowson, M. A., & Yu, H. (2013). Protection by face masks against influenza A(H1N1)pdm09 virus on trans-Pacific passenger aircraft, 2009. *Emerging Infectious Diseases*, 19(9), 1403–1410. https://doi.org/10.3201/eid1909.121765