Ius Novum
2024, vol. 18, no. 3, pp. 34–46

THE 'BLACK SWAN' THEORY IN AVIATION SAFETY

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DOI 10.2478/in-2024-0021

Abstract
The article is a review and focuses on the analysis and interpretation of Nassim Nicholas Taleb's 'Black Swan' theory in the context of aviation safety, considering various aspects of risk management and preparation for unforeseeable events in aviation.

We present the thesis that the Black Swan theory has significant implications for the development of risk management strategies in aviation, emphasising the need to prepare for rare but catastrophic events that traditional risk analysis methods may overlook.

The aim of the research is to understand how the Black Swan theory can be integrated into existing aviation safety frameworks and how it can contribute to the aviation industry being better prepared for extreme events.

The article stands out for its original approach to the analysis of the Black Swan theory in the context of the specific nature of aviation safety, highlighting new perspectives in aviation risk management. It provides valuable insights into the practical aspects of applying the Black Swan theory to aviation, offering a novel approach to predicting and responding to unexpected aviation events. This is important for both aviation safety theorists and practitioners in this field.

The research covers extensive literature analysis, including case studies, risk management theories and current aviation safety strategies, providing a comprehensive overview of the issue.

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Keywords: Black Swan theory, aviation safety, risk management in aviation, Nassim Nicholas Taleb, crises in aviation

'The things that have never happened before, happen all the time.'
Scott D. Sagan, *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons*, Princeton, 1993[1]

INTRODUCTION

The Black Swan theory, formulated by Nassim Nicholas Taleb in 2007,[2] refers to unpredictable and rare events that have a significant impact but are outside the realm of everyday expectations. These events, such as natural disasters, terrorist attacks and unique aircraft accidents, pose significant challenges in risk management, especially in a dynamically changing technological world.

In the context of aviation safety, this theory emphasises the need to continually adapt strategies and procedures to effectively manage unexpected threats. Examples of such 'Black Swans' include disasters such as the 2004 Indian Ocean tsunami, the 2010 volcanic eruption in Iceland, and the September 11, 2001 attacks.

The article observes that most aviation accidents result from human error and examines changing approaches to investigating and preventing accidents, such as the Germanwings flight disaster. These events compel experts to reflect on the nature of risk and to implement effective countermeasures to both prevent and respond to unpredictable events.

In the context of the Black Swan theory, the article points to the need for a holistic approach to risk management in aviation, taking into account both predictable and unexpected challenges.

A REVIEW OF THE LITERATURE ANALYSING THE BLACK SWAN THEORY IN THE CONTEXT OF AVIATION SAFETY

The literature on Black Swan theory in the context of aviation safety ranges from fundamental theoretical works to detailed case studies, risk analyses, and considerations of aviation policy and regulation.

With regard to Nassim Nicholas Taleb's Black Swan theory, several key sources are noteworthy. The first is Taleb's book entitled *The Black Swan: The Impact of the Highly Improbable*, which offers a detailed description of the theory and its applications in various fields. Lee Clarke, in his book *Mission Improbable: Using Fantasy Documents*

[1] Sagan, S.D., *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons*, Vol. 53, Princeton, 1993, https://doi.org/10.2307/j.ctvzsmf8r.

[2] Taleb, N.N., *The Black Swan: The impact of the highly improbable*, New York, 2007.

to Tame Disaster,[3] discusses risk management and unpredictable events, providing context for the Black Swan theory. Additionally, Taleb, in his article 'The Fourth Quadrant: A Map of the Limits of Statistics', published in *The Edge*, expands on the concept of 'Black Swans', particularly in the context of the statistics limitations.[4]

Examples of 'Black Swans' can be found in the *Encyclopedia Britannica*'s analysis of the 2004 Indian Ocean tsunami[5] and *National Geographic*'s description of the 2010 eruption of the Eyjafjallajökull volcano in Iceland.[6] Both sources illustrate the impact of these events on aviation. *Encyclopedia Britannica* also contains a comprehensive analysis of the September 11, 2001 attacks, another event often cited as an example of Black Swans.[7]

The Aviation Safety Network discusses Germanwings flight crash,[8] providing a detailed description and analysis of the event, and highlighting the human error aspect of aviation. An article by Terje Aven entitled 'On the Paradoxes of Risk Management in the Light of the Black Swan Theory', published in the *Journal of Risk Research*, addresses the paradoxes of risk management in the context of this theory.[9] Scott D. Sagan, in his book *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons*, analyses accidents and organisational safety, which may be useful for understanding the concept of Black Swans in the context of aviation safety.[10] Daniel Kahneman, in his book *Thinking, Fast and Slow*, discusses cognitive biases and their impact on decisions, which is important in relation to human errors and unpredictable events.[11] These sources provide valuable information for deepening one's understanding of the Black Swan theory, its applications, and its context in risk management and aviation safety.

Another key work examining the Black Swan theory in the context of aviation safety is the book *Safety Accidents in Risky Industries: Black Swans, Gray Rhinos and Other Safety Animals* by Sasho Andonov. This publication examines incidents and accidents in risky industries, including aviation, using mathematical analysis of these events through statistics and probability. The book covers topics such as real-time monitoring, stress testing, change management, predictive maintenance, management system, contingency plans, human factors, behavioural safety,

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[3] Clarke, L., *Mission Improbable: Using Fantasy Documents to Tame Disaster*, Chicago and London, 1999.

[4] Taleb, N.N., 'The Fourth Quadrant: A Map of the Limits of Statistics', *The Edge*, 14 September 2008, https://www.edge.org/conversation/nassim_nicholas_taleb-the-fourth-quadrant-a-map-of-the-limits-of-statistics [accessed on 23 August 2024].

[5] *Encyclopaedia Britannica*, 'Indian Ocean tsunami of 2004', https://www.britannica.com/event/Indian-Ocean-tsunami-of-2004 [accessed on 23 August 2024].

[6] 'Eyjafjallajökull volcano eruption in Iceland', *National Geographic*, https://education.nationalgeographic.org/resource/eyjafjallajokulls-volcanic-ash/ 2010 [accessed on 23 August 2024].

[7] *Encyclopaedia Britannica*, 'What were the September 11 attacks?', https://www.britannica.com/question/What-were-the-September-11-attacks [accessed on 23 August 2024].

[8] 'Germanwings flight disaster', Aviation Safety Network, https://asn.flightsafety.org/asndb/320334 [accessed on 23 August 2024].

[9] Aven, T., 'On the meaning of a black swan in a risk context, Safety Science Volume 57, August 2013, Pages 44–51, https://www.sciencedirect.com/science/article/abs/pii/S0925753513000301 [accessed on 23 August 2024].

[10] Sagan, S.D., *The Limits of Safety…*, op. cit.

[11] Kahneman, D., *Thinking, Fast and Slow*, New York, 2011.

anticipatory failure determination, resilience engineering, resilience management, the Swiss cheese model, and probability distribution. It is an essential resource for professionals working in the fields of health and safety, quality engineering, compliance engineering, aerospace engineering, workplace health and safety, and industrial engineering.

The literature also includes case studies of specific plane crashes considered Black Swans, and a selection of these is presented in this article. Case studies often focus on analysing the causes, effects, and lessons learned from these events.

Moreover, there is considerable work focusing on aviation risk management methods in the context of Black Swans. These publications analyse how airlines and airports can better anticipate and prepare for unexpected, catastrophic events. Both technical and organisational issues are discussed in this article.

Major plane crashes are often followed by changes in policy and regulation. An analysis of the literature in this area focuses on how regulations are adapting to better cope with unexpected events and how these changes are affecting airline operations around the world.

New technologies can both generate Black Swans and help predict them and minimise their effects. The literature in this area examines how technological innovations, such as the development of drones and advanced monitoring systems, impact aviation safety.

In the context of Black Swans, the role of human decisions and behaviours is also important. The literature in this area examines how human factors, such as pilot errors, can contribute to unexpected disasters, and how these risks can be minimised.

THE BLACK SWAN THEORY IN AVIATION SAFETY

The Black Swan theory takes its name from the widely known but false belief that all swans are white. In fact, some are black and live in Australia.

In 2007, Nassim Nicholas Taleb defined a Black Swan event as one that 'is an outlier' because it lies outside the realm of regular expectations. Black Swans, by this definition, are mostly unforeseen, rare, and may be created by, among others, natural environmental, geopolitical, economic factors, or other unexpected circumstances and events.

Black Swans pose a challenge to risk management, especially in our rapidly changing technological landscape. On the other hand, transformative changes in emerging technology increase the ability to analytically forecast and attempt to mitigate events related to this phenomenon.

In 2004, the Indian Ocean tsunami killed 230,000 people. In 2010, an Icelandic volcano erupted, closing the airspace over Europe for almost a week and grounding millions of passengers at a cost of over $200 million a day. On 11 September 2001, four commercial airliners were hijacked to be used as missiles to destroy American infrastructure and human lives.

Most aviation accidents are caused by human errors. It is estimated that currently, as many as 80% of incidents related to aviation safety originate from the so-called 'human factor'. In order to identify current safety threats and develop possible solutions, the role of human factors as the root cause of aviation accidents has transformed the nature of aviation accident investigation over the years. Typically, countermeasures to avoid certain types of accidents focus on error management. Unfortunately, new types of accidents are becoming more frequent, such as unlawful interference, as in the case of the Germanwings plane crash. In this incident, the pilot deliberately and consciously crashed the plane into the ground, committing suicide and simultaneously killing all passengers and crew members. Public opinion was shocked and demanded stringent preventive measures. But how do you address this type of accident given your awareness of such behaviours and risks?

After each aircraft accident, investigators use a variety of measures, methods, and investigative models to understand how the aircraft incident occurred, what its main causes are, and to develop countermeasures to prevent the situation from recurring in the future. Most interpretations depend on the paradigm used. Until now, different paradigms have led to different interpretations and remedies. The Germanwings case, in which a pilot intentionally crashed a plane full of passengers, poses a challenge to safety researchers. Is this event a Black Swan, an unpredictable and surprising phenomenon, or perhaps a manifestation of a broader trend affecting flight safety?

Currently, while transportation security experts have to deal with preventing terrorist attacks, those involved in security in the sense of preventing aircraft accidents focus their efforts, among others, on preventing human errors. In fact, reinforced doors, as in the case of the Germanwings plane crash mentioned above, which were created as a solution, have become a problem. Between 2013 and 2015, we witnessed a disturbing series of accidents and serious incidents in which the pilot voluntarily caused the plane to crash into the ground. In most of these cases, one of the pilots was locked outside the cockpit thanks to the locked and additionally reinforced door.

The first case was a LAM (Mozambique Airline) aircraft that crashed in Namibia in 2013; after the captain locked himself in the cockpit while the co-pilot was away, the plane began to dive from cruising altitude until it finally hit the ground.

Shortly thereafter, in 2014, the co-pilot of Ethiopian Airlines locked himself in the cockpit while the captain was away and, instead of beginning his descent to his original destination, Rome Fiumicino airport, he continued to Geneva, landing virtually on the last of his fuel. After landing, the co-pilot tried to escape from the plane and asked for political asylum.

Another example is Malaysian Airlines flight MH 370 which took place in 2014 and which still remains a mystery. So far, in the history of aviation, there has been no record of an aircraft disappearing from radar screens and whose wreckage cannot even be found.

In the final report, which was prepared after the 'Germanwings flight', investigators compiled a list of events due to the deliberate actions of the pilots, and that included a description of the Malaysian plane case. Of course, as regards

the flight MH 370, caution should be exercised in dealing with this case because, in the absence of conclusive evidence, reliable documents and flight data recordings so far, there is no certainty as to its causes. Nevertheless, there are facts about some deliberate actions of the pilots (or those on board at that time) in the minutes before the plane disappeared from radar screens.

Such prior disturbing events, which should have raised alarm bells among the entire aviation community, occurred in countries far from Europe (with the exception of the Ethiopian plane, as this case took place in Europe but involved a plane belonging to an African airline). In March 2015, the 'Germanwings case' suddenly came to the attention of the European public. The world has also started to become interested in that incident. Attention was drawn to the fact that this is not a sporadic or random occurrence, as we are talking about four events in a relatively short period of time. If we can assume that – excluding the Germanwings plane – three cases suffice as a proof, we are faced with a disturbing phenomenon that cannot be defined as an improvised, exceptional and isolated case.

We can, therefore, conclude that the 'Germanwings case' is a symptom of a trend that is highlighted as a real threat to aviation safety. The final report filed by the BEA (Bureau d'Enquête et d'Analyses) on the Germanwings crash cited a number of events in which the pilot's poor mental state caused (or could have caused) criminal behaviour.

This could be another turning point in analysing aviation safety. Is this a Black Swan as Nassim Taleb put it? Do we need a new paradigm to capture such a phenomenon? What can we do to prevent such dangerous behaviour? By now, we are used to training people to avoid, detect, or mitigate errors. Deliberate behaviour intended to destroy aircraft and passengers has, until now, been beyond the attention and study of security experts. Where to start working on remedies?

Perhaps the first step is to understand what is happening to the pilot community, assessing organisational aspects, individual lifestyle and their impact on personal mental resilience as a tool to overcome the imbalance that may arise during, for example, a forty-year career.

In addition to the obvious qualifications, a pilot is also hired for certain specific personality traits, such as self-confidence, mental balance, physical stamina, and sound judgment. Nevertheless, the pilot is human and, like every human being, is affected by negative life events (illness, financial problems, bereavement, divorce, moving, etc.). The ability to resist and return to a healthy mental state is not always an easy task. In such situations, the pilot should be able and willing to seek help. For example, by participating in dedicated support programs for crew members temporarily mentally incapable of flying, which is already implemented in some airlines.

Usually, to become a pilot, individuals need to have a leadership personality. Being a captain requires specific approach to commanding and leading other people. Typically, such a person does not dwell on problems. And even if they notice and experience them, they do not talk about them. It is rare for these types of personalities to share their problems with specialists and psychologists.

A more effective way to support such people is to ensure they establish relationships with colleagues with similar experiences who have been in the same situations, who are acting not as 'assessing judges' but as partners.

SELECTED CASE STUDIES OF THE BLACK SWAN THEORY IN AVIATION SAFETY

The Black Swan theory in aviation safety, as already mentioned, refers to unpredictable, rare, but extremely influential events that can significantly affect the aviation industry. In the context of aviation, there are several key case studies that exemplify this theory:

1. Air France Flight 447 crash (2009). Flight AF447 from Rio de Janeiro to Paris disappeared over the Atlantic. Subsequent investigation revealed that the cause was a loss of speed due to frozen speed sensors, which, combined with crew errors, led to the disaster. This case is often referred to as a Black Swan due to the unexpected sequence of events and mistakes that led to the tragedy.
2. Disappearance of Malaysia Airlines flight MH370 (2014). Flight MH370 from Kuala Lumpur to Beijing suddenly disappeared from radar and has not been found to this day. This case is the quintessence of the Black Swan, because despite modern technology, the plane and its passengers disappeared without a trace, which was an unprecedented event and difficult to explain.
3. Attacks of September 11, 2001. The use of airliners as weapons in the terrorist attacks on the World Trade Center and the Pentagon was an event that no one saw coming. The use of aircraft as tools of terror not only had tragic immediate consequences, but also changed the global approach to aviation safety in the long term, introducing strict safety controls and new regulations.
4. Eyjafjallajökull Volcano Eruption (2010). The eruption of an Icelandic volcano caused massive disruptions to air traffic around the world. While volcanic eruptions are known, the scale of the event and its impact on aviation were unexpected, making it a Black Swan in the context of global air travel. The incident demonstrated how natural phenomena can have far-reaching impacts on global airlines and airports, leading to mass airspace closures and financial losses.
5. Challenger Space Shuttle Disaster (1986). Although this event took place in space, it is often cited in the context of the Black Swan theory in aviation. The explosion of the space shuttle shortly after launch was a shocking event that highlighted the unpredictability and potential risks of space exploration.
6. Tenerife Flight Disaster (1977). The most tragic accident in the history of aviation occurred when two Boeing 747s collided at Los Rodeos Airport in Tenerife. The incident, which resulted in the deaths of 583 people, was due to a series of unfortunate circumstances, including poor visibility, misunderstandings, and communication errors. It was a Black Swan due to the unexpected convergence of several negative factors.

7. Chernobyl Reactor Accident (1986). Although not directly related to aviation, this event had a huge impact on commercial aviation, especially in Europe. The emission of radioactive dust into the atmosphere forced many airlines to change flight routes and led to the introduction of new flight safety protocols in the event of a nuclear threat.
8. Attack on Pan Am Flight 103 over Lockerbie (1988). The terrorist attack on a plane flying from London to New York, which exploded over Lockerbie, Scotland, was a shocking and unexpected event. It resulted in changes to global aviation security standards, particularly around baggage screening and airport security measures.
9. Germanwings Flight 9525 Crash (2015). This incident, already discussed, occurred when the first officer intentionally caused an Airbus A320 aircraft to crash into the ground, resulting in the deaths of all persons on board. This tragedy led to changes in regulations regarding pilot mental health and cockpit procedures.
10. Computer System Failure at British Airways (2017). A global IT system failure at British Airways led to mass flight cancellations and significant chaos at airports. It emphasised the importance of IT system resilience and business continuity planning in the aviation industry.
11. American Airlines Flight 191 Crash (1979). Immediately after take-off from Chicago's O'Hare Airport, an engine separated from the DC-10's wing, leading to the deadliest aviation accident in U.S. history. This event, although caused by technical and design errors, was unpredictable and had a profound impact on aircraft safety and maintenance regulations.
12. Electrical Failure on a Boeing 787 Dreamliner (2013). A series of problems with lithium-ion batteries in modern Dreamliner planes prompted a global grounding of the model. This was unexpected given the newness and technological sophistication of the aircraft, and resulted in a review and change in regulations regarding batteries used in aircraft.
13. Turkish Airlines Flight 981 Crash (1974). This accident, caused by a failure of the cargo door latch, led to the crash of the McDonnell Douglas DC-10 aircraft shortly after take-off from Paris. The causes of the accident were unforeseen and prompted a review of aircraft design and safety protocols.
14. Swissair Flight 111 Disaster (1998). The plane burned down and crashed off the coast of Nova Scotia due to a fire caused by faulty electrical wiring. This accident led to changes in regulations regarding combustible materials used in aircraft and fire safety standards.
15. The Concorde Disaster (25 July 2000). It is often cited as an example of a Black Swan in aviation. The plane, which was a symbol of luxury and innovation in transatlantic air travel, crashed shortly after taking off from Charles de Gaulle Airport in Paris. The cause of the disaster was a tire burst, which damaged the fuel tank and started a fire. This event had far-reaching consequences, not only in terms of the loss of life, but also in how it affected perceptions of safety and the economic feasibility of high-speed supersonic flight, ultimately leading to the discontinuation of Concorde use.

16. Emergency Landing of US Airways Flight 1549 on the Hudson River (2009). This incident, in which the plane lost engine power after hitting a flock of birds and had to make an emergency landing on the river, is an example of effective crisis management and the high professionalism of the crew in the face of unexpected events.
17. Bomb Attack at Brussels Airport (2016). The terrorist attacks on Brussels Airport showed how attacks can not only cause human and material losses, but also affect public confidence in aviation safety and cause long-term disruptions to air traffic.
18. Delta Air Lines IT System Failure (2016). A computer system failure caused global disruptions to Delta Air Lines operations, including flight cancellations and delays. This incident highlighted the importance of IT system resilience in the aviation industry.
19. Cyber Attack on British Airways IT Systems (2017). A hacking attack on the airline IT systems caused significant operational disruptions, including flight delays and cancellations. This event highlighted the importance of cybersecurity in the aviation industry.
20. Boeing 737 MAX Crisis (2019, 2020). After two plane crashes (Lion Air Flight 610 and Ethiopian Airlines Flight 302) in which the new 737 MAX model was involved, the series was globally grounded. The event raised questions about safety standards, certification processes and the wisdom of trusting automated on-board systems.
21. Drone Incidents in Dubai (2016). Dubai International Airport has experienced several incidents involving drones that violated the airspace, causing the airport to temporarily close. These incidents sparked a discussion about the need for better regulation and monitoring of the airspace around airports.
22. Collision of a Drone with a Passenger Plane (2017). A collision between a drone and a passenger plane during landing was reported in Canada. Although the incident did not cause serious damage, it highlighted the potential risk of drones colliding with manned aircrafts.
23. Gatwick Airport Closure (2018). One of the most notorious drone incidents occurred at Gatwick Airport in the UK, where drone sightings near the runway led to the closure of the airport for several days. The incident caused massive disruption to air travel, highlighting the problem of unauthorised use of drones in airport airspace.
24. COVID-19 Pandemic (2020). The outbreak of the pandemic in 2020 was an event of unprecedented scale for the aviation industry. It has created a global aviation crisis, with mass flight cancellations, border closures and the introduction of new health and safety protocols.

These case studies demonstrate how unpredictable and rare events can have a profound impact on aviation safety, forcing changes to policies, procedures and approaches to risk management in the aviation industry.

ANALYSIS OF THE LEGAL CONDITIONS OF THE BLACK SWAN THEORY IN AVIATION SAFETY

When analysing the legal conditions of the Black Swan theory in the context of aviation safety, it is worth referring to a number of important sources. The theoretical basis is the previously mentioned work by Nassim Nicholas Taleb, *The Black Swan: The Impact of the Highly Improbable*, which introduces the concept of Black Swans.[12] To understand legal implications of the theory, it is worth reading *The Principles and Practice of International Aviation Law* by Brian F. Havel and others, offering a perspective on aviation law.[13] Lee Clarke in *Mission Improbable: Using Fantasy Documents to Tame Disaster* discusses risk management in unpredictable situations, which is important in the context of the Black Swan theory.[14] The International Civil Aviation Organization in its 2018 *Safety Management Manual* presents international standards and practices for safety management, which may be helpful in understanding legal requirements.[15] Alan J. Stolzer and others analyse aviation safety management systems in *Safety Management Systems in Aviation*.[16] Andrew Hoskins and John Tulloch look at the impact of technology on risk perception in *Risk and Hyperconnectivity: Media and Memories of Neoliberalism*.[17] Daniel Kahneman examines cognitive biases in the context of crisis decisions in *Thinking, Fast and Slow*.[18] The International Air Transport Association provides recommendations for the industry in its 2017 *Airline Safety and Security Guidelines*.[19] Nawal K. Taneja in *Airlines in the Age of Information* focuses on the role of information technologies.[20] Robert W. Poole Jr. in *Rethinking Airport Security* offers an overview of aviation security strategies.[21]

The analysis of the legal conditions of the Black Swan theory in the context of aviation safety focuses on how current aviation law and regulations can prepare the industry and relevant institutions to deal with unpredictable, rare, but potentially catastrophic events. As already mentioned, this theory, formulated by Nassim Nicholas Taleb, describes events that depart from the norm, beyond the scope of regular expectations, and, consequently, beyond what is usually included in standard safety procedures and emergency plans.

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12 Taleb, N.N., *The Black Swan*…, op. cit.

13 Havel, B.F., Sanchez, G.S., *The Principles and Practice of International Aviation Law*, Cambridge, 2014.

14 Clarke, L., *Mission Improbable*…, op. cit.

15 International Civil Aviation Organization, *Safety Management Manual*, ICAO, 2018.

16 Stolzer, A.J., Goglia, J.J., *Safety Management Systems in Aviation*, London, 2016.

17 Hoskins, A., Tulloch, J., *Risk and Hyperconnectivity: Media and Memories of Neoliberalism*, Oxford, 2016.

18 Kahneman, D., *Thinking*…, op. cit.

19 International Air Transport Association. *Airline Safety and Security Guidelines*, IATA, 2017.

20 Taneja, N., Airline Industry (1st ed.). Taylor and Francis. Retrieved from https://www.perlego.com/book/1569239/airline-industry-poised-for-disruptive-innovation-pdf [accessed on 23 August 2024], original work published 2016.

21 Poole, R.W. Jr., *Rethinking Airport Security*, Reason Foundation, Rethinking Airport Security-A 2011 Window of Opportunity?", 2016, https://reason.org/airport-policy/airport-policy-and-security-news61/ [accessed on 23 August 2024].

In aviation law, incorporating the Black Swan theory would mean increasing flexibility and adaptability in safety planning. This requires regulators and aviation organisations to consider scenarios that may seem unlikely but have potentially huge consequences. This also means that regulations must be dynamic enough to be quickly adapted in the event of unexpected occurrences.

Moreover, in the context of this theory, it is crucial that legal systems focus not only on preventing and mitigating the effects of potential disasters but also on ensuring effective response mechanisms after such events occur. This includes provisions for investigations, rescue operations, compensation for victims and their families, and quick and effective communication with the public.

In the context of 'Black Swans', the role of continuous training and education in the aviation industry is also significant. Workers in the aviation industry must be prepared for emergencies that may fall outside standard emergency procedures. This underscores the need to invest in advanced training and simulations that can help prepare staff for unpredictable scenarios.

The legal framework for the Black Swan theory in aviation safety focuses on the identification and adaptation of legal frameworks for managing rare, unpredictable, but potentially catastrophic aviation events.

Firstly, these conditions emphasise the importance of flexibility and adaptation in aviation legislation, enabling quick reactions and changes in response to unexpected events. The law must be prepared for situations that were not previously foreseen, which requires constant evaluation and updating of regulations and safety standards.

Another important aspect is advanced risk management. Aviation regulations should promote and implement risk management strategies that go beyond traditional statistical models and take into account potentially unpredictable threats. This includes both predicting and minimising the effects of rare events.

In the context of Black Swans, it is also important to establish comprehensive procedures for investigating and reporting after aircraft accidents. Such procedures should aim to thoroughly investigate the causes of events, identify unforeseen factors, and develop recommendations on how to avoid similar situations in the future.

Moreover, these conditions highlight the need for international cooperation and harmonisation of regulations. Aviation is a global industry and Black Swan events often have international implications. It is therefore important that safety regulations are consistent and effective worldwide.

Finally, innovation and technology play a significant role in aviation law. Modern technologies such as advanced monitoring systems, data analytics, and artificial intelligence can be crucial in identifying and preventing Black Swan events. The law should support the development and implementation of such technologies, while ensuring that they are used in an ethical and privacy-compliant manner.

CONCLUSION

The metaphor 'Black Swan' refers to an unexpected, unlikely, or even impossible, catastrophic event that no one plans for, situations that no one anticipates or realises that could even happen. The definition of the Black Swan phenomenon shows that these phenomena are unpredictable or very difficult to predict. Therefore, you should assess your level of exposure to these phenomena and develop countermeasures.

The probability and frequency of their occurrence should be assessed and the possibility of reducing them should be analysed through training, continuous updating, and expansion of the evaluated list of negative phenomena. Conducting tests and practical exercises that implement specific threat scenarios is also an essential element of appropriate response and risk reduction.

Other important aspects include assessing sensitivity and reducing the impact of negative phenomena by, for example, introducing additional 'firewalls' in the organisation that mitigate the impact of events or prevent their occurrence. All types of preventive actions, forecasting negative phenomena and developing appropriate actions and their implementation are crucial to reducing the effects of Black Swans.

Analysis of the legal conditions of the Black Swan theory in aviation safety requires an integrated approach that includes a flexible legal framework, continuous training and preparation, as well as effective planning and response to rare but potentially catastrophic events. This means that lawmakers, regulators and the aviation industry need to be constantly vigilant and ready to adapt in the face of unforeseen challenges.

Legal considerations of the Black Swan theory in aviation safety also require a holistic approach that includes flexibility, advanced risk management, thorough investigations, international cooperation and technological innovation. This comprehensive approach is key to effectively addressing unpredictable, rare, but potentially catastrophic aviation events.

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Cite as:

Balcerzak T., Kostur K., Rajchel J. (2024) '*The "Black Swan" theory in aviation safety*', Ius Novum (Vol. 18) 3, 34–46. DOI 10.2478/in-2024-0021