

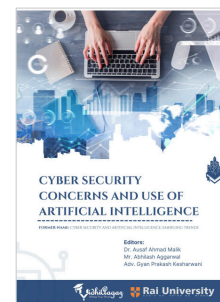
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IMPLEMENTATION OF ARTIFICIAL INTELLIGENCE IN INTERNATIONAL AVIATION: A CRITICAL STUDY

Sidhant Gupta⁴¹ and Sunavo Ray Chowdhury⁴²

ABSTRACT

Artificial Intelligence (AI) will provide the aviation sector with \$8 billion in operational efficiencies by 2022. The implementation of AI in Aviation could minimize human-error and other risks. This paper investigates the legal viability of the implementation of Artificial Intelligence in Commercial Aviation, it further includes the examination of the central structural treatise on the topic, the study of regional Bilateral Aviation Agreements, and Multilateral Agreements (Mas). To identify the lapses of the current laws and identify policy-spaces. The paper contains a review of the existing literature, analysis of key trends and developments of international law, and a correlation with the International Law harmonization efforts. Part I of the paper lays down the definition of AI and its scope in aviation. Part II of the paper investigates the International Legal Framework for Aviation, existing legal regimes and 'Structural-Regimes' of International Aviation Law, Bilateral Investment Treaties and MAs. Part III investigates the existing liability mechanisms and its viability for suitable implementation of AI into Aviation. Part IV presents Data-Protection and Privacy related concerns arising out of AI implementation. Part V supplements the paper with the most relevant case studies. Part VI presents the future trends and challenges into the implementation of AI in aviation. Part VII of the paper presents the conclusions and the policy recommendations. The study concludes, based on the analysis of the relevant aviation law, that the way forward is to implement AI related nomenclature and Data-Privacy related specific concerns as 'minimum standards' in the model BITs and MAs, as a part of the harmonization efforts so that the liability regimes and multiple other forms of dilemmas could be effectively resolved. There should be a centralized legal framework consisting of the major aviation stakeholders a regulatory authority. Every automation effort should have a human supervisor to minimize overall risks and dilute the AI liability dilemma.

Keywords: Aviation Law, Artificial Intelligence, International Investment Law, Bilateral Investment Treaties, ICAO, Data Privacy.

INTRODUCTION TO AI IN AVIATION

Artificial Intelligence (AI) is gaining significance by the day, generative AIs and Large Language Models are being used in various fields save for an extensive implementation in the Aviation Industry. AI technologies may provide the sector with an estimated \$8 billion in operational efficiencies by 2022. In present-day if, all the pilots of an aircraft have been incapacitated it would mean that all the lives on board will be lost but, with usage of a properly trained AI, the day could be saved. The AI technologies can enhance Aviation in multiple ways for instance, support efficient air traffic flow management, aircraft servicing, or passenger service. AI can supplement the tasks of the human counter-parts from pilots to even ground staff.

An introduction of AI to aviation raises a number of legal questions, there are a number of gaps in the judiciary which need to be addressed. The primary focus of this paper is to analyse how the established legal regime of aviation supports the idea of implementation of AI or stands against it. The paper is

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formulated as a purely doctrinal research paper, as a critical study of the established norms through a comprehensive analysis of existing international and European guidelines, regulations, and directives, as well as reports, guidelines, and statements published by relevant independent bodies.

Definition and Scope of Artificial Intelligence in Aviation

Artificial Intelligence (AI) in aviation has no strict proven definition yet, though some research works define it rather broadly as a system with learning capabilities, irrespective of special linkages to the aviation domain in which it is applied. On the other hand, it is also argued that AI covers a variety of diverse concepts, including self-regulating systems, machine-learning, cybersecurity interventions, and softwares that are able to adaptively engage in their surrounding environment. As per the existing scholarships studies on the application of AI in aviation are confined to implementing AI as an overarching term for the different AI concepts and technological tools such as, automated systems, robotics, high-level data systems, and advanced analytics. It further includes predictive-maintenance, air-traffic management, security, filtering, baggage handling, sensor data analysis, flight optimization or intelligent-engines, dispatch reliability, consumer services or robotics, operations of drones and unmanned systems for landing. On this premise the linkages of AI and Civil Aviation have the promise of becoming a very effective and optimized system, in terms of both cost and time but at the same time it there is no space for mistakes as even the smallest mistake in this sector could mean the loss of many lives.

INTERNATIONAL LEGAL FRAMEWORK FOR AVIATION

The international legal framework for air transportation consists of more than 12 conventions and 19 annexes developed by enacting global standards. Thus, there is a very substantial legal basis upon which the analysis of implementation of AI in aviation has to be conducted upon. The primary documents that regulate the legal premise of Civil Aviation are Chicago Convention on International Civil Aviation (1944), ICAO Annexes, ICAO Regulations, and all the other framework that has been laid down by ICAO, other than that, specific routes are regulated by BITs and Multi-lateral Agreements (MLAs) like erstwhile NAFTA and USMCA and etc. Also, the International Federation of Air Line Pilots Associations (IFALPA) Standards and International Air Transport Association (IATA) Regulations are additionally important. This section of the paper gives a brief summary of the various international documents that might bear upon the incorporation of AI into aviation. The 1944 Convention on International Civil Aviation established the organization and authorized it "to adopt all practical measures that may be necessary or expedient ... for the safety of air navigation and the regularity of air transport". The formation of the International Aviation law is such that the enforcement of jurisdiction depends on a number of things, including location, state of the aircraft-owner, state of registration, state of the operator or state of the leasing, state of the occurrence or the action committed has a 'connection factor' with the state concerned. Although the requirement of the existence or creation of a connection is key to the rule, the notion is not defined in the treaties and the intentional usage of extraterritoriality of flight status in the committing of the crime is also not covered by the texts. In these scenarios it is the regional aviation agreements that appropriate the primacy, e.g., the European and U.S. regional

agencies, for example, both give weight to foreign approaches when considering high-level, system, and higher risk regulations.

The primary reason behind the above discussion was to elucidate that the implementation of AI in global civil aviation does not conform to one document or one piece of legislation, there needs to be taken a sectoral or regionally conformist approach based on the regional Multilateral Agreements (MLAs) or specifically useful Bilateral Agreements. In the event of conflict of approaches, it is so far beyond a doubt that AI systems are not, categorically, approved but at the same time they are not disapproved, which puts them in a grey area. As aviation industry is subject sectoral regulations, it is compliance to those regulations that would permit the use of AI systems.

International Civil Aviation Organization (ICAO)

Sustainability of global air transport is an important goal. It is the task of the International Civil Aviation Organization "to promote safety, the safety of flight operations, efficiency, regularity, and the planning of air transport." The ICAO's legal mechanism makes it possible to create an enabling environment for the use of AI technologies in aviation however, with the consent of the state parties involved. The state parties need to develop technical co-operation by providing assistance, sharing relevant practices and by creating a recommendations system for the effective implementation and creation of guidelines.

For these purposes the inter-state co-ordination and harmonization of the relevant legal framework are needed. Consequently, in order to discuss the integration of AI in the policies of modern civil aviation. As such it should be emphasized that harmonization might very well be the key to successful implementation of AI into aviation. These parameters result from the ICAO's co-ordination, research, and development efforts. Due to the ICAO's framework with respect to the obligations of the Member States for the implementation of SARPs, it is necessary to consider an appropriate ICAO mechanism to address this field, in particular, given the legal aspects of this integration in the aviation field. There will arise a number of disputes or disagreements amongst the state parties and for the effective resolution of the same within the ICAO mechanism itself there needs to be a Dispute Resolution mechanism, for disputes regarding AI, and inclusion of such Dispute Resolution mechanism must be within all the BITs and MAs, preferably construed as 'minimum standards'.

Regulation and Oversight of Artificial Intelligence in Aviation

In the aviation sector, robust regulation and oversight mechanisms are in place to ensure safe and secure operations. Regulatory authorities and organizations are tasked with setting and monitoring compliance with international or regional standards and best practices in relation to, in particular, the airworthiness of aircraft, their systems, equipment, and parts, as well as the fitness of the crew and air traffic controller. This area of the law is highly complex and has developed extensively in specific national legal systems, but it also now includes many international treaties and agreements that regulate the various international aspects of civil aviation. In the recent past, new and adapted rules have been developed and implemented to regulate, in particular, the use of drones and electronic identification of aircrafts. AI is based on machine learning and can self-improve by using and analysing data. Due to this there is a serious co-relation between AI implementation and Data Privacy related concerns in the Aviation due

to which there is a potential of rise of serious ethical concerns relating to the usage of AI in aviation. A number of such issues have also surfaced. No doubt the legal and regulatory questions are often complex and difficult. They often deal with uncertain predictions and balance conflicting and many times undefined rights and interests. They often challenge economic and safety concerns and require that the difficulties of the legal regime interact with deep scientific hypotheses. As such, advancement in the law and the way scientists and engineers react to it will help shape the direction and speed of AI in aviation.

Regulatory Authorities

Several players are involved in the regulation of AI technologies in the aviation sector. At an international level, two key authorities play a specifically relevant role. One is a specialized agency of the United Nations, whose role is to set the standards and regulations necessary for aviation safety, security, efficiency, and regularity, as well as for the environmental protection of aviation. As AI in aviation has a direct implication for aviation safety, this agency develops standards and recommended practices, procedures, and guidance material to be used by member states to enable a global effective and harmonized implementation of safety measures.

A regulatory product impact assessment of advanced AI in aviation revealed a strategic priority to shape the standards and recommended practices on AI, which further refers to a joint effort concerning commercial aircraft certification.

Among the many challenges, issues such as jurisdiction, accountability, and in general the enforceability of new AI regulations could slow down the regulatory action of the aviation authorities. But the implementation of the services in the end would make it faster and even safer. There is no mention regarding how, aviation authorities will enforce compliance with these measures. At the same time, the paper contends that the role of the authority is indeed instrumental in the aviation safety regulation of AI and automated vehicles. Continuous monitoring is necessary to detect problems with AI and intervene promptly for corrective purposes. This begs questions, should standards and recommended practices be inversely developed taking into account the level of technological development to establish certain theoretical requirements, including the human-factor? In this case, global aviation safety will require the introduction of standards for civil aviation to ensure the coordination and understanding of measures corresponding to the readiness of the individual states. However, it must be acknowledged that there are currently no aviation agreements concerning the mutual recognition of pilot competencies, which limits the practical performance of functions in another country. This also prevents providing for a management system with different automated systems between nations of varied technologies.

LIABILITY AND ACCOUNTABILITY IN AI AVIATION SYSTEMS

As AI systems are introduced into aviation, questions about liability and accountability may emerge, including who is liable for the actions of AI systems when failures occur. It can be expected that introducing AI will alter or complicate traditional aviation liability paradigms, including concepts of strict products liability for manufacturers who sell airplanes, which are not usually thought of as being

"defective" in the sense of a product causing personal injury. Illustrative questions are: (1) Who may be at fault when an AI system fails to meet a reasonable standard of care? (2) How do we prove it acted negligently or in a way that falls below ordinary care? (3) Does it matter whether or not an AI system is "ultra-high-fidelity"? (4) What standards of care credit should be assigned to human operators and AI systems, and what percentage of each would be necessary to avoid liability in operational failures? (5) How does this interrelate with the need for developing a proactive safety culture that replaces a reactive blame culture?

Legal principles that may guide liability for AI in aviation include standard principles of tort law and product liability, as well as agency law and antitrust law. The law principally directs inquiry to liability and away from regulation. One can see this in the discussion of tort liability considerations on AI. In discussions of AI in other critical sectors, scholars and policymakers have shown thoughtful prudence, acknowledging the risks that newly introduced technologies will have in large-scale harm events. Scholars have noted that AI may change how we allocate legal burdens, and in courts of law, jurors who adjudicate blame can struggle with unexplainable AI decisions. Comparative observations from liability gaps may be instructive. For example, the literature points out that data spans beyond national borders and that a possible gap could arise in assigning liability when data is combined to train AI from different countries. Moreover, case law points to potential gaps in applying existing doctrines of causation, including in the application of legal causation principles and the unit of liability in propositional machine learning. Cutting across laws and jurisdictions, work has elaborated on legal and ethical considerations for accountability, while consideration has been given to liability in the introduction of unmanned aircraft, focusing also on the importance of public trust. The foundation of international aviation law segregates liability and safety. Not unlike other sectors of international law, this framework is based on an agreement that bureaucrats should operate without fear of tort liability

However, tools like the Aviation System Oversight Program signal a growing understanding that individuals do not operate aircraft in vacuums and should not be seamlessly segregated where they are part of a system. This is particularly pertinent where an AI-dominated flight deck is being integrated into an existing system that has liability regimes in place.

Legal Principles of Liability

In this subsection, we briefly explore the legal principles of liability and discuss whether and, if necessary, how these general principles should be modified to fit AI technologies, specifically AI for aviation. The principles of liability remain the basis for any legal order, including the question of liability in the context of AI. Legal traditions recognize different concepts of liability, such as contractual, non-contractual, and other liability regimes like liability for ultrahazardous activities and compensation for fault-based defects in the legal process.

In the aviation domain, liability questions with respect to AI can mostly be traced back to either the negligence of the AI developer, the manufacturer, or the human system designer, the air operator, etc. There is also strict liability, liability without fault; a further development of such liability is safety liability. Finally, historical principles or assumptions on accountability, such as vicarious liability and

respondent superior, are being discussed with respect to AI. These legal principles apply more or less to AI as well, but of course, the characteristics of machine learning, for instance, require a specifically adapted understanding of each of these. If we look at the situation in the aviation domain, the question arises whether our principles of liability are sufficient to cover the cases concerned with AI. The legal regime of liability cannot cope with AI technology. One argument for this position concerns the increasing autonomy that is connected to machine learning: AI will develop and apply its own courses of action and strategies in the face of unforeseen events in a way that human operators do not comprehend and do not even foresee.

Abandoning such an approach and sticking to traditional concepts would imply closing our eyes to those operational contexts of AI application that heavily rely on machine learning, thus limiting its deployment. AI running on machine learning, due to humanly unforeseeable action strategies of its own, represents the greatest challenge for liability. Several case studies are mentioned where human operators lost track of what their algorithms are doing and how they reach decisional conclusions. This is particularly the case for data-driven AI.

DATA PROTECTION AND PRIVACY CONCERNS

AI is likely to generate significant concerns regarding privacy and data minimization, mainly due to its need for a large amount of data to learn and train itself. The fact that new solutions seem to be mainly functioning based on the collection, storage, and further processing of personal data brings a range of compliance challenges.

In light of the massive amount of personal data stored by aviation stakeholders, the sector raises concerns about the possibility of machines inadvertently making protected data public. Such fears are particularly pronounced following the failure of airlines to safeguard their customer data. The sheer size of these pools of data suggests that data breaches involving biology are no longer laughable – samples handled by new software could now comprise thousands of individuals, opening the door for large-scale data harvesting. A recurrent thread running through the AI narrative, therefore, concerns itself with the implications of the technology for passengers in terms of data protection, surveillance, and privacy. In short, the idea of availing oneself of an AI-powered or drone service opens passengers up to a host of data protection risks. The gravity of these risks is further amplified by the strict provisions applied across the EU under the General Data Protection Regulation. Due to the heavy penalties imposed, airlines are understandably anxious to ensure they are not only compliant but also seen to be compliant. With so much at stake, one might expect airlines to take more robust forms of verification and proof by adopting the reverse burden of production. All considered, there appears to be a well-trodden path towards a harmonious relationship between AI technology and rules, etiquette, and ethics. Given this, current political challenges associated with the implementation of AI technologies in aviation seem to arise rather from a lack of information among the traveling public, or at least among segments thereof. Thus, a number of low-level daily struggles and objections have emerged, focusing on privacy and the data protection potential that AI technology raises for citizens.

GDPR Compliance in Aviation

Given the amount of passenger information that is being stored, whether for just the time of the flight or longer, it is important to ensure that this is carried out correctly. The regulation holds a number of principles that all data users within the European Union must adhere to. The first is that processing should be lawful, fair, and transparent. In AI, this means that any passenger data that is collected, used, or stored must be done so legally. This means either that the passenger has given clear consent for this action, that the action meets the need to process for a contract that is being engaged in, or that there is a regulatory requirement for this to occur.

The data that is collected by AI must also be used for the purpose for which it was collected. In aviation, this means providing services such as booking, baggage carriage, flight safety, and medical information. In general, AI may collect more information to improve customer service, sales, or operations. The data obtained should be relevant and not excessive, and passengers should be told how long it will be stored, as it should not be held longer than what is needed. This includes the passenger having a right to ask for their data to be deleted. This also includes ensuring that the data is accurate and up to date. Where there are concerns that larger AI systems will struggle with assessments, versions specifically looking for bias in AI have been suggested as a way to lower the time and economic costs to the company.

The risks can be reduced by controlling who has access to the data and maintaining confidentiality. In practice, many existing operations can be updated, and an organization can use privacy by design methodology to ensure that the whole organization is aligned for these privacy changes. Similarly, non-identified identifiers or anonymization strategies can be used for data to ensure its isolation, preventing individuals from being specifically identified. This requires a company to use sufficiently strong protection mechanisms; however, otherwise, the controller will still be liable should this be compromised.

Ethical Considerations in AI Aviation Systems

As AI systems are intended to operate in real environments, a lot of attention is given to establishing a set of ethical guidelines to ensure that data science and AI technologies are used for the public good and that trust in them is maintained. While it is logical to look closely at established benefits and risks of AI systems in healthcare and social welfare, these should also be investigated in aviation, where the benefits of AI implementation are predicted to be significant. The safety and efficiency of AI systems should be balanced together due to the fact that benefits and risk trade-offs do exist. The transparent, explainable, accountable, and fair AI applications bring great benefits to the aviation industry, but, on the other hand, may slow the introduction of new functionalities and applications. A comprehensive decision-making process involving the alignment of different ethical principles in AI is required between the social desirability and technical possibility of a solution.

Given the recent ethical controversies on data processing, it is highly relevant, although speculative because new data are due, to report on how various approaches can be used for identifying meaningful dilemmas, which require explanation at several levels. Dilemmas are considered at the level of function with special focus on the relationship between AI and pilots and within the safety culture dimension while paying attention to the process-oriented perspective. Given the recent ethical controversies on

data processing, it is highly relevant, although speculative because new data are due, to report on how various approaches can be used for identifying meaningful dilemmas, which require explanation at several levels. Dilemmas are considered at the level of function with special focus on the relationship between AI and pilots and within the safety culture dimension while paying attention to the process-oriented perspective.

A study group report also proposes a draft code of conduct. It currently addresses professionals connected to AI technology, and companies that manufacture, repair, overhaul, or use systems containing AI technology. Despite these efforts, more regulations will be necessary to take into account new types of technologies and their ramifications.

CASE STUDIES AND LEGAL ANALYSIS

So far, the usage of AI in aviation has been similar to how Airlines envisage and use Data Analytics. Dynamic pricing is an aspect for which AI is known for being used by the Airlines, Lufthansa, Emirates and Southwest, apart from these major operators there are some small-time operators as well that use AI augmented predictive systems for multiple reasons.

It was laid down in the case of *Max Schrems v. Facebook Ireland Ltd* the usage of user generated data for the purposes of analysis do raise data rights related concerns and as per EUGDPR if it is at all used for a purpose not specified prior leads to the violation of the EUGDPR.

Furthermore, from the case of *United Airlines v. Department of Transportation* on the issue of Algorithmic Bias and Discrimination, it can be stated that algorithms perpetuate existing biases in the interpretation of data, and even in AI augmented models it has been observed to persist. This often leads to discriminatory pricing, or impact services in a discriminatory manner including boarding and security screening and etc.

Determination of legal responsibility for accidents is prior or presumptive concern for usage of AI in Aviation, as the liability regimes aren't defined or properly laid down yet, from the case of *Google v. Waymo*, it can be stated that every case leads to a conflict of liability amongst the manufacturer, operator and even the AI itself. As such, as this is still an emerging area, the ICAO is working on the regulation focusing on harmonization attempts at regional BIT models and Multilateral agreements as well.

FUTURE TRENDS AND CHALLENGES IN AI AVIATION

The future trends indicate an increasing integration of AI technologies into the aviation sector. The development of advanced analytics of big data extracted from a plurality of operations enables the augmentation of human ability in performing decision-making processes. Also, the introduction of algorithms strongly based on a machine learning approach can be adopted in the aeronautic scenario. In addition, as a direct evolution of machine learning techniques, one of the most relevant challenges of current aviation is digitalization, regarded as the introduction of autonomous systems and the redesign of current systems in order to safely introduce this enhancing technology in the aviation market. These advancements lead to a growing potential of using AI and related tools or techniques in aviation for the implementation of autonomous aircraft able to make their own decisions based on

acquired data. Implementing AI and autonomous systems will introduce various benefits for aviation, such as cost reduction, flexibility in carrying out operations, limiting human errors, and potentially significantly increasing safety.

At the same time, these advancements will introduce different facets to be carefully covered in a legal framework, for example ensuring that no ethical considerations are violated, or obligations related to the explainability and the level of trust in AI utilized. Other emerging challenges relate to the continuous maturity of AI capabilities that will be needed both in the design of suitable training tools and in the monitoring of their proper use. Also, the adaptation of current regulations to AI capabilities in air traffic management and systems will be an arising issue in the future. Legal frameworks are likely to establish ideals while empowering international and national authorities and industry players with the mandate, capacity, and tools to develop practices adapted to the nature of the emerging technologies. They do, however, carry the potential for lack of agility if they are only adjusted through formal channels. A cooperative and efficient process to manage this complexity and ground the high-level guidelines into practical requirements will be needed between various industry stakeholders and creative authorities looking to safely support innovation. This changing landscape supports the call for further research in the field. Up-to-date analysis of how AI is integrated into aviation will allow better monitoring of aviation system safety aspects and timely adaptation of existing practices. Also, the increasing ability to autonomously analyse big data regarding hazardous situations and the new normal will not only enable predictive and seamless adaptation of monitoring and enforcement but also enhance the safety case. Synergies and possible conflicts considering AI in the different domains will have to be addressed by the authorities and industry in a cooperative manner, enabling proper technology evolution and the reduction of synergistic and discriminatory risks.

Commercial deep learning-based systems have gained traction in many applications that require people to analyse and predict asset prices, government policies, and other areas motivated by properties of the training data. Examples of this that have particular relevance for aviation include predicting maintenance schedules based on engine and aircraft data, predicting wind shear and turbulence for pilot assistance and flight planning, predicting touchdown deceleration for aircraft pavement loading and approach control, traffic route optimization to reduce airspace congestion and improve security, foreign-object debris detection and reduction, automation of air traffic control, and a more realistic and flexible simulation for pilot training and entertainment. As a result, deep learning has the potential to introduce new research avenues and should be understood and applied to improve aircraft safety, comfort, efficiency, and capacity worldwide.

The various applications of these robotic systems address the issue of the conduct of remotely operated and autonomous systems in the common domain, i.e., the airspace and the right to access from one state to another. This has significant ethical and legal implications that must be addressed, such as rights to privacy and end users' authority to opt out of data sharing in countries such as the EU Member States. This highlights a primary focus on governance and political economy issues and how shaping policy can unlock technological, economic, and social development potential by driving technology deployment at scale in a privacy-compliant and democratically legitimized manner. It also reinforces

the caution supported by regulators in heavily regulated industries who have noted that algorithmic decision-making technologies are relatively immature and any use of the uncertainties can be very high. The speed at which technology is advancing significantly in comparison to enacted legal measures poses a core issue for both generalist and specialist regulators.

CONCLUSION AND RECOMMENDATIONS

This study has shown that the development of AI technologies has begun to change the field of aviation law. The most critical challenge is to develop solutions based on existing legal frameworks. Besides, the moral and ethical aspects of AI and the legacies of the ultimate step for safety and the identification of responsible parties increase the risk of damage. Based on the analysis of the relevant aviation laws it can be concluded that the way forward is to develop recommendations that can be adopted by authorities and stakeholders regarding the use of AI technologies. Accordingly, the first recommendation suggests that legal technologists, legal experts, authorities, and stakeholders from throughout the aviation value chain should be working proactively to ensure that a legal framework governing the area of AI technologies can be implemented effectively. To develop policy and legal norms, regulatory impact assessment should be prepared. It is also recommended to include all stakeholders in the regulatory process. A regulatory committee should be established on issues where different opinions can be expressed.

For the implementation of AI in aviation, the harmonization of International Law is of paramount importance, uniformity in model BITs and MAs, facilitated by the International Investment Law are a key to it. Furthermore, to dilute AI related liability dilemmas and diminish the risk of failures, there should be human supervision on every task that has been automated by the usage of AI.
