

Disruptive Technology Adoption and Technology Sustainability in Aviation Sector: Multi-Stakeholders Case Study Analysis

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Abstract: The aim of this paper is threefold: to discuss the theoretical underpinning of disruptive technology in the aviation context; to explore technology development in the aviation industry; and to classify the key challenges of technology in the aviation industry by exploring how human factors in the aviation sector react in line with technology development. This study employs an inductive research approach with multiple case study analysis. Cross-case analysis was performed to identify data patterns across aviation types of organizations. This qualitative multiple case study is exploratory in nature, interviewing managers in the aviation sector. The case comes from the airline, cargo, manufacturing, and Maintenance, Repair and Overhaul (MRO) perspectives. One of the interesting findings of this study is that technology in the aviation industry is controlled by aviation regulators globally and locally. The use of new technology in the aviation industry should be tested and approved by the local authorities to ensure airworthiness. Thus, there is a strong contribution to the current literature that offers new insights into the technological role of the aviation industry. This study is regarded as novel because the main data come from the key players in air transport, namely the airline, cargo players, manufacturing, MRO and policy maker. This study is novel as it draws primary insights from key stakeholders across the air transport ecosystem. The findings contribute a conceptual framework and practical implications for understanding technology adoption in the aviation industry. The study introduces the notion of technology stalemate to describe how sustainability-oriented technological initiatives are shaped by regulatory, safety, and security considerations, reflecting a context of cautious and risk-aware decision-making rather than outright resistance.

Keywords: Disruptive technology, Multi-stakeholders, Theory of planned behavior, Aviation, Sustainability.

I. INTRODUCTION

Transport systems play a significant role in driving economic and social development [1] Since the advent of commercial jet flights in the 1950s, aviation has become a cornerstone of modern society but continues to face persistent challenges. The industry grapples with the high costs and long lifespans of aircraft, which demand continuous, efficient maintenance, while breakthrough technologies such as hydrogen-powered aircraft remain unlikely within the next five decades [2]. Given aviation's critical social, political, and economic role, technological adoption has become central to sustaining growth; however, while global demand rises 5% annually, technological and operational gains remain limited to 1–2% [3], and environmental impacts pose a mounting barrier. Extant research on the aviation–technology nexus has predominantly examined passengers, emphasizing technological readiness, self-service kiosks, and mobile applications [4-7]. These studies, largely conducted in industrialized nations, overlook emerging economies and neglect employees' perspectives, despite calls for research on workforce perceptions of technology adoption in aviation [8].

Most studies on technology adoption in aviation focus on developed countries and narrowly examine the airline industry, overlooking emerging economies such as Malaysia. This study addresses the gap by providing broader insights into key and emerging technologies across diverse aviation contexts. The Malaysian airline industry provides a valuable context as an emerging economy, offering an alternative to the developed country focus dominant in existing literature. It is important to note, however, that Malaysia represents a specific regulatory and transitional aviation ecosystem, and findings should be understood within this bounded context rather than as universally generalizable. Malaysia's aviation sector operates under the oversight of the Civil Aviation Authority Malaysia (CAAM) and is subject to both national regulatory frameworks and international standards set by International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA). As an emerging economy with a growing but maturing aviation industry, Malaysia occupies a transitional position between developing and developed aviation markets. The transferability of findings to other jurisdictions particularly those with more established regulatory infrastructure or different institutional environments should therefore be approached with caution. Despite value for money and safety being key criteria for airline choice [9-11], persistent issues such as delays, poor service quality, and uncomfortable seating have damaged its reputation [12].

Global airline sales now exceed £600 billion annually, and passenger demand is projected to reach 7.8 billion by 2036 [13], highlighting the urgency of addressing aviation's opportunities and challenges through technology. Yet, the industry remains a complex and highly integrated system of stakeholders, regulations, and business models that demands deeper exploration. Deloitte (2019) [14] observed that aviation's technological landscape is polarized between large-scale legacy suppliers offering end-to-end solutions and specialized vendors providing fragmented point solutions. While prior studies have examined isolated challenges and technologies, little attention has been given to aviation as a whole. This study responds by analyzing the role of emerging technologies in overcoming industry-wide challenges and by examining stakeholder perceptions across the aviation ecosystem. Technology utilization and digital transformation foster active user participation and competitive knowledge creation, supporting sustainable operations across business actors [15]. In the era of Industry 4.0, with technologies such as Artificial Intelligence (AI), Internet of Things (IoT), blockchain, cloud computing, and big data analytics shaping aviation, research shows a growing disconnect between macro-level institutional logics in the industry and micro-level aviation management programs, widening the gap between managerial needs and educational offerings [16-18]. This, in turn, contributes to the gap between industry and academia. Therefore, it is increasingly important to explore key issues within the aviation industry through a number of stakeholders.

The lack of studies on the perceptions of various stakeholders within the aviation industry can be attributed to the fact that aviation industry players are diverse [19]. The aviation spectrum ranges from airlines, airports, manufacturing MRO organizations, ground handling, cargo operators, general aviation, and aviation training providers. As many have discussed the technology-sustainability dyad within manufacturing and other industries, this research aims to explore various technological applications in the context of the aviation industry. In doing so, the study focuses specifically on managerial and organizational perspectives within Malaysia's aviation ecosystem, encompassing airlines, cargo operators, MRO organizations, manufacturers, and policy makers. Frontline operational staff, international operators, and non-Malaysian regulatory bodies fall outside the analytical boundary of this study. The findings are therefore most applicable to emerging-economy aviation contexts characterized by active regulatory oversight, transitional technology infrastructure, and multi-stakeholder coordination. Thus, the following research questions were developed:

- What are the perceptions of technology amongst various stakeholders within the aviation industry?
- To what extent is the aviation industry implementing technological advancements to overcome the key operational challenges?
- What are the challenges associated with technology adoption within the aviation industry?

Accordingly, this study examines technology adoption in the aviation industry to bridge existing literature gaps and capture diverse perspectives across the sector. It outlines the data collection and analysis methods, highlights contributions, and offers implications for future business-to-business technology research, aligning closely with calls for further scholarly exploration.

II. LITERATURE REVIEW: TECHNOLOGY, SUSTAINABILITY AND AVIATION INDUSTRY

1. TECHNOLOGY

Research linking technology and aviation remains limited, despite technology studies gaining prominence since the 1970s and accelerating in the late 1990s [1, 5, 6]. While technology now underpins business operations and organizational interactions, literature on its adoption for sustainability and performance in aviation is scarce, with only a few studies highlighting its role in enhancing firm outcomes [15, 20, 21]. Sivarajah et al. (2019) [15] explored the role of Big Data and social media analytics in achieving Business-To-Business (B2B) sustainability. Moreover, another study, by Müller et al (2018) [22] discuss the impact of digitalization, mobile marketing and social media. At present, this kind of technology is among the most popular and mostly used by business organizations to keep updates on their business as well as to maintain their customers. The findings suggest that the production and management functions within the industrial market largely use mobile devices for industrial buying. This reflects the importance of technology in the b2b markets. Studies [23, 24, 25] have examined big data challenges in business. A general review published by Strong (2014) [20] suggests industry findings patterns in any data analysis performed in the organization. Findings variables, as well as relationships between variables, could lead to improving current activities within the organization. Mahroof (2019) [21] investigated how technology can be used to create smart warehousing.

2. SUSTAINABILITY

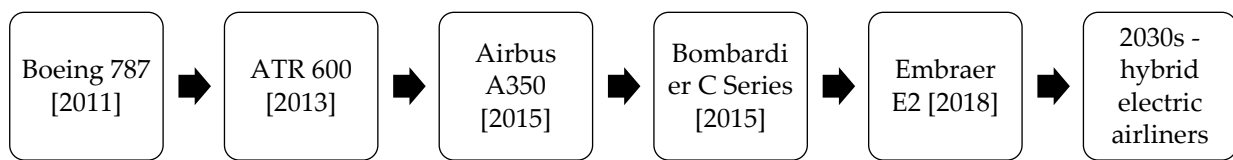
Sustainability spans business, economic, social, environmental, and political dimensions, with technology increasingly recognized as a key enabler. In the context of this study, sustainability is understood across four interconnected dimensions. Environmental sustainability refers to reducing aviation's carbon footprint, improving fuel efficiency, and supporting the industry's net-zero commitments, as outlined by IATA's Fly Net Zero 2050 initiative and aligned with United Nation (UN) Sustainable Development Goal 13 (Climate Action) and SDG 9 (Industry, Innovation and Infrastructure). Economic sustainability concerns the long-term financial viability of aviation organizations, including cost management, revenue generation, and technology investment returns. Operational sustainability relates to maintaining safe, efficient, and reliable aviation processes encompassing maintenance, airworthiness, and regulatory compliance. Social sustainability encompasses workforce development, passenger safety and experience, and the broader societal value of aviation connectivity. Beyond technology, maintaining strong relationships with supply chain partners also enhances business sustainability [26]. Effective use of digital platforms and communication technologies reduces disruptions in supply chains and meets customer expectations for information access through corporate websites, social media, and mobile channels [27-29]. Yet, achieving sustainability remains particularly challenging in aviation, an oligopolistic industry where competition is limited, and critical challenges intersect with economic and policy domains [30, 31].

3. AVIATION INDUSTRY AND ITS TECHNOLOGY EVOLUTION

The aviation business is universally acknowledged as a highly regulated sector that is essential for enhancing tourism and driving economic prosperity in any nation. Recent technological improvements in the service business, particularly in aviation, have facilitated a transition from face-to-face service delivery to self-service technologies. The aviation sector is renowned for its broad and diverse range, stringent regulations, and dynamic characteristics. The spectrum encompasses Aviation Organizations in Design and Certification (DOA), Manufacturing (POA), Operations (AOC), Air Traffic Control (ATC), Aerodrome), Maintenance and Repair (Part 145), Continuing Airworthiness (Part M), and Education & Training providers (Part 147). Every organization must obtain approval from its appropriate National Authority, such as the CAAM (Civil Aviation Authority Malaysia), European Aviation Safety Agency (EASA), and Federal Aviation Administration (FAA).

Technology holds a pivotal role in aviation [32, 33], with the industry embracing innovation alongside aerospace, automotive, telecommunications, and electronics. Novel technologies allow researchers and stakeholders to capture extensive data on passengers, markets, and sales, extending far beyond traditional approaches to aviation research. This capability strengthens competitiveness but also intensifies concerns about sustainability and societal implications within aviation and higher education [34, 35].

The aviation sector underpins tourism, manufacturing, and business, while technology binds the entire supply chain and enables aerospace and related industries to adopt innovations such as robotics, 3D printing, virtual and augmented reality, Unmanned Aerial Vehicles (UAVs), and repair-capable robots, which enhance productivity and spawn new business models but can also disrupt established frameworks [36]. Recent data highlight aviation's enduring trajectory of fuel-efficiency gains, each new generation of aircraft has reduced emissions by around 15–20%, and fleet-wide efficiency has improved by nearly 80% over the past five decades alongside the emergence of electrification and propulsion technologies that promise radical future improvements [37]. Additionally, IATA highlights that new aircraft and propulsion technologies, including electric and hydrogen propulsion systems, are key to achieving net zero emissions by 2050, with each new aircraft generation delivering roughly a 15–20% improvement in fuel efficiency. From the airline perspective, for instance, the evolution of electric aircraft technology reflects its technological revolution. For example, from 2011 to 2015, five electric aircraft were produced through digital and technological advancements (see Figure 1). According to [38], cleaner and more efficient forms of air transport should be developed by adopting technological advances such as electricity. Figure 1 illustrates the electric innovation of aircraft technology from year 2011 till 2030s.



Source: Developed by the Authors (2025).

FIGURE 1. Technology advances in aviation and the future of electric aircraft (2011 to 2030s).

Technology plays a pivotal role in shaping the aviation industry's competitiveness and sustainability. Modern aircraft designs enhance fuel efficiency by over 15% compared to models from a decade earlier, leading to a 40% reduction in emissions and improved environmental performance. The aviation and aerospace sectors, alongside industries such as transportation, automotive, telecommunications, and electronics, actively embrace technological innovation to remain relevant in highly competitive markets. Technology not only permeates daily life but also provides aviation researchers with tools to collect and analyze large volumes of passenger, market, and sales data, surpassing the limits of traditional market research. Ashworth and Free (2006) [34] highlighted stakeholders' concerns, particularly in aviation and higher education, about the implications of sustainability and technology for society, a view reinforced by [39]. Within aviation, technology influences aircraft design, Global Positioning Systems (GPS), airport operations such as security screening, flight management, and Flight Information Displays (FID), as well as ATC. Moreover, simulation technologies have become critical for cost-effective and safe pilot and ATC training, as real-world training carries significant risks. Simulators are thus recognized as indispensable tools for training pilots on new aircraft [40].

III. THEORETICAL FOUNDATIONS: TPB AND INSTITUTIONAL PERSPECTIVES ON REGULATION

A plethora of studies have highlighted user resistance to technology as a major barrier to its adoption and its role in hampering the realization of benefits that it may bring. User resistance to technology may be ascribed to variables such as regret avoidance, inertia, perceived value, switching costs, perceived danger attitude, subjective norms, and perceived behavioral control [41]. Thus, intention to use can be considered an important factor, when it comes to the application and successful utilization of technology. Accordingly, the Theory of Planned Behavior (TPB) provided appropriate theoretical lenses to explore users' perceptions, relating to technology adoption [42] and outlines that in order to predict an individual's intention to perform a certain behavior, such as adopting and utilizing a certain technology, one needs to understand whether the individual has a favorable opinion regarding the intended behavior, whether the individual feels social pressure to engage with the particular behavior, and whether, by doing so, the individual is in control of the action [43]. TPB is also widely utilized in qualitative studies, and TPB is applied

by taking a qualitative approach to focus on the perceptions and intentions of aviation stakeholders to engage with Diffusion Technology (DT).

While TPB provides a robust individual-level framework for understanding technology adoption intentions, the findings of this study reveal that regulatory authority plays a central and structuring role in shaping organizational behaviour in aviation. To account for this, the study draws additionally on institutional theory and regulatory governance perspectives. Institutional theory [44] suggests that organizations conform to regulatory, normative, and cognitive pressures in their environment a dynamic clearly evident in aviation, where ICAO, EASA, FAA, and national bodies such as Civil Aviation Authority Malaysia (CAAM) exercise coercive isomorphic pressure, requiring compliance as a precondition for operational legitimacy. Regulatory governance theory further highlights how rule-making bodies shape the boundaries within which organizations can act, particularly in safety-critical industries [45]. Together, these theoretical perspectives complement TPB by situating individual adoption intentions within the broader institutional and regulatory environment that structures aviation decision-making.

IV. QUALITATIVE RESEARCH METHODOLOGY

This study adopts a qualitative approach to address the limited research on technology in aviation. Unlike quantitative methods, which emphasize objectivity and generalization, qualitative research enables deeper exploration of complex phenomena and theory building. Using an inductive multiple case study design, the study applies replication logic to validate or challenge prior findings [46, 47]. The case study method is well-suited for answering (why and how) questions in context [48, 49]. The research focuses on the aviation sector, examining technology's role in addressing industry challenges across airlines, MROs, ground handlers, and related stakeholders. By leveraging intra-industry insights and cross-case comparisons, the study develops and refines conceptual ideas grounded in empirical evidence.

Multiple case sampling, interview, interview guide and unit of analysis

To provide solid findings on the use of technology in the aviation industry, this study collects data from multi-aviation organizations, such as airlines, MRO, cargo, and manufacturing organizations. Diverse investigative perspectives enhance study rigor and provide a diverse account of information and detailed evidence [50]. The primary sources in this study were interviews conducted with respondents. Semi-structured interviews were conducted with representatives from each category of aviation organization. All interviewees were well-appointed to the goal of the interview.

We also took notes during the interviews. According to [51], semi-structured interviews are the best and most suitable method for generating an analytical understanding of observable events. Because this research employed a qualitative method using semi-structured interviews, a list of eleven (11) interview questions was compiled. This is in line with the aim of this study to explore technology development that covers the role of technology and key challenges from the aviation perspective. In addition, an interview protocol, known as an interview guide, was developed to guide the researcher to collect data beyond the research topic. As mentioned by [52], interview guides, also called interview protocols, are very useful in interview sessions, as they comprise a group of topics to be discovered and questions that can be asked in different ways for different cases or respondents. In general, interviews were developed with three main sections: warm-up or introductory questions, main questions, and closing questions. An introductory question covered the respondent's profile by obtaining information on the respondent's name, position, age, years of experience, and gender. Five questions were established as opening or warm-up questions. Eight main questions have been crafted for the focus of this research, which consist of two dimensions: the view of technology development and technology key challenges. As for the conclusion question, two questions were asked to the respondents in this research by getting their view for any recommendation on technology application for improvement, followed by the respondent idea or suggestion with regard to the policymaker perspective. Table S1 shows a list of the semi-structured interview questions proposed in this study.

- Data collection procedures and Data Analysis

This project adhered all the ethical guidelines and has approved from Research and Innovation department at Universiti Kuala Lumpur Malaysian Institute of Aviation Technology (5/9/2025). All interview sessions were conducted in accordance with the ethical guidelines and voluntary basis. Prior to each session, participants were

provided with a Participant Information Sheet that outlined the purpose of the research, the voluntary nature of participation, procedures involved, and assurances of confidentiality and anonymity. All data collected were stored securely in password-protected institutional repositories, accessible only to the research team. No personally identifiable information was retained in the final dataset, and all transcripts were anonymized prior to analysis in accordance with the university's data protection policy. Participants were informed that their personal data and responses would be used solely for academic and research purposes and that they could withdraw from the study at any time without penalty.

A purposive sampling strategy was adopted to select cases relevant to the research objectives. Eight aviation-related organizations were selected to represent key segments of the aviation ecosystem, including airlines, air cargo services, maintenance and engineering, manufacturing, and regulatory bodies. Access to organizations was obtained through professional networks and formal institutional contacts. Respondents were selected based on their managerial or decision-making roles, direct involvement in technology adoption processes, and a minimum of five years of industry experience. This approach ensured that participants possessed sufficient strategic and operational insight relevant to the study. Table 1 present the description of the questions that included in the interview.

Table 1. Interview guide.

Construct	Interview questions
Demographic questions	Respondent name, age, gender, ethnicity, status, education and income, industry experience
General questions	What do you understand of disruptive technologies?
	How much do you know about DT?
Attitude	What are your expectations towards DT?
	What do you think are the advantages of using DT? (What are the positive feelings of using DT?)
	What do you think are the disadvantages of using DT? (What are the negative feelings of using DT?)
Subjective Norms	Who do you think would approve or support you if you use DT?
	Who do you think would disapprove or discourage you from using DT?
Perceived Behavioural Control	What are the factors or motivators that make it easy for you to use DT?
	What are factors or barriers that make it difficult for you to use DT?

Source: Developed the authors (2025).

While interviews were conducted with individual respondents, the unit of analysis in this study is the organization. Data from multiple respondents within the same organization were aggregated to generate organization-level interpretations, which formed the basis for the subsequent cross-case analysis. Table 2 serves as a guide for readers on the respondent profile and aviation spectrum data source.

Table 2. Respondent profile and aviation spectrum.

Respondent Case	Gender	Years of experience in aviation industry	Position	Aviation spectrum
L.S	Male	8	Assistant Manager	Airline
S. Z	Female	12	Assistant Manager	Cargo
N. A	Male	12	Manager	MRO
M.Q	Male	9	Head of country	Manufacturing
H.H	Female	6	Cargo Manager	Cargo
M.S	Male	17	Regional Manager	Airline
M.K	Male	14	Assistant Manager	MRO
W.H	Male	21	Manager	Manufacturing
A.H	Male	25	Assistant Director	Policy maker

A. F	Male	20	Assistant Director	Policy maker
S. K	Male	22	Head	Policy maker
F.R.	Male	4	Asst Manager	Airline
Z. I	Male	4	Senior Executive	Airline

Source: Developed by the authors (2025)

Consistent with [53], semi-structured interviews were conducted with informants in the middle management tier of each organization. This is crucial because they have interpretative responsibilities and technical expertise in the field. To guarantee the data's authenticity, we used a 'courtroom questioning' methodology as recommended by [47]. This approach prompted each responder to provide an example to substantiate their comments, focusing on facts and events, rather than their interpretations. The unit of analysis in this research is an aviation organization. As recommended by a qualitative scholar [54], who argues in inductive research, a case study is built from individual cases of the organization itself. It starts with gathering interview transcripts and archival materials. Qualitative content analysis of archival materials, known as thematic analysis, is known as a text interpretation method. As suggested by [55], thematic analysis and qualitative content analysis are the most appropriate methodologies for exploratory research, as they provide triangulation to validate the results. The results presented in this research and the ensuing cross-case analysis are derived from all eight aviation organizations participating in this study. Thirteen respondents from eight organizations participated in this survey, including six aviation sectors, namely air cargo, manufacturing, MRO, airlines, and aviation policy. Barring the latter, each spectrum is represented by two or more organizations. Cross-case analysis is performed to critically understand the similarities and differences in technology applications within these aviation spectrums. The next section briefly highlights the key findings from this research.

Additionally, data analysis in this research followed a systematic qualitative coding process. Open coding was first conducted to identify initial concepts and patterns from the interview transcripts. These codes were then refined through axial coding to establish relationships between categories and to develop higher-order themes. The coding process was iterative and involved repeated comparison across cases. To enhance analytical rigor, peer debriefing was also undertaken among the research team to review and validate the emerging themes. Data collection was concluded when thematic saturation was reached, as no new themes or substantive insights emerged from the final interviews during the iterative coding and cross-case analysis process. To enhance trustworthiness, we triangulated interview transcripts with interview notes and relevant archival materials where available, maintained an audit trail (for example, codebook iterations and analytic memos), and conducted peer debriefing within the research team to confirm the interpretations and confirm cross-case patterns.

V. ANALYSIS AND KEY FINDINGS

Perceptions relating to adoption of disruptive technology adoption in the aviation industry: Multi stakeholder perspective Guided by TPB, findings are organized into Attitude, Subjective Norms, and Perceived Behavioral Control (PBC). Themes under each construct are derived from cross-case analysis and are supported by evidence from multiple organizations across the aviation ecosystem (see Table 3 below). The initial emerging themes were captured for each research participant, and data that shared similar meanings were then categorized, leading to the identification of broader, more meaningful themes. The broader themes and their subthemes are reflected in the thematic analysis summary in table 3. Accordingly, these superordinate themes highlighted the attitudes, perceived behavioral control, and subjective norms held by the key stakeholders within Malaysia's aviation sector regarding DT.

Table 3. Qualitative thematical analysis and the generation of theme.

Themes and Sub themes	TPB Construct	Brief description of sub themes	Evidence across cases (Organizational Spectrum,)
Local aviation authority influence	Subjective norms	Any technology introduces in the aviation industry especially in airline should be tested and approved by local and international authority.	Manufacturing,
a. Tested before use		Any technology used in aviation industry must adhere to the highest authority locally and globally.	MRO, Manufacturing, Airline
b. Rules and regulation to confirm			
Sustainability and superior performance	Attitude	Performance associated with spare parts management, aircraft maintenance.	MRO, Airline, Manufacturing, Cargo
a. Greater maintenance performance		Associates with improved process at the maintenance and inspection check of aircraft.	MRO
b. Quicker check process		Through technology, aircraft design has been improved and the system used in the aircraft is tremendously developed.	Airline, Manufacturing
c. Enhanced performance in designing and producing aircraft		System used at the warehouse to improve cargo supply chain process, as well as improved operational and financial performance. Similar to communication system used in-flight catering organization.	Cargo, Flight caterer
Smart technology runs cargo smoothly			

Technology maturity & Scalability		Refer to technology features that explain the network, software, system or the ability of any process which more adaptable and flexi to change the need or demand of the users. Discuss on the pillars of technology.	Airlines, Manufacturing, MRO
a. Current technology used	Perceived Behavioral Control (PBC)	All technology used in aviation sector for example in MRO and manufacturing, additive technology and 3d printing are current technology.	Airlines, Manufacturing, MRO, Cargo,
b. No new technology		The respondent highlight on no new technology introduced in the aviation. Since it should be tested first, most of the technology used in aviation are already used in different sector such as construction, automotive, agriculture etc.	Caterer, policy maker
Challenges & Lack of trust		It was clear that in the aviation industry, the implications of technology failing can be catastrophic, therefore trust was highlighted as a key issue. In addition, the fear of job losses and skilling factor was also prevalent.	Airlines, Cargo, Manufacturing, MRO, Caterer
a. High cost		High expenditure associated with the usage of technology such as system, maintenance of the system etc, the focus on technology investment is majority on the manufacturing.	Airlines, Cargo, Manufacturing,
b. Security		The security of the system used by the aviation players which directly affects their safety and efficiency.	MRO

Source: Developed by the authors

1. SUBJECTIVE NORMS RULES AND REGULATION

“We are slow movers we do not go straight in”

Most respondents agreed that aviation was a highly regulated industry. In the case of airlines, even though they adapt technology, they are acquainted with rules and regulations to conform. They are reluctant to be technology leaders, especially in the airline sector, as the industry is vastly regulated. For example, rules regulations from state authorities Civil Aviation Organization Malaysia (CAAM) and international authorities such as International Civil Aviation Organization (ICAO). For instance, one of the respondents L.S says: “We don’t like to be the first mover especially in the airline business, because we’re a highly regulated industry. Whenever we adopt any technology into our business, we have to make sure that it is tried and tested first”.

He added that in the airline industry, technology is different from other industries, such as the grab industry. Grab was very different in the taxi industry, a very innovative way of doing business; however, it is not applicable in the airline business. MS from the airline spectrum added that ...we are always slow movers in technology. Whenever we adopt technology into business, it should be experienced first. MS refers to a well-verified process by the authority, as it concerns the airworthiness issue in airlines and the safety of passengers and crews.

2. PBC - MATURITY OF TECHNOLOGY

‘There is very little technology development. It is more about utilizing the current technology, better’

Many respondents, including one of the policymakers, highlighted the maturity of technology within the aviation sector as a key factor; therefore, the focus is on existing forms of technology rather than pursuing newer forms of technology. For example, respondents mentioned how automation, which is being used in manufacturing and airlines, is not necessarily a new technology. A. H., one of the policy makers remarked “technology development, yes, of existing technologies, not new technologies”. On the other hand, another participant, Z.I, highlighted technology maturity as a critical challenge for aviation players. He mentioned that the maturity of technology, availability of materials, and alignment of industry requirements will be a challenge for aviation research and technology. He argued “some industries and sectors may be open to adopting new technologies, however in this industry, we tend to be more reluctant to adopt new technology, till it is proven to be safe and error free of course”. In this study, technology maturity refers to the extent to which a technology is proven, reliable, and certification-ready for aviation use.

3. PBC – SCALABILITY

“The technology embodiment will be based on the availability of the legislation” Local aviation authority influence.

Respondents noted that the ability to scale a technology beyond pilot use depends on both organizational deployment capabilities; such as infrastructure and resources; as well as the national regulatory. In this study, scalability refers to the extent to which a validated technology can be implemented consistently across sites, fleets, or operational units within and across aviation organizations. For example, digital platforms supporting cargo tracking and airline passenger processing were viewed as easier to roll out across operations once approved, whereas safety-critical technologies require more extensive validation and staged deployment. As highlighted by one of the respondents from policy makers, he says that: “Any technology associated with the aircraft safety, only proven safe technology can be used in the industry. There are immature technology causing catastrophic accident”.

This immature technology, which has not been proven or extensively used in the aviation industry, is not permitted. This is because of the safety of the passengers and the airworthy issue of the aircraft. Aircraft can only fly when they are secure, proven, or safe to fly. At the same time, respondents emphasized that aviation has limited tolerance for trial-and-error due to airworthiness, passenger safety, and security requirements, which reinforces phased scaling even after initial adoption. This is an interesting finding from the aviation perspective compared to other sectors that may apply any technology at any time. In the aviation industry, there is no trial or error as it involves human life.

4. ATTITUDE - SUSTAINABILITY AND SUPERIOR PERFORMANCE

“With technology, any early detection of malfunction can be quick fixes”

The participants highlighted that the underlying role of technology is not only about the interaction with the passengers, but also between the operation, safety, and security of the passengers onboard, with the organizations, and all the relevant stakeholders. This is particularly interesting given the focus to date on in-flight customer-related studies. The focus and potential of technology were articulated within the Maintenance, MRO sector. It was revealed that the most significant aspect of technology in MRO is related to systems being used for monitoring and maintenance purposes, ordering spare parts, engineering, and the logistics requirements of the parts. As mentioned by one of the interviewees: “Different airlines have its own MRO activity. Different airlines use different system to plan for their MRO activities such as planning for the spare parts, ordering, maintenance and others”.

Therefore, technology adoption in the aviation industry can assist industry players in impacting performance. M. K. from MRO highlights “with technology..... any early detection of malfunctions so that quick fixes can be done or quicker parts replacement”.

It is clear that M. K. sees the benefits that technology can bring to assist in operational efficiency. Any malfunction or failure case of any system in the aircraft is quickly communicated to the right departments, which represents the ease of the operational procedure. This is further articulated by M. Q. from MRO “... we have internet of things being leveraged to increase operational efficiency. Sensors are placed in key places and data is collected, followed by forecasting activity of best timing for an airplane to be grounded for maintenance...any early detection of malfunctions so that quick fixes can be done or quicker parts replacement. All of these increase the efficiency of an airplane to achieve maximum utilization as well as reliability in term of safety”.

Interestingly, the role of interconnected technology in overcoming risk and detecting faults is in contrast to the insights presented by the policy makers, A.F. The latter mentioned the need for technology to mature for it to be trusted and applied due to possible errors; alternatively, technology is seen to help overcome risk through earlier detection. Furthermore, LS highlights: “the ability of the technology used in aviation could help to expedite on MRO process in recognizing the aircraft to do checking or repair”. This further highlights the defensive suggestion that technology can be used to improve aircraft performance detection as well as the safety issues of aircrafts and passengers. Again, these undertones the highest priority of aviation and issues with regard to maintenance and technology is put at the most precedence to ensure that the aircraft is airworthy and safe for passengers and crew.

We conclude that MRO technology is also needed to monitor the supply chain of aircraft spare parts. Being the pioneer or the latest advanced technology results in increased demand, which leads to better revenue for the organization. As added by MQ: “...technology helps to achieve a lean supply chain and reduce wastage”. This finding reveals that the schedule and maintenance database are one of the key issues in MRO; the use of technology such as the system helps the MRO players manage their MRO spare parts. Similarly, in the airline spectrum, the interviewee F.R. posit that the aviation industry is definitely keeping up with the technological developments and the focused is on the passenger experience or known as ‘Pax Ex.’ As highlighted in (International Air Transport Association) technology roadmap, technology is the main driver and challenge in the aviation sector. LS says that: “some airline and airport are deploying facilities which allow passengers to check in and board their aircraft using only biometric information (for example face recognition, iris scanning and fingerprints). One of the other respondents emphasize alike statement: MS says, “...this technology provides for a quicker processing and boarding experiences, therefore enhancing a passenger’s overall journey experience. ...These are part of an IATA led initiative called IATA fast travel to create uniform standards and recommended best practices for better passenger facilitation”.

Technology also plays a vital role in other aviation sectors such as manufacturing. From this perspective, the interviewees provided tremendous technological development in designing and producing aircraft. All interviewees agreed that aircraft production has improved tremendously since the 1960s and the 1990s. One of the interviewees (MQ) says that: “Earlier, aircraft were designed by hand...and they have now progressed to fully computerized design, testing and developed of aircraft prototype”. He added: “.... Technology allows deficiencies to be addressed prior to full production to present costly program overruns. In addition, improvements in aircraft engines have

enabled the reduction of fuel consumption, carbon emission, as well as reduced noise footprint". As highlighted in the technology roadmap in the aviation industry by the IATA, one of the statements mentioning technology delivers results for CO₂ reduction. In fact, it has been the key strategy for achieving the aviation industry's emission-reduction goals. MK added that: "Enabling aircraft to continue operating into airports with strict environmental controls. Improved aircraft with technology also enable reduction in overall operating costs, which create opportunities for airlines to fly routes more efficiently or being able to start routes which were not possible before due to prior aircraft capabilities". It can be concluded that technology helps improve aviation organizational performance.

Intriguingly, technology in the cargo spectrum helps to improve the smoothness of cargo operation in the ordering and receiving process, warehouse, and loading process to the aircraft belly. This contradicts the viewpoints of manufacturing and the MRO. This is a real difference in MRO and manufacturing, whereby technology use is focused more on aircraft performance. From a cargo perspective, the technology used focuses on the operational efficiency of cargo operations.

As highlighted by participant H.H, she notes that: "technology is used to assist cargo handling services such as to record in reservation, check in, online payment, tracing and tracking and others".

She added that smart technology would help the company to run smoothly. She continues: "Better system and machine use will help us to have leaner operation management and improve financial performance. For instance, the implementation of icargo, a cargo management solution from IBS our service provider, it can keep up with real time freight demands and ensure their cargo makes it to the right place at the right time, improved monitoring on cargo positioning within the cargo terminal".

What has been said above is absolutely agreed, since cargo space needs to be carefully determined and optimized to avoid space waste. Aircraft space optimization will not only ensure a profitable margin for the airline, but also for the passengers on board. The weights of the cargo and passengers must be balanced to avoid accidents. In fact, different aircraft have different cargo-space configurations. The use of technology or systems could help the cargo operator and airline deliver the cargo on time and reduce delays or mistakes in the operation.

- The key challenges with regards information technology in the aviation industry

From the findings, two critical challenges are faced by aviation industry players with regard to technology. These are cost and revenue, as well as aviation security. The findings suggest that the cost of investing in technology is always high. For instance, the technology used in aircraft can help the airline reach the destination faster. The airline can charge people more quickly to reach their destination. As mentioned by one of the respondents, as discussed above, every new technology introduced in aviation must be approved and verified by the authority. The second issue concerns security.

5. PBC – HIGH COST

'The better technology you use, the higher cost you bear'

Interestingly, the aviation industry is classified as an oligopoly market, which consists of a small number of business players. The oligopoly market in aviation exists when it is dominated or controlled by a small group of firms, such as a small group of airlines, a small group of air cargo operators, a small group of aviation manufacturers, and a small group of MROs. Technology is always regarded as expensive. From the airline perspective, the respondents underscored the importance of technology use with on-time performance or dispatch reality. As recommended by LS: "...as an airline, the main asset is the aircraft and technology or the system used.... if you can't control the cost, you will go bankrupt... the better technology you used, the higher cost you bear...". Furthermore, aircraft operations are always involved in the cost. This should become serviceable over time. MQ added that: "You have to ensure your on-time performance at dispatch reliability. You have to ensure you can conform to your schedule. You must also ensure the dispatch reliability, the thing that equip in your thing, components. Must ensure they are always serviceable on time". In addition, WH says: "Yes, you can fly a plane. but once they have in a time, the plane has to be grounded. The components must be replaced. These are all involved cost. This clearly shows that the cost or price of the adopted technology is one of the key challenges, especially in the MRO spectrum. To sustain in the aviation industry, for example, airlines, the cost must be balanced with the yield or revenue they receive. In

fact, if they cannot balance revenue and cost, they are unable to sustain aviation. As a result, businesses have closed. This is aligned and similar to that discussed for the airline. From the airline perspective, MS underline that: "If you have the revenue problem, like one of the problem the airline is facing, they have revenue problem, you can't control your cost, you lose money again, so you can't cut cost all the way. Thus, what is the fastest way of reducing the cost in the airline? Closed...."- MQ

A similar perspective from policymakers also agrees that cost is the most critical barrier for the aviation industry to invest. However, on the other hand, he mentioned that even though it is costly, but with the use of technology it will lead to efficiency. When a business or operation is efficient and sustained, the cost that you actually invest earlier will generate revenue. Below is one of the interesting quotations highlighted by the respondent: "Technology derive efficiency in design, manufacturing and providing the services. Efficient drive the cost down, and resulting in being competitive and more profit margin". -AH

Regarding the cost and funding of technology investment in aviation, as highlighted by the respondents, there is no specific funding for new technology development in the aviation industry. The funding is more on the capability of manufacturing the current technology used by manufacturing organizations. Moreover, as highlighted by other respondents, manufacturing is the aviation stakeholder that invests the most in technology. This is because manufacturing is more open to technology adoption because it can continuously develop research and development (R&D) activity. For example, manufacturing can be related to fuselage development, such as aerodynamics, to reduce drag and fuel consumption.

6. PBC- SECURITY

"New-fangled technology should be monitored"

As discussed earlier, regulations have become the main challenge for aviation players in adopting new technology, as they affect operational efficiency. Another challenge highlighted in this study regarding technology is the security issues. Both the respondents from the airlines revealed the importance of cybersecurity. MS says that: "I would say cybersecurity is top priority in any running organization to ensure data protection, secured payment channel and other.... what do we do is that our company developed cyber security policy, database policy, access policy which indicates that for instance: only approved personnel could to access certain data bank. Every access that requires our organization need to follow Standard Operating Procedure (SOP)for user access". Compared with the MRO perspective, it does not emphasize the cybersecurity issue. This is because most of the data used are for internal perspectives that relate to the line maintenance of the aircraft. WH states that for maintenance organizations, the most significant data are for maintenance purposes. He says that: "... In maintenance perspective, the data requires are mostly to man-hours, equipment's, tooling, hangarage, preventive maintenance action etc.". It has been argued that from an airline perspective, cloud and cybersecurity should be the most important aspects for aviation organizations because the two should run hand-in-hand. As mentioned by one of the interviewees, the need to have a cloud-based application that is accessible anytime anywhere should be supported by adequate cybersecurity protection". LS added that: "The advantage of having cloud-based application is that the virtual whereabouts of your servers which makes it a hard target for attackers due to multiple site hosting. The recovery is also faster compromised because of real time backups and replicates."

Manufacturing and Cargo have the same perspective as airlines do. They stated that many commercial aircraft systems are hackable. He added that the airline is the most exposed organization to cybersecurity issues. He highlighted that the potential of the airline system to be hacked is on reservation systems, cargo handling and shipping, cloud-based data systems, and flight traffic management systems. As mentioned by SZ, cargo is also exposed to the need to tighten security issues. She mentions: "... Since our company has moved to a cloud-based solution other than Microsoft Office, there is a biggest challenge for us to protect our data, especially on the security filing such as information to the custom on incoming shipment for instance'.

As recommended by previous scholars, it is important for researchers to consider the initial findings generated from the study to be shared with industry practitioners, scholars in the same field, and policymakers. The next

subsection presents research contributions from the theoretical, methodological, and practitioner perspectives. The discussion in this section continues with limitations and proposals for future research.

5.1.6 “New technologies have lots of potential, but we can’t afford trial and error in aviation” - Lack of trust

Along with technology maturity, it was evident that participants were also cautious about new technologies and seemed to have a lack of trust. Given the nature and focus of the aviation industry, S.K emphasizes the need for technology to mature and that too existing technology, not necessarily new forms of technology prior to it being considered for adoption.

‘The technology must be proven to mature before it can be implemented. Immature technologies are still causing catastrophic accidents’

It is evident from policy makers that trusting new technology can be problematic, given their macro level influence of policy makers, it pinpoints one of the reasons as to why there may be a lack of opportunities for certain spectrums within Aviation sector, thus highlighting the resistance of technology uptake within the Malaysian aviation sector. All of these pillars are related. However, the challenge is technological maturity. In aircraft, the technology must be proven mature before it can be implemented. However, immature technologies still cause catastrophic accidents.

7. SCALABILITY OF TECHNOLOGY

Interestingly, key findings from the interviews suggest the scalability of the disruptive technology (DT) in aviation within a specific spectrum. After exploring the adoption of technology across all spectra, a taxonomy shedding light on the specific technology highlighted by the respondents and the link to the specific spectrum of aviation is included in table 4.

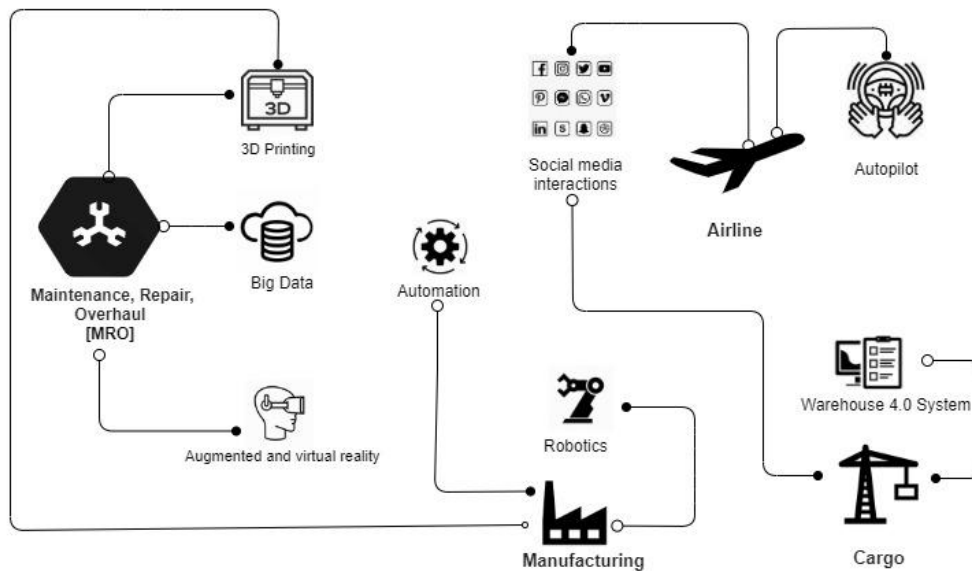
Table 4. DT application within aviation sector.

DT	Explanation from the respondents	Supported by all respondents
Cybersecurity	All respondent agree that every spectrum of the aviation sector requires security. They argue without security, chaos will happen. One of the challenges in cybersecurity related to large investment and reluctance of some organizations to invest.	Yes
Cloud computing	Cloud computing was seen as highly vital for the participants, given the volumes of data being processed, the was a real need for sophisticated cloud infrastructure	Yes
Big data and analytics	Data analytics was seen as a driver for operational performance and proactive decision making. The larger the sector, the bigger organizations operating within it, thus providing large volumes of data. Challenges were cited around data quality and analytical skillsets	Yes
Advanced Robotics:	Significant interest from within MRO and manufacturing. The challenges for this were the costs and maintenance of these advance robotics.	Yes
Additive Manufacturing	More applicable to MRO and manufacturing. The challenges, again centered on large set up costs and maintaining the performance and quality of 3D printed spare parts.	Yes
Augmented reality	MRO and Manufacturing. Challenges, cost to own the technology and to train staffs to use the technology.	Yes
Simulation	MRO and Manufacturing. Challenges, cost to own the technology and to train staffs to use the technology.	Yes

Horizontal and vertical integration	All spectrum may reflect. Challenges, cost to own the technology and to train staffs to use the technology.	Yes
Internet of things	All respondents suggested the importance of internet of things such as social media, website etc to all airline, manufacturing, MRO, cargo and caterer. Since aviation is worldwide business and all airline team were all around the globe, ease of communication system, social media, are vital for greater communication in their network.	Yes

Source: Developed by the authors (2025).

Based on the insights from the respondents, below Figure 2 articulates the key DT and its application across various aviation spectra.



Source: Developed by the authors (2025).

FIGURE 2. Infographic depicting the application of DT across the Aviation sector.

Based on the analysis, table 5 highlights the potential of DT in the aviation industry, as highlighted by the research participants. Table S5 offers further insight into the application of DT across different contexts.

Table 5. Role of DT in overcoming aviation sector challenges.

Challenges within aviation industry	Proposed	Application within Aviation	References
High costs and human related errors	Autonomous robots	In aviation industry, autonomous robot can be referring to unmanned aircraft. Pilotless drone aircraft is an example of autonomous robot in the aviation sector.	[56]
Risks associated with inexperienced pilots	Simulation	The simulation in aviation mostly used for aircraft simulation. It mostly used for pilots training in the airline and military, as well as in the design of the aircraft process in manufacturing.	[57]
Middle manager communication challenges	Horizontal and vertical integration	Horizontal and vertical integration are common across industries, including aviation. For example, Air Canada's 2001 merger with Canadian Airlines (a horizontal integration) positioned it as the world's twelfth-largest airline in the early 21st century. Improving passenger experience: <ul style="list-style-type: none"> • Assist with automating passenger processes such as check-in process. Safety: connecting different components of the aeroplane to improve the efficiency and safety of the aircraft, <ul style="list-style-type: none"> • Execute diagnoses in real time Offer preventive interventions Operational Saving: taking the most efficient routes, at the same time as optimizing fuel consumption,	[58]
Efficiency and safety of aircraft	IoT (Internet of Things)	Management of goods/luggage: tracking systems keep passengers informed about shipping companies and enable real-time monitoring of their belonging Cloud technology reduces reliance on on-premise servers and hardware while transforming customer engagement by enabling airlines to connect directly with passengers through mobile and social channels.	[59]
Lack of transparency	Block chain	Operational Saving: taking the most efficient routes, at the same time as optimizing fuel consumption, Management of goods/luggage: tracking systems keep passengers informed about shipping companies and enable real-time monitoring of their belonging	[60]
High storage and overhead costs	The cloud computing	Cloud technology reduces reliance on on-premise servers and hardware while transforming customer engagement by enabling airlines to connect directly with passengers through mobile and social channels.	[61]
Specialist spare parts and supply chain delays	3D printing	3D printing reduces production time for aircraft parts while enhancing efficiency by making planes lighter, more cost-effective, and sustainable.	[62]
Large, disparate data sources	Big data and analytics	Smarter maintenance and diagnostics enhance safety by enabling precise analysis of in-flight telemetry, air traffic control data, and weather forecasts.	[63, 64]

Source: Developed by the author (2025).

8. TECHNOLOGY STALEMATE

Across the cases, the findings reveal a recurring pattern in which organizations acknowledge the potential benefits of digital and sustainability-oriented technologies, yet adoption decisions remain cautious and incremental. Participants described how regulatory requirements, safety and security considerations, cost implications, and technological readiness were consistently evaluated alongside anticipated performance and sustainability benefits. This pattern was observed across multiple organizational cases within the aviation ecosystem.

VI. DISCUSSION

With reference to the application of disruptive technology, all respondents agreed that disruptive technology can be a driver of organizational success across many sectors, including aviation, and that technology is considered a tool or strategy for many businesses to achieve competitive advantage and sustainability.

Interestingly, one of the respondents highlighted that modern aviation derives its roots from the military, and the subsequent development in commercial aviation was adapted from the military requirements of the past. A.F states: "Aviation has its roots from trenches and skies of previous wars, and following the major wars, aviation designers utilized their skills to create 'birds of transport' instead of the 'birds of prey'...". Similarly, respondent M.Q too emphasized the disparity in technology development between countries, which were involved in World Wars 1 and 2 and those who were not, stating "those who have been 'forced' to develop the aircraft for war versus countries that have been colonized or did not have this need have very different aviation capabilities, I mean take a look at UK, USA, Russia, Germany, France, Japan for example".

It is evident through the analysis that the respondents each had a particular 'view of technology' and its potential within their operations and core business. It is deduced from the findings that different forms of technology can play a significant role across the entire aviation spectrum, ranging from manufacturing, airlines, MROs, cargo, caterers, and others. For instance, respondents from design and manufacturing largely referred to technologies such as automation technology systems, robotic technology, and additive 3D manufacturing as enablers and drivers for productivity. W. H. posits "Manufacturing or any other process driven contexts, will always have room for disruptive technologies, such as automation and 3D printing". Another participant stated, these newer forms of technologies, not only grant you volumes, but also precision, both which are highly valued in aviation industry"

From other spectra, such as airlines, the potential of DT has been discussed more in terms of automation, such as autopilot, communication systems, navigation, and unmanned traffic management systems. From the cargo perspective, technology serves as a key enabler of communication, supporting warehouse operations and internal and external coordination through connected systems and networks. These include communication platforms with agents, company websites providing service and policy information, and the use of drones or UAVs to monitor warehouse activities.

Findings from the MRO perspective highlight technology's potential to transform industry operations, shifting from human touch to human-led processes. Additive manufacturing, or 3D printing, was cited as a solution to challenges in spare parts stock, cost, and quality, while also improving warehouse efficiency. Key technologies include augmented and virtual reality, 3D printing, big data for predictive maintenance, and the Internet of Things, which can streamline outsourced aircraft maintenance. In contrast, airline catering applies technology mainly for communication and meal-ordering systems, making it one of the least technology-intensive segments. Policymakers and consultants view technology as broad and transformative, with enablers such as blockchain, cybersecurity, robotics, and advanced analytics. Yet, in aviation, adoption remains tightly controlled due to mandatory approval by local and international authorities. These findings are summarized in Table 6.

Table 6. Summary of DT across each aviation spectrum.

Aviation Spectrum	Key technology Involved	Overcoming challenges	Source
Manufacturing	Automation system, Robotic, Additive manufacturing, 3D	The rising of aviation labor cost worldwide	N.A M.K L.S M.S
Airline	Autopilot system, communication system, navigation system, social interaction	Human error, automation of inspection task	F.R Z.I
Cargo	Warehouse system, automated cargo scanning, internal external communication system, social interaction via website	security concern on cargo	S.Z H.H
MRO (maintenance, repair and overhaul)	Augmented and virtual reality, 3D printing, big data	Automation of inspection task, optimizing the balance between the need, cost and quality of the spare parts. To comply with last minute request before departure, aircraft delay, short turnaround time etc, slow communication	M.Q W.H
Flight Kitchen Caterer	Communication and ordering system, automated machine for washing		H. S
Policy maker	View all technology are related in aviation field but with some limitation, control as the industry is highly regulated, all the technology introduced should be get tested and approved by both national and international authority	Human error, slow communication	A.H. A.F S.K.

Source: Developed by the authors (2025)

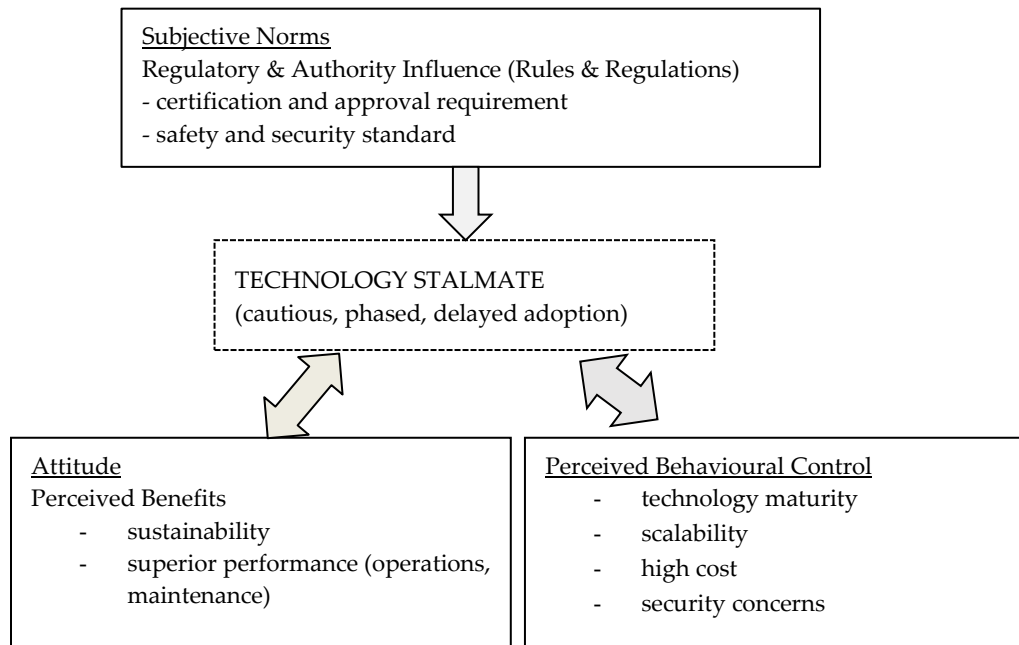
All respondents emphasized that new technologies in aviation require approval from both local and international authorities, with rigorous testing mandated before implementation. Unlike other industries, such as automotive, aviation faces stricter regulatory oversight, making its technological development distinct. The following section presents key themes from the analysis, offering deeper insights into aviation stakeholders' perceptions of disruptive technologies.

Building on the cross-case findings, this study conceptualizes "technology stalemate" as a condition in which organizations recognize the potential benefits of technology adoption but remain in a state of cautious, phased, or delayed implementation. Rather than indicating resistance to innovation, technology stalemate reflects risk-aware decision-making shaped by the interaction of perceived benefits, regulatory expectations, and feasibility constraints within a safety-critical aviation environment.

Drawing on the TPB, the findings indicate that attitudes toward technology are largely positive, driven by perceived sustainability and performance benefits. However, strong subjective norms manifested through regulatory and authority requirements related to safety, certification, and security, encourage cautious adoption. At the same time, perceived behavioral control is constrained by concerns over technological maturity, scalability, high costs, and cybersecurity risks. When these constraints outweigh perceived control, organizations remain in a technology stalemate, despite favorable attitudes toward adoption. These dynamics are further reinforced by the institutional pressures described by [44], whereby coercive isomorphic forces from regulatory authorities compel aviation organizations to conform to established safety and certification norms before adopting new technologies. This regulatory conformity, while essential for safety, structurally constrains the pace and scope of technology diffusion a pattern consistent with [65] risk society framework, in which actors in high-stakes environments priorities precaution over innovation speed. Based on these insights, a TPB-grounded conceptual framework (see Figure 3) is proposed to explain the

emergence of technology stalemate in the aviation sector and to provide a foundation for future empirical testing.

Figure 3 illustrates a TPB-based conceptual framework explaining the emergence of technology stalemate in the aviation sector. The framework shows how technology adoption is shaped by the interaction of attitudes toward perceived sustainability and performance benefits, subjective norms arising from regulatory and authority requirements, and perceived behavioral control constrained by factors such as technological maturity, scalability, cost, and security concerns. Together, these elements contribute to a condition of cautious and phased adoption, conceptualized as technology stalemate, reflecting risk-aware decision-making rather than resistance to innovation.



Source: The authors.

FIGURE 3. Conceptual framework on Technology stalemate TPB-based conceptual framework.

Based on the proposed TPB-based conceptual framework, this research advances three propositions to guide future empirical investigation of technology stalemate in the aviation sector. These propositions articulate how attitudes, subjective norms and perceived behavioral control interact to shape cautious and phased technology adoption within a safety-critical and highly regulated environment.

- Proposition 1: Positive attitude toward technology adoption, driven by perceived sustainability and performance benefits, are associated with a lower level of technology stalemate.
- Proposition 2: Stronger regulatory and authority influence, reflecting subjective norms related to safety, certification and security requirements, is associated with a higher level of technology stalemate.
- Proposition 3: Lower perceived behavioral control, arising from concern over technological maturity, scalability, high cost and security risks, is associated with a higher level of technology stalemate.

VII. CONCLUSION

This research develops an in-depth understanding of how disruptive technology are perceived and evaluated across the aviation ecosystem, contributing to knowledge on technology adoption and utilization within a highly regulated, aviation industry. Drawing on insight from key stakeholders across multi sector aviation including manufacturing, MRO, airlines and cargo, the findings highlight both the perceived benefits of technology shaping decision making and practical constraints shaping adoption decisions.

This study is context specific to Malaysia and reflects managerial and regulatory perspectives accessed through professional networks, which may introduce access bias and limit transferability to another jurisdiction. More specifically, the findings are most applicable to emerging-economy aviation contexts that share similar characteristics with Malaysia: active national regulatory oversight, transitional technology infrastructure, and multi-stakeholder coordination environments. Jurisdictions with fully liberalized aviation markets, more mature regulatory frameworks, or different institutional cultures such as those in Western Europe or North America may exhibit different adoption dynamics, and direct comparisons should be made cautiously. Additionally, regulatory and confidentiality constraints may restrict the availability of certain operational data and breadth of the perspective, for example from frontline staff, which should be considered when exploring the findings.

The findings suggest that adoption pathway should be tailored to each aviation spectrum: for instance (i) airlines and cargo operators can prioritize cloud, analytics and IoT-enabled platforms to improve passenger/cargo processing and real-time visibility, while strengthening cybersecurity controls; (ii) MRO and manufacturing can leverage additive manufacturing, augmented/virtual reality and advanced robotics to improve inspection, maintenance planning and parts availability, subject to certification; and (iii) cross-sector initiatives should emphasize data governance, staged pilots and regulator engagement to support safe scaling. These recommendations are further aligned with the UN Sustainable Development Goals, particularly SDG 9 (Industry, Innovation and Infrastructure), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals), as well as IATA's Fly Net Zero 2050 commitment, underscoring the importance of balancing technological innovation with environmental and social responsibility in aviation.

From a theoretical standpoint, this study extends the TPB by introducing the concept of technology stalemate as an explanatory framework for understanding cautious and phased technology adoption in aviation. While stakeholders generally express positive attitudes toward disruptive technologies, strong subjective norms arising from regulatory and authority requirements, together with constrained perceived behavioral control related to technological maturity, scalability, cost and security concerns, collectively shape a condition of risk-aware decision making rather than outright resistance. This study further contributes to the theoretical literature by integrating institutional theory, regulatory governance theory, and risk society theory alongside TPB, offering a multi-level explanatory framework that situates individual adoption intentions within the broader structural and institutional context of aviation regulation. This integrated perspective advances current existing TPB based technology adoption research by accounting for the multi-stakeholder and system-wide nature of the aviation industry.

This study offers three key contributions. First, it provides a conceptual foundation for future research examining aviation specific disruptive technology components and analytical capabilities across interconnected aviation functions, including airlines, airports, ground handlers, caterers and MROs. Second, it offers practical insight for industry practitioners and policymakers by highlighting the importance of balancing innovation with regulatory, safety and security considerations in technology adoption decisions. Third, the findings underscore the structural challenges of accessing and integrating industry data.

Building on the proposed TPB based conceptual framework, future research may empirically test the propositions developed in this study using quantitative or mixed-method approach to examine the relationship between attitudes, subjective norms and perceived behavioral control and technology stalemate. Longitudinal studies could also further explore how changes in regulatory environments, technological maturity or cost structure influence the evolution of technology stalemate over time. Such research would deepen understanding of how digital transformation unfolds in complex and safety-critical industries beyond aviation.

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and A.A.H.; data curation, N.A.A.R.; writing—original draft preparation, N.A.A.R. and A.A.H.; writing—review and editing, N.A.A.R. and A.A.H.; visualization, N.A.A.R. and A.A.H.; supervision, A.A.H.; project administration, N.A.A.R. and A.A.H.; funding acquisition, A.A.H. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest.

Data Availability Statement

The data will be made available upon reasonable request from the corresponding author Abdelsalam Hamid"

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