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Forward-Looking Strategies for Safely Adopting Digital Transformation in Aviation

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Abstract

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Abstract

Aviation leaders in the U.S. federal government face challenges in adopting technical evolution and advancing modernization while adhering to the rigor of a deeply entrenched safety culture. The purpose of this qualitative modified Delphi study was to determine how a panel of 21 aerospace experts based in Washington, DC viewed strategies for adopting to new technologies while ensuring safety. The management concepts that framed the study were safety culture and digital transformation. The study addressed the research question of how a panel of aviation experts viewed the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. Data analysis included content analysis of narrative responses to the digital transformation statements, statistical analysis of desirability and feasibility ratings to determine consensus, weighted average calculations to determine the importance ranking, and statistical analysis to determine confidence in the final results. The purposively selected panelists completed four rounds of data collection and reached consensus on the 10 most desirable, feasible, and important strategies in four categories derived from the Federal Aviation Administration Strategic Plan for 2019–2022. Aviation leaders may use the results to positively impact the safe adoption of Industry 4.0 technologies and impact social change by fostering stronger economic conditions for aviation customers and improving quality of life for travelers.

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Dedication

This dissertation is dedicated to my husband, John Latta, who encouraged me through all the challenges and covered for me in so many ways to keep our family together while I focused on this goal. I could not have done this without your love and support. This work is also dedicated to my children, Alex King, Alex Latta, Randi Latta, Ryan Latta, Jessica Mulligan, and grandson Jasper Latta. Thank you for your patience and inspiration. I love you all and I am so proud of you.

Also, I dedicate this work to my brothers and sisters, who encouraged me to reach beyond our beginnings: Nancy, Bob, Jane, Chad, John, Dar, Clancy, and Sue. You gave me the greatest examples of how to live well. Finally, I dedicate this dissertation the memory of my parents, Clarence and Jane, for instilling a spirit of independence, ability to rise above adversity, and capability to be transformative.

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To my personal board of directors Gen, Lisa, and Rosie, thank you for your steadfast encouragement in this and all endeavors. Barb and Lilian, my dear friends, I appreciate your wonderful feedback and encouragement. Many thanks to the Federal Aviation Administration leaders and colleagues at the U.S. Department of Transportation who encouraged the project, supported this work, and participated in the study. Anne, you came into my life and this project at just the right time. You all played an important role in the production of this dissertation.

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Chapter 1: Introduction to the Study

Aviation is a mainstay in the U.S. economy and was projected to be an $87.8 billion industry by 2024 prior to the COVID-19 outbreak (Materna et al., 2015). Although projections are unstable as a result of the pandemic, aviation still holds a key position in the economy (M. Patton, 2020). The digital transformation that resulted from the fourth industrial revolution, or Industry 4.0, has accelerated the modernization of the aviation industry (Crouch, 2003; Schwab & Davis, 2018). Industry 4.0 is a digitally based network amplified by cloud computing, Cyber-Physical Systems, Internet of Things , big data, and artificial intelligence (AI) working together to deliver a wide variety of results (Y. Lu, 2017; Schwab & Davis, 2018; Siebel, 2019). The adoption of digital transformation, or the integration of digital technology into all functions of a business, is usually faced with challenges at the organizational level, and the aviation industry is no exception (Nwaiwu, 2018). Digital transformation in aviation has taken various forms, including drone-based operations, suborbital and supersonic flight, advances in electronic communications, and quantum computing (Schwab & Davis, 2018). Infrastructure modernization of aerospace-related technologies has placed pressure on safely managing the national airspace during this period of digital transformation (Song et al., 2014; Wallace et al., 2018).

Chapter 1 contains background information related to the problem addressed in the study. The chapter includes the purpose and significance of the study for the future of the aviation industry; the ubiquitous impact of digital transformation and aviation on social change; the nature of the study; the conceptual framework used to structure the study; and assumptions, limitations, and delimitations of the research. The chapter concludes with a summary and transition statement to Chapter 2.

Background

Digital transformation is taking place all around the world. Adamik and Nowicki (2018) researched several key concepts for competitive advantage through the utilization of digital transformation indicating, and found that Industry 4.0 is the means to blend the physical world with the digital world through cyber-physical systems, robots, digitization, and a network economy operating in the spirit of the smart factory. Nwaiwu (2018) provided further evidence of the value of Industry 4.0 and digital business transformation in achieving and maintaining competitiveness. Nwaiwu identified a lack of alignment between industry-based research and academia regarding the concept of digital business transformation related to the effects of new digital technologies in organizations. Nwaiwu compared a set of conceptual digital transformation frameworks from the business and academic environments.

Business and industry are not the only domains for digital transformation. Chatfield and Reddick (2019) proposed the use of digital transformation for better delivery of services that meet the public interest. Chatfield and Reddick pointed to the challenges pertaining to the use of technology across government and argued for urgency on internet-related policy to enable smart government by articulating the adversity of adopting the IoT as a systemic driver of a smart society. The opposition to more robust use of IoT applies to the aviation industry, whose oversight is a function of the government.

Rhoades (2015) reported on the state of U.S. aviation, asserting that leaders are clinging to old ways to the detriment of critical technical advancement. Rhoades critiqued the U.S. aviation system as being resistant to the modern world of aviation by documenting challenges with the implementation of new technologies in the next generation of aerospace programs. Song et al. (2014) warned of the complexities in the U.S. aviation network, indicating the delicate balance of implementing change while keeping the current system operating safely. Song et al. addressed the challenge of adopting disruptive technologies by deconstructing the multidimensional nature of the national air space while identifying the implications of uncommon aircraft in crowded airspace.

Besides the problems of adopting digital technologies in the aviation industry, there are concerns about safety in the industry. The criticality of the safety mission in aviation is reflected in the vast amount of research dedicated to the topic of safety culture. Morrow and Coplen (2017) provided a perspective on safety culture through an analysis of approximately 500 references obtained from a Scopus search of the term *safety culture*. The industries included health care, manufacturing, energy production, and transportation. Morrow and Coplen offered a 10-element list of items needed for an effective safety culture: (a) leadership commitment to safety, (b) open and effective communication, (c) employee ownership of the safety mission, (d) continuous learning, (e) safety consciousness, (f) reporting without punishment, (g) safety prioritized over other performance drivers, (h) mutual trust, (i) fair response to safety concerns, and (j) safety-related training and resource allocation. Together, these elements mean that human behaviors are the underpinning drivers of a safety culture.

After the explosion and crash of TWA flight 800 on July 17, 1996, the White House formed a commission whose work inspired the current focus on the aviation safety management systems (Gore, 1997). The committee report addressed the advantages of information technology for improving aviation safety. The report became a call to action for the safety and security in the aviation industry. Later, Mills et al. (2018) examined distributed accountability for safety through voluntary reporting, taking the outcomes of the Gore (1997) report to its most advanced behavioral level. Mills et al. examined the transition from government-based regulatory accountability for safety to the distributed model of safety accountability to all participants in aviation safety while explaining the accountability frames (with trade-offs) that shape current safety compliance in aviation. The Federal Aviation Administration’s resulting approach to voluntary disclosure programs created a shift in institutionalizing collaborative accountability for safety. The level of trust improved between regulators and the private sector service providers, which enhanced the caliber of safety accountability throughout the system.

In aviation forecasting, Fleming and Leveson (2016) offered concept development and safety analysis of future transportation systems pointing to the value proposition in various decision-making models and indicating the high cost of overlooking key safety elements in the design process. Fleming and Leveson presented a compelling case for a digital transformation in aviation that is beyond the current functionality of air traffic management and aircraft control systems. In contrast, Wallace et al. (2018) investigated aviation safety through the lens of unmanned aerial vehicles (UAVs) or drones. Wallace et al. specified the safety risk presented by UAVs and identified needs for improvement in UAV safety strategy.

Problem Statement

The social problem addressed in the current study was that aviation leaders in the U.S. federal government face challenges in adopting technical evolution and advancing modernization efforts due to federal appropriations, human capital limitations, economic shifts, and safety culture (Chatfield & Reddick, 2019; Elwell, 2018a; Wallace et al., 2018). Advances in aviation technology enhance safety in the entire system, yet introducing change presents risks (Song et al., 2014; Wallace et al., 2018). People in the aviation industry will witness major changes in the future as industry leaders choose to adopt evolutionary technical advances while operating in a regulatory environment dedicated to keeping people safe (Blind et al., 2017; Nakamura & Kajikawa, 2018; Schwab & Davis, 2018).

The leaders in the aviation marketplace strive for profitability. Government regulators require compliance with rule sets to ensure safety, which may slow the pace of digital transformation that underpins the demand for profitability (Dwivedi et al., 2017; Mills et al., 2018). The specific problem was the difficulty of adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation (Fleming & Leveson, 2016; National Research Council, 2014). There has been limited consensus among aviation experts on strategies for adopting comprehensive safety-driven digital transformation strategies (Kistan et al., 2018; Materna et al., 2015;

New, 2018; Song et al., 2014). Failing to generate comprehensive strategies for integrating technological advancements into the national airspace leaves aviation regulators trailing behind the need for balancing innovation with flight safety (Schwab & Davis, 2018).

Purpose of the Study

The purpose of the qualitative modified Delphi study was to determine how a panel of 21 aerospace experts based in Washington, DC viewed the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. The aviation industry continues to grow in complexity (Liu et al., 2015). Aviation leaders’ ability to keep pace with the modernization of airspace is essential to the continued evolution of the industry. However, the safe implementation of these digitally based transformations introduces change to the system and requires further research (Song et al., 2014; Troung et al., 2018). To protect the public, the FAA workforce ensures safety by requiring compliance with specific policies and procedures through highly choreographed actions, which may cause challenges with adopting to digital transformation for FAA leaders (FAA, 2020a; Wallace et al., 2018).

This gap may be bridged by creating strategic approaches for safely adopting digital transformation in the complex and dynamic national airspace through the perspectives of a panel of aviation experts. As an original contribution to the field, the results of the current study may augment and extend the FAA Strategic Plan (FAA, 2020b). Working with the experts who contributed to the FAA Strategic Plan enables further exploration of their views as to the desirability, feasibility, and importance of recommended forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation.

Aviation epitomizes technical evolution and endures as one of the most momentous inventions of the modern day (Bilstein, 2003; Crouch, 2003). Flight is inextricably bound to technical advancement, globalization, and development of the modern world and may enable positive social change by bringing billions of people of the world together each year (Crouch, 2003; Pisano, 2003). Failure to secure a prominent position for aviation safety in the fourth industrial revolution slows the societal benefits of the new technologies promoting the common good (Schwab & Davis, 2018).

Research Questions

This study addressed the following primary research question and subquestions:

How does a panel of aviation experts view the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 1: How does a panel of aviation experts view the desirability of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 2: How does a panel of aviation experts view the feasibility of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 3: How does a panel of aviation experts view the importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Conceptual Framework

The study was grounded in two management concepts: Safety culture and digital transformation. The nexus of these two management concepts was examined by providing expert views on safely integrating digital transformation in aviation to inform future strategies for the FAA. Although digital transformation has been identified as a way to enhance safety in aviation, leaders have hesitated to adopt it into the National Airspace System (NAS) due to concerns pertaining to protecting the safety of the current system or the safety culture (Elwell, 2018a; Gore, 1997).

Safety culture is rooted in Schein’s (2017) premise that norms and values motivate the behaviors that help to define culture. The norms and values of a safety culture in aviation evolved through an International Safety Advisory Group. Safety culture arose from the more inclusive concepts of safety policy, organizational embeddedness, managerial action, and the engagement of staff at all levels for the benefit of the individual and the organization (Guldenmund, 2000). The aviation safety culture emerged as a national aerospace issue in the mid-1990s after a series of fatal commercial aircraft crashes and a subsequent formation of the White House Commission on Aviation (Gore, 1997; Morrow & Coplen, 2017). The concept of safety culture now serves as a core value throughout the aviation industry, which matured from a regulatory compliance approach to a collaboration between industry and regulators through open dialogue (Mills

& Reiss, 2014; Nævestad et al., 2018). Safety culture is evident in the FAA mission to provide the safest and most efficient aerospace system in the world (FAA, 2020b).

Digital transformation is the fourth phase of the industrial revolution (Schwab, 2016). This evolutionary phase stands out from other industrial transformations due to the interrelated concepts of the speed of innovation boosted by the depth and breadth of disruptive technology adoption (Christensen, 2016). The connection between safety and digital transformation through the lens of esteemed aviation professionals was the framework for the current research inquiry.

Nature of the Study

The research method for the study was qualitative, with the application of a modified Delphi technique as the research design. Linstone and Turoff (1975) described the Delphi technique as a forecasting procedure through expert opinions with early success in automation and aerospace. The purpose of this research was to obtain a consensus-based view from experts on strategies for safely integrating digital transformation in aviation. The Delphi process is a valued method to collect needed data to address the yet unknown phenomenon; thus, it aligns with forward-looking perspectives (Hsu & Sandford, 2007; Skulmoski et al., 2007). Given the future-oriented nature of the current study, the Delphi design was more appropriate than other research approaches that are focused on past performance.

In a classic Delphi study, data are initially collected through an open-ended brainstorming survey (McKenna, 1994). Because the Round 1 survey items in the current study were based on existing literature, specifically the strategic statements in the FAA

Strategic Plan (FAA, 2020b), the study was designed as a modified Delphi approach. The study was an extension of the FAA Strategic Plan (FAA, 2020b), which includes 64 strategic statements regarding digital transformation in aviation. The aerospace experts who contributed to the FAA Strategic Plan were asked to join the study as the expert panel participating in four rounds of data collection via electronic survey. Panelists had expertise in various but associated fields such as information technology (IT), engineering, aviation, aerospace strategy, cybersecurity, and human resources. As a panel, participants represented FAA leadership.

In the Delphi design, feedback from each round of survey responses was analyzed to formulate the next round of inquiry, and basic statistical analysis was applied to determine convergence of opinions (Heitner et al., 2013). Anonymity among the panelists was preserved through the administration of an electronic survey process (von der Gracht, 2012). During the four rounds of surveys, participants were asked to examine the list of 64 items from the FAA Strategic Plan (FAA, 2020b) and work through a process to assess their desirability, feasibility, and importance.

In Round 1, the experts were asked to edit the items as needed. Changes provided by the panel members were presented for review in Round 2 where the experts were asked to rate each statement using a 5-point Likert-type scale for desirability and another 5-point scale for feasibility providing comments for any low-rated items. To complete the Round 3 questionnaire, the panel members were asked to identify the top 10 most important items and rank them on a scale of 1 to 10. The results of the experts’ ranking were presented as a final set of top strategic statements, and in Round 4 the experts were asked to indicate their confidence in the top 10 items ranked as most important in Round 3. Statistical measurements were used to determine consensus among the panel and internal consistency of results. Consensus was determined to have occurred when 60% of the panel members rated a statement at a Category 4 or 5 with a median of 3.5 or greater in the Round 2 results at a minimum (Hsu & Sandford, 2007).

Definitions

Several terms relevant to the study are defined in this section:

Big data: Big data refers to the volume, variety, and velocity of information assets that require advanced technologies to capture, store, and distribute information needed for achieving organizational goals (Gandomi & Haider, 2015; I. Lee, 2017). Big data was a key consideration for Industry 4.0 and digital transformation in aviation because the industry generates vast amounts of data that can be leveraged to create greater efficiencies in the overall system (Badea et al., 2018). In the study, big data applied to considerations for smart systems to produce applications using a variety of advanced technologies, including artificial intelligence. To achieve artificial intelligence, big data relies on data analytics, quantum computing, and machine learning. The study instrumentation included a set of statements for review on smart systems focused on the data management.

Cyber-physical systems (CPS): CPS refers to the collection of technologies that interconnects the physical world and computer-based technologies (Trappey et al., 2016). These are the network and communications systems that connect the location of objects to a person’s need for that object (Jawhar et al., 2018). CPS were important in the study because they are a foundational element for Industry 4.0 and a factor in forward-looking strategies in aviation.

Desirability: Desirability refers to having a positive effect, being beneficial with a positive impact, and being reasonable; the opposite considerations for the undesirable effect are being substantially negative, being harmful, and not being reasonable (Linstone & Turoff, 1975). In the current study, desirability pertained to forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation.

Digital transformation: Digital transformation is the process of moving from an earlier generation to more advanced technologies that could include cloud computing, big data, IoT, and AI (Siebel, 2019). The movement to more advanced technologies was a pivotal consideration in the current study. The FAA Strategic Plan (FAA, 2020b) contained strategic statements pertaining to digital transformation.

Feasibility: Feasibility refers to having practicality for implementing the item or solution. Highly feasible means that the item is easy to execute, whereas low feasibility signifies the solution is not implementable in the opinion of the expert panel member (Linstone & Turoff, 1975). In the current study, feasibility pertained to forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation.

Importance: Importance refers to having the relevance, priority, or condition of direct bearing on the issue at hand (Linstone & Turoff, 1975). In the current study, importance pertained to forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation.

Industry 4.0: Industry 4.0 or the fourth industrial revolution refers to the digitally based networks amplified by cloud computing, CPS, IoT, big data, and AI working together to deliver a wide variety of results (Y. Lu, 2017; Schwab & Davis, 2018; Siebel, 2019). Industry 4.0 was the driving force behind digital transformation in aviation. Industry 4.0 principles were evident in the FAA Strategic Plan (FAA, 2020b) that formed the basis of the current study. The examination of these Industry 4.0 principles was used to inform the strategic planning work needed to create the future direction of aviation.

Internet of Things (IoT): IoT is the worldwide network of objects identifiable by standard data tagging (Gubbi et al., 2013). IoT is the information conduit that underpins data movement essential to all technical aspects of digital transformation (Bisio et al., 2018). The IoT served as the delivery system for the NAS operational information exchange, which allowed for data transmission to support digital transformation. The current study instrumentation included a set of statements for review on the NAS operational information exchanges.

Safety culture: Safety culture is “the set of beliefs, norms, attitudes, roles, and social and technical practices that are concerned with minimizing the exposure of employees, managers, customers and members of the public to conditions considered dangerous or injurious” (M. D. Cooper, 2000, p. 113). Safety culture governs aviation decision making and serves as a foundational element for examining forward-looking strategies for aviation. Given that the FAA Strategic Plan (FAA, 2020b) contains a section on safety, the instrumentation for the current study included statements about safety.

Safety Management System (SMS): SMS “is a systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures” (Batuwangala et al., 2018, p. 2). SMS provides the management tools needed to support the safety culture in aviation. SMS is the management tool used to document the key measures that reinforce a safety culture. The operational elements for certification and regulation are reported through the SMS. Statements included in the current study instrumentation focused on certification and regulation as a consideration of aviation safety.

Assumptions

There were three primary categories to consider for assumptions pertinent to the modified Delphi study. The initial set of assumptions pertained to the panel members. First, the assumption was that members would be willing to participate in the study. Aviation is a sensitive industry, and aviation professionals take deliberate action. The study could have been perceived as a distraction from normal duties and responsibilities.

The next assumption was that the panel members who decided to participate had the expertise needed to provide well-reasoned responses to the survey. Another assumption was that panel members felt comfortable enough to be honest in their views given the perception of controversy surrounding some of the survey items. A final assumption regarding the panel members was that they would be able to participate in all four survey rounds.

The second set of assumptions pertained to me as the researcher. The assumption was I had the expertise, support, and resources needed to design and deliver the four survey rounds. These assumptions pertained to having the ability to distinguish the nuances in the technical considerations for the future of the federal leadership of the aviation industry and the fortitude and resources to lead the experts through four survey rounds.

The third set of assumptions pertained to the overall implications of the study. First, the assumption was that the organization would not oppose the study, particularly due to the inability to mask the identity of the organization given the industry sector that was the focus of the study. Second, the assumption was that there would be some value in considering the results of the study for aviation strategic planning. Third, the assumption was that the results of the study could help to ease the process of safely integrating digital transformation into the national air space.

Scope and Delimitations

Delimitations are defined as controllable boundaries, and the scope refers to limits that a researcher sets on the study to keep it manageable (Yin, 2017). Delimitations stem from the choices of the researcher to control the range of the study (Simon & Goes, 2013). Defining the scope of the study in terms of the FAA Strategic Plan (FAA, 2020b) gave structure to the research that could have excluded innovations that were incubating outside the frame of the project. The world is at the beginning of the fourth industrial revolution (Schwab & Davis, 2018). Innovations are being implemented more rapidly now than at any other time in human history. The aviation industry is on the cusp of profound developments (Valdés et al., 2018). The desirability and feasibility components of this study could have excluded technologies that were being developed for other industries with a future impact on aviation that would be unknown at the time of the study.

Another delimitation of this study was that the panel of aviation experts were based in the United States. Aviation growth in other regions of the world created a different dynamic for emerging technologies (Air Transport Action Group, 2018). Although the U.S. national airspace is the largest and most complex in the world, it is also well established. Retrofitting digital transformation is more challenging than building it into newer aviation systems that are emerging in Asia, the Middle East, and Africa.

Limitations

Limitations are the weaknesses of the research that are beyond the control of the researcher. In the current study, limitations existed in terms of the participants, caliber of processes, and bias. Appropriate selection of the expert panel is a limitation for the Delphi technique (Vernon, 2009). The participants for the study were leaders who participated in creating the FAA Strategic Plan (FAA, 2020b). Given the process of outreach and input management, not all contributors were able to participate in the study.

The expert panel members' willingness and openness to participate honestly also presented a threat. The job performance demands on FAA executives are intense: They may have found it difficult to devote the needed time to the study. Some participants may not have wanted to express concerns about the aviation system that could have emerge from the study for concern over creating an undue influence on the industry or the flying public. Participants could have also feared reprisal from their peer participants for the expression of a point of view. The informed consent form indicated that panelists would remain anonymous to one another, and that all results would be reported in the aggregate and not attributed to individual panelists.

Another set of limitations of the study pertained to two aspects of trustworthiness: Transferability and dependability (Lincoln & Guba, 1985). According to Hasson and Keeney (2011), the Delphi technique is subject to criticism in trustworthiness because researchers provide incomplete information about rigor, which is prone to ever-adapting applications. Vernon (2009) identified the lack of scientific method as a limitation of the Delphi process.

The Walden University standards for thoroughness in academic research helped ensure trustworthiness, reinforced by integrity and objectivity. Rigors of the doctoral process supported the transferability of the study so others could follow the steps of the project for replication by following an inquiry audit trail (Landeta, 2006; Skulmoski et al., 2007). Dependability refers to the stability of the results across various data collection activities (Cornick, 2006). The processes associated with the study were transparent so that future researchers could follow the same protocols leading to the stability of the results across various data collection activities.

Davidson (2013) identified two types of bias pertaining to the Delphi technique. Researcher bias could have been a concern in the current study because of my prior participation in the FAA strategic planning work, role in aviation leadership, and expressed interest in transformation. All communication regarding the study was reviewed and approved by the dissertation chair to minimize this threat.

Bias among panel members could have presented another risk. Expert participants could have used the study to promote a self-serving agenda (Hussler et al., 2011). However, a mixture of expertise on different aspects of an overall topic created a balance of experts and nonexperts in a heterogeneous panel. The combination of expertise created a variety of opinions and provided a counterbalance to a self-serving agenda (Hussler et al., 2011). The panel for the current study had a variety of expertise, as reflected in the FAA approach to strategic planning.

Significance

The study focused on forward-looking strategies for safely integrating new technologies in the NAS. The NAS is a complex, dynamic, and risk-intolerant environment (Song et al., 2014; Troung et al., 2018). The FAA mission is to provide the safest, most efficient aviation system possible for the U.S. public and to deliver the gold standard for safety in the world (FAA, 2020b). Transportation of the future requires a capacity to balance the safety mission with the fast-moving transformative technologies that will bring about new ways to travel (Dickson, 2020). Although FAA leaders are looking at the difficulty of adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation, this study offered an original contribution to examining the specific problem.

Significance to Practice

The Transportation Statistics Annual Report (Sprug et al., 2018) stated that in 2017 airlines carried over 73 million passengers per month in foreign and domestic travel. To ensure the safety of the flying public and the general public at large, the FAA follows specific protocols and takes highly choreographed actions. The ability to manage a massive high-risk operation and integrate new entrants into the system requires a focused approach (FAA, 2020a; Wallace et al., 2018).

Air transportation serves as a backbone for integrated international economic prosperity (O'Connell & Williams, 2015). From the safety of travelers and the workforce to the economic impacts of aviation to environmental protection, the relevance of aviation exists even for people who do not fly (Materna et al., 2015). A system that can grow and modernize with the latest technological advances has far-reaching societal influences (Rhoades, 2015). On an individual level, digital transformation in aviation could save lives with drone-based package delivery that moves organ donations from hospital to hospital faster than the more traditional mean of transportation (Valdés et al., 2018). On a worldwide scale, the economic vitality of the aviation industry translates to global economic opportunities through aviation, travel, and tourism (Weinelt & Moavenzadeh, 2017). The elements of a digital transformation strategy that emerged from the current study have the potential to be an underpinning driver for the far-reaching impact of the aviation industry.

Significance to Theory

New technologies offered by digital transformation or Industry 4.1 prompt greater efficiencies and increased capability for improving safety (Schwab & Davis, 2018). Those technologies could also transform aviation by providing people with new, more cost-effective, and more energy efficient ways to travel (Pradeep & Wei, 2018). E. M. Rogers's (2003) theory on the diffusion of innovation explains how the adoption of new ways of doing things follows a predictable curve from early adopters through the masses to the late adopters. However, Christensen (2016) noted that disruptive innovation creates more upheaval than would be suggested by E. M. Rogers's perspective.

Schwab and Davis (2018) argued that digital transformation is disruptively upending society today, much like the way electricity changed some fundamental societal tenets. The Industry 4.0 technologies will change many of the systems prevalent today, creating new ways to produce and transport goods and services that impact people's use of transportation systems. D. L. Rogers (2016) offered a roadmap to help organizations navigate the digital transformation process. The societal shift emerging from digital transformation is new. The current study provided research on this topic by exploring this phenomenon and guiding forward-looking strategies in a complex industry.

Schein (2017) described the concept of cultural DNA, which evolves from shared learning around beliefs, values, and desired behaviors intended to lead to success. As a group has repeated accomplishments based on a common set of norms, the cultural DNA or the shared behaviors become more deeply embedded (Schein, 2017). The transformations in aviation emerging from digital transformation will cause the culture to shift around the safety concept. Safety in the world of autonomous vehicles changes when transportation policy writers have to consider that a driver may be something other than a human being in control of the vehicle. Similar implications exist in the application of autonomous flight, as in the case of drone swarm operations.

Significance to Social Change

The examination of forward-looking strategies for safely integrating new technologies in the NAS through a modified Delphi approach may contribute to positive social change by identifying the importance of strategies that would increase efficiency and maintain the safety standards essential in aviation. The results of this qualitative study may contribute to the emerging body of knowledge in digital transformation by providing insights from a large scale and complex industry. Application of the study results could inform future strategic planning that helps leaders to usher in the next generation of aviation designed to overcome current limitations of aviation-based transportation systems. Aviation was one of the most impactful innovations in the 20th century (Crouch, 2003). Modernization is transforming aviation that, in turn, influences society (Crouch, 2003; Rhoades, 2015).

On a broader scale, Schwab and Davis (2018) pointed to the fragile state of society with rising inequality, increases in vulnerable populations, and constant harm to the natural environment. Representing the World Economic Forum, Schwab and Davis suggested that the radical shifts that will emerge from Industry 4.0 present a force for good. Thought leaders in digital transformation are still writing the rulebook, so now is the time to promote application for the betterment of humanity. The SpaceX Starlink project with the mission to deploy a mega satellite constellation to deliver broadband services to over 50% of the world's population that is currently without connectivity is an example. Full global coverage of an accessible telecommunication network enables economic development, social development, and environmental protection (Wiltshire et al., 2016).

Influencers have the opportunity to shape the fourth industrial revolution to enhance human dignity creating benefits for all, not only the privileged few. Digital transformation can improve life for individuals, communities, organizations, and governments (Schwab & Davis, 2018). Mixed reality, quantum computing, and big data are technologies that can alter society at every level. The current study offered a glimpse of how these applications could transform a significantly impactful industry.

Summary and Transition

This chapter included an introduction to the modified Delphi study about how a panel of aviation experts viewed the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation (Fleming & Leveson, 2016; National Research Council, 2014). Adoption of advanced technologies in aviation presents many challenges, and one of the foundational considerations is the impact on safety. There was limited consensus among aviation experts on strategies for adopting comprehensive safety-driven digital transformation strategies (Kistan et al., 2018; Materna et al., 2015; New, 2018; Song et al., 2014).

The current study was an extension of the FAA Strategic Plan (FAA, 2020b) with a list of 64 considerations for digital transformation aviation. During the four rounds of surveys, participants were asked to examine the list of items created from the FAA Strategic Plan (FAA, 2020b) and work through a process to assess their desirability, feasibility, and importance, as well as panelists' confidence in the final list of forward-looking strategies. The study was grounded in the management concepts of digital transformation and safety culture. Findings from the study could be used in future FAA strategic planning work concerning the implementation of Industry 4.0 technologies in the NAS. Limitations of the study included participant involvement, rigor of processes, and bias that could have influenced the quality of qualitative research. The impact on practice, theory, and social change may make the study noteworthy to the aviation community and the emerging scholar-practitioner community focused on the fourth industrial revolution.

Chapter 2 centers around the interconnections among digital transformation, safety culture, and organizational strategy in the aviation environment. The chapter includes a review of research pertaining to digital transformation and the evolution of the safety culture concept, which were the two management concepts underpinning the study. Safety culture is a vast research topic with publications spanning decades that illustrate a maturation of principles, techniques, and approaches with application in a wide array of industries. Digital transformation also cuts across many industries; however, it is a relatively new topic for the research community, and it is evolving rapidly as new discoveries in technical application propel more technological advancement. The literature review supporting the study included the scholarly research that braces the key elements of the FAA Strategic Plan (FAA, 2020b). The methodology literature section contains the common methods, designs, and techniques reflected in the research literature with an emphasis on the Delphi process.

Chapter 2: Literature Review

This chapter contains a review of the literature regarding the research problem. The social problem was that aviation leaders in the U.S. federal government face challenges in advancing technological evolution and modernization efforts due to federal appropriations, human capital limitations, economic shifts, and safety culture (Chatfield & Reddick, 2019; Elwell, 2018a; Wallace et al., 2018). The specific problem was the difficulty of adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation (Fleming & Leveson, 2016; National Research Council, 2014). The purpose of this qualitative modified Delphi study was to determine how a panel of 21 aerospace experts based in Washington, DC viewed the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation.

The study was grounded in two management concepts: Safety culture and digital transformation. The nexus of these two concepts was examined by providing expert views on safely integrating digital transformation in aviation to inform future strategies for the FAA. Even though digital transformation has been identified as a way to enhance safety, aviation leaders strain to adopt it into the NAS due to concerns for protecting the safety of the current system fortified by the safety culture (Elwell, 2018a; Gore, 1997).

Although the concepts of digital transformation and safety culture have strong representation in the literature, there was little literature that examined them combined or applied to the strategic direction for managing the national airspace. This gap in the literature supported the need to examine the specific problem. The remainder of Chapter 2 begins with a description of the search strategy used to identify relevant sources for the literature review. This section justifies using digital transformation and safety culture as guiding principles in exploring the strategic technological advancement in aviation. The review of the literature establishes the foundation for surveys that were administered with a panel of aviation experts and shows how this methodology has been used similarly in other industries. This chapter concludes with a summary of the gap in the literature, conclusions, and a transition to the research methodology chapter.

Literature Search Strategy

The relevant historical literature for the study included sources from varied disciplines including management, systems theory, information technology, organizational culture, and strategy. This review of the literature focuses on the relevant literature published since 1951. The review includes publications regarding the conceptual framework for this study and provides historical context as needed. The search for relevant literature was conducted using multiple databases from the Walden University library and the Google Scholar search engine. Specific databases used during this review included ABI/INFORM Complete, Academic Search Complete, Business Source Complete, Directory of Open Access Journals, EBSCOHost, Emerald Management, ProQuest, Sage Premier, ScienceDirect, SpringerOpen, Taylor & Francis, and Wiley Online. The search results came from a combination of the following keywords: *Aviation*, *safety culture*, *safety management system*, *digital transformation*, *industry 4.0*, and *Delphi method*. The reference sections of the articles found while searching the literature were also used to identify additional relevant sources for the study.

Table 1 shows a breakdown of the resources available for this literature review. When the four concepts of aviation, safety, digital transformation, and Delphi were combined, the search yielded no results. The sources considered for the literature review were short-listed from the initially reviewed resources by evaluating the titles and abstracts to examine the relevance of each source to the study and its framework.

Table 1

Breakdown of the Resources Initially Scanned for the Literature Review

Topic	*n* articles
Aviation safety culture	15,200
Aviation safety management system	7,670
Aviation digital transformation	1,810
Aviation Industry 4.0	2,750
Aviation Delphi method	2,600

Table 2 shows the breakdown of literature included in this review from a seminal, historical, and current perspective. Almost 50% of the articles referenced in the study had been published during or after 2016. The literature review included peer-reviewed articles, reports, books, and studies from credible organizations and associations relevant to the discussion of digital transformation strategies in an aviation safety culture. Ulrich's (2018) periodical directory provided a peer-reviewed status on the resources included in this review. The search continued until all relevant sources for the study could be examined and synthesized in this literature review.

Table 2

Breakdown of the Resources Included in the Dissertation

Publication period	*n* articles	%
Seminal (1951–2000)	40	17.0
Historical (2001–2015)	80	35.0
Current (2016–2021)	110	48.0

Conceptual Framework Literature

The management concepts that framed the study were safety culture and digital transformation. As a mode of the United States Department of Transportation, the FAA has a responsibility to provide oversight to ensure the safety of flight. The FAA works with the International Civil Aviation Organization (ICAO) to present a consistent worldwide standard for safety in global aviation. These two organizations have led the policy and organizational culture charge for safety to be the top priority for any aviation organization. The safety standards in aviation today grew from the evolution of the concept of a safety culture.

Safety culture finds its roots in the Schein’s (2017) seminal work in organizational culture, which described culture as the unwritten rules that dictate how things are done. M. D. Cooper (2000) built on the seminal culture work with greater fidelity on the essential drivers of organizational culture that induce behavior grounded in social learning theory suggesting that behavior is heavily influenced by the behavior of others in their environment creating a uniformity in behaviors. Pidgeon (1998) and La

Porte (1996) suggested that organizations have subcultures with their norms that may differ from other groups in the organization. The challenge for aviation is to coalesce behaviors for a full aviation community around safety.

The safety culture perspective grew to prominence in response to the Chernobyl disaster (Batuwangala et al., 2018; Heras-Saizarbitoria & Boiral, 2013; Stolzer et al., 2016). The combination of organizational culture, safety culture, and total quality management came together around the concept of a Safety Management System in high-risk environments (Grote, 2012; Robertson, 2016). The regular reporting, rigorous adherence to procedure, and organizational action focused on safety helps to bring the members of the community together for a common purpose.

Although safety in aviation is rulebound, the drivers for digital transformation present a seemingly unbound upheaval to society. Digitally based game changing organizations like Uber, AirBNB, and Google are changing the way people travel. Schwab and Davis (2018) identified this transformation of the world through the concept of the fourth industrial revolution, Industry 4.0, or digital transformation. The new use of technology offers the ability to provide ongoing real-time connectivity (Bisio et al., 2018).

The global phenomenon gained prominence in manufacturing for increasing speed, efficiency, and product customization (Bag et al., 2021; Chiarello et al., 2018). The phenomenon has been driven by the intersection of cloud computing, big data, IoT, and AI (Siebel, 2019). D. L. Rogers (2016) simplified the approach to implementing digital transformation with an explanation of five primary considerations or domains for leveraging the benefits of digital transformation: Value, customer, competition, data, and innovation.

Research showed that keeping up with the pace of Industry 4.0 has presented challenges. The connection between organizational strategy and digital transformation can lead to greater success (Davenport & Westerman, 2018; X. Li et al., 2021; Nwaiwu, 2018). Aviation governance is working to sort out the best path forward to digest the impending game-changing innovations within the rigors of a deeply entrenched safety culture.

This section focuses on key elements underpinning the safety culture and digital transformation management concepts. The section on safety culture contains an explanation of its roots in the principles of organizational culture. The section also covers the evolution of the safety culture concept and includes the varying perspectives on safety culture. The section concludes with an explanation of the current view on the safety management system and how it applies in aviation. The digital transformation section encompasses the value of the strategic approach to digital transformation. This section covers the connection between digital transformation and the fourth industrial revolution and how new technologies are emerging. The section concludes with the connection to the aviation industry.

Safety Culture

Foundations in Organizational Culture

Safety culture is rooted in principles of organizational culture and cultural anthropology (Deal & Kennedy, 2008; Guldenmund, 2000; Kotter & Heskett, 1992;

Schein, 2017). Deal and Kennedy (2008), who coined the phrase “corporate culture,” posited that all organizations have a culture defined by a set of norms and values that motivates behaviors. Deal and Kennedy indicated that some organizational cultures are easy to identify while others are less clear; they suggested that a well-developed and mission-specific culture leads to stronger organizational commitment. Schein (2017) described the concept of cultural DNA, which emerges from shared learning around beliefs, values, and desired behaviors that are intended to lead to success. As a group has repeated accomplishments based on a common set of norms, the cultural DNA or shared behaviors become more deeply embedded. The group may not be aware of the presence of these basic interaction assumptions, yet they feel dissonance in variance from the norms. This discord generates organizational resistance to change.

Kotter and Heskett (1992) pointed to a group’s culture as a common understanding of what is important that persists over time despite changes in the group membership. The unspoken shared values support the maintenance of a particular status quo, thereby posing difficulty with accepting change. Williams et al. (1993) argued that culture varies among workgroups and individuals within an organization often in support of or in contrast to a larger cultural theme. Moreover, Deal and Kennedy (2008) acknowledged the evolution of culture conceptualization through reinforcing the dominant role it plays in holding people together. Culture provides focus and meaning to people’s efforts, thereby emphasizing their value in organizations.

Evolution of Safety Culture

Seminal work on organizational safety culture includes risk perception considerations as an influencer of individual behavior (M. D. Cooper, 2000; Reason, 1997; Woods et al., 2017). M. D. Cooper (2000) indicated that safety culture is a subcomponent of corporate culture unless the organization operates in a high-risk industry where safety is the dominating characteristic of the corporate culture, as in aviation. Reason (1997) distinguished between individual and organizational accidents, characterizing the former as more frequent and the latter as catastrophic. Reason presented a case for transparency in safety information through five key aspects of the safety culture: Data gathering, open reporting of errors or near misses, organizational trust earned through open communication on potential risks, ability to make changes to avoid risks, and learning from mistakes. Reason identified aviation as a high-risk industry that has inherent complexity through technology. That complexity emerged from advances in mechanical technology combined with the human-to-machine interface (Reason, 1997).

M. D. Cooper (2000) provided a model that permeates the literature on safety culture, drawing from the concepts of social learning theory and reciprocal determinism (Bandura, 1977, 1986). The underpinning premise was that people are a product of the interplay among each other and with their environments when it comes to safety considerations. More specifically, individuals operate in a bidirectional psychosocial state influenced by their surroundings.

M. D. Cooper (2000) noted that three fundamental considerations serve as the foundation for a safety culture. The first is the individual psychological elements that are most easily expressed in terms of how people in the organization feel about safety. The second is observable behavior that demonstrates what people do to support safety. The third is the situational factors or organizational perspectives that support safety. The situational factors include policies, procedures, management systems, control systems, communication systems, and workflow systems. Safety culture experts considered M. D. Cooper's three-point model as universally applicable (Guldenmund, 2000; Lawrenson & Braithwaite, 2018; Mearns et al., 2013; Morrow & Coplen, 2017).

Varying Perspectives on Safety Culture

Pidgeon (1998) offered a view on safety culture that suggested management control was the primary driver for creating a safety culture focusing on high-risk organizations such as aviation. This view contradicted the safety culture theory (M. D. Cooper, 2000) that emphasized organizational unity on a common view of safety in the organizational culture. La Porte (1996) set the stage for Pidgeon by suggesting that high-risk situations required subcultures that allowed for a variance from the rules to respond to the unexpected occurrences in the environment, such as a pilot with an equipment failure while in flight.

Pidgeon (1998) advised that organizations construct subcultures that operate in direct opposition to each other. The typical manifestation of this conflict appeared between safety standards and urgency to deliver results. A case in point was the NASA Challenger disaster (Vaughan, 1990). Reviews of this accident showed awareness of the

O-ring failure in the solid rocket booster as the technical reason for the explosion. A deeper investigation revealed the complexity of obtaining systems where safety risks were perceived as barriers to implementing the new technology that was needed to deliver the final product within the anticipated timeline. La Porte (1996) identified the allure of organizational visions focused on utilizing complex, powerful, and costly systems that were inherently dangerous working in conflict with an expected delivery of low-risk and precise performance.

The design process for the Challenger included safety analysis of the parts with violation parameters that allowed for the progress of the overall project while addressing nonperformance risks through a team evaluation process (Vaughan, 1990). The Challenger represented the cutting edge of high-performance aerospace technology, where elements of safety concern were negotiated through a decision-making process marked by the imperfect knowledge of groundbreaking advancements. In other words, acceptable risk became a social negotiation rather than an objective process. The O-ring hazard was caught between the competing demands of managing a complex technical implementation and the pressure to deliver according to stakeholder expectations (La Porte, 1996). Pidgeon (1998) saw the Challenger disaster as a safety culture failure that neglected the power of organizational forces to normalized risk at the detriment of the overall goal. Reason (1997) identified this as an “organizational accident” (p. 295), indicating that influences at the organizational level combined to adversely trigger catastrophic failure.

Safety Management Systems and Aviation

Beckmerhagen et al. (2003) offered a blend of M. D. Cooper's (2000) theory and Pidgeon's (1998) perspective with the integrated management system (IMS) approach. Beckmerhagen et al. presented IMS to identify safety as a management strategy rather than an additional work responsibility. Beckmerhagen et al.'s (2003) integrated approach suggested that safety pervade all aspects of organizational performance, including cost and achievement of performance goals to bring diverse business functions together around a common purpose. They offered their concept in the context of the nuclear industry on the premise that any small error in a reactor can have profound catastrophic outcomes. In responding to the Chernobyl disaster, they promoted a harmonization between safety and total quality management as the critical organizational connection (Batuwangala et al., 2018; Heras-Saizarbitoria, & Boiral, 2013; Stolzer et al., 2016). Beckmerhagen et al.'s (2003) model set the foundation for the Safety Management System (SMS) movement in high-risk environments (Grote, 2012). The aviation safety culture emerged as a serious national aerospace issue in the mid-1990s after a series of fatal commercial aircraft crashes and a subsequent White House Commission on Aviation (Gore, 1997; Morrow & Coplen, 2017).

The aviation industry followed the lead offered by the FAA, National Aeronautics and Space Administration (NASA), and the International Civil Aviation Organization (ICAO) to adopt safety management systems into their operations (Robertson, 2016). The FAA first issued formalized SMS guidance in 2006, NASA in 2008, and ICAO in 2008. SMS looks at the risks associated with aviation activity to reduce or control them to an acceptable level (Batuwangala et al., 2018). There are four key components to the aviation perspectives on the SMS. First is the safety policy that defines the methods, processes, and organizational structure needed to achieve organizational safety goals. Senior management commitment to these policies is considered a critical success consideration for them.

The second component addresses safety risk management in response to the premise that there is always risk in aviation operations. It addresses the acknowledgment and consideration of risk. The third element is safety assurance that focuses on the control strategies to minimize known risk and the identification of new hazards. The final component is safety promotion that focuses on training, communication, and other actions to create a positive safety culture (Stolzer et al., 2016; Velazquez & Bier, 2015). The concept of safety culture now serves as a core value throughout the aviation industry which matured from a regulatory compliance approach to a collaboration between industry and regulators through open dialogue (Mills & Reiss, 2014; Nævestad et al., 2018).

Ibánez, et al. (2016) offered the Integrated Safety Assessment (ISA) method as one of the most contemporary approaches to safety management. It follows the dynamic event tree as a framework using data to predict times when a safety limit would likely to be exceeded. Although the ISA was developed for the nuclear industry, it has applications in aviation. The fundamental principle with ISA is in risk-based decision making with an ability to perform projections based on uncertainly analysis. The model supports a calculation of safety limit and a prediction of events exceeding the frequency of that limit. The ISA uses big data and advanced analytics to create a warning system for safety challenges that goes beyond the capabilities of less automated safety systems.

The FAA Strategic Plan states the agency’s “continuing mission is to provide the safest, most efficient aerospace system in the world” (FAA, 2020b). The 2019 ICAO safety report compared 2018 and 2019 aviation fatalities: 50 and 514, respectively (International Civil Aviation Organization, 2019). This stark increase led regulatory organizations to take a renewed commitment to improve aviation safety. The aviation industry is at the cusp of digital transformational technologies that will fundamentally shift it for greater efficiency and safer operations (Valdés et al., 2018). However, leaders grapple with the strategic implications of integrating new technologies into their operations, especially in a high-risk industry like aviation (Reason, 1997). Therefore, an examination of digital transformation in aviation must include the safety culture as a primary consideration for the conceptual framework, supporting the need for the study.

Digital Transformation

Digital technologies are transforming society (D. L. Rogers, 2016). The competitive advantage goes to the organizations with the most effective strategy for adapting to digital transformation and thriving in the execution of it (Adamik & Nowicki, 2018; H. Li et al., 2021). The digital economy, for instance, is redefining the business environment as a result of digital transformation (Pînzaru et al., 2019). Success with digital transformation resulted not simply from integrating technology, but from targeted organizational strategy and the ability to embrace new thinking as a factor of organizational culture (Adamik & Nowicki, 2018; Pînzaru et al., 2019; D. L. Rogers, 2016; Schein, 2017; Schwab & Davis, 2018).

Since digital transformation involves technology, much of the literature focused on the computer science discipline (Liao et al., 2017). Liao et al. (2017) reported that out of 224 papers reviewed in a digital transformation meta-analysis, 41% were from computer science, followed by 28% in engineering. The remaining 31% was split over 13 other disciplines, including business, management, and decision sciences. Less than 10% of the studies reviewed addressed the strategic, financial, or market for the use of transformative technology.

Recognizing the gap, D. L. Rogers (2016) argued that there are five domains for digital transformation: Value, customer, competition, data, and innovation, suggesting that organizations needed to take a holistic view to ensure that transformation succeeds. Davenport and Westerman (2018) concurred, indicating that digital transformation driven by intriguing technologies in information technology or engineering but lacking in strategic connection results in failure. These digital transformations were not connected to the marketplace or the value proposition that would result from the application of groundbreaking technologies.

Strategic Approach to Digital Transformation

Pînzaru et al. (2019) conducted a content analysis of published interviews with 10 CEOs highly regarded for successful strategic approaches to digital transformation. The goal was to understand the CEOs' perspectives on five elements pertinent to successful organizational transformation: Culture, technology, agility, customer focus, and sustainability. Pînzaru et al. wanted to understand how these five factors contributed to the reconfiguration of the organizational accountabilities to meet the demands of these factors. All CEOs in the study addressed these issues as part of their strategic perspective on successful digital transformation and they emphasized the criticality of integrating the components into the fabric of the organization rather than treating them as a set of novelties.

Davenport and Westerman (2018) presented organizational failures associated with transformation and suggested that there are key lessons to learn from organizations that lost the battle of digital transformation under the pressure of financial returns. The first key learning was that many factors drive successful organizational performance and that digital capability only has value in the context of market demand rather than in the glitz of shiny new technology. Second, digital technologies are not plug and play operations; they change the existing business and so the supporting structure, systems, and skills need to adapt to the new way of working. Third, the marketplace must align with the digital product both in terms of consumer readiness and competitive offerings. Finally, the organization needs to consider the existing business while introducing the new technology despite the temptation that regards new technology alone as interesting. In sum, Davenport and Westerman (2018) warned that a digital strategic framework must be comprehensive and presented with an understanding of the important and long-term commitment to execution.

Nwaiwu (2018) believed that success in digital transformation resulted from the solid connection between strategy, culture, and the conceptual framework. Nwaiwu indicated that there were too many frameworks with a lack of consensus on how they should work in achieving digital transformation. Like others, Nwaiwu promoted the critical need for digital transformation to deliver market differentiation and better customer experience as identified in the Six Keys to Success framework (Kavadias et al., 2016) stipulating the following elements as essential for success in digital transformation: Personalization of products and services, closed-loop (focusing on sustainability and reusability), asset sharing (like Uber and Airbnb), usage-based pricing, collaborative ecosystem (including members of the supply chain), and organizational agility to shift at the speed of the market. Nwaiwu (2018) claimed that the strength of the Six Keys framework resides in its tight linkage with strategy and organizational culture.

The Fourth Industrial Revolution

The fourth industrial revolution, or industry 4.0, technologies are transforming the world (Schwab & Davis, 2018). This evolutionary phase stands out from other industrial transformations due to the interrelated concepts of the speed of innovation boosted by the depth and breadth of disruptive technology adoption (Christensen, 2016). Industry 4.0 offers the ability to provide ongoing real-time connectivity (Bisio et al., 2018). According to Nadella, in the forward to *Shaping the Fourth Industrial Revolution* (Schwab & Davis, 2018), the immense computation power of Industry 4.0 technologies will transform society. As a key driver for digital transformation, Industry 4.0 is based on the principle of perpetual communication through the internet for the multidirectional and continuous exchange of information among people, between people and machines, and among various machines (Roblek et al., 2016). Y. Chen (2017) reported that four foundational elements drive the fourth industrial revolution included big data analytics, cloud computing, applications, and mobile devices.

Shaping Industry 4.0

Researchers and authors have a variety of perspectives on the composition of industry 4.0. Lasi et al. (2014) pointed to the fundamental paradigm shift in industrial production that grows from the fusion of internet technologies and advanced digitization to control manufacturing processes. Intelligent or smart manufacturing presents benefits like reduced design time, increased production efficiency, and improved service levels (Zhong et al., 2017).

A greater understanding of Industry 4.0 came from a more detailed perspective on technologies that are considered advanced digital technologies. Trappey et al. (2016) used the cyber-physical systems perspective to further clarify this distinction. CPS means a collection of technologies that interconnects the physical world and computer-based technologies. The core technologies behind the transition from Industry 3.0 to Industry 4.0 from the CPS perspective include sensors, data acquisition systems, and computer networks. Trappey et al. also saw the criticality of CPS as advanced digital technologies to support the manufacturing environment and, ultimately, organizational profitability.

Chiarello et al. (2018) suggested that Industry 4.0 is a highly complex amalgamation of technologies that are difficult to delineate and cluster. To map Industry 4.0 technologies, they determined that there is disagreement about what technologies constitute the fourth industrial revolution. Chiarello et al. called attention to a different aspect of CPS defining it by five Cs–connection, conversation, computation, cognition, and configuration, with three additional considerations: Architecture, ontology, and applications.

Their review of the Industry 4.0 literature showed that the highest levels of published research were in computation and applications. The tentacles of system interfaces that emerge from CPS make it a pivotal consideration for the fourth industrial revolution. Accordingly, Chiarello et al. anticipated that CPS would play a major role in the future capabilities that emerged through this stage of industrial developments

In addition to CPS, M. Lee et al. (2018) heralded the Internet of Things as a critical component of the fourth industrial revolution. Gubbi et al. (2013) identified the IoT as a primary driver for a future of data-sharing networks that accelerated information distribution across platforms via the cloud. Gubbi et al. alluded to a future state where the vast amount of data moving through the network would present a new IT challenge compelled by the demands of managing enormous amounts of data generated as information is stored, processed, accessed, and reprocessed. Ashton (2009), the self-proclaimed originator of the IoT concept, claimed that the only purpose of data was to be working in service of things, thus highlighting the importance and practical purpose of the internet. Even in this early perspective on the purpose of the IoT, the concept of vast amounts of data comes through as a substantial marker.

Big Data

Big data is a product of CPS and IoT; it is the foundation of the data-driven nature of organizations that allows them to leverage business intelligence and build competitive capabilities (I. Lee, 2017). I. Lee (2017) identified the three-V model of big data:

Volume, velocity, and variety, recognizing that the information coming from various devices needed to be managed via a framework. Volume refers to the huge amounts of data generated by various devices and sensors. The frequency at which data update results in exponential data growth, signifying velocity, while variety denotes the multiple formats of data, such as numeric, textual, photographic, and video. Kaplan and Haenlein (2019) suggested that data can also come from a broad range of sources, from social media applications to corporate networks and proposed that artificial intelligence is the means to handle the vast amounts of data that accompany the fourth industrial revolution.

The academic community has clutched onto the Industry 4.0 topic over the past 10 years. Savastano et al. (2019) conducted a systematic review of 156 publications focused on digital transformation since 1998. Eighty-one percent of the publications on this topic appeared between 2014 and 2018, showing a rapid growth in literature in recent years (Savastano et al., 2019). The complexity in the industrial sectors ranges from the use of technology in production equipment, to the integration of the IoT in the manufacturing process, to artificial intelligence controlling production processes. A new level of connectivity emerged as the “digital thread” (p. 2) permeates the value chain, suggesting the redefinition of the connection between man and machine in this “smart revolution” (p. 3) to create a new digital manufacturing ecosystem (Savastano et al., 2019). The review revealed the discrepancy between the growth in overall content and the lack of a digital strategy to accompany the technological advances.

Schwab and Davis (2018) aimed to bring simplicity and clarity to the concept of Industry 4.0 by creating a 12-point framework presented in four main categories. The first category of extending digital technologies included new computing technologies, blockchain, and IoT. The second category is reforming the physical world containing artificial intelligence and robotics, advanced materials, and additive manufacturing with multidimensional printing. The third category focused on altering the human being in terms of biotechnologies, neurotechnology, and virtual/augmented realities. The fourth category related to the environment by addressing energy capture, storage, and transmission, geoengineering, and space technologies.

Digital Transformation in Aviation

Valdés et al. (2018) proposed that the time has come for the aviation industry to join the fourth industrial revolution by staking a claim on aviation 4.0. Valdés et al. argued that the evolution of aviation parallels the maturation of industry into its four-phased evolution, although the timeline for aviation evolution starts later than industry 4.0. Valdés et al. outlined the phases of the aviation revolution as Aviation 1.0 introduction of visual flight rules (VFR), Aviation 2.0 the use of electronic devices in aircraft, Aviation 3.0 massive incorporation of electronics in the cockpit augmented by digital data processing and data communications technology.

Aviation 4.0 is still a visionary stage of evolution that incorporates cyber-physical systems with autonomous operations to make a smart plane. The application of this technology is focused on avoiding such an instance as the Germanwings flight 9525 incident in 2015 where the pilot intentionally crashed the plane into the French Alps. The air traffic control tower knew the aircraft was on an anomalous trajectory and the aircraft emitted warnings, but remote flight control could not be activated to avoid the crash because it is not active on commercial airliners. Valdés et al. (2018) pointed to aviation use of Cyber-Physical connection, IoT, advances in aviation manufacturing, and the use of big data as the junction points for aviation 4.0 to provide an increased level of aviation safety.

In the spirit of Trappey et al.’s (2016) CPS, Valdés et al. (2018) gave an example of the aircraft engine loaded with over 5,000 sensors that continually emit signals about the health and location of the equipment. Those engines are loaded on a plane that can release up to 400,000 more sensor-based signals per flight. M. Lee et al. (2018) considered IoT with CPS as an overarching benefit of the fourth industrial revolution. Valdés et al. addressed this same combination as a driver for efficiency and safety. According to Jawhar et al. (2018), the data-driven nature of the national airspace has a critical need to adopt the Industry 4.0 strategies to fit commercial aircraft and unmanned aerial vehicles into the overall integrated data platform associated with the smart cities of the future. Despite these advantages and needs, Valdés et al. (2018) warned that the overall aviation system has little visible drivers for claiming Industry 4.0 or aviation 4.0 as a state of the industry.

Airline manufacturers offered some early adoption strategies: Flexible and precise production, smart factories, and augmented reality in fabrication (Frigo, et al., 2016; Jackson et al., 2016; D. Schumacher, 2016). Jackson et al. (2016) emphasized the significance of aerospace manufacturers being able to reconfigure the production space to meet the varying product needs while maintaining the very strict standards for making any aviation-related components. D. Schumacher (2016) presented ways that NASA is involved with and supports advancement in aerospace manufacturing with the examples of the forward-thinking topics of 3D printing in space that allows astronauts to produce parts for a spacecraft as needed and redesign streamlining to reduce engine parts, sub-manufacturing processes, and overall engine weight. Frigo et al. (2016) wrote on the use of virtual and augmented reality in several of the world's premier aircraft manufacturing organizations. While A. Schumacher et al. (2016) examined Industry 4.0 maturity in aviation manufacturing.

Big data considerations flowing throughout the industry were a common denominator in the aviation 4.0 perspective (Valdés et al., 2018). Badea et al. (2018) explained the fundamental nature of big data in aviation with the fact that the 5,000 sensors on each engine generate 20 terabytes of data per hour of flight. The multiplication of the number of engines per plane and the number of planes in flight at any given hour sets the magnitude of data volume associated with the aviation system. Vagdevi and Guruprasad (2015) also recognized the vast amounts of data associated with aviation by adding airline, airport, and customer-related data to the in-flight data and suggested cloud computing as a feasible way to manage massive data. To match the big data environment that is the foundation of aviation, Wang et al. (2019) brought the case back to aircraft manufacturing to show the need for data-driven and cloud-based principles in aviation equipment production.

Mangortey et al. (2019) offered a paper at the Sci-Tech aviation industry meeting that captured the essence of the big data landscape for aviation. Conferences offer opportunities for advanced concepts in an industry to be presented. Papers at the Sci-Tech conference are not peer-reviewed (AIAA Sci-Tech Forum and Exposition, 2019). However, Mangortey et al.’s paper is influential because it provides a comparable insight into the future of aviation that emerges from the FAA Strategic Plan (FAA, 2020b). Mangortey et al. specified the technical data sources in aviation to include system-wide information management, flight publication data, and traffic flow systems. They discussed data retrieval, parsing, and fusion as the next wave of aviation big-data management that is likely to inform a powerful aviation prediction model.

Pereira et al. (2021) identified 57 peer-reviewed publications from 1999 to 2018 that addressed innovation and value creation in the aviation sector. Among the ten main themes identified were: Technology, systems and processes. Innovation occurring within the theme areas correlates to digital transformation. Pereira et al. (2021) found that 95% of the articles included in the review had some reference to a factor of digital transformation in aviation in such areas as check in and booking systems; maintenance, prediction and control; and sustainable fuel. Although these topics do not relate managing the national airspace system, they do represent digital transformation in the larger context for aviation.

The conceptual framework for the study was rooted in the safety culture and digital transformation arenas. Safety culture came to the current state through a long and sometimes painful history. The losses that occur from aerospace-related accidents are catastrophic. Those losses cause aerospace professionals to make a deep personal commitment to safety. Aerospace professionals can draw upon the decades of research dedicated safety culture to support the practices needed to keep travelers and the public at large safe. In contrast, digital transformation is a relatively new phenomenon that occurs in the depersonalized space of bits and bytes. Although digital transformation is intended to improve the human experience, it seems distant from the raw consequences experienced by people who face the reality of an aviation-related accident. Both disciplines must consider the future of the industry and how to build it in a way that considers the benefits from each perspective. A Delphi study can help to frame the comprehensive strategic approach for the future of aviation.

Literature Review

The first recorded example of aircraft automation, a gyroscope, was patented in England in 1891 (Billings, 1997). The device created the stability needed for a tethered aircraft to keep it aloft. The Wright brothers advanced the gyroscopic application to create an aircraft stability system that won the prestigious Collier award in 1913 and was the forerunner of the automatic pilot (National Aeronautics Association, 2020). Elmer Sperry took gyroscopic stabilization to the next level of sophistication and became associated with aviation automation for decades to follow (Mohler & Johnson, 1971). The innovations in aviation today remind aviators of the exciting breakthroughs that happened at the time of the Wright Brothers (Elwell, 2018b). In the early 1900s, aviation pioneers could not imagine how they would change the world (Crouch, 2003). Today’s aviation creators engage in focused strategy sessions to help them strategically plan for the future they imagine.

The FAA Strategic Plan

The FAA issues a strategic plan at regular intervals to serve as the guiding direction document for the agency's workforce. The 2019-2022 plan aligns to the four overarching goals issued by the U.S. Department of Transportation as follows. Safety focuses on reducing fatalities and serious injury in the operation of the aerospace industry. Infrastructure refers to the many physical and technology-based elements that keep the overall system functioning safety while stimulating economic growth and productivity. Innovation sets the standard of encouraging the innovative practices that improve the safety and performance of the national airspace system. Accountability includes speaks to the commitment for upholding the regulatory responsibility to safety achieve efficiency and effectiveness in the aviation industry (FAA, 2020b). The seven subthemes that deliver the key elements of the strategy are supported in research.

The first of the seven subthemes, NAS infrastructure, was defined by the physical buildings and equipment used for air traffic monitoring, such as air traffic control towers or a Terminal Radar Approach Control Facilities [TRACONs], power systems, information technology, navigational aids, communications and surveillance equipment, and weather systems as identified in the FAA budget (U.S. Department of Transportation, 2018). The vision for the future NAS infrastructure paralleled the Industry 4.0 considerations of a completely information-based system (Schwab & Davis, 2018). The aviation-specific considerations included space-based navigation and surveillance-based operations with innovative air vehicle technologies.

Stroup et al. (2019) referenced the importance of aviation related strategic planning work as a means to address challenges with national airspace with its capacity, technology, and fluidity constraints that contribute to the conundrum of integrating new entrants into the system (Welch, 2018). Stroup et al. (2019) reinforced the current complexity of the national airspace by articulating the system of systems dependencies in the entire operation by pointing to the skyway routes, take-off and landing processes, time-based flow management, ground delays, and the overall efficient air traffic management with minimal delays. As aviation experts, Stroup et al. outlined the call to action for digital transformation in aviation through the regulatory framework established in the FAA Reauthorization Act of 2018, the Executive Order on Maintaining American Leadership in Artificial Intelligence, and the Eurocontrol AI Conference.

The second subtheme was smart systems, or the focused use of data analytics, machine learning, autonomous transportation systems, artificial intelligence, robotics, and quantum computing (FAA, 2020b). These same technical considerations define the fourth industrial revolution (Y. Lu, 2017). The writers of the FAA Strategic Plan acknowledged the criticality of federal government involvement in promoting smart systems in aviation. The primary matter for smart systems integration centered around two crucial human factors: Acceptance of smart systems by the traveling public and adoption of the human-machine interface as a key function for systems operations (FAA, 2020b).

In their industry 4.0-focused literature review, Roblek et al. (2016) pointed to resistance among consumers in accepting concepts like smart or autonomous vehicles suggesting that expanding digital technologies can create fear associated with the loss of privacy and security because personal information is more visible and more susceptible to theft. Roblek et al. articulated the concern that someone in the digital world could be watching the actions of people in their data networks and that a digital footprint can lead to negative consequences. Roblek et al. synthesized the theories and practices regarding Industry 4.0 to help anticipate the changes that would result from industry 4.0, especially those pertaining to the perspective of consumer behavior. Roblek et al. provided a comprehensive examination of the emerging state of digital transformation, however, they did not offer any methodological information on how they selected the articles included in the review. Despite that shortcoming, Roblek et al. delivered a foundational review that set the academic groundwork for future Industry 4.0 research.

Y. Lu (2017) presented a literature review on Industry 4.0 that serves as a direct methodological contrast to Roblek et al.'s (2016). Y. Lu examined digital considerations such as IoT, CPS, and Internet of Services (IoS) as communication conduits from machines to machines and humans to machines. The topic of the human-machine interface played a key role in Y. Lu's analysis, which echoed the same consideration expressed in the FAA Strategic Plan. Lu's treatment of the digital transformation topic was highly data-oriented with a detailed data set reduction strategy, culling 88 articles from the original 103 ones identified. Y. Lu presented tables showing counts on research categories, numbers of Industry 4.0 references cited per year, author citation frequency, and interoperability items among the smart systems topics. Both Roblek et al. (2016) and Y. Lu (2017) promoted the use of smart systems for increasing the speed and accuracy of complex and dynamic information exchanges which lead to more efficient operations, a desirable outcome also identified in the FAA Strategic Plan (FAA, 2020b).

The third primary category was certification and regulation, which is the heart of the safety accountability for the FAA Strategic Plan (FAA, 2020b). This category ensures that airmen, aircraft, and airports pass inspection and are certified to operate (FAA, 2020a). The experts in the future planning activity recommended that private sector manufacturing adoption of digital transformation would serve as the model for an aviation-based certification and regulatory framework. The experts involved in the FAA Strategic Plan expressed concern about systems certification processes that are different from the physical certification processes (FAA, 2020b). A certification for an artificial intelligence system is very different from certification for an aircraft.

Borangiu et al. (2019) addressed the system certification topic specifically in their introduction to a special issue of the *Computers in Industry* journal focused on digital transformation. They introduced the concept of the industry of the future that consisted of the two compelling aspects of industry 4.0: Cyber-physical production systems, and the IoT. Addressing concerns identified in the FAA Strategic Plan (FAA, 2020b), Borangiu et al. highlighted the issue of certification to verify that systems do what they are supposed to do. They paid particular attention to the certification of systems connected to the integration of cloud computing and manufacturing equipment. The certification process ensures appropriate access to the information transmissions, the security of the information, denial of service without certified access, and protection from impersonation (Borangiu et al., 2019). Although the certification for aviation-related systems is currently more oriented to physical systems and people, the principles are the same and could be modified for aviation systems. The certification helps to ensure that the interdependent pieces of the system work correctly, work together, and are secure.

In contrast, Kistan et al. (2018) considered digital transformation in air traffic management and focused mainly on the considerations for certification, given the automation arising from machine learning and artificial intelligence. Like other aviation scholars, Kistan et al. pointed out the challenges in the aviation system, especially in light of new entrants into the national airspace (Welch, 2018). Kistan et al. reinforced the conservative culture of aviation, acknowledging the rigor of certification as a way to help break through the barriers associated with digital transformation in aviation while identifying a set of scales used to articulate automation authority. They pointed to Sheridan's (1992) model that has been widely adopted in aviation: (a) human does it all; (b) machine offers alternatives; (c) the machine narrows the alternatives to a few; (d) the machine suggests one alternative; (e) the machine executes the recommended alternative with human approval; (f) the human has a set time to veto; if no action, then the machine executes the recommended alternative; (g) the machine executes the selected alternative and informs the human; (h) the machine informs the human upon request; (i) the machine informs the human after execution if notification is deemed necessary; and (j) the machine acts autonomously. According to Kistan et al., connecting these stages of automation with certification procedures can help to overcome the resistance to digital transformation in aviation.

The fourth subtheme identified in the (FAA, 2020b) focused on access to information, which echoed a core principle of Industry 4.0: Open access to information exchanges. The future state of radically open information exchanges propelled by smart systems requires an evolutionary process of maturation. One of the incremental considerations linked to aircraft is age. Older aircraft and air systems may not be able to transition to the most current technology that is already existing in newer aircraft for engaging in high-end technical information exchanges. The variability in aircraft age and, therefore, the digital footprint of our national aircraft creates constraints for big data management (FAA, 2020b).

M. Lee et al. (2018) noted how the fourth industrial revolution stimulates open connections as new dynamic combinations grow, especially among technologies, markets, regulations, and human behavior. Referencing Schwab and Davis's (2018) seminal work in industry 4.0, M. Lee et al. highlighted the complexity of the connected concepts and provided clarity through a design-thinking methodology with a people-centric approach. M. Lee et al. aimed to understand the human-technology interface from three perspectives. First is substitution, or the technology replacing people's perspective. Second is integration, or the use of technology to extend human capacity, improve precision, and enhance the quality of human action. The third is mediation, or the way technology intercedes to enhance people's interaction with each other, machines, or other physical objects (Madeira et al., 2021). These different levels of system autonomy require separate access to the dependent data sets (M. Lee et al., 2018).

Badea et al. (2018) added to the debate with their treatment of big data in aviation. They identified the volume constraints associated with the amount of data being generated by current aviation systems compared to the capacity of standard database management tools and data processing applications. Badea et al. illustrated the compounding information tsunami that results from each aircraft generating terabits of data per flight. The digital aircraft of today necessitates the use of data capacity parameters that can only be provided by cloud computing technologies. Although the volume of data is overwhelming, the benefits apply throughout the systems via the availability of information to reduce air traffic congestion and delays, improve maintenance efficiency, and provide more real-time information for travelers (Badea et al., 2018).

The fifth subtheme was cybersecurity (FAA, 2020b). Cybersecurity was a high priority topic throughout the aerospace system. This topic is a crux concern in the counterbalance with system information exchange. As the NAS becomes more universally open and machine-based, it also becomes more susceptible to cyber attackers. Cybersecurity in transportation systems is inextricably bound to consumer acceptance. Trust in cybersecurity builds trust in new modes of transportation, like autonomous vehicles. The conceptual approach to secure systems is to use the advances in technology to also advance cybersecurity with the parallel evolution of self-diagnosing, self-healing, and dynamic encryption.

Chatfield and Reddick (2019) reviewed the cybersecurity issue through a literature review and case study focused on a use case in the U.S. federal government by conducting a literature review and content analysis of government websites involving IoT technology assessment, the IoT use cases, and IoT cybersecurity policies in four domains: Transportation, energy, smart cities, and defense. Although Chatfield and Reddick suggested that the U.S. government needs to do more, they reported strength in the U.S. Department of Transportation. According to Chatfield and Reddick, transportation systems have control points and consumer access that augments the pathway for digital transformation. In addition, the U.S. Department of Transportation (2020) website contained robust information on cybersecurity. Despite these positive reviews, these researchers also expressed concern as the U.S. ranked as 14th in a worldwide listing of a cybersecurity vulnerability index (Chatfield & Reddick, 2019).

Urban (2017) wrote explicitly about the cybersecurity risks in international aviation, indicating that the industry’s dependence on interconnected technologies makes it a target for cyber attackers. Urban identified the vulnerabilities linked to new technologies. As an element of critical U.S. infrastructure, aviation presents a conundrum in cybersecurity because of the shared responsibility for protection among the U.S. government, private airlines, and aircraft manufacturers. The weaknesses emerge from the many stakeholders who construct information systems to work for their organizations. Sharing among the stakeholder community could impact a competitive advantage in the marketplace, so the key players are reluctant to collaborate on system designs. Despite the silos among airline systems, all parties work through conventional airport networks and the internet. These entry points could create an access gateway through the passenger check-in systems. Without appropriate cybersecurity, this same type of internet connectivity could allow for access to air traffic or sensitive airline information.

The sixth subtheme of the FAA Strategic Plan (FAA, 2020b) was space operations. The satellite industry has been the foundation of commercial space since its inception. The NASA space exploration project broke through many technological barriers to make space travel a regular occurrence (Carton, 2018). Then, the commercial space activity moved to the private sector with regulatory oversight from the FAA. The impact of space vehicle launches and recovery activity on the airspace requires accommodations among commercial, cargo, and general aviation air traffic (Stilwell, 2016). Future projects for microsatellites, space tourism, hyperbolic flight, and interplanetary missions have a direct impact on the management of the National Airspace System (FAA, 2020b).

According to Stilwell (2016), the commercial space industry is rapidly expanding and the regulatory environment is behind the growth curve. Stilwell viewed the challenges of commercial space flight from an international consideration since activity happens throughout the world. As a legal aviation expert, Stilwell identified challenges to the commercial space industry that mirror the technology and regulation problems in standard aircraft listed in the FAA Strategic Plan (FAA, 2020b). Commercial space activity occurs in the airspace that is usually occupied by regular air traffic. From a regulatory perspective, the systems to accommodate commercial space take-off and landing activity still operates on an anomaly standard. That is, the FAA issues Temporary Flight Restrictions (TFR) to direct air traffic around commercial space activity (Welch, 2018). The virtual fence around a spacecraft is necessary because of wake turbulence. Similar to the wake that a boat leaves in the water, the air behind a spacecraft ripples because of the vehicle passing through it. Stilwell noted that the wake turbulence of space-bound vehicles impacts normal aircraft routes, disrupting the typical use of airspace.

Davidian (2017) discussed a Center of Excellence (COE) program established by the FAA Office of Commercial Space with a mission to research the critical components of air space management. The FAA uses a unique authority to support research at colleges and universities that focus on supporting sections of aviation. Davidian wrote about the COE work in the following key research areas for commercial space: Space traffic management and spaceport operations, space vehicles, human spaceflight, and space transportation industry viability. Although there was no formal link between the COE and the FAA Strategic Plan (FAA, 2020b). the topics that require further research in commercial space are fully aligned.

The seventh subtheme in the FAA Strategic Plan (FAA, 2020b) focused on the workforce. The writers of the FAA Strategic Plan forecasted divergent considerations for the future Industry 4.0-style workforce. One side of the spectrum considers the in-depth technical knowledge required in the workforce, whereas the other side points to the need for more general knowledge workers who understand the interconnected aspects of the technology along with the human interface. Strategies for workforce management included recognizing the competitive disadvantage in government employment for hiring people with deep knowledge of advanced systems and finding talent that can bridge the understanding of human emotion and human reactions to the complex machine-based world.

Kagermann et al., (2013) projected the value of Industry 4.0 to the German economy in a concept paper which paid special attention to the workforce implications of the future digital age. Kagermann et al. suggested that the role of employees would change significantly due to the redesign of production to real-time deliverables resulting from the IoT-connected process. The workforce competencies would shift to controlling the digital production commands through electronic means, which results in less hands-on interaction with the products. Kagermann et al. promoted the criticality of training to produce a workforce that is composed of highly skilled technical experts while advocating for greater autonomy emerging from the workforce investment that would serve as a motivational factor. Kagermann et al. envisioned a transformational shift in the human-technology and human-environment interaction that would provide smart assistance through user-friendly interfaces, making work more interesting and more pleasant.

Colbert et al. (2016) looked at the changing digital competencies of the workforce in response to the impact of the fourth industrial revolution by exploring the concept of digital fluency. As a generationally based phenomenon, people who began using computers at an early age demonstrated strong proficiency with data manipulation, ability to creatively present information and engage in systems thinking to resolve problem and design new products. Colbert et al also examined how the cognitive processes from video gaming translated into work place competencies in risk taking, seeing failure as an opportunity to learn, and demonstrate design thinking through comfort with trial and error. Colbert et al deduce that digital fluency is actually creating a new generation of workers that are neurologically wired for advance function in the emergent digital age.

New (2018) suggested that the government is responsible for cultivating digital transformation-oriented talent and that it can tackle the projected talent gap issue through a more focused approach to computer science education. This author presented Canada and the United Kingdom as models for their initiatives to promote education in artificial intelligence by funding Ph.D. candidates in this field. Therefore, New recommended that the U.S. National Science Foundation provide competitive awards for artificial intelligence researchers in long-term programs as a way to build an innovation ecosystem. New also recommended issuing research and development tax credits for organizations that invest in new artificial intelligence applications.

Flores et al. (2020) echoed New’s (2018) concern about the readiness of the workforce to meet the talent demands of Industry 4.0. Flores et al. acknowledged the lack of consideration for the requisite skills needed among the workforce of the future to program the next generation technologies and affectively adapt to the ways of work that could require advanced knowledge for functioning in a more digital society. The corresponding considerations for human capital 4.0 takes a wholistic approach to creating the talent needed to meet the demands of the future by considering new learning formats, location and time independence, individualized learning, globalization, skills sharing, and lifelong learning. Flores et al. also suggested that organizational structure also needed to shift to match the fluidity of the Industry 4.0 organization by allowing for a more adaptive, looser, and free-flowing approach to common organizational hierarchies. Flores et al. adopted the Plonka (1997) view that human factors should play a central role in the consideration of the revolutionary changes as industry evolves into a new phase of digital transformation.

Murawski and Bick (2017) examined digital competencies of the workforce to understand how to build the knowledge workers capable of supporting the way of working in the age of the fourth industrial revolution with services provided by drones, the Internet of Things and robots. Murawski and Bick argued that the research into the building workforce capability to meet the emerging digital age is too limited. It points to the detriment of the workforce vulnerable to poor employment opportunities and the technical world at risk for lack of human resources to manage it. Murawski and Bick suggested that technical competences must evolve with the pace of the advancements of the emerging technologies and therefore could never be stagnant.

As a wrap up for the seven subthemes, the FAA Strategic Plan (FAA, 2020b) included ways to continue environmental scanning on new technologies that would impact the National Airspace System: Internal government systems and private sector innovations. The report identified NASA, private sector, and academic institutions as organizations that are most likely to experience substantial technological advances occurring in aviation and in tangential transportation systems.

Valdés et al. (2018) reinforced the concept of government based new thinking in aviation by presenting a case for aviation 4.0 and suggesting a radically advanced set of system changes that encompasses the hallmarks of Industry 4.0 applied to aviation.

Valdés et al. suggested that levels of automation, digitalization, and data exchanges are ripe for application to the future of aviation. Valdés et al. made a groundbreaking case for Automatic/Autonomous Flight Rules (AFR), or the use of more on-board technologies to control the aircraft, especially when the human pilots are not capable of safe flight. This level of flight control far exceeds the autopilot systems that initiated with the Wright brothers' use of the gyroscope (National Aeronautics Association, 2020). This kind of shift in aviation flight rules would require government organizations to be heavily involved in setting the new regulatory framework for establishing these controls (Valdés et al., 2018).

A case in point was the crash of Germanwings Flight 4U 9525 on March 24, 2015, in the French Alps (Hopkin, 2019). According to Valdés et al. (2018), all the aircraft systems correctly detected that a crash was imminent and could have autonomously averted impact, especially with a human-automation interface that would indicate that the pilot was not responding to the aircraft alerts. Theses authors projected that the same human-machine connectivity could provide a link between the aircraft and the air traffic systems. Valdés et al. anticipated that CPS, IoT, and cloud computing would be the essential conduits to the quantum computing environment and concurred with the FAA Strategic Plan (FAA, 2020b), which called for a culture of continuous improvement with a regulatory focus to stay connected to the next evolution of technological advancements.

Through all seven subthemes in the FAA Strategic Plan (FAA, 2020b) the writers recognized the dynamic nature of digital transformation and acknowledged the ongoing nature of strategic planning. Researchers and industry leaders provided various forms of evidence to support the strategic drivers of digital transformation in aviation. Assumptions about the future are proven inaccurate as technologies continue to evolve, yet the pursuit of strategic planning persists as organizational leaders utilize it to anticipate the road ahead.

Digital Transformation and Organizational Strategy

The concept of a new social order centered around information technology is a multifaceted impact of digital transformation. Bell (1973) leveraged his intellectual notoriety and argued that the future world economy would rely on information and communication technology. Waters (1996) discussed the tension between Toffler (1970) and Bell (1973), explaining Bell’s view that the information age would usher in a new social order for mankind based on how goods and services are produced and consumed.

Science and technology have evolved through periods of radical disruptions, leading to the current world of digital transformation defined by the intersection of cloud computing, big data, IoT, and AI (Siebel, 2019). Since the mechanization of the textile industry with spinning and weaving, industrial revolutions have changed the world (Schwab & Davis, 2018). Predecessors include the first industrial revolution, which began in the late 1800s, with mechanical manufacturing (Bisio et al., 2018). Over the next 100 years, mechanization led to steel manufacturing, the steam engine, and railways (Schwab & Davis, 2018). The second phase occurred with mass production powered by electricity and the division of labor (Y. Lu, 2017). Methods of communication were transformed by the telegraph and telephone while automobile and aviation revolutionized transportation (Bisio et al., 2018). The third revolution occurred through leveraging information technologies driving improved organization performance through such applications as robotics operated by programmable logic controllers using information technology (Y. Lu, 2017). Computer-based technologies created opportunities for new generations of storing, processing, and transmitting information that dramatically change the way people live and work (Schwab & Davis, 2018).

Each of the previous industrial revolutions transformed manufacturing through mechanization, electricity, and information technology (Y. Chen, 2017; Qin et al., 2016; D. L. Rogers, 2016), thus introducing the advancements required for the subsequent phase to emerge (Schwab & Davis, 2018). Mechanization was necessary for the construction of the electrical grid needed for the second industrial revolution. The maturation of mechanization and the electrical grid was essential for the application of information technology to manufacturing. All the pieces of the previous three revolutions were indispensable to spur the digital infrastructure supporting the smooth and fluid blending of the digital and physical worlds in the fourth industrial revolution (Adamik, & Nowicki, 2018; Schwab & Davis, 2018). Like the previous industrial revolutions, Industry 4.0 will alter current life (Maynard, 2015).

As a contemporary concept with support from national leaders, Industry 4.0 emerged from the German government’s desire to promote improved performance in manufacturing as a means of economic stimulus by leveraging advanced digitization with internet-based information transmission (Lasi et al., 2014). The U.S. government embarked upon a similar path under the Advanced Manufacturing Partnership (AMP) which included a public-private partnership to accelerate advanced manufacturing (Rafael et al., 2014).

The fusion of the advanced technology and business strategy serves as a business value creator when it integrates existing capabilities with technology-based responsiveness to market conditions (Chanias et al., 2019; Sebastian et al., 2017). This melding of strategies is only as strong as the alignment of the organizational structures that support digital transformation (Yeow et al., 2018). A strategic approach to digital transformation includes the IT organization working in collaboration with operations, distribution, sales and marketing, finance, and human resources.

The future digital transformations in aviation depend on the effective collaboration between advanced technologies happening in organizational environments and a robust strategic approach to promoting value through technology (FAA, 2020b). The federal government does have a role in spurring the evolution of digital transformation in the private sector. New (2018) issued a warning from the Center for Data Innovation that the U.S. government is missing a strategy for a critical element of digital transformation in artificial intelligence. New claimed this gap might have a far-reaching impact on our collective ability to guide a global competitive connection between digital transformation and strategy as a means of building organizational strength (Berente & Yoo, 2012; Chanias et al., 2019; Yeow et al., 2018).

D. L. Rogers (2016) offered a digital transformation playbook that helps organizations navigate the process of transformation by leveraging a set of specific strategic domains: Value creation, customers, competition, data, and innovation. As research in digital transformation strategy shows, the organizations that considered all these domains experienced the most remarkable successes (Liao et al., 2017). The presentation of research that follows demonstrates the Schwab and Davis' (2018) definition of the fourth industrial revolution as the radical change based on recent diverse technologies (M. Lee et al., 2018). The first two research projects identified relate to value creation through financial systems.

Value Creation

Berente and Yoo (2012) examined a digital transformation at NASA with a post-ERP financial system implementation field study, while reporting on the difficulty at NASA pertaining to the prior financial management system. A GAO report indicated cost overruns and procurement challenges, which were a root cause for the external tile failure that resulted in the space shuttle Columbia incinerating upon reentry into the earth's atmosphere. Implementation of a more digitally enhanced integrated financial management system represented a fundamental transformation for an organization that had failed with two prior attempts to upgrade its financial infrastructure. A new agency head joined the organization heralding this implementation his top strategic priority, thereby shifting the organizational focus on this transformational issue.

To conduct a thorough analysis of the transformational project, Berente and Yoo (2012) used a grounded analysis to conduct a nine-month qualitative field study of the transition. The system went live in 2003. Berente and Yoo followed a grounded theory approach to examine the stages of adaptation for the new system by shuttling between data and literature with constant cross-checking throughout the data collection and analysis processes.

Berente and Yoo (2012) conducted 68 interviews with employees at three locations: NASA’s Glenn Research Center in Cleveland, Ohio, The Marshall Space Flight Center in Huntsville, Alabama, and the agency headquarters in Washington, DC, drawing a sample randomly from users representing the population of employees and managers. Berente and Yoo balanced the research with over 200 project-related documents, including internal NASA project management information, news reports covering the project, and U.S. Government Accounting Office (GAO) audit reports concerning the implementation. For triangulation, Berente and Yoo produced a full organizational case study to include in the messaging with the participants and management.

The results of their research led Berente and Yoo (2012) to uncover technological adaptation shockwaves that blasted through the workforce as the employees learned new ways of managing the agency’s money. The greater financial fidelity translated into the movement toward more efficient operations and the means to leverage more profound technological breakthroughs. Berente and Yoo reported their research in a way that added to the agency’s overall ability to adapt to new technologies, thereby creating value for the organization.

Chanias et al. (2019) also examined value creation through a financial services application by conducting a case study on the formulation and implementation of Digital Transformation Strategy (DTS) in a UK based financial services firm. The firm provided consultative services for traditional industries, such as retail, automotive, and financial services, that wanted to leverage their financial success by investing in the technologies to propel them to the next generation of organizational growth. Leaders at the firm, with the pseudonym of AssetCo, had to take it through a digital transformation to provide value to its customers.

To examine AssetCo's digital transformation process, Chanias et al. (2019) framed the research around the question: "What processes and strategizing activities are underlying DTS formulation and implementation in pre-digital organizations?" (p. 18), suggesting this research question would help to uncover the key structural and organizational changes needed to support the value creation emerging from the use of advanced information technologies for AssetCo and, ultimately, their customers. Chanias et al. used an interpretive in-depth case study spanning the 12-month timeframe when AssetCo undertook their digital transformation gathering information from 16 people; some were interviewed several times throughout the process while others engaged in informal conversations regarding the change. Chanias et al. reported 9.6 hours of recorded interviews and 20.2 hours of informal conversations while collecting data from 28.8 hours in field observations of workshops, working sessions, and project team meetings in addition to archival data from 132 documents, such as internal communications, project plans, annual reports, company presentations, and media reports.

Leveraging the Pettigrew (1987) guideposts through the change management process, Chanias et al. (2019) analyzed their results using the context-process-content framework. The Pettigrew method led Chanias et al. to organize their results into a seven-step change model that included the following: (a) recognizing the need for change, (b) setting the stage for change, (c) formulating the change strategy, (d) preparing for the change, (e) implementation, (f) stabilization, and (g) optimization. Upon formulating the seven steps, Chanias et al. surveyed the organizational participants in the study to obtain feedback on the accuracy of the steps of the organizational change process. Chanias et al.'s actions fall in line with the spirit of the Delphi process (Linstone & Turoff, 1975) of obtaining consensus on collected data.

Although Chanias et al. (2019) did conduct a deep analysis of AssetCo's progression through this change process, there were some challenges in their research. The data collection process had many informal data collection points that represented a challenge for transferability or the ability to replicate the findings in other contexts or with other respondents (Lincoln & Guba, 1985). In addition, Chanias et al. reported insufficient details to understand the context of these informal conversations. Also, Chanias et al. claimed ownership of the seven-step model emerging from their research without acknowledgment of the many change management scholars who have very similar views on change models and specifically did not reference Yin (2017), the classic reference for a case study research project. Despite these challenges, AssetCo did have a digital transformation model that it used to help its customers through adopting new and advanced technologies that added value for those organizations.

D. L. Rogers (2016) saw value creation as linked to financial performance noting that financial systems are the tools to monitor performance and those systems need to be on a level playing field with overall digital transformation. As with most transformational efforts, both Berente and Yoo (2012) and Chanias et al. (2019) reported on change management efforts as the more advanced systems became embedded in their respective organizations. The commonality with financial systems and change management worked despite the public sector and private sector differences in the organizations studied.

Customers

D. L. Rogers (2016) saw the customer as the primary reason for digital transformation. Customers redefine the organization from the transformational perspective due to control over the acquisition of products and services (Kagermann et al., 2013). The industrial shift changed the perception of customers from the mass market to customer networks. Influence in the network comes from the individual experiences communicated in the connected digital network. Rethinking products and services in this model are keen examples of merging technology and strategy. Digital transformation delivers a new type of customer experience.

Yeow et al. (2018) conducted a case study to examine organizational alignment to a fused business and IT strategy for Hummel, a German lifestyle apparel company. The business strategy emerged from challenges presented by larger organizations dominating the market share in large sports retail chain stores and smaller sports specialty shops. The top leadership at Hummel decided to shift from a business to business (B2B) strategy to a business to consumer (B2C) strategy via a digital channel for customer interaction. The technical infrastructure and organizational resource allocations had to shift to meet this new approach to the marketplace.

Yeow et al. (2018) used a longitudinal case study to trace the alignment actions taken to reconfigure resources to meet the strategic shift in the business. Yeow et al. collected data from August 2010 to December 2014 through 158 interviews and an examination of company documents, including departmental and organizational strategic plans, management update presentations, marketing materials, emails, customer contracts, and meeting minutes. Yeow et al. organized the data into three chronological phases: Exploratory, building, and extending, while looking for challenges or tensions that indicated misalignment and the actions taken to rectify them to create strong organizational alignment.

Yeow et al. (2018) captured the sense of urgency expressed in the exploratory phase as the organization grappled with the risk of alienating the current retail customers with a completely new product channel distribution strategy and a limited capability to execute on the technical demands of the strategy. Yeow et al. reported the ways that top management reduced tension with an organizational restructure and voluminous communication supporting the new direction and new structure, which set the stage for the next phase. Yeow et al. identified the vital directional decisions and quick win activities that helped the organization move to the new approach with the customer.

Yeow et al. (2018) identified that the tension in this phase emerged from the revised operations, which shifted from large fulfillment to processing orders for individuals. Not all of the preplanning for this change worked as the new strategy took hold and the change required additional redesigning and reconfiguring operations. The extending phase began approximately two years into the change, where the organization conducted a series of fine-tuning efforts to grow the business from the new digital sales platform. Overall, the study revealed that alignment was in a constant state of flux. Each major phase brought about a new set of tensions, as the organizational leadership responded to the challenges, then a new set emerged requiring another set of mitigating actions. Yeow et al. applied a rigorous and scholarly process of studying alignment in the fusion of a business and digital transformation strategy.

D. L. Rogers (2016) saw the value proposition in the customer networked economy residing in brand reputation and individualized digitally based service. The mass market to individual market shift required the move from fewer large orders to many more very small orders. The customer demand for service on that small order scale created a production shift that changes the way organizations operate in the digital economy (M. Chen et al., 2021).

Competition

D. L. Rogers (2016) also understood the role of the competition in taking on a digital transformation. Yeow et al. (2018) showed that Hummel had to move to the new digital strategy because the company could not compete with the bigger players in the mass-market approach. Once the new strategic approach began to take shape, its operational strategy had to follow suit. Hess et al. (2016) examined a very different industry in Germany to explore how competition created pressure to rethink their approach to competition in a shrinking market.

Hess et al. (2016) studied the connection between business strategy and digital transformation through reporting on three companies in Germany while distinguishing between a digitally based business strategy and an IT strategy. According to Hess et al., a digital business strategy provided for the interconnected components of the business to pull together around the change in technology. In contrast, the IT strategy was focused on the technical transformation and other aspects of the business serving in support of the digitally based change.

Using that distinction, Hess et al. (2016) selected three German media companies as the focus for their case studies arguing that the media segment is a bellwether of the digital revolution since the failure of organizations to transform to digital media resulted in organizational demise. The companies had different target markets: TV broadcasting, news publishing, and board games/print publishing, and each company had undergone a digital transformation between 2009 and 2011. All three companies selected for this review held a dominant market position before the transformation and saw the need for change to be essential to their survival.

Hess et al. (2016) conducted two rounds of interviews with senior leaders in each of the companies and collected secondary data sources, including financial statements, company presentations, and media coverage about the company to supplement the information gathered from the interviews. The interviews took place between May 2013 through May 2015. There were seven interviews conducted during the first round of data collection and three interviews in the second round. The interview questions fell into four broad categories: Use of technology, changes in value creation, structural changes, and financial aspects.

Hess et al. (2016) employed these categories to serve as the four dimensions of the Digital Transformation Framework (DTF), which emerged from 11 questions posed in the interviews, and the application of subcategories to distinguish the responses. Hess et al. grouped the responses on the strategic role of IT to be either enabler or supporter of the transformation strategy. In terms of the technical ambition of the change, Hess et al. considered the response to reflect one of the following categories: Innovator, early adopter, or follower. These categories are similar to focus areas in the FAA Strategic Plan (FAA, 2020b).

A key result from Hess et al.'s (2016) research was an articulation of the partnership between the CEO and the CIO to deliver a successful digital transformation. Although Hess et al. provided a clear framework and a highly usable set of interview questions, the publication misses some key points of academic rigor. The case study research method is not clearly identified as a deep dive into the change processes in these companies. There was no distinction between the interview questions in the first and the second round. There is no rationale provided for distinguishing or conducting the two rounds. Nine of the10 interviews occurred in 2013, with one occurring in 2015, which makes it seem like an afterthought and casts doubt on the validity of data collected under what may be different circumstances. Hess et al. concluded that leaders who are engaging in digital transformation must be able to ask the right questions inferring that the questions provided in the study were the ones that needed to be asked.

D. L. Rogers (2016) suggested that rethinking the competition allowed organizations to free themselves up to approach the market differently. Hess et al. (2016)

reported on organizations that weathered their transformation with an internal focus on what to do, following a consultative approach. For these organizations, the internal work did lead each organization to maintain its market leadership after completing the internal transitions.

Data

D. L. Rogers (2016) implored transformation leaders to reconsider data. In the past, data had a purpose for measurement, business process management, and forecasting to optimize operations. The Industry 4.0 world unleashed data with quantum computing and cloud data management, and the computational tools for analyzing big data have introduced a new era of data as a strategic intangible asset. The breakthroughs in big data management include cognitive computing, or the ability to process spoken language, and machine learning which helps to bring the most relevant data to a synthesized forefront.

In support of the new approach to data, L. Li et al. (2018) explored how data transformed organizations by conducting qualitative research on small and medium-sized enterprises in China that underwent a digital transformation by using a third-party platform to distribute their products internationally. L. Li et al.'s goal was to understand how entrepreneurs with limited capabilities and resources achieved double-digit yearly growth rates. L. Li et al. articulated principles of strategic change in established organizations through the dynamic managerial capabilities model, which considers change management in terms of managerial cognition, managerial social capital, and managerial human capital (Helfat & Martin, 2015). Specifically, the human capital factor suggests that organizations need to have minimal capability to navigate the digital transformation. The population studied did not have the requisite capability nor the cognition to understand the market conditions where business could thrive (Adner & Helfat, 2003).

L. Li et al. (2018) used a purposeful sampling of seven organizations that had limited experience distributing to international markets, underwent a transformation pertaining to the use of a third-party platform, and proceeded to achieve an annual growth rate of approximately 30% per year for seven years. The researchers used semi-structured interviews, focus-group interviews, and field observations to collect data. The interviewers conducted sessions with senior organizational leaders following a specific question template that focused on the history of the organizations, activities involving the introduction and implementation of the third-party platform, usage of the platform, and the resulting transformation changes to the organization. In addition, the researchers conducted site visits to observe operations after the transformations.

L. Li et al. (2018) conducted a three-step analysis of the data. Step one involved a Vivo coding that obliged the researchers to become very familiar with all of the data collected and build consensus among the research team regarding the meaning of interviewee responses. Step two entailed examining the data for similarities and differences to draw themes from the responses. In step three, the researchers constructed the dynamic relationship among the themes to create a storyline to describe these unlikely transformations.

Since interpreting these results, L. Li et al. (2018) concluded that the leaders in their sample were able to break away from a pre-existing managerial cognition to accept a new way of doing business offered by a third party that would not have normally been part of their belief system; these leaders had to accept the ambiguity of the unknown to progress. Openness to build new capability became the human capital shift essential to supporting the ability to function effectively in the new digital environment.

L. Li et al. (2018) missed mentioning a substantial concern area by only including organizations that used Alibaba as the digital platform underpinning the transformation. The company name is mentioned 175 times in the article. Many of those brand identifications promote tools and features that would be of interest to organizational purchasing the platform. It creates the impression that this piece of scholarship is a product placement masked in rich methodological rigor. It follows in the path of IBM and SAP that produce the same level of pseudo-scholarship to sell their digital transformation products (Berman & Marshall, 2014; Rashid et al., 2018).

Despite the implicit advertising nature of L. Li et al.'s (2018) study, D. L. Rogers (2016) suggested that the current surge in a data-driven economy comes from the computing giants of the world who created this demand by building business value through data. In terms of transportation, autonomous vehicles require geospatial data to function. The competitive environment representing the big data companies wanted to be part of creating this futuristic mode of transportation. As a relative upstart in the market space of big data companies, Google possesses a trove of cartographic data as a result of the Google maps application. Google invested in this market space early on by sending cars equipped with cameras to drive the roadways all around the world to capture photographic data and measure everything. Google continued to reinvest in the foundational data through regular data cleaning and resetting to achieve greater fidelity and update for accuracy.

D. L. Rogers (2016) reported on the Apple effort to usurp the Google cartographic data by removing the Google Maps app on the iPhone default setting and replacing it with Maps. Apple failed to invest in the cartographic data and was forced to purchase the Maps product from a third-party vendor. The customer complaints escalated and Apple had to acquiesce to the market demand for the preferred product. As the tech giants continued their debate of who had the better product, Google cartographic data worked for a new application not considered in the days of video-equipped car collecting data. Now that data are a cornerstone for the autonomous vehicle industry. To make its money back on the original investment, Google needs to tap into this new market through the automakers, and thus it is following the same strategy as Alibaba used in creating successful small family businesses in China through applications of big data (L. Li et al., 2018).

Innovation

Innovation is “any change to a business product, service or process that adds value” (D. L. Rogers, 2016, p. 124). Like Birkinshaw et al. (2008), D. L. Rogers indicated that innovations could be either incremental changes or something completely new and different. The process of innovation is to create a climate for ideas to be developed, tested, and brought to the market (Mahmood & Mubarik, 2020). In the pursuit of digital transformation, the evolution of ideas is all about speed, rapid experimentation, and continuous learning. The idea to market cycle has to occur with low cost, low risk, and additive learning to drive volume so that organizations have more ideas hitting the marketplace to increase the odds of producing a game-changer (D. L. Rogers, 2016).

Rogers (2016) pointed to partners and stakeholders as a key factor in driving innovation through information sharing. The Caterpillar (industrial equipment manufacturer) web analytics tool was highlighted as a data sharing platform that gave their marketplace partners information that helped them to grow their businesses. Frito-Lay leveraged retailer sales information to drive product innovations. Both cases show how building upon the stakeholder relationship to promote innovation benefited all the parties in the ecosystem.

The articles that follow represent two approaches to literature reviews on digital transformation as a means to support innovation. Both sets of researchers wanted to understand the dynamics of research on digital transformation to bring forth innovative solutions for organizations. Liao et al. (2017) took a specialized approach considering the most current advances in technology to assess the landscape of digital transformation overall. Meanwhile, Nadeem et al. (2018) reviewed the topic of digital transformation from the perspective of organizational strategy. Liao et al. and Nadeem et al. wanted to bring a better understanding of innovation-related digital transformation to the academic community.

Liao et al. (2017) presented the case of enabling innovative technologies for digital transformation through their contextual analysis identifying modeling technology, visualization technology, big data, and cloud computing offering, the strongest foundations for accelerating innovation in the escalation of industry 4.0. Liao et al.

explained who was publishing on Industry 4.0 from a summary analysis of authors, institutions, and geographic locations. Liao et al. reported on the current research in terms of eight categories ranging from the most referenced as standardization and system architecture to the least referenced as the regulatory framework, which would be highly relevant to the aerospace industry.

Liao et al. (2017) conducted an extensive systematic literature review of Industry 4.0 publications as part of a larger research effort to understand the worldwide effort in digital transformation as a springboard to innovation. Their project was guided by a set of research questions focused on the enabling features of Industry 4.0, who was working on it, the current research efforts, and application fields. Liao et al. applied a mixed-methods approach to producing qualitative and quantitative literature review (Curry et al., 2009).

Liao et al. (2017) began with 479 papers resulting in database searches of publication covering Industry 4.0 and down-selected to a more focused set of publications based on a four-step process: Identification, screening, eligibility, and inclusion (Moher et al., 2009). Liao et al. screened the results to remove duplicates and non-academic articles to find 346 and reduced the number to 249 with a full-text eligibility standard. Liao et al. applied a final reduction by removing articles that did not relate to IoT or CPS and publications with only a loose connection to Industry 4.0, bringing the total to 224 papers included in their review.

Before conducting the quantitative analysis, Liao et al. (2017) used a qualitative analytical process to pre-process the data (Curry et al., 2009). The first step was to equalize the data among different formats to unify data terminology because authors of these articles used different terms or abbreviations or synonyms to mean the same thing. The second step was to conduct a close examination of each source to obtain a clear understanding of contextual meaning to establish the foundation for clustering. The third step was to determine the terms to include in a frequency analysis considering singular and plural noun usage and three co-occurring words that form a meaningful noun phrase. This quantitative review was necessary to sort out the complexity of a term like cyber-physical system(s), which could be presented as cyber-physical systems, CPS(s), industrial cyber-physical systems, cyber-physical assembly systems, and on to many more variations.

Liao et al. (2017) applied data analytics to their findings. Their foundational analysis identified the databases for their collection of sources. Liao et al. specified a categorization of discussion, theoretical or practical solution as well as journal or conference papers. Liao et al. provided a detailed breakdown of the domains for Industry 4.0 research, with 28% of the publications dedicated to engineering and 41% focused on computer science. Liao et al. drilled to further fidelity to provide context; indicating that 5% of the engineer applications focused on aerospace, and 7% of the computer science studies focused on artificial intelligence. Liao et al. used a variety of visual data representations, such as bar charts, pie charts, and line graphs to depict their findings.

Nadeem et al. (2018) also conducted a systematic literature review that compared to Liao et al. (2017) but differed in focus. Nadeem et al. concentrated on the relationship between innovative digital transformation and organizational strategy. The research objective was to analyze articles focused on leadership-driven enterprise-level technical change intended to transform core services (H. M. Cooper, 1988). Nadeem et al. wanted to gain a greater understanding of the organizational capabilities needed to achieve success with innovations pertaining to digital transformation.

Nadeem et al.'s (2018) methodology followed a concept-centric approach to determine the content of the review through a two-step process of selecting relevant sources to be searched and defining the search strategy by time frame, search terms, and search fields (Webster & Watson, 2002). Nadeem et al. analyzed the selected articles by coding the articles into dimensions and attributes categories then conducted a comparative analysis of the results (Wolfswinkel et al., 2013)

Nadeem et al. (2018) identified the organizational shifts to digital happening in multiple industries, including health care, telecommunications, transportation, banking, and manufacturing. Nadeem et al. referenced the integration of digital transformation with the business strategy to create value in innovative new business opportunities. Nadeem et al. noted organizational failures in the transformation, which served as a compelling reason to better understand the topic and critical success considerations for implementation.

Nadeem et al. (2018) and Liao et al.'s (2017) literature reviews showed a steady increase in literature on digital transformation since 2009. Through their analysis, Nadeem et al. (2018) identified innovation in a collaborative ecosystem of the digital platform that leads to the successful implementation of digital transformation. Their analysis surfaced the key strategic considerations of digital acumen and aligned organizational structure with the capabilities of digital leadership, agile, and scalable operations, digitally enabled customer service units, and digital artifacts. The combination of these factors underpinned the ecosystem and represented the culture of digital transformation.

Although Nadeem et al. (2018) added considerable value to the academic dialogue on the link between strategic business models and digital transformation, the research does have an important limitation. Nadeem et al. overlooked a basic characteristic of the literature review regarding the caliber of sources as they included unpublished conference presentations, peer-reviewed documents and promotional materials that highlighted research as a means to gain clients for consulting services. Nadeem et al.'s article selection poses a challenge to the credibility of the research (Rolfe, 2006).

Liao et al. (2017) and Nadeem et al. (2018) based their extensive digital transformation literature reviews on the central link to innovation. D. L. Rogers (2016) claimed that integrating innovation into a transformational culture focuses on building a discipline around high-quality experimentation grounded in principles of continuous learning. Liao et al. (2017) and Nadeem et al. (2018) supported this perspective on learning as an essential underpinning for the innovation and digital transformation link. The driver for innovation is to deliver customer value, which emerges from a deep understanding of success considerations in digital transformation (Liao et al., 2017; Matarazzo et al., 2021; Nadeem et al., 2018; D. L. Rogers, 2016).

The D. L. Rogers (2016) digital transformation playbook helps organizations navigate the process of transformation by leveraging a set of specific strategic domains:

Value creation, customers, competition, data, and innovation. Research supports each of D. L. Rogers' five domains that lead to success in technologically based transformational work. Berente and Yoo (2012) examined a digital transformation with a financial system at NASA to create value in a government organization, although Chanias et al. (2019) also studied value creation through financial services application in the private sector.

Yeow et al. (2018) captured an organizational transition focused on direct access to the customer via a different distribution channel. Hess et al. (2016) selected three German media undergoing a digital transformation with a priority of maintaining market position in highly competitive industries. L. Li et al. (2018) studied how data transformed organizations for small and medium-sized companies in China. Liao et al. (2017) and Nadeem et al. (2018) conducted literature reviews based on the interdependent nature of innovation and digital transformation. Liao et al. and Nadeem et al. identified support for specific elements in D. L. Rogers' (2016) five domains model, while highlighting the interrelationship among the domains.

Safety Culture Research

The earliest publication linking safety to culture involves a survey conducted with workers at an Internal Harvester tractor manufacturing facility (Keenan et al., 1951). Keenan et al. investigated the impact of organizational performance goals on accident rates, setting the foundation for the assertion that safety culture has an impact on safety outcomes (Christian et al., 2009; Clark, 2006; Morrow & Coplen, 2017). An evolutionary milestone in safety culture emerged in the mid-1980s after the Chernobyl disaster that initiated a heightened focus on the safety culture (M. D. Cooper, 2000; La Porte, 1996;

Lawrenson & Braithwaite, 2018; Morrow & Coplen, 2017; Nævestad et al., 2018; Pidgeon, 1998; Reason, 1997).

van Nunen et al. (2018) published a comprehensive literature review on safety culture research with a goal to provide a macro view of the topic. van Nunen et al. used a bibliometric analysis to look at research patterns and synthesize the evolution of the topic (W. Li & Zhao, 2015). The bibliometric analysis helps to identify how research is trending concerning key focus areas, the volume of content covering various aspects of the overall topic, and the latest advances in the subject as identified in the literature; the bibliometric method can also help to detect gaps in content (Wang et al., 2014). Ugolini et al. (2015) suggested that data from a bibliometric analysis could be useful in providing input for policymakers and those who must allocate funding because it yields analysis of the growth, size, and distribution of literature on the topic of interest.

van Nunen et al. (2018) grounded their perspective on safety culture in the 1986 Chernobyl disaster, which initiated the increased attention of safety culture as a focused research area (Reason, 1997). Despite the continued attention to the topic, accidents still happen and research on safety continues. Guldenmund (2000) presented a seminal review of the theory and research on the nature of the safety culture. At that time, research came through the social psychology or organizational psychology tradition and did not offer a consensus on what it meant to have a safety culture in aviation. One goal of this research was to define the concept of safety culture as “those aspects of the organizational culture, which will impact attitudes and behavior related to increasing or decreasing risk” (Guldenmund, 2000 p. 251).

Guldenmund (2000) presented a summarized literature review of the safety climate and culture without specifying a research methodology. Guldenmund provided an overview of the 16 authors who published on the topic from 1980 to 1996, looking at the causal model for a safety culture. Guldenmund stated that the essence of the model was to determine what actions, at the organizational level, led the workforce to instill safety-oriented behaviors postulating that core values created the foundation for a safety culture to thrive. Guldenmund identified those baseline factors as the establishment of expectations, promotion of organizational values focused on perceptions and beliefs about the safety priority, policies and practices that support safety-related attributes, utilization of data and safety analysis reporting, and collective understanding of the concept of a safety culture.

Guldenmund (2000) also reported on organizational goals identified in the articles included in the literature review, indicating that the overarching goal for all organizations was to reduce accidents and injuries. Guldenmund pointed out that some organizations promoted specific tools to help achieve that goal. One organization implemented a survey instrument to gather feedback from the workforce on safety-related activity in their worksite (Ostrom et al., 1993). Another compared safety tracking actions among similar organizations to determine the correlations of behaviors and results (Coyle et al., 1995). In a third study, R. L. Brown and Holmes (1986) analyzed employees who experienced trauma due to a safety accident by examining pre- and post-perceptions of organizational safety culture.

Guldenmund (2000) centered the research on Schein’s (2017) view on organizational culture which looks for three levels of basic assumptions, espoused values, and artifacts. Guldenmund found evidence on basic assumptions in all the organizations examined; however, the assumptions varied. Some organizations saw varying degrees of reward and punishment associated with safety-based behaviors (R. L. Brown & Holmes, 1986). Guldenmund pointed to the work in safety culture surveys as a way to gather information on the perception of espoused values (Ostrom et al., 1993). The Schein (2017) model offered artifacts as the third primary component of safety culture analysis. Guldenmund found the following elements in the research that illustrate safety-oriented artifacts: Safety inspection processes, output reports of safety inspection activity, reporting of accidents and near misses, wearing of personal protective equipment (PPE), policies, and posters about safety (Coyle et al., 1995). In summary, Guldenmund suggested that organizational systems influenced safety culture and that instilling those organizational systems required a deliberate approach that needed time and discipline to create it.

A comprehensive historical perspective emerged as van Nunen et al. (2018) explored the complex and cross-disciplinary focus on safety culture that has grown since the time of Guldenmund’s (2000) study. van Nunen et al. wanted to show this evolutionary growth of the topic through their analysis by setting their literature review time frame from 1900 to 2015 using the term “safety culture” as their topical focus in the Web of Science database. van Nunen et al. identified 1789 publications with 1472 of them from articles and conference proceedings. Other sources, such as meeting abstracts and editorial materials, were also included in the final data set. van Nunen et al. established their statistical framework to report eight factors, including publication output, growth trends, and citations analysis.

The van Nunen et al.’s (2018) publication output and growth trends showed a steady upswing in the number of articles published on the topic of safety culture. From 1900 to 1991, there were eight published articles on the specific topic of safety culture. However, from 1991 to 2005, there was a modest and stable increase of fewer than 50 publications per year. The most prolific years for safety culture publication occurred in 2013 with 225 sources, 2014 with 191, and 2015 with 173. From another perspective, in the 20 years from 1991 to 2011, 1000 sources were created for the safety culture topic. In the following 4 years from 2012 to 2015, almost 800 new sources emerged.

The citation analysis from van Nunen et al. (2018) offered an insight into the most influential authors in the safety culture arena using VOS viewer software to create a visual diagram depicting the relationship in the citations data set. The software created a clustering to show citation mapping with the size of dots, indicating the frequency with which a particular author’s work was included in subsequent publications. The frequently referenced sources generated a clustering around them for ease in following the authors who picked up on the previous work.

The three most impactful publications could be identified as a result of van Nunen et al.’s (2018) citation analysis. Due to the seminal nature of Guldenmund’s (2000) work, it was among this top group as a primary source for theoretical work with an emphasis on accident prevention. Reason (1990, 1997) showed up in two different segments of the map. Reason (1997) was a foundational source for a cluster of articles focused on occupational safety with an emphasis on safety climate, attitudes, and behavior. Also, Reason (1990) showed on the segment of the map focused on health care which is a major discipline for safety culture literature.

van Nunen et al. (2018) reported that although Reason (1990) influenced the health care domain; Sexton et al. (2006) held the most citations in this discipline. The Sexton et al. work was important because it launched the University of Texas Safety Attitudes Questionnaire (SAQ) for health care providers. This introductory study collected data from 10,843 health care providers spanning 203 clinical areas, including critical care units, operating rooms, and ambulatory clinics. The survey results reported rating data on a six-factor model of safety culture, including teamwork climate, safety climate, perceptions of management, job satisfaction, working conditions, and stress recognition. Each of these six factors has a set of subscales that combines to show a roll-up total for each element. The SAQ produces a summation of the safety culture through the eyes of the frontline worker.

Sexton et al. (2006) adopted the following definition of safety culture for their survey, “the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization’s health and safety management” (p. 2). The SAQ (Sexton et al., 2006) pulls from the Hospital Survey on Patient Safety Culture survey, which provided data from 331 hospitals and 50,513 respondents commenting on the patients’ experience through the hospital staff perspective that had direct interaction with patients (Sorra &

Dyer, 2010). This survey drew on the safety culture concept in high-reliability organizations focused on error-free operations, such as aviation.

Sorra and Dyer (2010) produced and pilot tested their survey in 2003 under a research contract and conducted their survey in 2004. The purpose of the study was to assess staff views on the patient safety culture in hospital settings. Sorra and Dyer studied 12 dimensions and 42 items which encompassed such topics as communication, management support of patient safety, and teamwork. Sorra and Dyer provided a robust statistical analysis to demonstrate a positive patient experience. Unfortunately, the survey was more oriented toward hospital culture than patient experience. As expected, Sorra and Dyer were unable to correlate the results of the survey to the patients' perceptions or any actual harm that came to the patient during their hospital stay. These gaps from Sorra and Dyer's (2010) study opened the research pathway for the SAQ (Sexton et al., 2006) to gain traction using similar principles and to focus on organizational safety culture.

Sexton et al. (2006) also credits the genesis of their tool from the aviation industry. The Flight Management Attitudes Questionnaire (FMAQ) emerged from accident investigation research showing that most aviation mishaps occurred because of interpersonal breakdowns among the crew with teamwork, interactions with leadership, and collaborative decision making (Helmreich & Merritt, 2019). Sexton et al. (2006) determined that 25% of the FMAQ items directly concerning the health care environment. The remaining items for the SAQ were pulled from other researchers focused on human factors in accident avoidance (Vincent et al., 1998).

After pilot testing, the SAQ became a 60-item questionnaire that can be answered using a 5-point Likert-type scale ranging from disagree strongly to agree strongly (Sexton et al., 2006). Sexton et al. (2006) expected survey participants to take 10–15 minutes to complete the assessment. The SAQ asks respondents to provide information on the collaboration and communication experienced with peer groups representing various clinical organizations in the hospital using another 5-point scale rating on the very low to very high range. To participate, respondents needed to be in their work-group for at least one month before the survey administration.

According to van Nunen et al.’s (2018) article, the SAQ (Sexton et al., 2006) provides the scholarly community with a highly effective measurement instrument on safety culture for any industry. Although the roots of the SAQ can be traced back to aviation, there is no survey activity at this level in the literature representing aviation. In fact, van Nunen et al. (2018) gave a mention to aviation in a listing of other industries that inherently focus on safety culture like the food industry and education.

Overall, the van Nunen et al. (2018) literature review on safety culture provides a comprehensive analysis of the research associated with this theory. Although van Nunen et al. examined almost 1800 publications focused on safety culture, their thoughtful analysis brought the most salient research to the surface while acknowledging the vast number of publications dedicated to the topic. van Nunen et al. found a way to highlight the most influential works while including the contributions of the many authors who also contributed to the field.

The humble gyroscope helps to conclude this literature with its standing as the first automation in aviation (Billings, 1997). To match the digital transformations in general aviation, commercial space and unmanned aerial systems, the gyroscope has evolved into a fiber optic precision device (Jin et al., 2018). It has grown through a digital transformation in the same way that so many products have shifted in function to support an Industry 4.0 world (Schwab & Davis, 2018). The digital gyroscope has many applications today from robotics to cell phones and, as such, is one piece of the digital transformation landscape (Passaro et al., 2017).

This review of the literature identified the preeminent thought leaders and researchers in the fields of digital transformation and safety culture. It also builds a case for the integration of digital transformation as a relatively new consideration in an organization’s strategic approach to the future. The newness of digital transformation sits in juxtaposition with the established priority for safety in a high-reliability industry.

Methodology Literature

The methodology literature spans several methods, designs, and techniques to create a greater understanding of the topics of safety culture and digital transformation. The common research designs reflected in the body of research reviewed in this chapter included literature reviews, case studies, surveys, interviews, and content analysis to support the literature review for the study. The Delphi technique had limited application with safety culture and digital transformation and even less use with aviation. There was no evidence of these management concepts combined in any research study, and hence there are no studies in aviation covering these topics using the Delphi technique.

Common Research Methods

The topics of safety culture and digital transformation represent two ends of a research temporal spectrum. The earliest published research on safety culture contained the results of a survey conducted in a tractor manufacturing facility in the mid-20th century (Keenan et al., 1951). In contrast, digital transformation as a research topic became prevalent with a content analysis focused on IoT after the start of the 21st century (Gubbi et al., 2013). Safety culture has research that extends nearly seven decades, whereas digital transformation research has less than one decade of dedicated research. Studies in both safety culture and digital transformation use a variety of common research methods.

The literature review was used as a research design for both topics. Guldenmund (2000) conducted a meta-analysis of safety-related publications spanning the previous 20 years to codify the concept of the safety culture. Over 2,000 publications to date referenced Guldenmund and the concepts that emerged through the review of the literature on the nature of the safety culture. The meta-analysis on safety culture literature grew from the Guldenmund foundation adding more scholarship on the subject (Christian et al., 2009; Clark, 2006; Morrow & Coplen, 2017). The literature review was also used to examine specific slices of safety-related research on such topics as asbestos (Ugolini et al., 2015), commercial aviation (Lawrenson & Braithwaite, 2018), and transportation organizations (Nævestad et al., 2018).

The literature review research design was also used for studies focused on Industry 4.0 as a facet of digital transformation (M. Lee et al., 2018; Liao et al., 2017; Y.

Lu, 2017; Roblek et al., 2016). The strategic approach to digital transformation was a source for the application of the literature review research approach (Helfat & Martin, 2015; Nadeem et al., 2018). Specific content areas where the literature review was used included environment assessment (W. Li & Zhao, 2015), cyber-physical systems (Trappey et al., 2016), IoT enabled smart government (Chatfield & Reddick, 2019). The literature review research design was applied to broad-based and narrowly scoped studies in both disciplines.

Case study was another commonly used research approach for both safety culture and digital transformation. La Porte (1996) examined cases of high-reliability organizations to gain a greater understanding of safety culture in organizations where lack of safety could result in loss of life. Beckmerhagen et al. (2003) used case study to examine the safety culture in the nuclear industry. Stilwell (2016) studied commercial space launch and reentry regulations through a case study approach. Case studies in safety culture from this literature review focused on critical applications designed to protect human life within the aerospace industry.

Organizational strategy and the transportation industry were focus areas for case studies in digital transformation. Hess et al. (2016) employed case study to examine Industry 4.0 applications in three German media companies. Kavadias et al. (2016) used case study to explore the digital business model framework for a high-risk pharmaceutical company, Healx, that specializes in rare diseases, while Yeow et al. (2018) used a longitudinal case study to track a strategic transformation of the Hummel sportswear brand through a direct to consumer digitally based distribution channel. Hess et al., Kavandias et al., and Yeow et al. connected Industry 4.0 technologies to organizational strategy through detailed case study analysis.

The transportation industry has been analyzed with the case study approach. Jawhar et al. (2018) used the case of smart cities to identify the digital technologies for improved coordination and controls of multiple transportation systems. Valdés et al. (2018) explained the interconnections of digital technologies for improving safety in aviation. Additionally, Mangortey et al. (2019) used a case study approach to examine the data fusion framework for big data in aviation. Frigo et al. (2016) and Jackson et al. (2016) showed improvements in aerospace manufacturing with Industry 4.0 technologies also using the case study approach. The use of case study provided these researchers with the opportunity to take a deep dive into a specific application of safety culture and digital transformation.

Surveys and interviews were also used to provide a greater understanding of safety and digital transformation. Sexton et al. (2006) designed a seminal survey to understand safety culture while Adamik and Nowicki (2018) created a survey to assess preparedness for companies to create a competitive advantage through digital transformation. Robertson (2016) used interviews to provide safety professionals' perception of the relationship between safety management and safety culture. Berman and Marshall (2014) applied interview results to explain an "everyone to everyone" economy where unprecedented access becomes the new core principles for transacting business. Sexton et al. (2006) and Robertson (2016) collected data from the workforce for safety-related studies. Adamik and Nowicki (2018) and Berman and Marshall (2014) collected information from organizational leaders and influencers.

Several studies involved content analysis to provide insight into digital transformation. Gubbi et al. (2013) analyzed current trends in IoT research to determine the vision and future direction of internet-based technologies. Pînzaru et al. (2019) examined the content of 10 published interviews with top global technology executives to determine the Industry 4.0 oriented trends reshaping companies. Zhong et al. (2017) analyzed literature pertaining to smart manufacturing to determine content linked to the elements of the fourth industrial revolution to find trends that enable mass customization, high-quality production, and efficient operations.

The Delphi approach offers another way to access experts to gather information. The technique is versatile and can be applied in many different content areas, settings, and for a wide variety of problems or research focus areas. The Delphi method is used frequently in the medical field (Fischer et al., 2018; Sim et al., 2018; Veenstra et al., 2017) and other industries; however, applications of the Delphi method in transportation or aviation is limited.

Delphi Technique and Safety Culture

As a research technique, Delphi goes by many different labels. It was described as a method in Linstone and Turoff (1975) and Dalkey and Helmer’s (1963) seminal work referring to the technique and application when explaining the process. Researchers who have applied the Delphi technique often identified it as a method. However, the method label becomes confusing in doctoral research because the tool sits within the qualitative method. So, to distinguish the concepts, Delphi was referred to as a technique or process for the study.

The Delphi technique has been used in safety studies in high-risk industries. Researchers in the medical field, for instance, applied the technique in a wide array of scenarios such as patient safety culture, clinical governance, and measuring the outcomes of a nursing practice (Fischer et al., 2018; Sim et al., 2018; Veenstra et al., 2017). Construction was another hazardous environment where researchers employed the Delphi technique for reinforcing a safety culture. Examples of research in the construction trades included such topics as determining leading indicators for safe building environments (Hallowell et al., 2013; Rajendran & Gambatese, 2009), risks with highway construction schedules (Esmaeili & Hallowell, 2013), and safety considerations in construction project design (Poghosyan et al., 2018).

Delphi studies in transportation were not as common. Girasek (2012) invited 31 traffic and human behavior experts to participate in a Delphi process for constructing a survey that aimed to measure aspects of a traffic safety culture. The expert panel represented psychologists, sociologists, human-factor specialists, civil engineers, an anthropologist, and an injury control researcher. The panel worked at universities, transportation agencies, and private consulting firms. Girasek collected data in two rounds. In the first round, Girasek asked for items that could be included in the survey for the public. Girasek distributed the resulting survey items to the panel requesting a rating on an inclusion scale of 1–4 as the second round of the survey. The resulting list was then turned over to a public survey team of experts who made some minor changes and then prepared the survey for distribution to the public.

Another traffic-related study came from Zhu et al. (2018), who examined cellphone usage among young drivers by examining behavioral and consequential indicators of cell phone use while driving. Zhu et al. invited two groups to participate: 22 experts who had published articles on cellphone use and seven young drivers who were first-year college students. In the first survey round, the respondents provided 20 behavioral and 17 consequential indicators through their open-ended responses. In the second round, the panel identified the five most important behavioral and two consequential indicators with an explanation for their choices. In the third and final round, survey participants received the summarized data from the previous round and provided feedback on importance ratings on the two issues. Girasek (2012) and Zhu et al. provided two example studies that show the limited use of the Delphi technique in the transportation sector compared to other high-risk industries.

Delphi Technique, Safety Culture, and Aviation

Studies designed around the Delphi technique to explore safety culture in aviation are emerging from fast-growing aviation markets in China and Turkey. W. Chen and Li (2016) used the Delphi technique to study aviation safety for China’s civil aviation authority while researching the FAA-based safety performance indicators to determine a hierarchical grouping to build an algorithm that would identify levels of safety concern to alert aviation professionals of safety risks. W. Chen and Li broke the 14 sub-elements into three main categories for review by an expert panel. The panel included 12 members representing airline and airport operation as well as air traffic services within a region in China. After three rounds of survey activity, the expert panel converged on the risk rating for each of the 14 sub-elements. The data set resulting from W. Chen and Li's study fed into a digital alert system used to assist in the monitoring of the key safety performance indicators.

Like W. Chen and Li (2016), Gerede and Yaşar (2017) conducted a classical Delphi study to investigate safety performance indicators with a flight training school in Turkey, with the desire to contribute to the improvement of the Safety Management System. Gerede and Yaşar collected data over five Delphi rounds spanning 1 year, identifying 64 indicators used to measure aviation safety practices that the experts identified as valid and most effective. The participants were from flight training organizations. The expert panel was comprised of 20 faculty and other subject matter experts who represented SMS managers, quality assurance, and flight operations.

Delphi Technique and Digital Transformation

Hartl and Hess (2017) used the Delphi method to examine the role of cultural values in digital transformation, emphasizing the role of digital technologies in causing organizations to evolve or fail. Hartl and Hess asked a panel of 25 research and industry experts to identify the 12 most important cultural values for success in the digital transformation. The panel was comprised of 10 researchers studying digital transformation and 15 practitioners involved in the day-to-day operation of the digital transformation experience. Hartl and Hess's study included four rounds of surveys, with one-week windows to respond to each survey round.

Hartl and Hess (2017) explained that the purpose of the first round of data collection focused on brainstorming the cultural values required for success in digital transformation, and it generated 143 values that were later consolidated to 20. In the second round, participants were asked to validate the values and the connected categorization. The participants engaged in a third-round survey to prioritize values through a selection of the 10 most important items, which determined the 12 most important aggregated values. In the fourth round, the participants ranked these 12 values. The results of this research helped Hartl and Hess to identify the role of cultural values for success in digital transformation.

Aircraft maintenance is an important concern for the future of aviation. Although there are not Delphi studies that examine this issue in aviation, there is a maintenance forecasting study for manufacturing. Bokrantz et al. (2017) sought to determine the likely future of the maintenance organizations that support the digital factories of the future in Sweden by conducting a three-round Delphi process with 25 experts in the manufacturing maintenance professional, based on future scenarios. Aerospace was listed among the industries represented on the expert panel. Bokrantz et al. asked the panel members to rate 35 future scenarios on three factors: Desirability, probability, and impact using a 5-point Likert-type scale. Bokrantz et al. anticipated that their results could serve organizational strategic direction to improve preparedness for Industry 4.0 in manufacturing. Bokrantz et al.’s study provided a model for this current study to follow.

Delphi Technique, Digital Transformation, and Aviation

Linz (2012) used the Delphi method to design scenarios for strategic planning for the future of aviation in the year 2025. Linz focused on the air cargo segments of aviation, not the whole national airspace system. Linz wanted to build scenarios for informing contingency planning to address uncertainty in the future of aviation. Linz organized the items into a four-category framework including social, technological, economic, and political developments. The first list of scenarios for the study emerged from a face-to-face brainstorming session. Linz did not count this as a survey round, but considered the output of the brainstorming session to be the first Delphi round. The brainstorming resulted in 66 initial concepts that were condensed to the final 40 items used in the first survey round.

All participants provided feedback using a 5-point Likert-type scale in two rounds of data collection focused on the probability and impact of the scenarios. Linz indicated that not all participants provided responses in the third round of data collection yet did not report a drop rate. The participants included airline strategists, C-level managers, aviation researchers, and aviation consultants. Linz’s criteria for expert inclusion covered mid-management or above level, job specification, functions inside and outside the organization and industry expertise. Of the 80 participants considered, 57 participated in the first and second rounds of data collection. From the list of 40 scenarios, Linz recommended 27 to the air cargo industry for consideration in strategic planning.

Efthymiou and Papatheodorou (2018) studied the concept of Single European Sky (SES) to address the concern that aviation in Europe is controlled in fragmented countryby-county systems rather than as comprehensive airspace. SES is one of the most ambitious initiatives for improving safety and capacity in the European transportation system. Airspace is not limited by national borders, yet the process to combine the region into a single airspace stalled. Efthymiou and Papatheodorou used a two-round Delphi approach, stopping at the second round because there were no major changes from round 1 to round 2. Efthymiou and Papatheodorou invited 30 experts, with 27 participating fully from airlines, Air national Service Providers, Civil Aviation Authorities, Individual experts, Government institutions, EUROCONTROL, and the International Air Transport Association (IATA). Efthymiou and Papatheodorou used a questionnaire that had seven main elements with a 59 sub-element Likert-type scale. Efthymiou and Papatheodorou planned to use these results in a strategic planning session on the future of aviation in Europe.

Digital transformation is both the largest risk and greatest opportunity facing organizations today (Rice, 2019). It is working up to a tipping point where the combined power of cloud computing, CPS, IoT, big data, and artificial intelligence creates exponential change (Siebel, 2019). That transformational change is already seeping through society and yet progress is hampered, even in aviation, by slow governmental processes (Schwab & Davis, 2018). Digital forces are rewriting the rules (D. L. Rogers, 2016). Recognition of the forecasted future is one key way to prepare for the yet unknown future that is likely to emerge from digital transformation.

The FAA Strategic Plan (FAA, 2020b) included a vision to operationalize the path to the future of aviation. The plan included references for the need to modernize aviation through innovation and accountability. The concept of the aviation safety culture and digital transformation permeated the plan and supported the overarching strategic perspective on the future of aviation (Stroup et al., 2019). The writers of FAA Strategic Plan (FAA, 2020b) supplied a foundation for this research study.

Conclusions and Summary

This chapter contains a review of the literature supporting the research problem. The social problem was that aviation leaders in the U.S. federal government face challenges in advancing technological evolution and modernization efforts due to federal appropriations, human capital limitations, economic shifts, and safety culture (Chatfield & Reddick, 2019; Elwell, 2018a; Wallace et al., 2018). The specific problem was the difficulty of adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation (Fleming & Leveson, 2016; National Research Council, 2014).

The study was grounded in two management concepts: Safety culture and digital transformation. Even though digital transformation has been identified as a way to enhance safety, aviation leaders strain to adopt it into the NAS due to concerns for protecting the safety of the current system fortified by the safety culture (Elwell, 2018a; Gore, 1997). The goal for aviation is to coalesce behaviors for a full aviation community around a safety purpose in accordance with the FAA Strategic Plan, which stated the agency’s “continuing mission is to provide the safest, most efficient aerospace system in the world” (FAA, 2020b, p. 5).

Schein’s (2017) seminal work in organizational culture, which describes culture as the unwritten rules that dictate how things are done, provided the foundation for the safety culture concept. The safety culture perspective grew to prominence in response to the Chernobyl nuclear plant disaster (Batuwangala et al., 2018; Heras-Saizarbitoria, & Boiral, 2013; Stolzer et al., 2016). The combination of organizational culture, safety culture, and total quality management came together around the concept of a Safety Management System in high-risk environments (Grote, 2012; Robertson, 2016).

Although safety in aviation is rulebound, the drivers for digital transformation present a seemingly unbound upheaval to society. Digitally based game changing organizations like Uber, AirBNB, and Google are changing the way people travel. Schwab and Davis (2018) identify this transformation of the world through the concept of the fourth industrial revolution, Industry 4.0 or digital transformation. The new use of technology offers the ability to provide ongoing real-time connectivity (Bisio et al., 2018).

The global digital transformation phenomenon gained prominence in manufacturing for increasing speed, efficiency, and product customization (Chiarello et al., 2018). The evolving digital world is driven by the intersection of cloud computing, big data, Internet of Things, and Artificial Intelligence (Siebel, 2019). D. L. Rogers (2016) simplified the approach to implementing digital transformation with an explanation of five primary considerations or domains for leveraging the benefit of digital transformation value, customer, competition, data, and innovation. There is a critical link between digital transformation and organizational strategy for successful implementation of new technologies that pave the way for significant change (Davenport & Westerman, 2018; Nwaiwu, 2018; Pînzaru et al., 2019). Although aviation is a highly complex industry adoption of more advanced digital technologies it faces limitations (Valdés et al., 2018).

The study was designed to expand upon the FAA Strategic Plan (FAA, 2020b). The plan presented seven subthemes for consideration: NAS infrastructure, smart systems, certification and regulation, information exchanges, cybersecurity, space operations, and workforce. The literature review provides evidence regarding the usefulness of each topic. Although the concepts of digital transformation and safety culture have extensive coverage in the literature, few published studies examined these topics together or applied to the strategic direction for managing the national airspace. This gap in the literature supported the need for the study.

The methodology literature focuses on common research methods and techniques used in the safety culture and digital transformation arenas, including literature reviews, case studies, surveys, interviews, and content analysis. Delphi studies in safety are more common than Delphi studies in aviation safety. Similar use of Delphi studies applies with more research in digital transformation with limited application in the aviation sector. The combination of Delphi studies on safety culture and digital transformation in aviation point to a gap in the literature.

Chapter 3 contains the research design and rationale for the qualitative modified Delphi approach used in the study. The chapter includes a discussion of specific elements of the Delphi technique, how those elements are applied in research, and the role of the researcher. The chapter includes methodological considerations such as participant selection logic, instrumentation, field testing, data collection, and data analysis. The chapter concludes by identifying the procedures for trustworthiness and ethical integrity that apply to the study.

Chapter 3: Research Method

The purpose of this qualitative modified Delphi study was to determine how a panel of 21 aerospace experts based in Washington, DC viewed the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. The resulting list of strategies provide a consensus-based set of perspectives on implementing Industry 4.0 technical advances in aviation oversight within the context of the safety culture. The panelists were aviation experts with experience in governing aviation in the United States who met the selection criteria.

The chapter includes a description of the research methodology for the study. The chapter presents a description of the research design and rationale, expert panel selection strategy, data collection instruments, method of data collection, and data analysis plan. This chapter also covers my role as the researcher, the relationship between me and the expert panel members, means for ensuring the confidentiality of the panel members, ethical considerations, and elements of trustworthiness of the study. The chapter concludes with a summary and transition to Chapter 4.

The need for technical evolution in aviation stems from the airline industry's obligation to operate profitably and safely (Mangortey et al., 2019; Velazquez & Bier, 2015). The role of federal regulators is to ensure that aviation service providers prioritize safety over profitability in their operations (W. Chen & Li, 2016). Government tends to be a step behind some of the technical advances in the marketplace (Chatfield & Reddick, 2019). The results of the current modified Delphi study were intended to help the FAA determine the best approaches for digital transformation in aviation in an effort for the government to stay current with the private sector. Aviation leads the advancement of technological innovation by researching, developing, and implementing digital transformation with each new generation of aircraft (Air Transport Action Group, 2018). The aerospace industry has been a global force for transformation since the Wright brothers and continually presents opportunities for social change (Bokrantz et al., 2017; Crouch, 2003; Wiltshire et al., 2016). The findings of the current study may affect the future of aviation, which has been a ubiquitous feature of social change in the world (Crouch, 2003).

Research Design and Rationale

The study addressed the following primary research question and subquestions:

How does a panel of aviation experts view the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 1: How does a panel of aviation experts view the desirability of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 2: How does a panel of aviation experts view the feasibility of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 3: How does a panel of aviation experts view the importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Qualitative Method

The Delphi study follows a qualitative research tradition (M. Q. Patton, 2015). The use of surveys and statistical reporting of results can create the perception of the Delphi technique as a quantitative research method; however, these components serve to structure and refine a group communication process to obtain a deep and complete understanding of the group’s shared viewpoint or consensus (Gupta & Clarke, 1996; Hasson & Keeney, 2011; Linstone & Turoff, 1975). The process drew upon a qualitative approach for gathering the information needed to initiate the Delphi technique using open-ended inquiries, literature analysis, and/or other group exchanges (Brady, 2015; Fletcher & Marchildon, 2014; Skulmoski et al., 2007). The philosophical roots for the Delphi approach emerged from the importance of opinions and perceptions as elements of communication from Locke, Kant, and Hegel, which further established the alignment to the qualitative research method (Linstone & Turoff, 1975).

The Delphi technique was appropriate to generate data to answer the research question and subquestions for the current study. Linstone and Turoff (1975) suggested that the Delphi approach suits an exploration of complex issues without proven evidence of a solution. Moreover, Gupta, and Clarke (1996) recommended the Delphi approach for providing value in future-oriented decision making, long-range forecasting, and planning. Markmann et al. (2013) pointed to the fit of the Delphi technique for leveraging expert knowledge to provide foresight in a complex multidimensional environment with inherent risk. Similarly, H. P. Lu and Weng (2018) promoted the Delphi approach to manage communication among technology experts to predict the future of smart manufacturing. These Delphi studies supported the value of the technique for determining how a panel of aerospace experts view the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation in an aviation safety culture.

The modification to the classical Delphi technique was appropriate because of the need to use existing literature, specifically the FAA Strategic Plan (FAA, 2020b), as the basis for the first round of the study. The current study was an extension of the FAA Strategic Plan (FAA, 2020b), which includes 64 strategic statements regarding digital transformation in aviation. The FAA Strategic Plan included four primary categories: Safety, infrastructure, innovation, and accountability. Because the Strategic Plan served as the basis for the 64 items to be evaluated by a panel of experts, the application of the modified Delphi technique was appropriate in contrast to the open-ended data collection that was used in the classical Delphi study for Round 1.

Delphi Technique

The Delphi technique is a process for obtaining consensus among a group of experts (Linstone & Turoff, 1975). The approach leverages multiple rounds of data collection and feedback with an expert panel as a means to build consensus (Dalkey & Helmer, 1963; Hsu & Sandford, 2007; Linstone & Turoff, 1975; Powell, 2002). The communication among the panel is managed to focus on a topic or challenge (Dalkey &

Helmer, 1963). The process reduces the influence of dominant voices in a face-to-face group interaction (B. B. Brown, 1968). The Delphi technique can be applied to many disciplines from information systems (Okoli & Pawlowski, 2004) and procurement systems (Chan et al., 2001) to family counseling (Blow & Sprenkle, 2001) and health care (Fletcher & Marchildon, 2014). Diamond et al. (2014) evaluated 98 Delphi studies across disciplines to examine the achievement of consensus. Romano (2010) reviewed the evolution of the Delphi technique in 25 studies that ranged over multiple disciplines, and Rowe and Wright (1999) examined 27 studies focused on forecasting in various types of organizations.

Roots of the Delphi Technique

The Delphi technique was named in reference to the ancient Greek oracle at Delphi who offered visions of the future (Gupta & Clarke, 1996). In modern times, the Delphi approach grew out of an Air Force sponsored project conducted by the RAND Corporation in the 1950s (Linstone & Turoff, 1975). Gordon and Helmer (1964) highlighted the need for forecasting tools to sort out possible future development and determine a path to achieve the future state. Gordon and Helmer’s study created a breakthrough in more generalized Delphi applications as a fundamental tool in forecasting and planning (Linstone & Turoff, 1975). Gordon and Helmer’s work set the stage for the current study.

Key Elements

Four key elements serve as underpinning principles of the Delphi technique: Anonymity, iteration, controlled feedback, and statistical group response (Dalkey &

Helmer, 1963; Davidson, 2013; Gupta & Clarke, 1996; Hsu & Sandford, 2007; Rowe & Wright, 1999; von der Gracht, 2012). For the purpose of the current study, anonymity did not mean that study participation was anonymous; rather, anonymity meant that the participants could not attribute contributions to specific members of the group, thereby eliminating the influence of dominant participants and groupthink (Dalkey, 1972; Davidson, 2013). Anonymity removes the social pressure of expressing opinions and judgments, allowing panel members to objectively offer their perspectives without deferring the merit of contributions to the status of other members (B. B. Brown, 1968; Rowe & Wright, 1999).

Iteration, controlled feedback, and statistical group response are interdependent aspects of the Delphi technique (Vernon, 2009). In the current study, iteration occurred through multiple rounds of surveys that built on the results of the previous round (Linstone & Turoff, 1975), which made the feedback controlled (von der Gracht, 2012). The controlled feedback happened when a statistical group response of the data from each survey iteration was provided to participants, who then had an opportunity to interact with the information in the next survey round (Davidson, 2013). The elements of iteration, controlled feedback, and statistical group response dovetailed throughout the Delphi data collection to ensure that the opinions of all members were included and the participants had a way to build off of each other while removing undue social influence (Dalkey & Helmer, 1963; Hsu & Sandford, 2007; Rowe & Wright, 1999).

Delphi Application

Structured group communication, the fundamental essence of the Delphi technique, has been applied in various ways (Linstone & Turoff, 1975). Linstone and Turoff (1975) encouraged the flexibility of the approach and inspired researchers to use the Delphi frame to obtain useful results. The research community responded: A recent Google Scholar search of the “Delphi method” returned over 79,000 responses.

In a classical Delphi study, the first round of data collection is unstructured, providing experts with the opportunity to focus on issues important to them (Linstone & Turoff, 1975). The process can start with open-ended interviews, surveys, or group data-gathering experiences. The results of a fluid brainstorming approach provide the foundations for everything that follows in the Delphi process. The brainstorming outcome is consolidated into a set of statements that are conducive to a survey in which a Likert-type scale can be used to facilitate the next round of data collection (Rowe & Wright, 1999).

Although there is a standard approach to the Delphi method, it is also adaptable to meet the needs of a study (Skulmoski et al., 2007). Variances to the method have been reported in the literature, including the following types: Modified, decision, real-time, policy, online, e-Delphi, technology, argument, disaggregative, fuzzy, and consensus conference (Hasson & Keeney, 2011; Murray et al., 1985; Rowe & Wright, 1999; Vernon, 2009). There was a crossover among the types of Delphi studies (Rowe & Wright, 1999). For example, real-time, online, e-Delphi, and technical designs can use electronic data collection and can still be considered classical or modified Delphi (Hasson

& Keeney, 2011). Although the variety of Delphi designs has left the technique open to criticism, the adaptability of the tool continues to be leveraged through modifications (Hasson & Keeney, 2011; Powell, 2002; Vernon, 2009). Hasson and Keeney (2011) identified the use of focus groups, interviews, and systematic reviews as sources for first-round data collection. W. W. Cooper et al. (1995) conducted a study of Latin American Airlines using a modified Delphi approach to examine organizational goals. W. W. Cooper et al. used organizational documents to inform the first round of data collection.

A modification similar to the approach used by W. W. Cooper et al. (1995) was applied in the current study. The items for the Round 1 survey were drawn from the FAA Strategic Plan (FAA, 2020b). In the spirit of controlled feedback, the second-round survey was designed to allow the experts to rate the statements on a 1–5 scale on two specific factors (desirability and feasibility) consistent with a modified Delphi approach (Day & Bobeva, 2005). Additional rounds of survey-based data collection followed, moving from ratings on key considerations to ranking for importance and finally to rating confidence in the final data set that represented the views of the entire group, also consistent with a modified Delphi (Dalkey & Helmer, 1963).

Alternate Research Considerations

Alternative research designs considered for the study included grounded theory, phenomenology, and case study. The goal of grounded theory is to explain a technique or emergent patterns in a social phenomenon (Corbin & Strauss, 1990). Phenomenology is used to uncover the meaning underlying an individual's experience (Giorgi, 2000; Moustakas, 1994). The case study method is considered when examining a previous timebounded occurrence using a variety of sources (Yin, 2017). None of these approaches were appropriate to address the future-oriented focus of the current study. Because the goal of the study was to explore a complex system with limited understanding of optimal solutions in a future-oriented way, the Delphi approach was best suited to the challenge (Heitner et al., 2013; Linstone & Turoff, 1975).

Role of the Researcher

The role of the researcher is to uphold high standards of academic rigor by ensuring adherence to the research methodology, ethically protecting the participants, and mitigating any threats to the integrity of the study (Avella, 2016; Brady, 2015; Skulmoski et al., 2007). I conducted a deep and thorough study by following the academic protocols that led to delivering the expected precision. In addition, I upheld all ethical standards for participant management to create confidence in the study. The credibility of the study depended on my ability to preserve the standards of ethics and manage the research to ensure integrity. Throughout the research process, I followed the principles needed to ensure the highest possible standards of rigor, quality, and truth.

Researcher bias can occur through the selection of panel members and the construction of the first survey round (Avella, 2016; Davidson, 2013). In the current study, the sample frame came from the leaders contributing to the creation of the FAA Strategic Plan (FAA, 2020b). Conducting research within my workplace created a risk of undue influence. Although I am an FAA executive, my work duties were outside the FAA directing an office at the Department of Transportation during the time of data collection. Although I have many connections at the FAA through my former role and participation in the FAA strategic planning work, all aviation experts included in the panel were in peer-level positions or were functionally distant from my current role in the organization to avoid a power differential. I had no authoritative, supervisory, or instructor-level influence on the panel members. This research was not connected to any formal FAA strategic work and had no direct impact on current FAA strategic planning. I managed this study independently from the FAA and under Walden University guidance. No incentives were used during this research project.

Methodology

Participant Selection Logic

Participants with deep knowledge and expertise of the topic are one of the most important requisites of the Delphi technique (Brady, 2015; Gupta & Clarke, 1996; Hsu & Sandford, 2007; Meskell et al., 2014). The expert panel is a specific group of respondents. The caliber of the panel is an important feature of an effective Delphi project (Okoli & Pawlowski, 2004). Selecting expert panel members is critical and determined by the respective discipline definition of expertise (Avella, 2016). Because of panel members’ expertise, they do not and should not reflect the general population.

Participants in a Delphi study are derived from a purposive sample of panel members (Linstone & Turoff, 1975). A purposive sample is chosen not for their representativeness but their connection to the research question (Schwandt, 2001). This sample is a relatively small non-probability group of experts that serves as a strong body of participants who can provide rich in-depth information on the topic of the study (M. Q. Patton, 2015).

The participants for this current study were FAA leaders who contributed to the strategic plan, which includes a core group of approximately 45 aerospace experts. These individuals were deemed experts as a result of a high-ranking decision-making body who selected the participants for the strategic planning work.

The following selection criteria were applied to the experts: At least 3 years at the director or above level in government aviation management with functional expertise, demonstrated by greater than 10 years of experience in any of the following areas: National airspace infrastructure, smart systems, certification and regulation, national airspace operational information exchange, cybersecurity, space operations, and/or workforce. The sampling frame ensured that the panel of experts have the requisite expertise, knowledge, and experience to provide data needed to answer the research questions.

The study was designed with a contingency plan if the number of FAA participants was seven or less. As a backup, conference presenters at aviation forums such as ICAO or the Transportation Review Board and/or members of the Aeroclub would have been invited to participate. Similar criteria for participants would have applied to establish the expertise of the panel members. Since the study had 21 participants through the four rounds, it was not necessary to employ the contingency plan.

Participants in the study were individuals who met the selection criteria and affirmed their willingness to participate. Solicitation of panel members occurred after securing the approval of the Walden University Institutional Review Board (IRB).

Sample sizes for Delphi panels vary widely. Cuhls (2003) suggested that the sample size is dependent on the study: A small local issue only needs a small panel but a forecasting project with a large scope may require more than 100 participants. Even though Hsu and Sandford (2007) indicated that there is no consensus on the recommended number of participants and suggested a general number between 15 and 20. Linstone and Turoff (1975) suggested a minimum sample size of seven. The target sample for the study was the 45 members of the FAA strategic planning process. Based on the estimate that more than 30% of the original offsite group, or their proxy, may not be interested or drop out through the process the resulting participant group could have been 20–30 experts. Twenty to 30 is believed to be a good sample size for obtaining saturation of judgment among experts concerning forward-looking solutions (von der Gracht, 2008). The sample size for this current study was 21 after all four rounds.

The range of divergence in expertise in the panel membership can affect the panel size. Förster and von der Gracht (2014) noted that the greater heterogeneity in perspectives on the subject required larger groups to take in the variety of opinions. Yaniv (2011) wrote about group process and suggested that homogeneous groups showed polarization of opinions that did not change over iterative rounds because those views operated in service to an ingrained professional position. Rowe and Wright (1999) maintained that group members with heterogeneous backgrounds presented advantages in providing high-quality consensus results. For the current study, the common mindedness of the panel members focused on the aviation and aerospace professional expertise. The differences in the group come from the organizations and functions they represented. The different member backgrounds helped to create a set of forward-looking strategies that take the complex and interconnected aspects of aviation into consideration.

Instrumentation

The Delphi approach is composed of a series of surveys for iterative data collection (Linstone & Turoff, 1975). The content and purpose of each round promotes a consensus view among the panel members by following a specific sequence. The purpose of each round was as follows:

- Round 1: Collecting demographic data and updating the 64 strategic statements from the FAA Strategic Plan (FAA, 2020b).
- Round 2: Rating the statements for desirability and feasibility.
- Round 3: Determining importance by selecting the top 10 statements and ranking them from 1–10.
- Round 4: Rating confidence in the results of Round 3.

Round 1

The items in the Round 1 survey (Appendix A) included demographic questions and 64 strategic statements regarding digital transformation in aviation from the FAA Strategic Plan (2020b). The Round 1 data collection occurred from March 22, 2021 to April 11, 2021. The demographic questions pertained to whether each panelist participated in the strategic planning process; the panelist’s years of experience at the director or above level in government aviation management, measured in year ranges; his or her area of functional expertise; and years of experience in his or her functional area, measured in year ranges. The responses facilitated the determination of participant criteria and helped to establish expertise.

The guidance for completion of the group input from the FAA Strategic Plan (FAA, 2020b) was for the expert panel member to review each statement. The experts were invited to adjust any statements to update wording, combine or separate statements to add greater clarity for their meaning, and/or identify any statements that can be eliminated because they were redundant or no longer relevant. The experts could add any new statements that might have been overlooked in the previous session or emerged since the workshop. The panel members were asked to explain their suggested changes.

Round 2

The updated statements resulting from the Round 1 feedback were the foundation of the Round 2 controlled feedback survey. The Round 2 data collection occurred from April 27, 2021 to May 1, 2021. Round 2 began with an instruction set that explained the definitions of desirability and feasibility. The definition for *desirability* referred to the item having a positive effect, beneficial with a positive impact, and reasonable on the positive side and the opposite considerations for the very undesirable with substantial negative effect, harmful, and not reasonable (Linstone & Turoff, 1975). *Feasibility* referred to the practicality for implementing the item or solution. Highly feasible means that the item was easy to execute, whereas low feasibility signifies the solution was not implementable in the opinion of the expert panel member.

The panelists were asked to evaluate each item considering two factors, desirability and feasibility based on Linstone and Turoff’s (1975) criteria. Two 5-point

Likert-type scales were provided for rating each statement on desirability and feasibility. The Likert-type scales allowed for the collection of statistical responses from the panel to be reported in Round 3 (Vernon, 2009). The 5-point scale reflected a higher numbered item associated with more positive designation as follows: The 5-point scale differs from the 4-point scale recommended by Linstone and Turoff (1975) to accommodate the neutral options for participants to use if they have no opinion in either a positive or negative direction. The use of the 5-point with the desirability and feasibility factors occurred in other Delphi studies (Bokrantz et al., 2017; Gnatzy et al., 2011; von der Gracht, 2012).

An open text comments area was provided at the end of each major content section (safety, infrastructure, innovation, and accountability). The free text comment area for each major category provided the participant with a place to record further comments on the statements that had been modified as a result of the Round 1 feedback. The experts were also be encouraged, through the instructions, to provide remarks on ratings especially for the 1 and 2 ratings to explain why they are not desirable or feasible. This information may help provide additional context data interpretation and for the panel work in Round 3.

Round 3

The Round 3 data collection occurred from June 7, 2021 to June 24, 2021. The SurveyMonkey landing page showed each item that had achieved the threshold criteria to advance to Round 3.

The experts were asked to select the top 10 items and then rank them in order of importance from 1–10, with 1 being most important and 10 being the least important (Davidson, 2013). The approach varied slightly from the Linstone and Turoff's (1975) guidance to ascribe an importance rating on a 1-4 scale ranging from very important to unimportant. The panel was asked to provide their rationale for their choices of importance ranking.

Round 4

The Round 4 data collection occurred from July 10, 2021 to July 24, 2021. The Survey Monkey landing page showed the Round 3 results indicating the most important items resulting from panel member input. The panelists were asked to provide one response in this round: To rate their confidence in the top item list that emerged from the Round 3 survey (Rowe & Wright, 1999), using the following rating scale (Linstone & Turoff, 1975) with the neutral rating: 1-Unreliable (great risk of being wrong), 2-Risky (substantial risk of being wrong), 3-Neither reliable or unreliable, 4-Reliable (some risk of being wrong), 5-Certain (low risk of being wrong). The respondents also were given an opportunity to provide comments.

Field Test

Before submitting the IRB application, I conducted a field test to validate the Round 1 instrument. Three individuals with expertise in either digital transformation, aviation strategic planning, or the Delphi technique were asked to review the Round 1 survey via a field test request (Appendix B). These experts received the Round 1 Survey statements taken from the FAA Strategic Plan (FAA, 2020b). The field testers were asked to identify and document any potential points of confusion or ambiguity that could undermine the effectiveness of the research project. Recommendations from the field test were summarized and used to revise the survey prior to submission of the IRB application. Each subsequent survey underwent an IRB review and approval prior to launching the next round of data collection.

Assessing Internal Consistency Reliability of the Scales

Cronbach's alpha provided a measurement of internal consistency reliability of the desirability and feasibility scales for the data collected in Round 2. The Cronbach's alpha reliability coefficient ranges from 0.0 to 1.0 with unreliable measures being closer to 0.0 and reliable measures being closer to 1.0 (Adamson & Prion, 2013). There is no commonly accepted minimal reliability value since it depends the type of application and population considerations (Bonett & Wright, 2015). Although a 0.70 reliability coefficient is considered acceptable, lower thresholds can be justified (Santos, 1999). Ahire and Devaraj (2001) indicated that 0.60 would be acceptable for an emergent construct scale, the current study focus was on views in the form of opinions about future-oriented strategies rather than measuring constructs. Thus, a threshold of .60 was used for the study to be consistent with previous Delphi studies (Heitner et al., 2013). Cronbach's alpha for the Round 2 and Round 3 questionnaires exceeded .90 overall. Detailed results of the analysis of internal consistency reliability for the two questionnaires are presented in Chapter 4.

Data Collection and Data Analysis

Prospective panelists received an invitation email (Appendix C) to their government email account as indicated in the Letter of Cooperation from the FAA. Permission from the FAA was obtained so there was no need to find email addresses for the alternative panel from the different partner organizations. This prospective panelist invitation provided the relevant information about the study including purpose, researcher contact information, criteria for expert panel designation, data collection start and end dates for each survey round, and overview of the data collection protocols. The invitation provided instruction that the survey activity must take place on the participant’s own time and it identified the anticipated time commitments for each round.

The invitation email also included information about the voluntary nature of the study and the participant’s right to withdraw from the project at any time. It clarified the standards of confidentiality and data security, along with anonymity among the panelists, with an explanation of the researcher’s accountability to uphold the integrity of the survey process through professional data and survey tool management. There was an affirmation that there was no monetary benefit associated with participation in the research. Each participant was asked to provide a nongovernment email address for use through the remainder of the study.

The surveys for the study were administered using SurveyMonkey, an online survey website. After the participant provided the alternate email address, the SurveyMonkey link was distributed. The landing page for the participant included the informed consent form (Appendix D) where the participant was required to acknowledge consent to proceed. If the participant did not consent, then the survey terminated. If the participant acknowledged consent, the Round 1 instructions appeared, asking the participant to complete a set of demographic questions and review, modify, add any new items, and provide a rationale for changes on the 64 strategic statements regarding digital transformation in aviation from the FAA Strategic Plan (FAA, 2020b). They were asked to complete three more iterative survey rounds to rate the desirability and feasibility of each item, rank importance of a set of strategic statements, and provide confidence rating for the final prioritized list of top items Each round offered an opportunity for the panel members to provide comments. In total, the panelists were asked to participate in four iterative survey rounds.

The Round 1 instruction set provided a context of the overall organization of the four surveys that were included in the study with a reiteration of the timeframes for survey distribution. The schedule for distribution reflected a 2-week cycle for each round where the participants had 10 days to respond to the survey. Survey Rounds 1, 2, and 3 were extended to allow the participants more time to respond. In the following week, data were analyzed and prepared for distribution for the next survey marking the start of the next 10 day-round.

Participants received three emails during the open survey response time as a reminder that the survey was open, that their contribution was important, and that they would be unable to participate in future rounds if they did not provide input for the current round. Additional reminder notices were sent to participants during the extension cycles every 2 days until the end of the additional time. Upon submitting the responses for each round, the panel member received an auto-generated thank you message and a reminder of the distribution date for the next-round survey. Once the survey window ended, I conferred with my dissertation chair to manage the responses and prepare the statements for release in the next cycle.

The demographic data collected in the Round 1 survey were analyzed via basic descriptive statistics to describe expertise of the panel. Frequency counts, percentages, and the mode were used to describe distribution of years of service in the director or above level in government aviation management. The same measures were used to describe the panelists’ area of functional expertise and years in the functional area of expertise.

The respondent input on the 64 items was consolidated into a list of statements used in Round 2 (Appendix E). The first step in the consolidation process was to organize the comments in an Excel file with the comments made on any of the statements. The comments were then copied in a Word document to management the reworking of the statements given the feedback. There were no statements without comments. The modified statements advanced to the Round 2 survey. For statements with comments, the nature of the comments was examined.

Statement with similar redirection were modified to match the nature of the comments provided. Statements with dissimilar or conflicting comments were modified to reflect the concerns identified. The original source documents or other pertinent literature helped to inform the statement modifications. Comments reflecting divergent opinions were presented in multiple ways to reflect the variance in views among the experts. The Round 2 statements were vetted by the dissertation chair to affirm the appropriateness for inclusion in the desirability and feasibility phase of survey activity.

The Round 2 invitation (Appendix F) was distributed to the participant’s nongovernment email address. The Round 2 instrument provided the means for the participant to rate each of the 61 items for desirability and feasibility (Appendix G). Participants received three emails during the open survey response time as a reminder that the survey was open. Additional reminder notices were sent to participants during the extension cycles every 2 days until the end of the additional time. Upon submitting the responses for each round, each panel member received an auto-generated thank you message. Once the survey window ended, I conferred with my dissertation chair to manage the responses and prepare the statements for release in the next cycle.

The Round 2 results were evaluated with descriptive statistics to provide tendencies toward consensus on the desirability and feasibility of each item. Consensus on the most favorable statements to be included in the Round 3 survey was determined through threshold criteria to facilitate an effective approach to data reduction. The thresholds allowed for a separation of the highest consensus levels and were helpful in case too many items would advance from Round 2 to Round 3. Consensus was determined to have occurred when 70% of the panel members rate a statement at a category 4 or 5 with a median of 3.5 or greater in the Round 2 results at a minimum (Hsu & Sandford, 2007).

Upon IRB approval the Round 3 invitation (Appendix H) was distributed to the participant’s nongovernment email address. In Round 3, participants selected the top 10 most important items and rank them in order of importance from 1 highest to 10 lowest for application of a weighted average (Appendix I). Each participant’s responses received a weight value as follows (a) ranking of 1 = a weight of 10, (b) ranking of 2 = a weight of 9, (c) ranking of 3 = a weight of 8, and so on. The result for each item ranked were totaled and divided by the number of instances the item was selected for ranking creating a weighted average for the items selected as most important.

The Round 4 invitation (Appendix J) was distributed to the participant’s nongovernment email address after the analysis and approvals were completed for Round 3. In Round 4, the participants were asked to provide a single response to rate their confidence in the top item list that emerged from the Round 3 survey using a Likert-type scale (Appendix K). Measures of central tendency, mean, median, and mode were used to determine panel member confidence in the prioritized list of items. Although the mean score shows an overall average, it lacked the further clarity that comes from analyzing the frequency count, percentages for each rating, and the median across the scale.

Trustworthiness

Trustworthiness was used to demonstrate that the work is worth notice (Lincoln & Guba, 1985). Trustworthiness reinforces the integrity and objectivity of the results by identifying the rigor that applied to the procedure which leads to quality results (Cypress, 2017; Hadi & Closs, 2016). Rigor refers to the disciplined execution of the research project delivered through the strength of the research design (Morse et al., 2002). According to Hasson and Keeney (2011), the Delphi technique is subject to criticism in trustworthiness because researchers provide incomplete information about rigor and the technique is prone to ever-adapting applications. To combat these concerns, Lincoln and Guba (1985) presented the qualitative equivalent to validity and reliability in quantitative research through four principles of trustworthiness: Credibility, transferability, dependability, and confirmability. The four principles have specific application to this study.

Credibility

Credibility equates the quantitative research concept of internal validity (Rolfe, 2006). Credibility can be established by building confidence in the "truth" of the findings (Lincoln & Guba, 1985). To demonstrate "truth value" (p. 294) respondents' multiple internal constructions of reality should be represented as a means of demonstrating internal validity (Lincoln & Guba, 1985). Credibility is dependent on the degree of believing the data are based on the ability of the researcher (Hasson & Keeney, 2011). The procedural clarity offered by Linstone and Turoff (1975) adds to the credibility of the technique.

Davidson (2013) suggested the need for two key items for credibility in the modified Delphi technique: An expert panel and anonymity among the panelists. The study included an expert panel, who participated in multiple, iterative rounds of data collection. Panelists were anonymous to one another throughout the study.

Credibility was enhanced through the field-testing process of the Round 1 questionnaire and the ability of the respondents to provide comments throughout the survey rounds. Through in-depth explanation of the study execution plan, credibility is built in the execution of the study (Hadi & Closs, 2016). The confidence rating in Round 4 added further credibility to the study.

Transferability

Transferability refers to the extent to which the findings are consistent in other contexts or with other respondents (Lincoln & Guba, 1985). Transferability is demonstrated by providing enough descriptive data, to enable replicating the study in a different context (Anney, 2014). Survey administration through the SurveyMonkey tool ensured that other Delphi panelists can experience the data collection in the same way as the panel members for the study. The criteria for selecting the purposive sample could be applied to another study focused on safely implementing digital transformation in aviation. The literature review provided in Chapter 2 showed other research in safety culture, digital transformation and applications for the Delphi technique which established a consistency standard for the study.

Dependability

Dependability refers to the consistency in findings when the study is repeated with similar respondents and/or contexts (Lincoln & Guba, 1985). It is equivalent to reliability in quantitative research. Dependability refers to the stability of the results across various data collection activities (Cornick, 2006). Use of Cronbach’s alpha to assess the internal consistency reliability of the Round 2 survey added to the dependability of the Round 2 survey instrument.

Another technique to support dependability is stepwise clarity in the execution of the research or an audit trail (Lincoln & Guba, 1985). The detailed presentation of the elements in the study supports replication of the study by another researcher. The information in Chapter 3 on methodology identified the Walden University standards for execution of the research plan. The proposal writing process contained a step-by-step outline for the project which includes information on the storage of raw data, clarity on data reduction and analysis procedures, and strategies for producing findings. Therefore, it also served as an outline for an audit trail.

Confirmability

Confirmability comes from a detailed description of the data collections and analysis process as a means of achieving objectivity (Hasson & Keeney, 2011). Specifically, the findings are not influenced by the researcher's bias, perspectives, interests, or motivations (Lincoln & Guba, 1985). Researcher bias can occur through the selection of panel members and the construction of the first survey round (Avella, 2016; Davidson, 2013). In the study, the sampling frame came from the prior strategic planning work. The items that populated the first-round came from the information provided in the FAA strategic plan (FAA, 2020b). The key considerations for researcher bias were mitigated by the use of a sampling frame and the 64 strategic statements regarding digital transformation in aviation found in the FAA Strategic Plan (FAA, 2020b). The items were reviewed for clarity and relevance in a field test of the Round 1 instrument. In addition, all communication regarding the study were reviewed and approved by the dissertation chair to further minimize this threat.

Ethical Procedures

The study depended on human participants. The Walden Institutional Review Board (IRB) application helped to ensure the ethical standards in research. Because this project was conducted in a workplace that was very familiar, approval from the organizational ethics office was requested via a letter of cooperation. Panel members were protected from any negative repercussions that could come from participating in this research project by ensuring their anonymity, confidentiality, and privacy. The invitation email informed the prospective participants of their rights, including the right to withdraw from the study at any time.

The informed consent document described the ethical commitment made to the participant. At several points in the study participants were reminded that their participation and responses were anonymous to each other and would remain confidential. All data was reported in the aggregate, which encouraged them to provide truthful responses without fear of retribution.

Security of communication was another ethical consideration that enhanced the integrity of the study. Moving the communication between myself and panel members out of the government’s email systems ensured the participants’ anonymity. The study was approved by the organization through the FAA ethics office. Data security was maintained via password protected files on laptop and flash drives. Access to the data was restricted to myself and two members of the supervising committee. The data will be destroyed 5 years after the university approves the dissertation. Electronic files will be destroyed by conducting a factory reset on the computers holding the dissertation files. Paper files will be shredded, and no cloud applications were used.

Summary

The purpose of this qualitative modified Delphi study was to determine how a panel of aerospace experts based in Washington, DC view the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. The Delphi technique was used to examine the research question and subquestions addressed in the propose study because it was best suited for forecasting an unknown future. The results of the study could be used to inform strategic planning of Industry 4.0 types of technologies for the future of aviation in the United States. Ethical concerns remained at the forefront of this research endeavor. Although other research methods and designs were considered for the study, they were not appropriate to meet the forward-looking focus of the research.

Chapter 3 contained a detailed description and justification of the sampling strategy, study instrumentation, data analysis plan, and research integrity. The purposive sample aligns to the FAA Strategic Plan (FAA, 2020b) where 45 participants were invited to be expert panel members for the study. The instruments for the study followed the modified Delphi technique (Linstone & Turoff, 1975), with surveys used in four iterative rounds of data collection and analysis. Round 1 involved updating the 64 strategic statements regarding digital transformation in aviation from the FAA Strategic Plan (FAA, 2020b). The focus of Round 2 was to rate the updated statements on two 5-

point Likert-type scales for desirability and feasibility. Round 3 included selection and ranking of the 10 most important items that advanced from Round 2. Round 4 consisted of a confidence rating for the data set of the most important items identified by the panel members. The survey was distributed at approximately 2-week intervals over a 10-week data collection cycle via Survey Monkey.

Chapter 4 focuses on the results of the study. Chapter 4 includes a summary of the research setting and procedures used. The results include a description of the field test, the demographic composition of the expert panel, and evidence of trustworthiness, followed by the results of the iterative rounds of data collection and analysis. The chapter also includes answers to the research question and subquestions.

Chapter 4: Results

The purpose of this qualitative modified Delphi study was to determine how a panel of aerospace experts based in Washington, DC viewed the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. The experts shared their views on a set of statements drawn from the 2019–2022 FAA Strategic Plan. The application of the results could inform future strategic planning that helps leaders to usher in the next generation of aviation designed to overcome the current limitations of aviation-based transportation systems. The overarching research question and subquestions that guided this study were as follows:

Research question: How does a panel of aviation experts view the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 1: How does a panel of aviation experts view the desirability of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 2: How does a panel of aviation experts view the feasibility of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 3: How does a panel of aviation experts view the importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Chapter 4 contains a summary of the research setting, demographic information on the expert panel, data collection and analysis, and evidence of trustworthiness. In Round 1, panelists commented on a list of strategic statements regarding digital transformation in aviation. In Round 2, panelists rated the desirability and feasibility of the refined list of strategic statements using Likert-type scales. In Round 3, panelists ranked the top 10 most important strategies. In Round 4, the expert panel rated their confidence in the top 10 list of strategies.

Research Setting

Due to the technical and strategic nature of the study, the expert panel members had to have experience in aviation and strategic planning in the governmental aviation sector. The 45 individuals invited to participate had been involved in forward-thinking strategic planning activities centered on the future of aviation. Expert panelists were anonymous to each other.

The only identifying information I collected was the nongovernment email addresses for the expert panel members, which I needed to distribute invitations for the rounds of data collection and the final results. I disseminated all survey rounds through the SurveyMonkey website. The use of an electronic data collection tool limited environmental factors that could have influenced the participants’ responses.

Demographics

The expert panelists were eligible to participate in the study if they met the following criteria: (a) participation in the FAA strategic planning process; (b) at least 3 years at the director or above level in government aviation management; and (c) functional expertise greater than 10 years of experience in any of the following areas: National airspace infrastructure, Information Technology (IT)/smart systems, certification and regulation, aviation safety, national airspace management, cybersecurity, space operations, and/or workforce.

Of the 45 participants invited to the study, 28 opted to complete the first round and access the survey URL. There were two opportunities at the beginning of Round 1 to affirm eligibility to participate in the study. The criteria for participation were identified, and the participants responded to the close-ended question: Do you meet the following criteria for participation in the study? The criteria referred to the three items listed in the previous paragraph. Any participant who answered “no” would have been automatically disqualified from participating in the study. All participants indicated that they met the criteria for participation.

As a second check on eligibility and a means to collect demographic data, the participants were asked to provide information on the years of experience they had in each of the criteria areas. Two participants indicated that they had less than 3 years of experience at the director level in government aviation management. These two participants were disqualified, and 26 remained in the study for the Round 1 data collection. As illustrated in Table 3, most of the 26 qualified participants had the lowest range of experience (under 10 years) and 8% (*n* = 2) had over 21 years of experience in government aviation management.

Table 3

*Years of Experience at Director or Above Level in Government Aviation Management (*N *= 26)*

Year range	*n*	%
4 to 10	17	65.4
11 to 20	7	26.9
21 to 30	1	3.8
31 or more	1	3.8

Although almost two thirds of the participants reported less than 10 years in government aviation management experience, the level of functional experience inside or outside of government was much higher, with all participants indicating having more than 10 years and over 70% having more than 2 decades as shown in Table 4.

Table 4

*Years of Experience in Functional Area (*N *= 26)*

Year range	*n*	%
11 to 20	7	26.9
21 to 30	14	53.8
31 or more	5	19.2

The panelists' areas of functional expertise were distributed across eight areas, represented in Table 5. The largest focus area for expertise was in the National Airspace System where 38% (*n* = 10) of the participants had a functional expertise in either the NSA infrastructure or the NAS management. More than 30% (*n* = 8) had expertise in safety considering the combined categories of certification and regulation with the aviation safety category. Space operations was represented by one participant. Although no participant identified functional expertise in cybersecurity, 15% (*n* = 4) of the participants selected IT/smart systems as their area of expertise.

Table 5

*Specific Areas of Functional Experience (*N *= 26)*

Area of functional expertise	*n*	%
NAS infrastructure	7	26.9
IT/smart systems	4	15.4
Certification and regulation	1	3.8
Aviation safety	7	26.9
NAS management	3	11.5
Cybersecurity	0	0.0
Space operations	1	3.8
Workforce	3	11.5

Although digital transformation is taking place throughout industry and government, aviation presents a unique set of challenges due to a deeply embedded safety culture. Drawing on a pool of aerospace experts who had knowledge and experience with aviation strategy provided the opportunity to consider the potential application of digital transformation in the future of the national airspace.

Data Collection

Upon receipt of Walden University's IRB approval of the current study (Approval Number 01-07-21-0102818), Round 1 data collection began with an invitation to potential participants sent to the publicly available FAA email addresses of 45 individuals. Of the 45 potential participants, 28 indicated their willingness to engage in the study by replying to the initial invitation with a nongovernment email address. I sent those who provided the alternate email address the Round 1 survey invitation via SurveyMonkey. This invitation included the link to the URL for the online informed consent. When the participant electronically acknowledged the informed consent, the Round 1 survey loaded. The only personal information collected from the panelists was the nongovernmental email address needed to invite the participant to the remaining survey rounds and send a copy of the final results.

The Round 1 instruction set provided the context for the overall organization of the four surveys that were included in the study with a reiteration of the time frames for survey distribution. The schedule for distribution reflected a 2-week cycle for each round in which the participants had 10 days to respond to the survey. In the following week, data were analyzed and prepared for distribution for the next survey marking the start of the next 2-week round.

Field Test

I conducted a field test to identify any potential confusion or ambiguity, allowing for modification of the survey instrument before distribution of the Round 1 survey to the expert panel. I sent a draft of the Round 1 survey to three experts with experience in aviation strategy or the Delphi technique. The experts reviewed the instrument and provided feedback pertaining to the digital transformation strategic statements and the instruction set for completing the Round 1 survey. The experts did not express any concern with the survey items or the instructions, so I did not make any modifications. I did not collect any data from the field test participants.

Participation Overview

The first invitation distribution to the FAA email addresses per the FAA-and IRB-approved communication yielded 28 individuals who provided their nongovernment email addresses. I distributed the Round 1 survey, with the embedded informed consent, to those email addresses. All 28 individuals acknowledged the informed consent; however, two did not meet the criteria for serving in the director role for at least 3 years and were therefore excluded from serving on the expert panel. A total of 26 qualified candidates participated in Round 1, as shown in Table 6.

Table 6

Survey Response Rate

Round	Invitations sent	*n* surveys completed	Response rate %
1	28	26	92.9
2	26	23	88.5
3	23	22	95.7
4	22	21	95.5

Location, Frequency, and Duration of Data Collection

Electronic data collection took 18 weeks to complete on SurveyMonkey between March 21, 2021, and July 24, 2021. The start date was the day that the survey was disseminated to the expert panel members. I gave the participants 10 days to complete the survey. For each round, I gave participants an extension if they were unable to complete the survey by the deadline. During the planned 10-day active data collection cycle, I sent the participants three reminder notices on approximately day 3, day 5, and day 8. During the extension cycle, I sent the participants a reminder every 2 days until the extension cycle ended.

The Round 1 cycle had a 10-day extension period due to concerns over low response rate. As of the eighth day in the first 10-day cycle, I had only 10 responses, which was a 36% response rate raising concerns that the study would be in jeopardy of not having enough respondents to support reaching consensus across multiple rounds. Two strategies emerged as possible means to address the low response rate. The first was to extend the deadline and provide more frequent reminders of the approaching extended deadline. The second was to modify the recruitment strategy to shift to a snowball sample. I chose the first option and rejected the second due to the constraints on the contact with the FAA community established by the Letter of Cooperation provided by the FAA Office of the General Counsel.

The extension with more frequent reminders resulted in 26 responses and a 93% response rate in Round 1. I extended the 10-day cycle for Round 2 survey completion for an additional 7 days to allow for more participation. I also applied a 7-day extension for Round 3 and a 4-day extension for Round 4. The extension cycle was shorter for Round 4 because more responses came in earlier in the cycle compared to previous rounds. Table 7 presents the timeline for data collection and analysis in each round.

Table 7

Data Collection and Analysis Timeline

	Survey dates		Analysis dates	
Round	Started	Ended	Started	Ended
1	3/22/2021	4/11/2021	4/01/2021	4/20/2021
2	4/27/2021	5/14/2021	5/01/2021	6/01/2021
3	6/07/2021	6/24/2021	6/15/2021	6/26/2021
4	7/10/2021	7/24/2021	7/15/2021	7/24/2021

Round 1

The Round 1 survey consisted of 64 statements regarding digital transformation derived from the FAA Strategic Plan 2019–2022. The response cycle was extended by 10 days to allow participants more time to complete the survey. The expert panel members provided input on the 64 strategic statements.

Round 2

The Round 2 instrument consisted of 61 statements of forward-looking strategies for aviation based on the feedback provided on the 64 statements included in Round 1. Round 2 began after the data analysis process from Round 1 was completed and the Walden IRB approval of the Round 2 survey instrument was obtained. Round 2 data collection cycle was extended by 1 week to allow participants more time to complete the survey.

Using two separate 5-point Likert-type scales, the expert panel rated each item for desirability and feasibility. Of the 61 forward-looking strategic statements in the Round 2 survey, 24 met the data reduction threshold of 60% of the panel members rating the statement at a category of 4 or 5 with a median of 3.5 or greater. Twenty four of the 61 items advanced to Round 3.

Expert panelists used the text box below each rating scale to give a rationale for choosing a rating of 1 or 2 or to give a general comment. There were 163 comments provided with seven respondents providing no comment and two respondents providing over 30 comments each. Four statements had no comments. One statement had the most comments (nine), and the average number of comments was 5.6 per item. The comments did not lead to changing any wording for the items that were provided in Round 3.

Round 3

In Round 3, the expert panel members ranked the 24 strategic statements that advanced from the Round 2 ratings of feasibility and desirability. The respondents selected the top 10 most important items and then ranked them from 1 (*most important*) to 10 (*least important*). The strategies with the highest weighted average advanced to Round 4. No panelists commented on their rankings. Round 3 data collection was extended by 1 week to allow participants more time to complete the survey.

Round 4

In Round 4, the expert panels member rated their confidence in the top 10 strategies presented. Confidence was the degree of certainty the member had in the collective panel’s view of the ranking on the scale of 1 (*unreliable–great risk of being wrong*) to 5 (*certain–low risk of being wrong*). Seven panelists commented on their rating. Round 4 data collection was extended by 4 days to allow participants more time to complete the survey.

Data Recording Procedures

SurveyMonkey provided the ability to electronically distribute the survey questionnaires and collect the responses. The results of each round were exported into a Microsoft Excel file for data analysis. I entered written data from Round 1, 2, and 4 comments into the Microsoft Word program for further analysis.

Variation in Data Collection

One change occurred between the data collection plan outlined in Chapter 3 and the data collection process used. Using the initial consensus threshold of 70% for top two responses and a median of 3.5 for desirability and feasibility in Round 2, I would have advanced only 9 statements to Round 3. I reduced the threshold for consensus in Round 2 to 60%, keeping the median at 3.5, so that 24 items could advance to the next round.

Data Analysis

With a large amount of data to analyze prior to commencing a new round and across all rounds, I used tools from SurveyMonkey, Microsoft Excel, and Microsoft Word. The respondents' input was exported from SurveyMonkey to Excel for an analysis of the overall opportunities to provide responses and the breakdown of the type of response. The data analysis approaches used aligned with the types of data collected in each round.

The 26 participants who completed the Round 1 surveys responded to the list of 64 statements with 1,600 response opportunities that fell into two categories. The first category included no comment on the statement as presented; 77% of the responses indicated no reasons for a change to the statement as presented. The remaining responses, 23%, showed a comment regarding a recommended change in the statement. All statements had at least two comments. One statement had the greatest number of comments at 14. The average number of comments per item was six.

To conduct the analysis of the specific comments, I exported the data to Microsoft Word. There were four statements with comments that were supportive of the statement indicating that no revision was needed. Through comments, the respondents indicated that nine statements should be deleted. The primary reason for their recommendation was redundancy. There were two statements where each included two concepts. I separated each of these original statements into two new statements. One statement with five subcomponents that became five individual statements.

The panelists made comments on 51 statements that indicated the need for revision. I reviewed the comments for each statement for continuity and divergence. Some changes were expressed consistently across the panel members. All six panelists who provided a comment suggested removing the word algorithms from a statement concerning artificial intelligence. The original statement was “employ algorithms and artificial intelligence to manage and utilize the data collected as data analysis technologies advance.” Based on the feedback, I changed the statement to “Employ artificial intelligence to improve effective decision making and enhance performance of core aviation management functions.”

Another statement drew divergent perspectives from the panel members. Specifically, comments about a statement regarding commercial space ranged from “Should be done” to “delete/eliminate entirely–not relevant.” The strategic plan has an entire section devoted to commercial space, so the topic is a key strategic driver. I consolidated the change comments into a revised statement. Referencing back the FAA 2019–2022 strategic plan helped to provide context for statement revisions.

Many of the comments focused on the readability of the statement. For example, the statement “Use data to develop and execute clear plans to prepare for weather events and other disruptions, and use operational forecasting, shared with operators,” drew 14 comments. These comments ranged from “adding a wide range of stakeholders” to “maintain safe operations during adverse weather events.” These concepts were not included in the original statement. Because they supported the overarching theme of safely adopting digital transformation in aviation and the strategic direction, I incorporated them into the revised statement. The revised statement became “Use weather forecasting data from both internal and external sources, paired with operational forecasting, to develop executable plans with a wide range of stakeholders to maintain safe operations during adverse weather events and other disruptions.”

From the 64 statements identified in the FAA Strategic Plan for 2019–2022 in support of Digital Transformation, the revised set of 61 statements went forward to Round 2. I organized the resulting 61 statements in four categories that mirrored the strategic initiatives identified in the 2019-2022 FAA Strategic Plan. The distribution of the statements per category for Round 1 and Round 2 appears in Table 8 below.

Table 8

Distribution of Statements Over Categories in Round 1 and Round 2

Category	Round 1		Round 2	
	n	%	*n*	%
Safety	11	17.2	12	19.7
Infrastructure	16	25.0	13	21.3
Innovation	31	48.4	27	44.3
Accountability	6	9.4	9	14.7
Totals	64	100.00	61	100.0

There were 37 items eliminated in the data reduction that occurred from Round 2 to Round 3. These 37 statements did not meet the threshold for consensus as 60% agreement for the top two ratings (4 or 5) and a median of 3.5 for desirability and feasibility. The items that did meet the standard for consensus represented the categories identified in the strategic plan. The distribution of the statements per category for Round 2 and Round 3 appears in Table 9 below.

Table 9

Data Reduction From Round 2 to Round 3 by Category

Category	Round 2 *n* statements	Round 3 *n* statements
Safety	12	4
Infrastructure	13	5
Innovation	27	10
Accountability	9	5
Total	61	24

Analysis of Round 2 data included determining internal consistency reliability via Cronbach's alpha scores for each statement in each category and the instrument overall using main study ratings of desirability and feasibility.

Table 10

Internal Consistency Reliability Coefficients for the Round 2 Instrument by Category

Category	Number of items	Desirability	Feasibility
Safety	12	.73	.57
Infrastructure	13	.87	.78
Innovation	27	.94	.90
Accountability	9	.77	.75
Overall	61	.95	.91

Evidence of Trustworthiness

The rigor in this current study comes from the study performance criteria established by Walden University. The process of following the specific research protocols ensured the integrity and objectivity of the results as evidenced by each round of survey questions obtaining approval from the IRB prior to the release of the survey to the panel members. I provided the details of this study in Chapter 3 and described the application of the steps in Chapter 4.

Credibility

I did not deviate from the proposed credibility approach and execution of this study. I enhanced credibility through the field-testing process of the Round 1 questionnaire and soliciting comments from the panelists throughout the survey rounds. The confidence rating in Round 4 added further credibility to the study. The panelists' ratings indicated only a slight risk that the results were wrong.

Transferability

Survey administration through the SurveyMonkey tool ensured that other researchers can collect data from another group of panelists in the same way. The process for designing and distributing the surveys would likely be very similar in future studies because of the SurveyMonkey system. The implementation plan in Chapter 3 is a roadmap for a future researcher to follow.

Dependability

Although conceptually the ability to engage an expert panel with the same participation criteria is possible, it could be challenging to have the same perspectives from a new panel. Even the passage of time changes the perspective of the panel members, as actions are already being taken on strategic approaches to digital transformation in aviation.

Providing an audit trail also supports dependability. The detailed presentation of the elements in the study supports replication. The detailed information in Chapter 3 on methodology for the execution of the research plan allows for others to conduct similar studies.

Confirmability

In this study, the sampling frame emerged from the prior strategic planning work. The items that populated the first round came from the information provided in the FAA strategic plan (FAA, 2020b). I mitigated the key considerations for researcher bias by the use of a sampling frame and the 64 strategic statements regarding digital transformation in aviation found in the FAA Strategic Plan (FAA, 2020b). In the field test, experts reviewed the items in the Round 1 instrument and the instructions for clarity and relevance. In addition, the dissertation chair and the IRB reviewed and approved all communication regarding the study.

Results

Participants in this modified Delphi study consistent of aviation experts who provided feedback on the current strategies identified in the FAA Strategic Plan and rated them for desirability and feasibility in Round 2. In Round 3, panelists ranked the importance of the top 10 strategies, then rated their confidence in the final list of strategies in Round 4. The results of the analysis of data collected in each of the four Delphi rounds follow.

Round 1

The analysis of panelists' comments on the digital transformation strategic statements mined from the FAA Strategic Plan informed revising some strategies, breaking down some strategies into separate items, and clarifying the wording of other strategies. The results generated 61 strategic items for the Round 2 survey, organized in four overarching categories of strategies that mirror the strategic initiatives identified in the plan. These categories are: (a) safety, (b) infrastructure, (c) innovation, and (d) accountability. From the 64 statements identified in the FAA Strategic Plan for 2019–2022 in support of Digital Transformation, the revised set of 61 statements went forward to Round 2.

Round 2

Panelists rated the desirability and feasibility of 61 items pertaining to strategies in four categories. The threshold for reaching consensus in Round 2 was 60% agreement for the top two ratings (4 or 5) and a median of 3.5 for desirability and feasibility. Twenty-four items met the threshold to advance to Round 3 (see Table 11).

Table 11

Items That Met Consensus for Both Desirability and Feasibility in Round 2

Category	Statement
Safety	S3, S5, S6, S8
Infrastructure	S13, S15, S18, S19, S21
Innovation	S27, S29, S30, S32, S44, S45, S47, S48, S49, S50
Accountability	S56, S57, S58, S59, S60

Panelists provided 163 comments on the ratings. They gave a wide variety of reasons for their ratings. Some of the low ratings resulted from a professional experience related to the topic. One participant stated, “I have become somewhat cynical about research unless it has a reasonably clear path to implementation. There are dozens of research reports and studies sitting, largely unread, and in some cases already obsolete by the time they're finished." Another participant added a similar professional familiarity-based response with a comment about commercial space launches:

> This sounds great, but I have direct personal experience that suggests it's not quite as easy as it sounds. Progress is being made but there are certain irreducible system capacity and efficiency impacts when you have to shut down certain types of airspace sectors, even for short periods of time, to accommodate launches.

There were a number of comments related to IT types of issues. For example, one participant offered a comment on cloud storage:

> I only question the inclusion of "cloud storage" here -- I think a lot of stakeholders misunderstand what that term actually means, esp. [*sic*] in a context like this. Where the data is stored is less important than the accessibility and security protocols around it.

Another comment focused on the internet-based applications, effectively identifying the true nature of adoption challenges, "While integrating aviation data with the internet is feasible, it drives the cyber warriors crazy! Again, the limitation isn't technology, but the human reaction to it's [*sic*] introduction!" A third comment addressed the trade-offs that come into consideration when introducing new concepts, "This would be great and can be accomplished from a technical perspective. Unless this is being achieved in current modernization efforts it would need to be done at the expense of other programs." The technical considerations received thoughtful comments.

The topic of innovation overall brought up concerns among the participants. Although the largest number of items on the survey was associated with innovation, the participants expressed reservations about the ability to support innovation. One panel member stated:

> A cross agency innovation office alone will still find it slow going, when you get into the layers of people involved in granting approval of new things. Rapid adoption of new technologies has to be a shared goal of the overall agency, not just an office tasked to innovate. The regulatory approval process is the problem, since there are many layers of resistance in government agencies!

Another panelist captured the challenge with digital transformation in aviation by stating, "implementing innovation is very difficult when it bumps up against a very conservative safety-based culture!" The participant comments reflected a deep concern and careful consideration for the implications of digital transformation in aviation.

Round 3

Panelists selected what they considered the 10 most important items listed in the Round 3 questionnaire and ranked them in order of importance. To reduce confusion for the participants and ease the ranking process, I renumbered the statements that advanced from Round 2 to Round 3. The renumbering matched the item categorization and flowed through the categories as follows.

Table 12

Item Number Conversion From Round 2 to Round 3

Category	Round 2 Item number	Round 3 Item number
Safety	S3, S5, S6, S8	S1, S2, S3, S4
Infrastructure	S13, S15, S18, S19, S21	S5, S6, S7, S8, S9
Innovation	S27, S29, S30, S32, S44, S45, S47, S48, S49, S50	S10, S11, S12, S13, S14, S15, S16, S17, S18, S19
Accountability	S56, S57, S58, S59, S60	S20, S21, S22, S23, S24

To analyze the rankings, I calculated the weighted average in Excel by assigning a weight to the selections. I gave the number 1 rank item a weight of 10, the number 2 ranked item a weight of 9, and so on. The resulting averages provided the overall ranking. The weighted average ranged from highest ranked 5.27 to lowest of the top 10 as 2.42, with a considerable distinction for the highest-ranked item, S2.

Table 13

Weighted Average of Ranked Items

Rank	Statement number	Weighted average
1	S2	5.27
2	S24	3.82
3	S8	3.73
4	S13	3.45
5	S19	2.95
6	S18	2.82
7	S20	2.82
8	S5	2.73
9	S10	2.50
10	S1	2.41

The category breakdown for the statements showed that two statements were in the safety category, two in accountability, two in infrastructure, and the remaining four in innovation. The full statements and their rank appear in Table 14.

Table 14

Weighted Average Ranking With Category

Rank	Strategic statement	Category
1	S2. Accelerate the integration of new transportation technologies and practices into transportation systems to improve safety, efficiency, and performance.	Safety
2	S24. Ensure the skills of the FAA workforce evolve as the technologies, operating models, and/or strategic priorities for the organization change.	Accountability
3	S8. Develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations.	Infrastructure
4	S13. Facilitate and enable the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's aviation system.	Innovation
5	S19. Support the development and deployment of innovative technologies by assessing existing regulatory approaches to address potential barriers.	Innovation
6	S18. Support the development and deployment of innovative technologies by partnering with industry and other stakeholders.	Innovation
7	S20. Ensure that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs.	Accountability
8	S5. Automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage and encouraging third parties to provide value-added applications.	Infrastructure
9	S10. Use the advances in data management capabilities to increase the efficiency and security of data transmission, collection, and analysis.	Innovation
10	S1. Help improve safety by making it easier to engage with industry stakeholders earlier in the technological development cycle.	Safety

Round 4

In Round 4, the expert panelists rated their confidence in the top 10 items they identified and ranked in Round 3. Confidence was the degree of certainty the member had in the collective panel view of the ranking on the scale of 1–unreliable with great risk of being wrong to 5 certain with low risk of being wrong. The median rating from the participants was 4-reliable with some risk of being wrong. Three participants rated the final listing was 3–neither reliable nor unreliable while 3 others rated it as 5–certain that the list presented a low risk of being wrong. All of the other panels rated their confidence as a 4–reliable with some risk of being wrong.

Seven panelists also commented on their rating. One comment stood out as a comprehensive statement regarding the broad impact of these strategic statements throughout the organization:

> It is important for the entirety of the organization be bought into these goals. Too often the regulatory side of agencies are mired in conservative group think that has to change for technology efforts to be successful. Having only small organizations pushing innovation won't work without the cooperation of the entire agency.

Other panels identified content that seemed to be under-represented in the final set of strategic statements. Specifically, one member asserted, "…wish there was more focus on safety, which is the inherent promise of the service we provide." Another stated, "I believe that there needs to be more emphasis on cyber security aspect. There is some mention, but it should be a priority.” These points reflect valid concerns regarding the final list of statements.

Contrary to the concerns expressed, several statements were generally supportive of the study results. One participant affirmed the top 10 list by indicating, “this is very consistent with the NAS System Requirements which emphasize the performance of information and not individual systems as the basis for safe and efficient operations.” Given the close connection between the strategic plan and the NAS system requirements, this statement adds credibility to the overall outcome of the study.

The ratings reflect the panelists’ overall confidence in the final listing of the top most important strategies for safely adopting digital transformation in aviation. The following section contains the answers to the research questions and subquestions.

Answering the Research Questions

The current modified Delphi study comprised four rounds of data collection, analysis of each round of data, and results. The intent of each Delphi round was to move toward consensus on forward-looking strategies to safely adopt digital transformation in aviation. The strategies fit within the four categories identified in the FAA Strategic Plan for 2019–2022: Safety, infrastructure, innovation, and accountability. This section covers the study results by research subquestions and the overarching research question.

Research Subquestion 1

This research subquestion pertained to how a panel of aviation experts viewed the desirability of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. Of the 61 statements the panelists rated in Round 2, 97% (*n*=59) met the consensus threshold for desirability. The three statements that did not meet the 60% consensus rating included (a) develop and execute a plan to provide a regulatory framework that will facilitate the development and certification of supersonic aircraft (S4), (b) create a formal cross-agency office dedicated to new entrants and innovation (S41), and (c) implement solutions that are integrated with other DOT modal systems and processes (S61).

Research Subquestion 2

This research subquestion pertained to how a panel of aviation experts viewed the feasibility of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. Of the 61 items the panelists rated in Round 2, 39% (*n*=24) met the criteria for feasibility, reflecting an actionable item for the strategic approach to digital transformation in aviation. All 24 statements met the criteria for desirability.

Research Subquestion 3

This research subquestion pertained to how a panel of aviation experts viewed the importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. From the list of the strategies that met the consensus for desirability and feasibility, the panelists selected the items they considered as most important, ranked from 1–10. The 10 items with the highest rankings based on weighted averages comprised the final list of strategies.

Overarching Research Question

The overarching research question pertained to how a panel of aviation experts viewed the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. The first three rounds of data collection and analysis resulted in a list of the 10 most desirable, feasible, and important strategies. The strategies clustered into all four categories: Safety (*n* = 2), infrastructure (*n* = 2), innovation (*n* = 4), and accountability (*n* = 2). The largest concentration of items in the final list was in the innovation category: (a) Strategy 13 (S13)-Facilitate and enable the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's aviation system; (b) Strategy 19 (S19)-Support the development and deployment of innovative technologies by assessing existing regulatory approaches to address potential barriers; (c) Strategy 18 (S18)-Support the development and deployment of innovative technologies by partnering with industry and other stakeholders; and (d) Strategy 10 (S10)-Use the advances in data management capabilities to increase the efficiency and security of data transmission, collection, and analysis.

In the category of safety, the two statements in the final list were: (a) Strategy 2 (S2)-Accelerate the integration of new transportation technologies and practices into transportation systems to improve safety, efficiency, and performance; and (b) Strategy 1 (S1)-Help improve safety by making it easier to engage with industry stakeholders earlier in the technological development cycle. In the category of infrastructure, the two statements in the final list were: (a) Strategy 8 (S8)-Develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations; and (b) Strategy 5 (S5)-Automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage and encouraging third parties to provide value-added applications. In the accountability category, the two statements in the final list were: (a) Strategy 24 (S24)-Ensure the skills of the FAA workforce evolve as the technologies, operating models, and/or strategic priorities for the organization change; and (b) Strategy 20 (S20)-Ensure that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs. The panelists indicated a high level of confidence in the final list of strategies, with a median rating from the participants was 4-Reliable with some risk of being wrong.

Summary

This chapter contained the results of a four-round qualitative, modified Delphi study designed to explore how a panel of aviation experts based in Washington, DC viewed the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. The first three survey rounds revealed the panelists consensus on the 10 most desirable, feasible, and important strategies clustered in four categories–safety, infrastructure, innovation, and accountability. In Round 4, the 21 expert panelists rated their confidence in the top 10 most important items that advanced from Round 3. The confidence rating indicated only a slight risk that the results were wrong. Chapter 5 includes an introduction, interpretation of the findings, limitations of the study, and recommendations. The implications to positive social change, methodology, and practice are also provided.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this qualitative modified Delphi study was to determine how a panel of aerospace experts based in Washington, DC viewed the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. The application of the results could inform future strategic planning that helps leaders to usher in the next generation of aviation designed to overcome the current limitations of aviation-based transportation systems. Through four survey rounds, the experts shared their views on a set of statements drawn from the 2019–2022 FAA Strategic Plan. A review of existing literature supported the selection of the strategic statements.

The results of the study indicated a consensus-based list of 10 recommended strategies grouped into four categories. The four categories matched the strategic drivers identified in the FAA strategic plan: Safety, infrastructure, innovation, and accountability. Chapter 5 includes the interpretation of findings, recommendations, and implications.

Interpretations of Findings

In this section, I focus on interpreting the results of the study, specifically the 10 strategic statements the panelists agreed on as the most desirable, feasible, and important. The panelists indicated a high level of confidence in the final list of strategies, with a median rating from the participants as 4 (*Reliable with some risk of being wrong*). Agreement among the 21 panel members provides insight into the literature focused on digital transformation in aviation.

The strategies clustered into all four categories: Safety (*n* = 2), infrastructure (*n* = 2), innovation (*n* = 4), and accountability (*n* = 2). The largest concentration of strategies in the final list was in the innovation category: (a) Strategy 13 (S13)-Facilitate and enable the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's aviation system; (b) Strategy 19 (S19)-Support the development and deployment of innovative technologies by assessing existing regulatory approaches to address potential barriers; (c) Strategy 18 (S18)-Support the development and deployment of innovative technologies by partnering with industry and other stakeholders; and (d) Strategy 10 (S10)-Use the advances in data management capabilities to increase the efficiency and security of data transmission, collection, and analysis.

In the category of safety, the two strategies in the final list were (a) Strategy 2 (S2)-Accelerate the integration of new transportation technologies and practices into transportation systems to improve safety, efficiency, and performance; and (b) Strategy 1 (S1)-Help improve safety by making it easier to engage with industry stakeholders earlier in the technological development cycle. In the category of infrastructure, the two strategies in the final list were (a) Strategy 8 (S8)-Develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations; and (b) Strategy 5 (S5)-Automate and streamline the data-sharing process for non-NAS users through new technologies, such as cloud storage and encouraging third parties to provide value-added applications. In the accountability category, the two strategies in the final list were (a) Strategy 24 (S24)-

Ensure the skills of the FAA workforce evolve as the technologies, operating models, and/or strategic priorities for the organization change; and (b) Strategy 20 (S20)-Ensure that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs. The following section is an interpretation of the results in the final list of strategies by category. The analysis shows where the top 10 strategies confirm, disconfirm, or extend the current body of research.

Innovation

The panelists viewed four strategies in the innovation category as the most desirable and most feasible, and ranked them in the 10 most important strategies. These four strategies were S13, S19, S18, and S10. All of these strategies connected to the literature on digital transformation in aviation.

Among the four innovation strategies in the innovation category, the panelists ranked S13 as the fifth most important of the top 10. The strategic statement encompassed three key concepts: Innovation, safety, and performance. This finding confirms the D. L. Rogers’s (2016) premise that digital transformation, and by extension innovation, drives performance improvement. D. L. Rogers claimed that integrating innovation into a transformational culture focuses on building a discipline around high-quality experimentation grounded in principles of continuous learning and performance improvement. The driver for innovation is to deliver customer value, which emerges from a deep understanding of success considerations in digital transformation (D. L. Rogers, 2016).

Mahmood and Mubarik (2020) wrote about the development and deployment of innovative practices and technologies from the perspective of bringing products to market. The current expert panel’s consensus around S13 shows that market position is not the only purpose for innovation. The FAA does not bring products to market; it regulates the products that are in the marketplace. The finding points to the value of innovations beyond creating an organization’s market position. Innovations can also provide value for the public through the regulation of the marketplace. Therefore, the panel members’ selection of S13 extends Mahmood and Mubarik’s perspective on the application for digital transformation.

Liao et al. (2017) examined growth in the literature on Industry 4.0, claiming that the topic of innovation did not receive enough coverage. The current panelists perceived innovation as a dominant component of digital transformation in aviation, confirming Liao et al.’s concern by identifying the need to support innovation as a factor of digital transformation in aviation.

The expert panel ranked S19 as the sixth most important strategic statement on digital transformation in aviation. Although the challenges of regulation exist throughout the new entrants in the aviation sector, some of the most significant considerations are in commercial space. According to Stilwell (2016), the commercial space industry is rapidly expanding, and the regulatory environment is behind the growth curve. The current panel’s views of S19 confirm Stilwell’s perspective on the challenges of commercial space flight.

The panel members' consensus around S19 substantiates Nakamura and Kajikawa's (2018) claim that regulation and innovation are inextricably bound in aviation. The panel members were aware of the regulatory environment surrounding the innovative uses for Unmanned Ariel Systems (UAS). The regulation for UAS came into being quickly to match rapid marketplace deployment, and regulation was highly restrictive due to the potential risk of foreign bodies in the airspace. As greater use around application emerged, the inflexibilities of the new regulatory framework inhibited the application of the new technology even for safety purposes. The panel's views of S19 aligns with the concern of Nakamura and Kajikawa. Blind et al. (2017) advocated for regulatory bodies to support emerging private sector innovations as a means of growing new markets. The inclusion of S19 in the final list of strategies confirms Blind et al.'s recommendation to examine regulation as a way to reduce barriers to innovation and clear a path for more innovation, which in turn results in economic development through the creation of new technologies.

The expert panel ranked S18 as the seventh most important strategic statement on digital transformation in aviation and agreed that partnerships with the stakeholder contributed to the development and deployment of innovative technologies. This finding converges with the innovation in digital transformation literature. D. L. Rogers (2016) pointed to partners and stakeholders as a key factor in driving innovation through information sharing. In addition, Matarazzo et al. (2021) examined the impact of digital transformation from an innovation perspective on customer value creation in the retail sector, while Pereira et al. (2021) considered the innovation and value creation in aviation as a causal relationship after implementation of the innovation without consideration for the partnerships occurring at the early stages of the innovation work.

The current expert panel's views of S18 highlights a gap in the literature on public–private partnerships in aviation. Although the White House Report on Aviation Safety and Security (Gore, 1997) called for public–private partnership on safety, the same call for collaboration on safety did not appear in the literature on innovation coupled with digital transformation. In the current study, the inclusion of S18 in the final list of strategies calls attention to a gap in the current body of literature by recommending that partnerships support the development and deployment of innovative technologies as one of the top 10 strategies for advancing digital transformation in aviation.

The expert panel ranked S10 as the eighth most important strategic statement on digital transformation in aviation. The current study's findings pertaining to the data dependency of digital transformation confirms the literature. Schwab and Davis (2018) identified the new era of pervasive systems through the concept of digital transformation driven by data. Although the term "digital transformation" was limited in aviation literature, the underlying principles manifest in the language of S10.

The expert panelists' view supported Bisio et al.'s (2018) notion of the new use of data-driven technology to provide ongoing real-time connectivity. The inclusion of S10 in the final list of strategies affirms the global phenomenon of digital transformation as it gains prominence in manufacturing for increasing speed, efficiency, and product customization (Bag et al., 2021; Chiarello et al., 2018). This finding confirms Y. Lu's (2017) examination of digital considerations such as IoT, CPS, and Internet of Services as communication conduits from machines to machines and humans to machines. As a key driver for digital transformation, the panel's selection of S10 in the final list of strategies matches with the concept that Industry 4.0 is based on the principle of perpetual communication through the internet for the multidirectional and continuous exchange of information among people, between people and machines, and among various machines (Roblek et al., 2016).

Valdés et al. (2018) claimed the aviation industry is on the cusp of digital transformational technologies that will fundamentally shift it for greater efficiency and safer operations. According to Jawhar et al. (2018), the data-driven nature of the national airspace has a critical need to adopt the Industry 4.0 strategies to fit commercial aircraft and unmanned aerial vehicles into the overall integrated data platform associated with the smart cities of the future. The inclusion of S10 in the final list of strategies supports the literature on the data management aspects of digital transformation in aviation.

Cybersecurity is an inherent risk underpinning S10. The expression of this concern among the current panelists is also consistent with the literature. Urban (2017) wrote about the cybersecurity risks in international aviation, indicating that the industry's dependence on interconnected technologies makes it a target for cyber attackers. Urban identified the vulnerabilities linked to new technologies. As an element of critical U.S. infrastructure, aviation presents a conundrum in cybersecurity because of the shared responsibility for protecting the information systems among the U.S. government, private airlines, and aircraft manufacturers. S10 included security of data transmission within the context of data management, which confirms the concerns expressed by Urban.

Taken together, the final strategies in the category of innovation confirm or extend the body of literature on digital transformation in aviation. The most prominent distinction between these findings and the literature is with S18. There was little published research on public–private partnerships in aviation. The panel viewed S18 as one of the top 10 most important strategies for the future of innovation in aviation, which indicates the need for more research.

Safety

The panelists viewed two strategies in the safety category as the most desirable and most feasible, and ranked them in the 10 most important strategies. These two strategies were S2 and S1. Both strategies focus on internal and external perspective of the integration of new technologies. The internal perspective links to optimizing the operations of the systems while the externally focused safety strategy pertains to the impact of digital transformation on the aviation business community. Together, the strategies reinforce the primary mission of the FAA: Safety.

S2 focuses on accelerating the integration of new transportation technologies and practices into transportation systems to improve safety, efficiency, and performance. The expert panel ranked S2 as the most important strategic statement on digital transformation in aviation. The panelists agreed that accelerating the integration of new technologies and practices was the most important work to do. The criticality of improvement to safety, efficiency, and performance was paramount to the panel of aviation experts.

The consensus among the panelists regarding the need to integrate new technologies and practices as drivers for improvement confirms prior arguments in aviation literature. Crouch (2003) pointed to aviation as the most influential technology of the 20th century and established the expectation of the continued influence of the industry as a leader in digital transformation because of the need for continued focus on safety, efficiency, and performance. The current panelists' view of S2 confirms the consideration of transformation for managing risk and enhancing safety (Morrow & Coplen, 2017).

The benefits of accelerating the integration of new transportation technologies in aviation mirrors the benefits discovered in other industries. For instance, Zhong et al. (2017) reported on elements of digital transformation leading to reduced design time, increased production efficiency, and improved service levels. The manufacturing industry proved the value of Industry 4.0 technologies for increasing speed, efficiency, and product customization (Chiarello et al., 2018). Meanwhile, Beckmerhagen et al.'s (2003) integrated approach suggested that safety pervades all aspects of organizational performance, including cost and achievement of performance goals to bring diverse business functions together around a common purpose in the nuclear industry.

Addressing similar concerns identified in the findings of the current study, specifically on the S2 strategy, Borangiu et al. (2019) highlighted the issue of certification to verify that systems do what they are supposed to do. Borangiu et al. paid particular attention to the certification of systems connected to integrating cloud computing and manufacturing equipment. Although the certification for aviation-related systems is currently more oriented to physical systems and people, the principles are the same and could be applied to the topic of certification in more advanced digital aviation systems.

Researchers have studied the integration of new transportation technologies and practices (Kistan et al., 2018; Nakamura & Kajikawa, 2018; Valdés et al., 2018). Visionaries have touted the value of accelerating the integration of new technologies (Elwell, 2018b; Stroup et al., 2019). However, research on how to accelerate integration was not found in my review of the literature. The panel members' views of S2 as the most important consideration for digital transformation in aviation highlights a need to extend the research on how to accelerate the integration of new digital technologies into the aviation system.

The expert panel ranked S1 as the 10th most important strategic statement on digital transformation in aviation. The panel viewed engaging with industry stakeholders early in the development cycle strategy as a key factor in improving safety. S1 is similar to S18 in the innovation category because both strategies reference early industry stakeholder involvement. The distinction with S1 is that it has strong confirmation in the literature because of the volume of safety research.

The inclusion of S1 in the final list of strategies confirms the lessons for leveraging stakeholders early in the technology development cycle as identified in the model established with the FAA's Next Generation of Aviation project (NextGen). According to Fleming et al. (2012), the transition of the National Airspace System from radar-based air traffic management to a satellite-based system of control was one of the most significant transformations in U.S. aviation history. It included multiple levels of digital transformation and early involvement from the stakeholder community. The NextGen implementation followed examples from implementing advanced manufacturing technologies (Chanias et al., 2019; Lasi et al., 2014; Rafael et al., 2014; Sebastian et al., 2017).

S1 references stakeholders in managing safety systems bolsters the premise of collaboration between industry and aviation regulators through open dialogue (Mills & Reiss, 2014; Nævestad et al., 2018). Accountability for safety resides with all entities in the system and it is stronger when all parties agree to the standards of performance ahead of any incident (Mills & Reiss, 2014). The expert panel's view on early stakeholder involvement with digital transformations geared toward improving safety validates Nævestad et al.'s (2018) premise that partnerships with stakeholders are needed to build a safety culture.

The expert panel's view of S2 and S1 confirms the literature on the criticality of using digital transformation to enhance safety in aviation (Fleming et al., 2012; Kistan et al., 2018; Mills & Reiss, 2014; Morrow & Coplen, 2017). Prior literature indicates the need to integrate new technologies into the aviation ecosystem (Nævestad et al., 2018; Nakamura & Kajikawa, 2018; Valdés et al., 2018). However, there is no published research to date that offers practical strategies for accelerating implementation. The ability to move faster toward implementation is as much of a challenge in the safety category as it is under the innovation category.

Infrastructure

The panelists viewed two strategies in the infrastructure category, S8 and S5, as the most desirable and feasible and ranked them in the 10 most important strategies. Taken together, the strategies represent two interdependent aspects of digital technology, with one focused on the network and ease of data flowing through it, the other centered on the value of the information in the network. Although infrastructure in the FAA Strategic Plan refers to the physical considerations of airports and aircraft manufacturing, it also includes information technology as reflected in these two strategies.

S8 is to develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations. The expert panel ranked S8 as the third most important strategic statement on digital transformation in aviation. The panelists' view marks an agreement that a modern information network supports and defines digital transformational efforts. This finding is aligned with the Internet of Things, big data, and cybersecurity as elements of the modern information and positions them as key factors in digital transformation, thus confirming prior research. Gubbi et al. (2013) wrote about the future when the vast amount of data moving through the network would present a new IT challenge. Big data was a key consideration for Industry 4.0 and digital transformation in aviation because the industry generates vast amounts of data that can be leveraged for greater system efficiency (Badea et al., 2018).

More recently, researchers defined Industry 4.0 as a digitally based network amplified by cloud computing, Internet of Things, Cyber-Physical Systems, big data, and artificial intelligence working together to deliver a wide variety of results (Y. Lu, 2017; Schwab & Davis, 2018; Siebel, 2019). IoT and CPS are the two primary components or the networked IT infrastructure. Together, these elements offer the platform to transfer data easily and securely in a usable format with the ability to transform existing tools and operations, as indicated in S8. However, as indicated in the data management consideration in S10 under the innovation category, data security remains a concern. The panelists' view of S8 confirms Urban's (2017) concerns about the cybersecurity risks in aviation, indicating that the industry's dependence on interconnected technologies makes it a target for cyber attackers.

S5 is to automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage, and encouraging third parties to provide value-added applications. The expert panel ranked S5 as the eighth most important strategic statement on digital transformation in aviation. The panel's views on S5 confirms the Adamik and Nowicki's (2018) research on key concepts for competitive advantage through the utilization of digital transformation indicating that Industry 4.0 is the means to blend the physical with the digital world through cyber-physical systems, robots, digitization, and a network economy operating in the spirit of the smart factory.

The inclusion of S5 in the final list of strategies also confirms the complication of managing big data in aviation to determine what information can be disseminated to third-party vendors to produce value-added applications. One underpinning aspect of S5 is the sheer volume of data generated in the aviation industry from the aircraft in flight to the ticketing systems and many other points throughout the system (Badea et al., 2018;

Vagdevi & Guruprasad, 2015). Mangortey et al. (2019) offered a conference paper that began to identify a way to parse aviation data to make it more accessible within the system and for third-party use. Pereira et al. (2021) represent a recent publication addressing greater usability for aviation-based data. However, the panel's views of S5 highlights the limited research to date on increasing the ease of aviation data for third-party usage for application outside the current systems (Mangortey et al., 2019; Pereira et al., 2021). Therefore, the panel's inclusion of S5 points to the need to extend the research to provide further perspectives on effective aviation data sharing with third parties.

Accountability

The panelists viewed two statements in the accountability category, S24 and S20, as the most desirable, most feasible, and ranked them in the 10 most important strategies. For the 2019–2022 FAA Strategic Plan (FAA, 2020b), human capital and the workforce fall under the accountability category.

S24 is to ensure the skills of the FAA workforce evolve as the technologies, operating models, and/or strategic priorities for the organization change. The expert panel ranked S24 as the second most important strategic statement on digital transformation in aviation. The panel's views of S24 confirm the literature on workforce evolution to meet the demands of digital transformation in aviation.

Murawski and Bick (2017) examined digital competencies of the workforce to understand how to build knowledge workers capable of working in the age of the fourth industrial revolution with services provided by drones, the Internet of Things, and robots. The research into building workforce capability to meet the emerging digital age is too limited, which leads to the detriment of the workforce vulnerable to poor employment opportunities and the technical world at risk for lack of human resources to manage it (Murawski & Bick, 2017). Murawski and Bick suggested that technical competencies must evolve with the pace of the advancements of the emerging technologies and therefore could never be stagnant, which the expert panel's inclusion of S24 confirmed.

Colbert et al. (2016) examined the changing digital competencies of the workforce in response to the impact of the fourth industrial revolution by exploring the concept of digital fluency. Colbert et al. deduced that digital fluency is creating a new generation of workers that are neurologically wired for advance function in the emergent digital age. Although Colbert et al. presented a more positive neurological perspective, the expert panel members' view of S24 confirms the need to build the knowledge workers need to keep up with the advances in aviation.

S20 is to ensure that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs. The expert panel ranked S20 as the seventh most important strategic statement on digital transformation in aviation. This finding expands the literature of a comprehensive approach to human capital management in response to digital transformation.

Kagermann et al. (2013) suggested that the role of employees would change significantly due to the redesign of production to real-time deliverables resulting from the IoT-connected process. The workforce competencies would shift to controlling the digital production commands through electronic means, which results in less hands-on interaction with the products. The criticality of training to produce a workforce composed of highly skilled technical experts while advocating for greater autonomy emerges from workforce investment and that training would serve as a motivational factor for employees (Kagermann et al., 2013). Kagermann et al. envisioned a transformational shift in the human-technology and human-environment interaction that would provide smart assistance through user-friendly interfaces, making work more interesting and pleasant. Although there are key considerations in Kagermann et al.'s perspective, the expert panel's views of S20 identified some missing aspects of a comprehensive human capital approach, such as succession planning and compensation systems.

Flores et al. (2019) expressed concern about the readiness of the workforce to meet the talent demands of Industry 4.0. Flores et al. acknowledged the lack of consideration for the requisite skills needed among the workforce of the future to program the next generation technologies and affectively adapt to the ways of work that would require advanced knowledge for functioning in a more digital society. The corresponding considerations for human capital 4.0 include new learning formats, location and time independence, individualized learning, globalization, skills sharing, and life-long learning. Flores et al. also suggested that organizational structure needed to shift to match the fluidity of the Industry 4.0 organization by allowing for a more adaptive, looser, and free-flowing approach to common organizational hierarchies. Similar to Kagermann et al. (2013), Flores et al. attempted to promote a comprehensive human capital approach. Hence, the expert panel's perspective regarding workforce readiness extends prior research.

In the accountability category, the expert panel viewed mature human capital practices among the top 10 most important strategies for digital transformation in aviation. The experts' inclusion of S24 confirms the concerns expressed in the literature regarding the lack of digital competencies of the workforce (Colbert et al., 2016; Murawski & Bick, 2017). The panel's views of S20 confirms the workforce implications of the future digital age (Flores et al., 2019; Kagermann et al., 2013). The factor of concurrence between the expert panel and these authors is that the workforce requires additional consideration to ensure readiness for the actual work involved in digital transformation.

The current study findings confirm the literature in such areas as the ability to facilitate and enable the development and deployment of innovative practices, the need to deploy technologies to improve safety, and the criticality of the networks along with the management of the information in them. The panel viewed the need to leverage human capital systems to prepare the workforce for the demands of digital transformation. The primary consideration from the expert panel that was not addressed in the literature was how to close the gaps in accelerating new technologies and prepare the workforce to handle the associated workload.

Limitations of the Study

Several limitations became apparent with the current study. First, the reworking of the strategic statements from Round 1 to Round 2 was a subjective process that could have been incumbered by researcher bias given my limited background in aviation. In the world of federal employment, 8 years in aviation is a relatively short period of time. To preserve the trustworthiness of the results, I used the language of the FAA Strategic Plan (FAA, 2020b) to guide the decision making for wording the statements. I also relied on my own understanding of the issues that emerged from my participation in long-range aviation planning activities.

Second, limitations pertaining to the aviation expertise on the panel could pose a problem. The panel experts could have provided input on areas that were not in their area of expertise. I did not verify the self-report of expertise. Additionally, bias among panel members could present a limitation. The panelists may have brought their own biases to the study based on their experience. Expert panelists could have used the study to promote a specific self-serving agenda (Hussler et al., 2011).

Third, if the panelists did not take the survey seriously, the accuracy of their responses might have been affected (Skulmoski et al., 2007). The expert panel members' willingness, honesty, and openness to participate presented a limitation. The job performance demands on FAA executives are intense: They may have found it difficult to devote the needed time to the study. Some participants may not have wanted to express concerns about the aviation system that could emerge from the study for concern over creating an undue influence on the industry, the flying public, or on their own jobs. Some panelists could have also feared reprisal from their peer participants for the expression of a point of view. The informed consent form helped to mitigate this limitation by stating that panelists would remain anonymous to one another; all results were reported in the aggregate and not attributed to individual panelists.

Fourth, other experts with vast knowledge of the content chose not to participate. Appropriate selection of the expert panel is a limitation for the Delphi technique (Vernon, 2009). The current study focused on the opinions of experts that met specific criteria and were agreeable to participate in the study. Positioning this research within the FAA and with the advocacy of the organizational leaders would have produced a different panel of experts with a different motivation to participate.

Fifth, the ability to replicate the findings of the study could be another limitation. Dependability refers to the stability of the results across various data collection activities (Cornick, 2006). The make-up of the panel would be different for another researcher in the future, which is likely to affect study results.

Sixth, the development and administration of the surveys could be another limitation of the study. The phrasing and ordering of the statements may have swayed the panelists’ opinions. Participant attrition was an issue throughout the four rounds, which began with 28 experts and concluded with 21 participants who completed Round 4. Time commitment may have been a factor in panelists’ decision not to participate in subsequent Rounds (Hsu & Sandford, 2007).

Seventh, the timeline extensions that were needed to keep the attrition rates as low as possible presented another limitation. The rigor of the doctoral process supported the transferability of the study so others could follow the exact steps of the project for replication by following an inquiry audit trail (Landeta, 2006; Skulmoski et al., 2007). Although the overall process followed the model of four rounds of data collection for a modified Delphi study, the extended time between the rounds would not be the expected practice for future studies.

Recommendations

Findings from the current study indicated that the expert panelists' views on the desirability, feasibility, and importance of forward-looking strategies for safely adopting digital transformation in aviation extended the knowledge in each of the four categories examined: Safety, innovation, infrastructure, and accountability. All the categories present areas for future research. The following recommendations extend the current body of knowledge on digital transformation in aviation as reflected in Chapter 2: Recommendations based on the conceptual framework, recommendations based on methodology, and recommendations based on findings.

Recommendations Based on the Conceptual Framework

The two major concepts that framed the current study were aviation safety and the fourth industrial revolution. Aviation leaders in the U.S. federal government face challenges in adopting technical evolution and advancing modernization efforts due to federal appropriations, human capital limitations, economic shifts, and safety culture (Chatfield & Reddick, 2019; Elwell, 2018a; Wallace et al., 2018). Advances in aviation technology enhance safety in the entire system, but introducing change presents risks (Song et al., 2014; Wallace et al., 2018).

The digital transformation that results from the fourth industrial revolution has accelerated the modernization of the aviation industry (Crouch, 2003; Schwab & Davis, 2018). Infrastructure modernization of aerospace-related technologies has placed pressure on safely managing the national airspace during this period of digital transformation (Song et al., 2014; Wallace et al., 2018). Despite the challenges, digital transformation is happening in aviation.

Based on findings in the safety category, the topic of accelerating the integration of new transportation technologies into transportation systems to improve safety, efficiency, and performance is suitable for further research. The concept of digital maturity explains organizational readiness to adopt digital transformation (A. Schumacher et al., 2016). An examination of the nine dimensions (strategy, leadership, products, customers, operations, culture, people, governance, and technology) can help organizational leaders to understand where barriers to the adoption of digital transformation exist. Although researchers could apply the digital maturity model to a federal agency, to date published research on digital maturity has focused on in the private sector (Zaoui & Souissi, 2020).

A recommendation for future research is to conduct a survey within the FAA using the digital maturity model (Babbie, 2017; A. Schumacher et al., 2016). The qualitative research would be administered with an FAA target population experienced in digital transformation efforts. The participants would rate the organization on 62 items for assessing Industry 4.0 maturity. The participants could rate their perception of the importance of each item to the organization on a 1- 4 scale. Zaoui and Souissi (2020) implied that all 62 elements are highly important (4) to the organization’s digital maturity. Median results below 4 would indicate a gap in the given aspect of digital transformation maturity. The results, presented in a graphical interface, would show maturity levels on each dimension. The real-time mapping of the organizational stance on digital maturity could provide leaders with the ability to action plan processes to advance the maturity in the dimensions with the most critical gaps. Action planning to reduce the gap areas leads to faster acceleration in digital transformation (Zaoui & Souissi, 2020).

A finding within the infrastructure category was to automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage and encouraging third parties to provide value-added applications. Organization ambidexterity is a new concept in understanding the Industry 4.0 ecosystem within an industry sector (Mahmood & Mubarik, 2020). The underpinning premise of organizational ambidexterity is that strength in the ability to experience success in digital transformation comes from a comprehensive set of capabilities that are shared in an industry segment which allows for the advancement of the segment as a whole. The four components of organizational ambidexterity are intellectual capital, human capital, structural capital, and relational capital. When the components are balanced in an organization focusing on innovation and areas of advancing market opportunities, they transform organizations and the whole industry segment (Mahmood & Mubarik, 2020).

A recommendation for future research is to conduct a survey of information technology professionals in the aviation industry using the Organizational Ambidexterity Questionnaire (Mahmood & Mubarik, 2020). The target population derive from purposive and snowball sampling of IT professionals in public and private organizations within the aviation sector. The panelists would rate the 44 items pertaining to organizational ambidexterity using a 5-point Likert-type scale corresponding to the level of occurrence in the organization (1-strongly disagree to 5-strongly agree). The elements of structural capital and relational capital would show the ability to achieve data sharing in the aviation sector.

Recommendations Based on Methodology

Based on the findings of this study, the topic of preparing the workforce for the fourth industrial revolution is a top 10 strategy. The need for preparation ranges from building the skill base in the workforce to the construction of human capital systems that reward, recognize, and succession plan for digital skill execution to both create the advanced systems and function within them. One of the challenges with this finding is the limited amount of research on this topic in the aviation sector. Forward-looking approaches to workforce preparation can help to set the supportive trajectory on workforce readiness.

A recommendation for future research is to conduct a Delphi study in aviation manufacturing on the most desirable, feasible, and important strategies for delivering human capital management in the age of Industry 4.0 while accomplishing the safety mission. The first round of data collection would be open-ended survey about the main considerations for human capital planning including training and skill development, strategic workforce planning, delivering organizational change, leadership development, succession planning, performance management, and Total Rewards programs. In the second round, the experts would rate the strategies for feasibility and desirability. The experts would rank the top 10 strategies in the third round and then rate their confidence in the results in the fourth round. The final set of strategies could be considered for application with the FAA strategic human capital plan.

Recommendations Based on Findings

A finding in the innovation category that was not reflected in the literature to date included supporting the development and deployment of innovative technologies by partnering with industry and other stakeholders. The National Science Foundation is a federal government organization that has published success in accelerating innovation by promoting partnerships between academic research and industry (Johnson, 2018).

A research recommendation is to conduct a case study of the National Science Foundation’s Innovation Through Partnerships project. Case study is an appropriate research methodology when there is a need for flexibility to determine the unit of study to be examined (M. Q. Patton, 2015). The units of analysis for the case study would be organizational documents that show the setup and execution of the partnership projects since these would be the most valuable results at the conclusion of the study. Specific documents that could be included would be the strategic documents identifying the need to establish the partnership, the internal tracking document that shows the determination of which organizations to establish partnerships with, ways the organization strategized to ensure there would be no conflict of interest between the NSF and the partnering organization and communications with the partner organizations. The results of the case study could provide the FAA with a roadmap for enhancing public-private partnerships in aviation.

Recommendations Based on Strategies Excluded Due to Low Feasibility

Five strategic statements in Round 2 had a high level of agreement (over 90%) on ratings of desirability but low agreement (under 60%) on feasibility. Thus, these strategies did not advance to the Round 3 selection and ranking of strategies for importance despite their high desirability in the panels' view. In this section, I address indications of support from the literature review and suggestions for the nature of future aviation research on these strategies. Two of these strategies were in the safety category and three were in the innovation category.

Within the safety category, a highly desirable but not feasible strategy was to increase sharing of harmonized and secure data with all aviation system stakeholders, domestic and international, through the joint development of an integrated safety assessment model. Ibánez et al. (2016) offered the Integrated Safety Assessment (ISA) method as one of the most contemporary approaches to safety management. ISA follows the dynamic event tree as a framework using data to predict times when a safety limit would likely to be exceeded. Although the ISA was developed for the nuclear industry, it has applications in aviation. The fundamental principle with ISA is in risk-based decision making with an ability to perform projections based on uncertainly analysis. The model supports a calculation of safety limits and a prediction of events exceeding the frequency of that limit. The ISA uses big data and advanced analytics to create a warning system for safety challenges that go beyond the capabilities of less automated safety systems. This field is a promising link between the capabilities of Industry 4.0 technologies and the advancement of safety management; thus, it warrants further study.

Another highly desirable but not feasible strategy in the safety category was to safely integrate commercial space transportation launch and reentry activities, and increasingly complex operations, into the NAS. Davidian (2017) discussed a Center of Excellence (COE) program established by the FAA Office of Commercial Space with a mission to research the critical components of air space management. The FAA uses a unique authority to support research at colleges and universities that focus on supporting sections of aviation. Davidian wrote about the COE work in the following key research areas for commercial space: Space traffic management and spaceport operations, space vehicles, human spaceflight, and space transportation industry viability. Although there was no formal link between the COE and the FAA Strategic Plan (FAA, 2020b), the topics that require further research in commercial space are fully aligned.

Within the innovation category, a highly desirable but not feasible strategy was to develop improved cybersecurity capabilities in coordination with interagency, industry, and international stakeholders. Chatfield and Reddick (2019) reviewed the cybersecurity issue through a literature review and case study focused on a use case in the U.S. federal government and conducted a content analysis of government websites involving IoT technology assessment, the IoT use cases, and IoT cybersecurity policies in four domains: Transportation, energy, smart cities, and defense. Although Chatfield and Reddick suggested that the U.S. government needs to do more, they reported strength in the U.S. Department of Transportation. According to Chatfield and Reddick, transportation systems have control points and consumer access that augments the pathway for digital transformation. In addition, the U.S. Department of Transportation (2020) website contained robust information on cybersecurity. Despite these positive reviews, Chatfield and Reddick also expressed concern as the United States ranked 14th in a worldwide listing of a cybersecurity vulnerability index. Cybersecurity remains a top concern for aviation experts and a panel member commented on the lack of a cybersecurity element in the top 10 strategies. Research in this area will continue to emerge.

The innovation category included the highly desirable but not feasible strategy to ensure enterprise capabilities enable the rapid development of data management platforms, applications, and technologies. Mangortey et al. (2019) presented a paper at the Sci-Tech aviation industry meeting that captured the essence of the big data landscape for aviation. Conferences offer opportunities for advanced concepts in an industry to be presented. Papers at the Sci-Tech conference are not peer-reviewed (AIAA Sci-Tech Forum and Exposition, 2019); however, Mangortey et al.'s paper is influential because it provides a comparable insight into the future of aviation that emerges from the FAA Strategic Plan (FAA, 2020b). Mangortey et al. specified the technical data sources in aviation to include system-wide information management, flight publication data, and traffic flow systems. Data retrieval, parsing, and fusion are the next wave of aviation big-data management likely to inform a powerful aviation prediction model (Mangortey et al., 2019). The current study findings support Mangortey et al.'s claim that the aviation industry is on the cusp of transformation on the use of advanced data management in support of more effective and efficient aerospace operations, underscoring the need for more research.

Another highly desirable but not feasible strategy in the innovation category was to seek, discover, and accelerate the adoption of advanced analytical methods, machine learning, and artificial intelligence to bring innovative solutions. Big data refers to the volume, variety, and velocity of information assets that require advanced technologies to capture, store, and distribute information needed for achieving organizational goals (Gandomi & Haider, 2015; I. Lee, 2017). Big data was a key consideration for Industry 4.0 and digital transformation in aviation because the industry generates vast amounts of data that can be leveraged to create greater efficiencies in the overall system (Badea et al., 2018). To achieve artificial intelligence, big data relies on data analytics, quantum computing, and machine learning. As indicated above, the Industry 4.0 technologies are just beginning and as more comfort with the technologies emerges, the study of them will grow.

Although these five strategies did not advance to Round 3 of the current study because of a perceived lack of feasibility, they warrant consideration because of the expert panel's high rating of their desirability, coupled with support from the literature. Future research could address barriers to the feasibility of implementing each of these highly desirable strategies. Technological, policy, and other changes may reduce or eliminate barriers to the feasibility of implementing these strategies in the future.

Implications

The 10 forward-looking strategies the expert panelists viewed as having the highest desirability, feasibility, and importance for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation can contribute to positive social change, the practice of managing digital transformation in aviation, and the conceptual frameworks. The recommended strategies identified in this study can influence approaches to enable the development and deployment of innovative practices and technologies, address regulatory barriers, encourage partnering with stakeholders, and increase the efficiency and security of data transmission, collection, and analysis. The recommendations in safety and infrastructure offer perspectives on accelerating implementation and fostering partnerships focused on understanding the transformational opportunities early and moving them through to operational application faster. Similarly, the recommendations in the accountability category call attention to the human capital considerations with digital transformation.

The NAS is a complex, dynamic, and risk intolerant environment (Song et al., 2014; Troung et al., 2018). The FAA's mission is to provide the safest, most efficient aviation system possible for the American public and to deliver the gold standard for safety in the world (FAA, 2020b). Transportation of the future requires a capacity to balance the safety mission with the fast-moving transformative technologies that will bring about new ways to travel (Dickson, 2020).

Implications for Positive Social Change

The current study revealed the most desirable, feasible, and important forward-looking strategies for safely integrating new technologies in the NAS. Implementation of these strategies could increase efficiency and maintain the safety standards essential in aviation. Application of the findings can inform future strategic planning that helps leaders to usher in the next generation of aviation designed to overcome current limitations of aviation-based transportation systems.

In government operations, strategy and policy are interdependent. Changes to strategy create changes in policy and vice versa. The findings of the current study support the contention that prioritization for digital transformation strategy can influence policy. Changes in federal aviation policy affect the entire aviation system. Aviation is one of the most impactful innovations in the 20th century (Crouch, 2003). Modernization is transforming aviation and that, in turn, influences society (Crouch, 2003; Rhoades, 2015).

Schwab and Davis (2018) pointed to the fragile state of society with rising inequality, increases in vulnerable populations, and constant harm to the natural environment. Representing the World Economic Forum, Schwab and Davis suggested that the radical shifts that will emerge from Industry 4.0 present a force for good. Thought leaders in digital transformation are still determining the path forward, so now is the time to promote application for the betterment of humanity.

A case in point is the SpaceX Starlink project with the mission to deploy a mega satellite constellation to deliver broadband services to over 50% of the world’s population that is currently without connectivity. Full global coverage of an accessible telecommunication network enables economic development, social development, and environmental protection (Wiltshire et al., 2016). The use of new digital technologies in aviation delivers accessible digital transformation tools to underserved populations and, therefore, creates game-changing equalization of access to services.

Influencers have the opportunity to shape the fourth industrial revolution to enhance human dignity creating benefits for all, not just the privileged few. Digital transformation can improve life for individuals, communities, organizations, and governments (Schwab & Davis, 2018). Mixed reality, quantum computing, and big data are technologies that can alter society at every level. The findings of this study offer a set of recommendations that can promote the safe adoption of digital transformation in aviation that can transform a large-scale and complex industry that transforms society.

Implications for Practice

Air transportation serves as a backbone for integrated international economic prosperity (O'Connell & Williams, 2015). From the safety of travelers and the workforce to the economic impacts of aviation to environmental protection, the relevance of aviation exists even for people who do not fly (Materna et al., 2015). A system that can grow and modernize with the latest technological advances has far-reaching societal influences (Rhoades, 2015).

On an individual level, digital transformation in aviation could save lives with drone-based package delivery that moves organ donations from hospital to hospital faster than the more traditional means of transportation (Valdés et al., 2018). On a worldwide scale, the economic vitality of the aviation industry translates to global economic opportunities through aviation, travel, and tourism (Weinelt & Moavenzadeh, 2017). The elements of a digital transformation strategy that emerge from the current study findings have the potential to be an underpinning driver for the far-reaching impact of the aviation industry.

On a practical level for the FAA Strategic Plan (FAA, 2020b), the ability to scour through it to mine the topic of digital transformation provided a unique perspective for a process to review the plan. The construction of the plan involves outreach to various entities that are responsible for a given aspect of the plan. The commercial space experts are asked to write the section related to commercial space and the human capital experts are asked to write the section about the workforce. The ability to look through all the contributors' work and pull-out content on a specific topic of digital transformation allows for an opportunity to focus the plan on a key driver for the future of aviation. The ability to look at the whole plan through a digital transformation lens creates the opportunity to consider how key considerations in the plan can lead to advances in social change. A public-private partnership in support of the EVTOL electric aircraft can create greater access for people to commute to jobs outside the limits of underserved communities. That access can support changes to individual economic stability and organizational talent needs.

Implications for the Conceptual Framework

The concepts that provide the framework for this study were digital transformation and safety. New technologies offered by digital transformation or Industry 4.1 prompt greater efficiencies and increased capability for improving safety (Schwab & Davis, 2018). Those technologies could also wholly transform aviation by providing people with new, more cost-effective, and energy-efficient ways to travel (Pradeep & Wei, 2018). E. M. Rogers' (2003) theory on the diffusion of innovation explains how adopting new ways of doing things follows a predictable curve from early adopters through the masses to the late adopters. The findings from the expert panel in the current study suggest that the diffusion of innovation needs to happen faster at the regulatory level to spur the implementation driven by the marketplace.

Schwab and Davis (2018) advocated that digital transformation is disruptively upending society today, much like how electricity fundamentally changed the way people live. The Industry 4.0 technologies will change many of the systems prevalent today, creating new ways to produce and transport goods and services that impact people's use of transportation systems. D. L. Rogers (2016) offered a roadmap to help organizational leaders navigate the digital transformation process. The societal shift emerging from digital transformation is new. The findings from the current study highlight the ways that disruptive technologies apply to the strategic perspective for the high-risk and highly complex aviation industry.

Schein's (2017) organizational culture theory described the concept of cultural DNA, which evolves from shared learning around beliefs, values, and desired behaviors intended to lead to success. As a group has repeated accomplishments based on a common set of norms, the cultural DNA or the shared behaviors become more deeply embedded. In simple terms, organizational culture is the way things are done in the workplace (Schein, 2017). Safety culture arose from the more specific concepts of safety policy, organizational embeddedness, managerial action, and staff engagement at all levels for the benefit of the individual and the organization (Guldenmund, 2000). The point of a safety culture is to influence the way things are done in the workplace to keep people safe.

The juxtaposition of implementing Industry 4.0 in a high-risk sector is the crux of the complication for safety adopting digital transformation in aviation. The research shows that the fourth industrial revolution is here to stay and it will affect the world, including aviation (Badea et al., 2018; Murawski & Bick, 2017; Schwab & Davis, 2018). The findings from the current study indicate that there are 10 desirable, feasible, and important strategies for progressing forward in combining the advances of digital transformation while adhering to the rigorous safety standards in aviation.

Conclusion

The social problem was that aviation leaders in the U.S. federal government face challenges in adopting technical evolution and advancing modernization efforts due to federal appropriations, human capital limitations, economic shifts, and safety culture (Chatfield & Reddick, 2019; Elwell, 2018a; Wallace et al., 2018). The leaders in the aviation marketplace strive for profitability. Government regulators require compliance with rulesets to ensure safety and may lag behind the pace of digital transformation that underpins the demand for profitability (Dwivedi et al., 2017; Mills et al., 2018). The specific problem was the difficulty of adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation (Fleming & Levenson, 2016; National Research Council, 2014).

Leaders implementing digital transformation in aviation face challenges in the aviation safety culture. The strategies that emerged in the current study are important to the future of aviation given the marketplace and political demands of embracing new technologies. Aviation leaders can benefit from this study by understanding the most desirable, feasible, and important strategies for digital transformation and investing in them to support the emergence of technologies that will ultimately positively affect safety.

The implementation of forward-looking strategies identified in the study could help to usher in the next generation of advances in commercial space applications-making access to the internet easier for underserved communities, drone delivery services-facilitating life-saving organ donation transport, or EVTOL aircraft implementation-providing access to jobs through faster transportation systems through densely populated cities. The applications for digital transformation in aviation have the potential to propel societal advances in transportation that changes lives.

The Wright Brothers created the innovation in flight that changed the world. Now the aviation industry is experiencing breakthroughs that remind aviation leaders of that first flight on the dunes of Kitty Hawk, North Carolina. Early aviation pioneers changed the world and the same is true for the aviation innovators of today. The knowledge gained from decades of experience in ensuring safe flight informs the strategies for adopting the digitally transformed future of aviation.

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Appendix A: Demographic Questions and FAA Strategic Plan Statements

Demographic Questions

1. How many years of experience do you have at the director or above level in government aviation management?
    - a. 0 to 3
    - b. 4 to 10
    - c. 11 to 20
    - d. 21 to 30
    - e. 31 or more
2. What is your area of functional expertise?
    - a. NAS Infrastructure
    - b. Smart Systems
    - c. Certification and Regulation
    - d. NAS Operational Information Exchange
    - e. Cybersecurity
    - f. Space Operations
    - g. Workforce
3. How many years of experience have you had in your functional area?
    - a. a. 0 to 3
    - b. b. 4 to 10
    - c. c. 11 to 20
    - d. d. 21 to 30

e. 31 or more

FAA Strategic Plan Statements

Please review each statement that emerged from the FAA Strategic Plan (FAA, 2020b). You may adjust any statements to update wording, combine or separate statements to add greater clarity for their meaning, and/or identify any statements that can be eliminated because they are redundant or no longer relevant. Please add any new statements that might have been overlooked in the plan. Use the space provided to explain suggested changes.

1. Employ algorithms and artificial intelligence to manage and utilize the data collected as data analysis technologies advance.
2. Improve access to and quality of FAA data assets.
3. Leverage aviation data application evolution and integration with the Internet of Things.
4. Use the advances in data automation to increase the efficiency and security of methods of data transmission, collection, and analysis.
5. Develop measure to enhance safety enabling technologies and analytical capabilities while also ensuring the security of data and its use.
6. Collaborate with data stewardship communities of practice (SCOP) to baseline and catalog existing data assets.
7. Identify data gaps, develop a roadmap and plan of action to address shortfalls to improve data integrity.

8. Provide enterprise capabilities to enable rapid development of data management platforms and technologies.
9. Increase sharing of harmonized and secure data across all stakeholders to include industry and international partners through joint development of a quantified Integrated Safety Assessment Model with FAA, other DOT modes, NASA, and Eurocontrol.
10. Automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage.
11. Leverage new technologies to increase the amount of data shared with stakeholders in a more cost-effective way.
12. Use data to develop and execute clear plans to prepare for weather events and other disruptions, and use operational forecasting, shared with operators.
13. Minimize the volume and length of time airspace is restricted by integrating real-time spaceflight data into the NAS management structure, reducing time to fuel costs to users.
14. Deploy tools to provide automated assessment by scoring proposed launch sites and launch vehicle types/missions, analyzing data across a host of air and ground safety hazards.
15. Leverage advance in the collection and wireless transmission of digital data to improve utilization of the radio spectrum.
16. Improve the radio spectrum and make it available for shared or non-federal use by consolidating surveillance radars.

17. Complete assessment of the evolution of the spectrum market and estimate values for spectrum bands and scenarios of interest.
18. Improve our own utilization of radio spectrum, and make it available for shared use through means such as consolidating surveillance radars.
19. Develop improved cybersecurity capabilities for secure collection, transmission, management and analysis of data in coordination in interagency, industry and international stakeholders.
20. Leverage advance in the collection and wireless transmission of digital data to improve enhance cybersecurity.
21. Sustain and improve cybersecurity in the aviation ecosystem through relationship with external, partners in government and industry.
22. Reduce aviation critical infrastructure risk by adopting the National Institute of Standards and Technology Cybersecurity Framework.
23. Promote FAA cyber community engagement with public sector, intelligence community, private sector and international partners.
24. Streamline the certification process for industry and reiterate the importance of a safety culture through all phases of the process to include engaging industry early with the introduction of new technologies.
25. Take steps to provide a regulatory framework that will facilitate the development and certification of new supersonic airplanes.

26. Maintain and modernize the physical, technical, and human infrastructure that enable flexibility in the air and space transportation systems to respond to shifting needs.
27. Advance the integration of new transportation technologies and practices into transportation systems to improve safety and performance.
28. Lead the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's aviation system.
29. Create a dedicated cross-agency effort dedicate to new entrant and innovation office.
30. Accelerate and expand the deployment of new technologies and practices by reducing barriers to innovation and actively promoting innovation that enhance the safety and performance of the Nation's transportation system.
31. Accelerate adoption of transformational technologies to enhance innovation.
32. Work with stakeholders to identify emerging technologies, opportunities, and gaps.
33. Leverage complementary research performed by partners in industry, academia, international consortiums.
34. Accelerate adoption of advance analytical methods, machine learning, and artificial intelligence to bring innovative solutions to business problems.
35. Support the development and deployment of innovation technologies by investing in targeted research, facilitating coordination and information sharing, partnering with industry and other stakeholders, assessing existing regulatory approaches to

address potential barriers and provide opportunities to expedite the and adoption of beneficial technologies.

36. Streamline regulatory processes to improve government efficiently and reduce impediments to innovation, project delivery, and program implementation.
37. Leverage the research landscapes with in the aviation and the broader research and development community.
38. Develop a comprehensive view of the research and development required to support a vibrant aviation sector.
39. Focus on research and development in improving the safety and performance of airport infrastructure and operations, air traffic, and airspace management capabilities.
40. Develop a comprehensive research plan for the integration of new entrants into the NAS.
41. Invest in people processes, and technologies to improve integration of commercial space into the National Airspace System, minimizing the impact on other NAS users and increasing overall system efficiency.
42. Engage with internal and external commercial space transportation stakeholders to develop, assess and recommend appropriate processes, procedures and infrastructure to integrate commercial space transportation with the NAS.
43. Safely integrate Commercial Space Transportation launch and reentry activities, as well as increasingly more complex UAS operation, into the NAS.

44. Promote public/private partnerships to foster and develop world-leading Commercial Space Transportation infrastructure.
45. Develop tools and processes to continue improvements in the integration of UAS and commercial space operations in the NAS, in partnership with other government agencies and industry.
46. Implement the FAA's Concept of Operation for integrating Commercial Space Operations Integration into the NAS.
47. Develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations to meet unique requirements in support of space operations mission planning and efficient NAS integration.
48. Focus on continuous improvement of safety oversight capabilities in countries or regions with strategic importance, as well as underserved rural areas.
49. Install NextGen Distance Measuring Equipment (DME), in addition to very High-Frequency Omni-directional Range (VOR) Minimum Operation Network (MON), to enhance infrastructure resiliency of Performance-Based Navigation (PBN) operations during Global Positioning System (GPS) outages.
50. Decommission legacy infrastructure to reduce rental as well as operational and maintenance costs.
51. Streamline public instrument flight procedures by cancelling those no longer needed as of cost savings.

52. Reduce errors in delivering precise route on both the ground and in the air, as well as sharing surface safety information between air traffic controllers and pilots by using digital communications.
53. Promote policies that will ensure multimodal infrastructure connectivity, while increasing foreign market access and opportunities for American business, services and the U.S. workforce.
54. Complete the integration of over 600 ADS-B ground stations into air traffic separation services and continue to promote the January 1, 202 ADS-B Out mandate for operations in rule airspace
55. Increase access, capacity and safety at airports by verifying remote towers.
56. Applying a portfolio-based approach to reducing regulatory burdens by developing an annual rulemaking plan that considers future years and potential cost savings.
57. Promoting performance-based regulation, which provide additional flexibilities to regulated entities and avoid “one-size fits-all” approaches.
58. Identify and implement processes to address strategic rulemaking objectives, such as Unmanned Aircraft Systems, commercial space, and supersonic flight.
59. Ensuring that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs.
60. Improving processes, systems and structures to enhance human resources services delivery.

61. Promote internship opportunities; develop partnerships with academia, industry and government stakeholders, as well as further programming for science, technology, engineering and math (STEM), and aviation and space (AVSED) programs.
62. Aligning FAA's internal organizations to maximize efforts toward workforce development, cyber, shared services ideals, and overall philosophy.
63. Ensure the skills of the FAA workforce evolve as the technologies, operating models and or strategic priorities for the organization change.
64. Implementing solutions that are integrated with other DOT modal systems and processes.

Appendix B: Field Test Request

Hello,

I am Melissa King, a doctoral student pursuing a PhD degree in Management and Technology at Walden University. For my doctoral dissertation, I am employing a qualitative methodology using a modified Delphi research design to determine how a panel of aerospace experts based in Washington, DC view the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. I am seeking your support for providing feedback as to the appropriateness and phrasing of the questions being asked of the study participants in relation to the purpose of the study.

The proposed study addresses the following primary research question and subquestions: How does a panel of aviation experts view the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 1: How does a panel of aviation experts view the desirability of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 2: How does a panel of aviation experts view the feasibility of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

Subquestion 3: How does a panel of aviation experts view the importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation?

The study will involve four iterative rounds of data collection and analysis. In Round 1, panelists will be asked to edit any statements as needed. In Round 2, the panelists will rate the items from Round 1 for desirability and feasibility. In Round 3, they will select and rank the importance of the top 10 items that meet the cutoff for desirability and feasibility. In Round 4, they will rate their confidence in the results. After reviewing the research questions, and the statements for the Round 1 survey, please respond to these four field test questions:

1. Based upon the purpose of the study and research questions, are the statements on the survey likely to generate information to answer the research question?

2. Are the participants likely to find any of the questions on the questionnaire (the nature of the question or specific wording) objectionable? If so, why? What changes would you recommend?

3. Were any of the items on the survey difficult to comprehend? If so, why? What changes would you recommend?

4. Feel free to provide any additional thoughts about the questionnaire, which were not covered in questions 1 through 3, above.

For your review, the Round 1 survey is attached. Should you choose to participate in this field test, please do not answer the survey questions intended for the study participants.

Thank you in advance for your time.

Respectfully,

Melissa King

Appendix C: Invitation to Participate in the Study

(Sent to the prospective participant's government email)

Dear _________:

My name is Melissa King, and I am a doctoral candidate in Management and Technology at Walden University. For my dissertation, I am studying how a panel of aerospace experts views the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation.

You have been identified as an aerospace expert by your participation in FAA strategic planning processes, and I am asking for your assistance in completing a series of online questionnaires that focus on future-oriented strategies for aviation identified in the FAA Strategic Plan 2019-2022. The criteria for participation in this study is previous participation in FAA strategic planning processes with at least three years at the director or above level in government aviation management and functional expertise, demonstrated by greater than 10 years of experience in any of the following areas: National airspace infrastructure, IT/smart systems, certification and regulation, aviation safety, national airspace management, cybersecurity, space operations, and/or workforce. If you are considered my subordinate in any way, you are not eligible to participate in this study.

Since this is not an FAA sponsored research project, our communication must occur through a nongovernment email address and on nongovernment time. The invitations for these surveys will be delivered to your nongovernment email address via

SurveyMonkey in four rounds of data collection distributed over approximately 8-10 weeks with 2-3 weeks between survey rounds. The surveys will take 15–30 minutes to complete for Rounds 1–3 and 5-15 minutes for Round 4. Your responses will be kept confidential and the results will be reported in the aggregate only. Panelists will be anonymous to one another. Participation in this study is voluntary.

The FAA has no obligation to use the results of this study for any official agency action. While you may know me from my former role as Chief Learning Officer at the FAA, I am conducting this study as a doctoral student, not as a government employee. My current role as Director of the Office of Innovation and Engagement at the Department of Transportation does not influence this research project or the selection of potential participants. If you are considered my subordinate in any way, you are not eligible to participate in this study.

If you think you might like to participate, reply to this email or send your reply to my email address stating your interest. Please include a nongovernment email address that I can use to send you the Round 1 invitation.

I am available by email or phone to answer any of your questions. I deeply appreciate your willingness to participate in this research project.

Sincerely,

Melissa King

Ph.D. Candidate

Walden University

Appendix D: Invitation to Participate in Round 1

(Sent to the panel member's nongovernment email)

Dear Panel Member,

Thank you for providing your nongovernment email address in response to the invitation to participate in this study. The purpose of this study is to explore how a panel of aerospace experts views the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. The criteria for participation include previous participation in FAA strategic planning processes with at least 3 years at the director or above level in government aviation management and functional expertise, demonstrated by greater than 10 years of experience in any of the following areas: National airspace infrastructure, IT/smart systems, certification and regulation, aviation safety, national airspace management, cybersecurity, space operations, and/or workforce.

This is your invitation to participate in the Round 1 survey, which will take between 15–30 minutes to complete. The link on SurveyMonkey will load an informed consent document for your review. You can reach the survey at the following link: URL

You have 10 days to complete the survey; please submit your survey by ____________. You can reach me at my email address or phone number with any questions. I appreciate your time and contributions to this study.

Warmest Regards,

Melissa King

This was the information panel members saw when they opened the Survey Monkey link for Round 1.

[Participant Name]:

Thank you for your interest in this study. My name is Melissa King and I am currently a student at Walden University pursuing a doctoral degree in management and technology. I am the person conducting this research. The purpose of this study is to explore how a panel of aerospace experts views the desirability, feasibility, and importance of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation.

The criteria for participation in this study is previous participation in FAA strategic planning processes with at least three years at the director or above level in government aviation management and functional expertise, demonstrated by greater than 10 years of experience in any of the following areas: National airspace infrastructure, IT/smart systems, certification and regulation, aviation safety, national airspace management, cybersecurity, space operations, and/or workforce. If you are considered my subordinate in any way, you are not eligible to participate in this study.

Following agreement to the terms of consent, you will be asked a question pertaining to the selection criteria. Only persons who meet the selection criteria will be able to access the survey. I am seeking a Round 1 panel of 33 participants.

The following information describes the parameters of participation as part of this process of informed consent. If you agree to the terms of consent for participation in the study after reading the informed consent information, please click on “Agree” to proceed to the survey questions.

Background

The panel of experts will review a set of statements regarding digital transformation and provide feedback on them via four iterative rounds of online questionnaires.

Disclosure

While you may know me from my former role as Chief Learning Officer at the FAA, I am conducting this study as a doctoral student, not as a government employee. The FAA has no obligation to use the results of this study for any official agency action. My current role as Director of the Office of Innovation and Engagement at the Department of Transportation does not influence this research project or the selection of potential participants. If you are considered my subordinate in any way, you are not eligible to participate in this study.

Since this is not an FAA sponsored research project, our communication must occur through a nongovernment email address and on nongovernment time. You will be asked to provide your nongovernment email address throughout the process to ensure that I send each invitation to the appropriate address.

Procedure

The following steps outline the process. Participation involves four rounds of data collection with surveys distributed at 2–3-week intervals over an 8–10-week duration. Participants will have 10 days to respond to the survey, and the researcher will have 1–2 weeks to analyze the results to prepare for the next round of data collection. The surveys will take 15–30 minutes to complete for Rounds 1–3 and 5–15 minutes for Round 4. The following actions will occur in each round:

Round 1–You will be asked to review the 64 items mined from the FAA Strategic Plan 2019-2022, adjust any statements to update wording, combine or separate statements to add greater clarity for their meaning, and/or identify any statements that can be eliminated because they are redundant or no longer relevant. You can add any new statements that might not have been included in the plan. Please explain any changes recommended. You will also be asked to answer three demographic questions on years of experience at the director or above level in government aviation management (range), area of functional expertise, and years of experience in that functional area (range).

Round 2–You will be presented with the list of items from Round 1 that are revised based on the panelist input. You will be asked to rate each item twice, first for desirability and second for feasibility. Space will be provided for any narrative input you would like to provide.

Round 3–The results from Round 2 will yield a listing of the most desirable and feasible items. Items meeting threshold criteria will advance to Round 3. You will be asked select the top 10 most important items and rank them from 1–10 in order of importance.

Round 4–The results from Round 3 will indicate the most important items by rank and you will be asked to rate your confidence in the final prioritized list of items.

Your responses to the survey will be anonymous to the other participants. The results will be reported in the aggregate only. Any comments provided by a participant will be summarized and not attributed to any individual panelists.

Voluntary Nature of the Study

Participation in this study is voluntary. You are free to stop your participation in the study at any time without penalty by not completing or submitting the current survey or not responding to the invitation to participate in subsequent rounds.

Risks and Benefits of Participation

There is minimal risk for participating in this study. This risk does not exceed the level of risk you may encounter during normal daily activity or in routine completion of surveys. There are no direct benefits, but you will be contributing to the body of knowledge on safely integrating digital transformation in the national airspace. Digital transformation in aviation has the potential to be a force for good. You may also gain a benefit from seeing how this Delphi technique can be applied to collecting feedback on forward-looking strategies.

Payment

No compensation will be offered to participants.

Privacy and Confidentiality

All information collected in this study is held in confidence by the researcher and only accessible to my research supervisors at Walden University. I will not use your information for any purpose outside this study. Your privacy and the confidentiality of your responses will be protected. Panelists will be anonymous to one another but not to the researcher. The only identifiable information to be collected on the surveys is a nongovernmental email address, which will be stripped from the submitted survey responses and used only to invite you to the next round of the study. Research data will be kept in a password-secure folder on my computer and all research data will be destroyed 5 years after the conclusion of the study per university standards.

Contact and Questions

Information regarding this research is filed with Walden University Institutional Review Board (IRB). Walden University's approval number for this study is 01-07-21-0102818 and it expires on January 6, 2022. If you want to talk privately about your rights as a participant or any negative parts of the study, you can contact Walden University's Research Participant Advocate, IRB administrator at the Walden University Institutional Review Board (IRB) by email at irb@mail.waldenu.edu or by phone at (612) 312-1210.

If you should need to contact me at any point during the research study, I can be reached via email by phone. You might wish to retain this consent form for your records. You may ask me or Walden University for a copy at any time using the contact information above.

Consent to Participate

If you feel you understand the study well enough to make a decision about your involvement and wish to volunteer, please indicate your consent by clicking the "Agree" button below.

o I Agree with the Terms of Consent

o I do not Agree with the Terms of Consent

If you click “Agree” you will proceed to the Round 1 screening question. If you click “Do Not Agree” you will exit the study and will not receive invitations to future survey rounds. The exit message states, “Thank you for your interest in this study.”

Appendix E: Round 1 Modifications for Round 2 Statements

Round 1 Statement	Round 2 Statement
1. Employ algorithms and artificial intelligence to manage and utilize the data collected as data analysis technologies advance.	S1. Employ artificial intelligence to improve effective decision making and enhance performance of core aviation management functions.
2. Improve access to and quality of FAA data assets.	S2. Improve quality of data and data management to enhance stakeholders' ability to utilize data.
3. Leverage aviation data application evolution and integration with the Internet of Things.	S3. Integrate aviation data with the Internet of Things to allow greater access on demand.
4. Use the advances in data automation to increase the efficiency and security of methods of data transmission, collection, and analysis.	S4. Use the advances in data management capabilities to increase the efficiency and security of data transmission, collection, and analysis.
5. Develop measures to enhance safety enabling technologies and analytical capabilities while also ensuring the security of data and its use.	S5. Improve safety-enabling technologies and analytics, while protecting data security.
6. Collaborate with data Stewardship Communities of Practice (SCOP) to baseline and catalog existing data assets.	S6. Work closely with experts in each field to be sure everyone knows which organizations have different types of data and create easier pathways to share that information.
7. Identify data gaps, develop a roadmap, and plan of action to address shortfalls to improve data integrity.	S7. Identify data gaps, develop a roadmap, and plan of action to address shortfalls to improve data quality and integrity
8. Provide enterprise capabilities to enable rapid development of data management platforms and technologies	S8. Ensure enterprise capabilities enable rapid development of data management platforms, applications, and technologies.
9. Increase sharing of harmonized and secure data across all stakeholders to include industry and international partners through joint development of a quantified Integrated Safety Assessment Model with FAA, other DOT modes, NASA, and Eurocontrol.	S9. Increase sharing of harmonized and secure data with all aviation system stakeholders, domestic and international, through joint development of an Integrated Safety Assessment Model

10. Automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage.	S10. Automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage and encouraging third parties to provide value added applications for the enhanced use of our data.
11. Leverage new technologies to increase the amount of data shared with stakeholders more cost-effectively.	S11. Leverage new technologies to increase the amount of data shared with stakeholders to deliver business solutions.
12. Use data to develop and execute clear plans to prepare for weather events and other disruptions, and use operational forecasting, shared with operators.	S12. Use weather forecasting data from both internal and external sources, paired with operational forecasting, to develop executable plans with a wide range of stakeholders to maintain safe operations during adverse weather events and other disruptions.
13. Minimize the volume and length of time airspace is restricted by integrating real-time spaceflight data into the NAS management structure, reducing time to fuel costs to users.	S13. Minimize the airspace disruptions resulting from commercial space operations by integrating real-time spaceflight data into the air traffic management systems.
14. Deploy tools to provide an automated assessment by scoring proposed launch sites and launch vehicle types/missions, analyzing data across a host of air and ground safety hazards.	S14. Deploy automated assessment tools to analyze data across air/ground safety hazards, commercial space launch sites, and launch vehicle types/missions.
15. Leverage advances in the collection and wireless transmission of digital data to improve utilization of the radio spectrum.	S15. Help employees and external stakeholders improve communication by using secure wireless transmission of digital data to efficiently use limited radio spectrum.
16. Improve the radio spectrum and make it available for shared or non-federal use by consolidating surveillance radars.	DELETE
17. Complete assessment of the evolution of the spectrum market and estimate values for spectrum bands and scenarios of interest.	S16. Complete assessment of the spectrum market to include a forecast of likely future demand and an estimate of likely spectrum band market value by industry sector.
18. Improve our radio spectrum utilization, and make it available for	DELETE

shared use through means, such as consolidating surveillance radars.	
19. Develop improved cybersecurity capabilities for secure collection, transmission, management, and analysis of data in coordination with interagency, industry, and international stakeholders.	S17. Develop improved cybersecurity capabilities in coordination with interagency, industry, and international stakeholders.
20. Leverage advances in the collection and wireless transmission of digital data to improve and enhance cybersecurity.	DELETE
21. Sustain and improve cybersecurity in the aviation ecosystem through relationships with external partners in government and industry.	S18. Improve aerospace cybersecurity by establishing agreement with external stakeholders including other government agencies, industry associations and commercial businesses.
22. Reduce aviation critical infrastructure risk by adopting the National Institute of Standards and Technology Cybersecurity Framework.	S19. Reduce risks to the critical aviation infrastructure risk by adopting the latest National Institute of Standards and Technology Cybersecurity Framework.
23. Promote FAA cyber community engagement with public sector, intelligence community, private sector, and international partners.	DELETE
24. Streamline the certification process for industry and reiterate the importance of a safety culture through all phases of the process to include engaging industry early with the introduction of new technologies.	2 STATEMENTS: S20. Help improve safety by simplifying the certification process for new technologies S21. Help improve safety by making it easier to engage with industry stakeholders earlier in the technological development cycle.
25. Take steps to provide a regulatory framework that will facilitate the development and certification of new supersonic airplanes.	S22. Develop and execute a plan to provide a regulatory framework that will facilitate the development and certification of supersonic aircraft.
26. Maintain and modernize the physical, technical, and human infrastructure that enables flexibility in the air and space transportation systems to respond to shifting needs.	S23. Sustain and enhance the physical, technical, and human infrastructure to enable flexibility and adaptability to respond to evolving needs.

27. Advance the integration of new transportation technologies and practices into transportation systems to improve safety and performance.	S24. Accelerate the integration of new transportation technologies and practices into transportation systems to improve safety, efficiency, and performance.
28. Lead the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's aviation system.	S25. Facilitate and enable the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's aviation system.
29. Create a formal cross-agency effort dedicated to new entrant and innovation office.	S26. Create a formal cross-agency office dedicated to new entrants and innovation.
30. Accelerate and expand the deployment of new technologies and practices by reducing barriers to innovation and actively promoting innovation that enhances the safety and performance of the nation's transportation system.	S27. Improve alignment of people, process and technology to allow greater opportunities to deploy innovation and achieve benefits for the nation's transportation system.
31. Accelerate the adoption of transformational technologies to enhance innovation.	S28. Seek, discover and accelerate the adoption of transformational technologies through innovation.
25. Work with stakeholders to identify emerging technologies, opportunities, and gaps.	S29. Work with stakeholders to identify emerging technologies, opportunities, and unmet needs.
26. Leverage complementary research performed by partners in industry, academia, and international consortiums.	S30. Take advantage of research performed by partners in industry, academia, other government agencies, and international consortiums.
27. Accelerate the adoption of advanced analytical methods, machine learning, and artificial intelligence to bring innovative solutions to business problems.	S31. Seek, discover, and accelerate the adoption of advanced analytical methods, machine learning, and artificial intelligence to bring innovative solutions.
28. Support the development and deployment of innovative technologies by investing in targeted research, facilitating coordination and information sharing, partnering with industry and other stakeholders, assessing existing regulatory	5 STATEMENTS: S32. Support the development and deployment of innovative technologies by investing in targeted research. S33. Support the development and deployment of innovative technologies by

approaches to address potential barriers, and providing opportunities to expedite the adoption of beneficial technologies.	facilitating coordination and information sharing. S34. Support the development and deployment of innovative technologies by partnering with industry and other stakeholders. S35. Support the development and deployment of innovative technologies by assessing existing regulatory approaches to address potential barriers. S36. Support the development and deployment of innovative technologies by providing opportunities to expedite the adoption of beneficial technologies.
29. Streamline regulatory processes to improve government efficiency and reduce impediments to innovation, project delivery, and program implementation.	S37. Streamline regulatory processes throughout the U.S. government processes to improve efficiency and reduce impediments to innovation, project delivery, and program implementation.
30. Leverage the research landscapes within the aviation and the broader research and development community.	S38. Work with research resources to identify emerging technologies, opportunities, and unmet needs (move to after 33).
31. Develop a comprehensive view of the research and development required to support a vibrant aviation sector.	DELETE
32. Focus on research and development in improving the safety and performance of airport infrastructure and operations, air traffic, and airspace management capabilities.	S39. Conduct research and development aimed at improving the safety and performance of airport infrastructure and operations, air traffic, and airspace management capabilities.
33. Develop a comprehensive research plan for the integration of new entrants into the NAS.	S40. Develop a comprehensive research plan to support the integration of new entrants into the NAS.
34. Invest in people, processes, and technologies to improve commercial space integration into the National Airspace System, minimizing the	S41. Invest in people, processes, and technologies to improve commercial space integration into the national air transportation system, minimizing the

impact on other NAS users and increasing overall system efficiency.	impact on other stakeholders and increasing overall system efficiency.
35. Engage with internal and external commercial space transportation stakeholders to develop, assess, and recommend appropriate processes, procedures, and infrastructure to integrate commercial space transportation with the NAS.	S42. Engage with internal and external commercial space transportation stakeholders to develop, assess, and recommend safety processes, procedures, and infrastructure to integrate commercial space transportation with the NAS.
36. Safely integrate Commercial Space Transportation launch and reentry activities, and increasingly more complex UAS operation, into the NAS.	S43. Safely integrate Commercial Space Transportation launch and reentry activities, and increasingly complex operations, into the NAS.
37. Promote public/private partnerships to foster and develop world-leading Commercial Space Transportation infrastructure.	S44. Support public/private partnerships to develop world-leading Commercial Space Transportation infrastructure, where needed.
38. Develop tools and processes to continue improving UAS and commercial space integration into the NAS in partnership with other government agencies and industry.	DELETE
39. Implement the FAA’s Concept of Operation for integrating Commercial Space Operations Integration into the NAS.	DELETE
40. Develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations to meet unique requirements in support of space operations mission planning and efficient NAS integration.	2 STATEMENTS: S45. Develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations. S46. Effectively use a modern infrastructure network to meet unique requirements in support of space operations mission planning and efficient NAS integration.
41. Focus on continuous improvement of safety oversight capabilities in	S47. Focus on providing a plan for Safety Management and demonstrate continuous

countries or regions with strategic importance and underserved rural areas.	improvement of safety oversight capabilities in countries or regions with strategic importance.
42. Install NextGen Distance Measuring Equipment (DME), in addition to very High-Frequency Omni-directional Range (VOR) Minimum Operation Network (MON), to enhance infrastructure resiliency of Performance-Based Navigation (PBN) operations during Global Positioning System (GPS) outages.	S48. Install NextGen Distance Measuring Equipment (DME) and Minimum Operation Network (MON), to enhance resiliency of Performance-Based Navigation (PBN) operations during Global Positioning System (GPS) outages.
43. Decommission legacy infrastructure to reduce rental as well as operational and maintenance costs.	S49. Decommission aging facilities to reduce rental, operational, and maintenance costs.
44. Streamline public instrument flight procedures by canceling those no longer needed as a result of cost savings.	S50. Streamline public instrument flight procedures by canceling those no longer needed.
45. Reduce errors in delivering precise routes on both the ground and in the air by sharing surface safety information between air traffic controllers and pilots by using digital communications.	S51. Reduce errors in delivering precise routes on both the ground and in the air by digitally sharing surface safety information between air traffic controllers and pilots.
46. Promote policies that will ensure multimodal infrastructure connectivity while increasing foreign market access and opportunities for American business, services, and the U.S. workforce.	NO REVISION S52. Promote policies that will ensure multimodal infrastructure connectivity while increasing foreign market access and opportunities for American business, services, and the U.S. workforce.
47. Complete the integration of over 600 ADS-B ground stations into air traffic separation services and continue to promote the January 1, 2020 ADS-B Out mandate for operations in rule airspace.	DELETE

48. Increase access, capacity, and safety at airports by verifying remote towers.	S53. Increase capacity, and safety at non-towered airports by integrating certified remote tower technology.
49. Apply a portfolio-based approach to reducing regulatory burdens by developing an annual rulemaking plan that considers future years and potential cost savings.	NO REVISION S54. Apply a portfolio-based approach to reducing regulatory burdens by developing an annual rulemaking plan that considers future years and potential cost savings.
50. Promote performance-based regulation, which provides additional flexibilities to regulated entities and avoids “one-size-fits-all” approaches.	S55. Promote performance-based regulation that provide additional flexibilities to regulated entities and avoids “one-size-fits-all” approaches.
51. Identify and implement processes to address strategic rulemaking objectives, such as Unmanned Aircraft Systems, commercial space, and supersonic flight.	NO REVISION S56. Identify and implement processes to address strategic rulemaking objectives, such as Unmanned Aircraft Systems, commercial space, and supersonic flight.
52. Ensure that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs.	S57. Ensure that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs.
53. Improve processes, systems, and structures to enhance human resources services delivery.	NO REVISION S58. Improve processes, systems, and structures to enhance human resources services delivery.
54. Promote internship opportunities; develop partnerships with academia, industry, government stakeholders, and further programming for science, technology, engineering and math (STEM), and aviation and space (AVSED) programs.	S59. Promote internship opportunities; develop partnerships with academia, industry, government stakeholders, and programming for science, technology, engineering and math (STEM), and aviation and space (AVSED) programs.
55. Align FAA’s internal organizations to maximize workforce development, cyber, shared services ideals, and overall philosophy.	DELETE

56. Ensure the skills of the FAA workforce evolve as the technologies, operating models, and/or strategic priorities for the organization change.	S60. Ensure the skills of the FAA workforce evolve as the technologies, operating models, and/or strategic priorities for the organization change.
57. Implement solutions that are integrated with other DOT modal systems and processes.	S61. Implement solutions that are integrated with other DOT modal systems and processes.

Appendix F: Invitation to Participate in Round 2

Dear Research Panelist:

Thank you for agreeing to serve on this panel and providing your input in Round 1. Welcome to the Round 2 survey for exploring how a panel of aerospace experts views the desirability and feasibility of forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation.

This survey should take between 15–30 minutes to complete. You may leave the survey in SurveyMonkey unattended, resume, and complete the survey at a later time. The indicators at the bottom of each screen help you to navigate back and forth through the pages. You have 10 days to complete the Round 2 survey; please submit your survey by Thursday, April 1. To conclude the survey, please click the “done” button to finalize your responses. Please provide your nongovernment e-mail address in the box provided so I may invite you to participate in Round 3 of this study.

There are 61 statements in the Round 2 survey organized by four categories that align with the overarching elements in the FAA Strategic Plan 2019-2022 Safety, Infrastructure, Innovation, and Accountability. Aspects of digital transformation appear throughout the four categories in the strategic plan. The list of strategic statements pertaining to digital transformation included in this survey is based on the panelists’ input in Round 1. Many of these statements were edited based on your feedback. In this round, you will rate the desirability and feasibility of each statement for furthering digital transformation in aviation.

Desirability refers to the item having a positive effect, beneficial with a positive impact, and reasonable on the positive side. The opposite considerations are for indicating the very undesirable with a substantial negative effect, harmful, and not reasonable.

Feasibility refers to the practicality of implementing the item or solution. Highly feasible means that the item is easy to execute, whereas low feasibility signifies the solution is not implementable, in your opinion.

There is a 5-point scale for indicating the desirability of each statement and another 5-point scale for indicating the feasibility of the statement. The higher number is associated with the positive designation as follows:

1-very undesirable/very unfeasible

2-undesirable/unfeasible

3-neutral/no opinion

4-desirable/feasible

5-very desirable/very feasible

An open text comment area is provided for each statement. Please provide remarks on any item with particular attention to items with a 1 or 2 rating to explain why you consider these items as not desirable or feasible.

You can reach me at my email address or phone with any questions. I appreciate your time and contributions to this study.

Warmest Regards,

Melissa King

Ph.D. Candidate
Walden University

Start Survey

Appendix G: Survey Instrument for Round 2

Please provide your nongovernment email address so I can include you in the

R

Statements

Category A: Safety

1. Increase sharing of harmonized and secure data with all aviation system stakeholders, domestic and international, through joint development of an Integrated Safety Assessment Model.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

2. Help improve safety by simplifying the certification process for new technologies.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

3. Help improve safety by making it easier to engage with industry stakeholders earlier in the technological development cycle.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

4. Develop and execute a plan to provide a regulatory framework that will facilitate the development and certification of supersonic aircraft.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

5. Accelerate the integration of new transportation technologies and practices into transportation systems to improve safety, efficiency, and performance.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

6. Develop a comprehensive research plan to support the integration of new entrants into the NAS.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

7. Invest in people, processes, and technologies to improve commercial space integration into the national air transportation system, minimizing the impact on other stakeholders and increasing overall system efficiency.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

8. Engage with internal and external commercial space transportation stakeholders to develop, assess, and recommend safety processes, procedures, and infrastructure to integrate commercial space transportation with the NAS.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

9. Safely integrate Commercial Space Transportation launch and reentry activities, and increasingly complex operations, into the NAS.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

10. Support public/private partnerships to develop world-leading Commercial Space Transportation infrastructure, where needed.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

11. Focus on providing a plan for Safety Management and demonstrate continuous improvement of safety oversight capabilities in countries or regions with strategic importance.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

12. Promote performance-based regulation that provide additional flexibilities to regulated entities and avoids “one-size-fits-all” approaches.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

Category B: Infrastructure

13. Automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage and encouraging third parties to provide value added applications.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

14. Use weather forecasting data from both internal and external sources, paired with operational forecasting, to develop executable plans with a wide range of stakeholders to maintain.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

15. Minimize the airspace disruptions resulting from commercial space operations by integrating real-time spaceflight data into the air traffic management systems.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

16. Help employees and external stakeholders improve communication by using secure wireless transmission of digital data to efficiently use limited radio spectrum.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

17. Sustain and enhance the physical, technical, and human infrastructure to enable flexibility and adaptability to respond to evolving needs.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

18. Conduct research and development aimed at improving the safety and performance of airport infrastructure and operations, air traffic, and airspace management capabilities.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

19. Develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

20. Effectively use a modern infrastructure network to meet unique requirements in support of space operations mission planning and efficient NAS integration.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

21. Install NextGen Distance Measuring Equipment (DME) and Minimum Operation Network (MON), to enhance resiliency of Performance-Based Navigation (PBN) operations during Global Positioning System (GPS) outages.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

22. Decommission aging facilities to reduce rental, operational, and maintenance costs.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

23. Streamline public instrument flight procedures by canceling those no longer needed.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

24. Reduce errors in delivering precise routes on both the ground and in the air by digitally sharing surface safety information between air traffic controllers and pilots.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

25. Promote policies that will ensure multimodal infrastructure connectivity while increasing foreign market access and opportunities for American business, services, and the U. S. work.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

Category C: Innovation

26. Employ artificial intelligence to improve effective decision making and enhance performance of core aviation management functions.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

27. Improve quality of data and data management to enhance stakeholders’ ability to utilize data.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

28. Integrate aviation data with the Internet to allow greater access on demand.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

29. Use the advances in data management capabilities to increase the efficiency and security of data transmission, collection, and analysis.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

30. Improve safety-enabling technologies and analytics, while protecting data security.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

31. Work closely with experts in relevant fields to create a data map ensuring that key stakeholders know which organizations have different types of data creating easier pathways to share that information.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

32. Identify data gaps, develop a roadmap, and plan of action to address shortfalls to improve data quality and integrity.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

33. Ensure enterprise capabilities enable rapid development of data management platforms, applications, and technologies.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

34. Leverage new technologies to increase the amount of data shared with stakeholders to deliver business solutions.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

35. Deploy automated assessment tools to analyze data across air/ground safety hazards, commercial space launch sites, and launch vehicle types/missions.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

36. Complete assessment of the spectrum market to include a forecast of likely future demand and an estimate of likely spectrum band market value by industry sector.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

37. Develop improved cybersecurity capabilities in coordination with interagency, industry, and international stakeholders.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

38. Improve aerospace cybersecurity by establishing agreement with external stakeholders including other government agencies, industry associations and commercial businesses.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

39. Reduce risks to the critical aviation infrastructure risk by adopting the latest National Institute of Standards and Technology Cybersecurity Framework.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

40. Facilitate and enable the development and deployment of innovative practices and technologies that improve the safety and performance of the nation’s aviation system.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

41. Create a formal cross-agency office dedicated to new entrants and innovation.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

42. Improve alignment of people, processes, and technology to allow greater opportunities to deploy innovation and achieve benefits for the nation’s transportation system.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

43. Seek, discover, and accelerate the adoption of transformational technologies through innovation.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

44. Work with stakeholders to identify emerging technologies, opportunities, and unmet needs.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

45. Take advantage of research performed by partners in industry, academia, other government agencies, and international consortiums.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

46. Seek, discover, and accelerate the adoption of advanced analytical methods, machine learning, and artificial intelligence to bring innovative solutions.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

47. Support the development and deployment of innovative technologies by investing in targeted research.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

48. Support the development and deployment of innovative technologies by facilitating coordination and information sharing.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

49. Support the development and deployment of innovative technologies by partnering with industry and other stakeholders.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

50. Support the development and deployment of innovative technologies by assessing existing regulatory approaches to address potential barriers.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

51. Support the development and deployment of innovative technologies by providing opportunities to expedite the adoption of new technologies.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

52. Increase capacity, and safety at non-towered airports by integrating certified remote tower technology.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

Category D: Accountability

53. Streamline regulatory processes throughout the U. S. government processes to improve efficiency and reduce impediments to innovation, project delivery, and program implementation.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

54. Apply a portfolio-based approach to reducing regulatory burdens by developing an annual rulemaking plan that considers future years and potential cost savings.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

55. Identify and implement processes to address strategic rulemaking objectives, such as Unmanned Aircraft Systems, commercial space, and supersonic flight.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

56. Ensure that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

57. Improve processes, systems, and structures to enhance human resources services delivery.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

58. Promote internship opportunities; develop partnerships with academia, industry, government stakeholders, and programming for science, technology, engineering and math (STEM), and aviation and space (AVSED) programs.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

59. Work across FAA’s various internal organizations to maximize workforce development, shared services and cybersecurity protection, in support of the diverse missions and cultures in the various units.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

60. Ensure the skills of the FAA workforce evolve as the technologies, operating models, and/or strategic priorities for the organization change.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

61. Implement solutions that are integrated with other DOT modal systems and processes.

	1	2	3	4	5
Desirability	○	○	○	○	○

Comments:

	1	2	3	4	5
Feasibility:	○	○	○	○	○

Comments:

Appendix H: Invitation to Participate in Round 3

Dear Research Panelist:

Welcome to the Round 3 survey for exploring digital transformation in aviation. Thank you for continuing to serve on this panel and providing your input in Round 2. There are 24 statements in the Round 3 that reflect consensus among the panel as most as most desirable and feasible forward-looking strategies for adopting digital transformation while adhering to the rigor of a deeply entrenched safety culture in aviation. For this survey, you will be asked to choose and then rank your top 10 most important.

There are two parts to this survey. In part 1, you will be asked to select the 10 most important of the 24 strategic statements by clicking the checkbox associated with the statement. Each statement is labeled S1 through S24 for identification purposes only and that label has no bearing on the order of importance that will be determined in this survey round.

After you select the top 10 statements, you will be asked to rank each statement in order of importance. The part 2 action involves clicking on the check box to indicate the ranking of 1 to 10. Use the number 1 to indicate the most important strategic statement and the number 10 to indicate the least important of the selected statements.

This survey should take approximately 10 minutes to complete. You may leave the survey in SurveyMonkey unattended, resume, and complete the survey at a later time. The indicators at the bottom of each screen help you to navigate back and forth through the pages. You have 10 days to complete the Round 3 survey; please submit your survey by Thursday, June 17. To conclude the survey, please click the “done” button to finalize your responses. An open text comment area is provided at the end of the ranking action for any comments you would like to provide.

Please provide your nongovernment e-mail address in the box provided so I may invite you to participate in final round of this study. As always, your email address will be kept confidential and will only be seen by me. No personal identifiable information will be shared with anyone. SurveyMonkey’s privacy policy also ensures information will be kept private and confidential.

You can reach me at my email address or phone with any questions. I appreciate your time and contributions to this study.

Warmest Regards,

Melissa King
Ph.D. Candidate
Walden University

Start Survey

Appendix I: Survey Instrument for Round 3

Please provide your nongovernment email address so I can include you in the Round 4 survey.

Part 1:

You are provided with the 24 statements reflecting consensus among the panel as most as most desirable and feasible forward-looking strategies. Please select your 10 most important strategies by clicking on the box to the left of the strategic statement.

- ☐ S1. Help improve safety by making it easier to engage with industry stakeholders earlier in the technological development cycle.
- ☐ S2. Accelerate the integration of new transportation technologies and practices into transportation systems to improve safety, efficiency, and performance.
- ☐ S3. Develop a comprehensive research plan to support the integration of new entrants into the NAS.
- ☐ S4. Engage with internal and external commercial space transportation stakeholders to develop, assess, and recommend safety processes, procedures, and infrastructure to integrate commercial space transportation with the NAS.
- ☐ S5. Automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage and encouraging third parties to provide value added applications.
- ☐ S6. Minimize the airspace disruptions resulting from commercial space operations by integrating real-time spaceflight data into the air traffic management systems.

- S7. Conduct research and development aimed at improving the safety and performance of airport infrastructure and operations, air traffic, and airspace management capabilities.
- S8. Develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations.
- S9. Install NextGen Distance Measuring Equipment (DME) and Minimum Operation Network (MON), to enhance resiliency of Performance-Based Navigation (PBN) operations during Global Positioning System (GPS) outages.
- S10. Use the advances in data management capabilities to increase the efficiency and security of data transmission, collection, and analysis.
- S11. Improve quality of data and data management to enhance stakeholders' ability to utilize data.
- S12. Identify data gaps, develop a roadmap, and plan of action to address shortfalls to improve data quality and integrity.
- S13. Facilitate and enable the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's aviation system.
- S14. Work with stakeholders to identify emerging technologies, opportunities, and unmet needs.
- S15. Take advantage of research performed by partners in industry, academia, other government agencies, and international consortiums.

☐ S16. Support the development and deployment of innovative technologies by investing in targeted research.

☐ S17. Support the development and deployment of innovative technologies by facilitating coordination and information sharing.

☐ S18. Support the development and deployment of innovative technologies by partnering with industry and other stakeholders.

☐ S19. Support the development and deployment of innovative technologies by assessing existing regulatory approaches to address potential barriers.

☐ S20. Ensure that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs.

☐ S21. Improve processes, systems, and structures to enhance human resources services delivery.

☐ S22. Promote internship opportunities; develop partnerships with academia, industry, government stakeholders, and programming for science, technology, engineering and math (STEM), and aviation and space (AVSED) programs.

☐ S23. Work across FAA’s various internal organizations to maximize workforce development, shared services and cybersecurity protection, in support of the diverse missions and cultures in the various units.

☐ S24. Ensure the skills of the FAA workforce evolve as the technologies, operating models, and/or strategic priorities for the organization change.

Part 2:

Please rank your top 10 most important strategies that you selected in Part 1. To rank the strategies, click on any of the checkboxes under numbers 1 to 10. Use the number 1 to indicate the most important strategic statement and the number 10 to indicate the least important of the selected statements. You can scroll to any of the statements in Part 1 to review the selections you made to indicate the most important strategies. If you choose to change a strategy selection from Part 1, you will need to change that selection in Part 2.

	1	2	3	4	5	6	7	8	9	10
Preferred solution by expert panelist	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	6	7	8	9	10
Preferred solution by expert panelist	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	6	7	8	9	10
Preferred solution by expert panelist	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	6	7	8	9	10
Preferred solution by expert panelist	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	6	7	8	9	10
Preferred solution by expert panelist	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	6	7	8	9	10
Preferred solution by expert panelist	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	6	7	8	9	10
Preferred solution by expert panelist	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	6	7	8	9	10
Preferred solution by expert panelist	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	1	2	3	4	5	6	7	8	9	10
Preferred solution by expert panelist	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

3. Please use the text box below to enter any comments regarding your ranking (optional).

Before clicking the “Done” button, please re-check that you ranked only 10 strategies in Part 2 and that these 10 ranked strategies are the exact strategies selected in Part 1.

Appendix J: Invitation to Participate in Round 4

Dear Research Panelist:

Welcome to the Round 4 survey for exploring digital transformation in aviation. Thank you for continuing to serve on this panel and providing your input in Round 3. I deeply appreciate your valuable time, expert insights, and commitment to seeing this project through with me. The statements in Round 4 reflect consensus among the panel on the 10 most desirable, feasible, and important items in digital transformation in aviation as originally identified in the 2019 -2022 FAA strategic plan. The items are ranked from 1–10 with 1 being most important and 10 being least important.

For this final survey, please rate your confidence in the top 10 strategies presented. Confidence is the degree of certainty you have in the collective panel view that the list shows the top strategic statements regarding digital transformation in aviation. Please use the numbers 1-5 for the scale. The confidence scale will be 1-Unreliable (great risk of being wrong); 2-Risky (substantial risk of being wrong); 3-Neither Reliable nor Unreliable; 4-Reliable (some risk of being wrong), and 5-Certain (low risk of being wrong).

This survey should take no more than 5 minutes of your time. You may leave the SurveyMonkey unattended, resume, and complete the survey. This survey will close on Sunday, July 20, 2021. Please click the done button after completing the Round 4 survey. An open text comment area is provided at the end of the rating section for any comments you would like to offer.

Please provide your nongovernment e-mail address so I may send you a copy of the final study results. As always, your email address will be kept confidential and will only be seen by me. No personal identifiable information will be shared with anyone. SurveyMonkey's privacy policy also ensures information will be kept private and confidential. Below is a list of the Top 10 most desirable, feasible, and important strategic statements related to digital transformation in aviation.

S2. Accelerate the integration of new transportation technologies and practices into transportation systems to improve safety, efficiency, and performance.

S24. Ensure the skills of the FAA workforce evolve as the technologies, operating models, and/or strategic priorities for the organization change.

S8. Develop and deploy a modern information network to assess and transfer data easily and securely in a usable format able to transform existing tools and operations.

S13. Facilitate and enable the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's aviation system.

S19. Support the development and deployment of innovative technologies by assessing existing regulatory approaches to address potential barriers.

S18. Support the development and deployment of innovative technologies by partnering with industry and other stakeholders.

S20. Ensure that the FAA has the human resources needed to accomplish its safety mission through robust strategic workforce planning, leadership development, succession planning, performance management, and Total Rewards programs.

S5. Automate and streamline the data sharing process for non-NAS users through new technologies, such as cloud storage and encouraging third parties to provide value added applications

S10. Use the advances in data management capabilities to increase the efficiency and security of data transmission, collection, and analysis.

S1. Help improve safety by making it easier to engage with industry stakeholders earlier in the technological development cycle.

You can reach me at my email address or phone with any questions. I appreciate your time and contributions to this study.

Warmest Regards,

Melissa King
Ph.D. Candidate
Walden University

Start Survey

Appendix K: Survey Instrument for Round 4

Confidence in the list being the top strategic statements regarding digital transformation in aviation.	☐ Unreliable	☐ Risky	☐ Neither Reliable nor Unreliable	☐ Reliable	☐ Certain

Please use the text box below to enter any comments regarding your ranking (optional).
