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Safety and Human Factors Challenges of Aircraft Berths: Problem Analysis and Optimization Approaches

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ABSTRACT

With the development of long-distance flight technology and the increasing demand for ultra-long-haul flights, ensuring passenger comfort and safety has become a critical challenge. Aircraft berth designs play a key role in addressing this issue. However, existing designs still exhibit limitations in safety, ergonomic adaptability, space utilization efficiency, and intelligence features. This study, through literature and case analysis, systematically examines the safety and human factors challenges in current aircraft berths, and examines the shortcomings of existing berth designs in collision protection, body support, spatial configuration, and intelligent integration. Based on the analysis, multi-dimensional optimization schemes are proposed to enhance berth safety, ergonomic adaptability, space utilization, and intelligent features. The findings contribute to the theoretical framework for intelligent cabin design, and explores innovative paths under the human-machine-environment model. This study provides insights for optimizing aircraft berth designs, ultimately improving passenger experience and safety in ultra-long-haul flights.

Keywords: Ultra-long-haul flights, Aircraft berth design, Human factors, Collision protection, Intelligent berth

INTRODUCTION

Introduction to Long-Haul Flight Demand

With the breakthroughs in aviation technology and the acceleration of globalization, the demand for long-haul direct flights has been continuously increasing, and long-haul and ultra-long-haul flights have progressively become a critical component of the global air transport network. Currently, new-generation wide-body aircraft such as the Boeing 787–9 and the Airbus A350-1000 have achieved non-stop flights of 18 to 20 hours, with ultra-long routes, including Singapore-New York and Auckland-New York, having been launched.

While the operation of long-haul flights has markedly enhanced intercontinental transportation efficiency, it has also revealed the limitations inherent in traditional economy class design, especially the contradiction between passenger comfort and airline economic benefits (Wang et al., 2021). Although existing seat designs have incorporated certain ergonomic considerations, such as backrest angle, legroom and lumbar support, these improvements have not adequately alleviated the fatigue and discomfort associated with long-haul flights. In this context, the design of airline berths has become a crucial solution to enhancing passenger comfort, particularly in economy class where the demand is increasingly prominent.

Current Aircraft Seat and Berth Design Limitations

In recent decades, the market share of air transportation has gradually increased, and an increasing number of passengers have opted for air travel. However, the design of contemporary economy class seats is often constrained by airlines' demand for maximizing the number of seats (Krause et al., 2023). In pursuit of greater economic returns, airlines have continuously reduced the seat pitch to accommodate the rapidly growing market demand. During the early 2000s, the standard economy class seat pitch was between 32 and 34 inches. Nowadays, the seat pitch in economy class typically ranges from 28 to 34 inches, with low-cost airlines commonly adopting the minimum pitch to maximize passenger capacity (Anjani et al., 2020).

Research shows that there is a positive correlation between seat pitch and comfort. When seat pitch is reduced,passenger discomfort tends to increase. Specifically, when the seat pitch is below 30 inches, passengers often experience increased discomfort due to the constrained space, which limits their ability to extend their lower limbs (Liu et al., 2019). This forced posture makes it difficult for passengers to achieve quality rest, which can lead to issues such as circulatory problems, back fatigue, and muscle stiffness, directly impacting the overall travel experience. Additionally, smaller seat pitches, such as those below 28 inches, significantly increase discomfort, as passengers are unable to stretch their legs fully and remain in cramped positions for extended periods (Anjani et al., 2020).

Besides the gradual reduction of seat pitch, passenger comfort is intricately related to support performance, personal space, contact surface characteristics and safety stability, among which support performance is regarded as the most important influencing factor (Wang et al., 2021). The support performance, includes multiple dimensions such as backrest, cushion, headrest and waist support, and the ergonomic support structure, can effectively assist passengers in maintaining a relatively comfortable posture during the long flight (Vanacore et al., 2019). However, due to the structural design limitations of economy class seats, it is difficult for passengers to adjust to a truly relaxed state, further reducing comfort.

On long-haul flights, sleep and rest are the primary activities for passengers. However, the current aircraft seat head and body support is insufficient, seat reclining Angle is limited, resulting in passengers can not get a comfortable sleep experience (da Silva Menegon et al., 2019).

Research Focus and Objectives

Research has shown that when evaluating the impact of different postures on passengers' sleep experience, lying down is more conducive to enhancing passenger comfort compared to sitting (Porta et al., 2019). Appropriate seat reclining angles help reduce the concentration of back pressure and improve blood circulation, thus alleviating the discomfort caused by prolonged sitting (Yao et al., 2023). In addition, many airlines equip their premium economy and business class cabins with seats that have adjustable reclining angles, allowing passengers to recline to a near-flat position. However, these seats are still designed based on seat structures. Although such seats can offer a near-flat experience, their design focus remains on ensuring safety and comfort while seated during the flight, and they cannot fully meet the comfort needs for extended rest. Therefore, they should not be equated with aircraft berths. Aircraft berths, on the other hand, are specifically designed to provide a completely horizontal resting position, typically offering more space than regular seats and equipped with support structures conducive to rest. Furthermore, According to the "Airworthiness Standards for Transport Aircraft" issued by the Ministry of Transport of China in 2016 (Ministry of Transport of China, 2016), Article 25.785 outlines specific requirements related to seat and berth design, requiring them to be equipped with a front-end padded panel, canvas dividers, or equivalent structures that can withstand forward inertia forces as outlined in Regulation 25.561. The design of berths must also avoid any sharp edges or protrusions that could cause serious injury to passengers in the event of an emergency. While current flat-bed seats can provide a near-horizontal resting position, they do not offer the same level of support or privacy as berths. Therefore, the introduction of aircraft berths is of paramount importance. Current aircraft seats have shortcomings in terms of support, adjustability, and space utilization, resulting in lower passenger comfort. However, berths, with their flat-laying design, independent space, and modular configuration, not only address these issues but also meet differentiated comfort needs, thereby enhancing the competitiveness of airlines.

This study systematically examines the current shortcomings of aircraft berths in terms of safety, ergonomic adaptability, space utilization efficiency, and intelligence features through literature and case analysis. Critical issues related to safety and human factors in current aircraft berths are systematically identified, and based on the analysis, multidimensional optimization schemes are proposed.

SAFETY AND HUMAN FACTORS DEFECT ANALYSIS OF EXISTING ECONOMY CLASS BERTHS DESIGN

Analysis of the Three-Seat Row Berth Solution and Its Limitations

The earliest economy class berth solution involved raising the armrests of three seats in a row in the original economy class configuration and combining them into a flatbed design, allowing passengers to lie down. Before boarding, flight attendants were required to unfold them into beds and provide mattresses, blankets, pillows and other supplies. This solution does not require additional modification costs and is easy to implement, so it is favored by airlines. However, this solution still has deficiencies in terms of safety, ergonomic adaptability, space utilization efficiency and intelligence level, and needs to be further optimized to meet industry standards and regulatory requirements.

Analysis of Safety Deficiencies in Three-Seat Row Berth

In terms of safety, airlines usually provide an extended seat belt to secure passengers in the sleeper mode. However, the effectiveness of the extended seat belt is constrained by the traditional two-point seat belt structure. When passengers are lying down, the mode of restraint and the direction of applied force change, leading to a reduction in dynamic restraintn performance, particularly during emergency landing or turbulent conditions (Guida et al., 2022). Due to the diminished fastening effectiveness of the seat belt, passengers face difficulty in quickly returning to the standard safety posture, which increases accident injury probability during sudden adverse conditions. Furthermore, the headrest of the original economy class seat is rigidly connected to the seat frame, providing effective protection against direct head injury upon impact. However, this berth design substitutes the fixed headrest with discrete soft bedding, which leads to passenger displacement under collision conditions, particularly in side-impact scenarios. As a result, the head is more likely to impact the hard structure of the seat or the seat back area in front, causing the energy-absorbing structure of the headrest to fail and preventing it from providing the intended energy absorption effect.

Some airlines in the use of this berth scheme, in order to enable passengers to lie flat to obtain more activity space, will design an additional seat foot, freely adjusted to 60 degrees can be used as a footstool, when the flat 90 degrees can be laid into a bed, however, under this seat conversion mechanism, passengers need additional time to adjust from the sleeper state to the sitting position. It may affect the efficiency of emergency evacuation, when multiple passengers use the sleeper mode at the same time, the evacuation channel may be blocked, which will affect the evacuation time of the entire economy class area (Ma et al., 2024).

Analysis of Ergonomic Adaptability Deficiencies in Three-Seat Row Berth

In terms of ergonomic adaptability, the current three-seat row berth design fails to meet the requirements for full leg extension for adult passengers, especially for taller individuals. This design does not allow passengers to maintain a naturally relaxed sleeping posture and lacks the ability to accommodate various body types and sleep habits. Additionally, as the berth structure has not been optimized according to the design specifications of a bed, prolonged use may place excessive pressure on passengers' cervical and lumbar vertebrae, negatively affecting their sleep quality and overall comfort.

Analysis of Intelligent Features Deficiencies in Three-Seat Row Berth

In terms of intelligent design, the current berth still relies primarily on manual adjustments and lacks advanced intelligent adjustment features. It does not offer personalized comfort settings tailored to passengers' individual needs. As a result, passengers are unable to customize the berth according to their body type and preferences during long flights, which negatively impacts their overall comfort and rest quality. Some modern aviation seating increasingly incorporates intelligent features such as sleep monitoring, adaptive lighting systems, and personalized climate control, significantly enhancing passenger comfort and overall flight experience. However, the current three-seat row berth lacks these innovations, limiting its adaptability and reducing the level of comfort it can provide.

Analysis of Space Utilization Deficiencies in Three-Seat Row Berth

In terms of space utilization, this design typically requires three seats to be combined into a single berth, which significantly reduces the number of available seats for sale and lowers the overall space efficiency in the cabin, thereby affecting the passenger capacity per unit of space. Particularly on high-traffic flights, this design may lead to wasted seat resources, reducing the operational efficiency of flights. For passengers, it is usually necessary to purchase three seats simultaneously to fully utilize the berth, which significantly increases travel costs. This not only adds to the passengers' economic burden but also reduces market acceptance, thereby limiting the broader adoption of this design in the market.

Analysis of Other Berth Designs

In addition to the above three row schemes, in recent years, several companies have proposed other creative solutions, developing the cabin's three-dimensional space through vertical stacking, providing passengers with more flat rest space and significantly improving space utilization. In 2020, Air New Zealand unveiled the "Economy Skynest" concept, with plans for it to be launched in 2024. According to the information provided on Air New Zealand's official website, the "Economy Skynest" consists of six independent berths, each approximately 203 cm in total length and 58.4 cm in width (Air New Zealand, 2025), equipped with specially designed seat belts, standard-sized pillows, sheets, blankets, and earplugs, meeting the needs for passengers to lie flat. The core advantage of this design lies in providing each passenger with an independent sleeping space, allowing them to enjoy a more private sleeping environment during long-haul flights. However, in the usage plan announced by Air New Zealand, the duration of each passenger's use of a berth is limited to four hours, and passengers need to alternate between regular economy class seats and the berth. This conversion mechanism not only increases the complexity and time for passenger emergency evacuation but also fails to meet passengers' needs for continuous deep sleep.

The "Sky Dream" solution proposed by ADSE Company offers a variable berth design concept. Based on the information provided on the company's official website, this solution mainly innovates the cabin design based on wide-body aircraft such as the Airbus A350, Boeing 787, and 777 (ADSE, 2020). The design utilizes the height in the middle of the economy class by removing the overhead luggage rack in the central area and relocating it under the redesigned extra-wide seats to create a double-decker berth space. During taxiing, takeoff, landing, and cabin service, the three-seat row remains in the conventional sitting position, with the middle berth rising to fit against the top berth to ensure headroom. Once in cruise mode, the three extra-wide seats merge and switch to the berth mode, with the middle berth lowering to form an evenly spaced vertical layering, allowing all three passengers to lie flat simultaneously.

The Zephyr Seat flat-bed seat proposed by Zephyr Aerospace and the Airsleeper design proposed by MMILLENNIUMM both adopt an upper and lower berth structure. Through a double-decker berth layout, these designs provide each passenger with a flat-bed resting area while maintaining the original seat count and ensuring that the aisle passage remains unobstructed.

Despite continuous optimization efforts, the market adoption of aircraft berths still faces significant challenges, primarily due to issues related to additional costs and market acceptance. A study on air travelers in Taiwan by Kuo (2022) highlighted several key factors influencing this adoption. First, demand for aircraft berths varies across different passenger demographics, with passengers traveling with children, frequent flyers, and high-income individuals showing a stronger preference for these berths. These groups prioritize higher levels of comfort and privacy during long-haul flights and are more willing to pay additional fees, especially when improved rest conditions are offered. However, the study also revealed limited awareness of the aircraft berth concept, as approximately 72.4% of respondents were unfamiliar with it, and only 0.9% had prior experience using such services. Furthermore, while some passengers expressed interest in trying aircraft berths, their willingness to pay was lower than the discounted prices set by airlines, suggesting that the demand is not yet sufficient to justify broader implementation. Finally, the overall low market awareness of aircraft berths further reduces consumer willingness to pay, limiting both their acceptance and the broader promotion of this service.

MULTI-DIMENSIONAL OPTIMIZATION OF AIRCRAFT BERTHS

Based on the deficiencies identified in previous research regarding aircraft berths, this study proposes a multi-dimensional optimization plan.

In terms of safety, the existing aircraft berths design still employ the traditional two-point seat belt, which is mainly designed for upright sitting positions and offers relatively insufficient protection in the sleeper mode. Especially, during turbulence or emergency landing situations, passengers are prone to significant displacement due to insufficient restraint, increasing the risk of injury. To enhance the safety restraint system, the integration of three-point or four-point seat belts should be considered to ensure that passengers remain fully secured while enjoying a restful sleep experience. Furthermore, support structures specifically designed for the lying position should be developed, and the energy absorption capabilities of headrests can be improved. Additionally, energy-absorbing materials and deformable safety guardrails can be incorporated around the berth (Russo et al., 2019). In the event of a side impact, these guardrails would effectively reduce the risk of secondary injuries to passengers.

In terms of ergonomic adaptability, the existing aircraft berth design is typically constrained by the dimensions and fixed Angle of the seat, which is difficult to accommodate individual passenger differences. resulting in symptoms such as back pain and impaired blood circulation following prolonged rest. Therefore, from the perspective of optimizing human body support structures, the aircraft berth should be designed to more effectively meet ergonomic principles (Wang et al., 2023). First of all, the dynamic adaptive mattress can be employed, which adjusts the support strength based on passenger weight, body type, and sleeping position, thereby maintaining the natural curvature of the spine; Secondly, the multi-angle adjustable headrest and waist support system can be designed, incorporating multi-stage and angle adjustments for the headrest and a dynamic feedback mechanism for lumbar support. This system would provide accurate support across various sleeping positions, including side-lying and supine postures. Additionally, a non-slip textured surface treatment, combined with a shock-absorbing seat base design, can be utilized to prevent passengers from sliding due to aircraft vibration or cabin attitude variations. Meanwhile, it can incorporate a sleep zone adjustment function, such as separately adjusting the tilt angles of the backrest, leg rest and headrest, to meet the individual needs of different passengers.

In terms of space utilization, the traditional aircraft berths design typically faces the issue of insufficient space utilization. The deformable modular layout can improve the efficiency of space efficiency and enhance the flexibility of seat conversion. The proposed solution involves adopting a folding berth design, enabling rapid switch between the standard economy class mode and the sleeper form through the mechanical linkage device. Additionally, a double-layer vertical overlay approach can be utilized, stacking two berths vertically within the limited cabin space. Under the condition that the number of original seats remains unchanged, the number of beds can be increased through the bunk structure to improve the overall economic benefits. Simultaneously, a modular cockpit concept can be incorporated, allowing seats to be adjusted according to flight requirements, such as maintaining a standard seat layout on short-haul flights and converting to sleeper mode on long-haul flights, thereby increasing seat flexibility.

In terms of intelligent features, the current level of intelligence in aircraft berths remains in its early stages, lacking intelligent functions based on biometric feedback and real-time adjustment. The existing mattress hardness is fixed and cannot respond to passengers' varying support needs during different sleep stages, resulting in suboptimal comfort for passengers. By introducing the concept of intelligent cabins, passenger experience optimization, real-time monitoring, and maintenance enhancement can be achieved, thereby opening new profit models for airlines. For instance, a biometric system can continuously monitor passengers' breathing rate, heart rate, and body temperature, automatically adjusting the berth angle, mattress firmness, and support strength to maintain the optimal sleep posture. Furthermore, an environmental sensing system can monitor cabin temperature, humidity, and noise levels in real-time, allowing passengers to autonomously adjust temperature, humidity, and airflow direction through smart touch panels or mobile berth applications, thus enhancing the personalized experience. Additionally, noise-cancelling headphones and intelligent lighting systems can be integrated to adjust light intensity according to passengers' physiological rhythms, aiding in faster transition into deep sleep. Moreover, by offering customized services such as smart in-flight shopping and personalized entertainment systems, airlines can generate additional revenue opportunities (Moraes and Ciaccia, 2023).

CONCLUSION

The aircraft berth, as an innovative solution for long-haul air travel, is undergoing a critical transition from conceptual exploration to technological implementation. This paper highlights the challenges it faces in terms of safety, ergonomic adaptability, space utilization efficiency, and intelligence features, while also providing multidimensional optimization suggestions for future aircraft berth designs. The optimization of berth design requires not only overcoming the limitations of traditional economy class seats but also promoting the deep integration of dynamic safety protection and intelligent space reconfiguration. The successful implementation of aircraft berths also necessitates the establishment of a collaborative mechanism between technological innovation, regulatory adaptation, and market development, transforming the aircraft berth from a disruptive concept into an inclusive solution that enhances the quality of global air travel.

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REFERENCES

Anjani, S., Li, W., Ruiter, I. A. and Vink, P. (2020). The effect of aircraft seat pitch on comfort. Applied Ergonomics, 88, p. 103132.

Air New Zealand. (2025). Unimaginable Economy Class "Economy Skynest". Air New Zealand. Retrieved March 18, 2025, from https://www.airnewzealand.tw/economy-skynest.

ADSE. (2020). ECONOMY SKY-DREAM-A new design that allows affordable full lie-flat sleeping on long haul flights. ADSE. Retrieved March 18, 2025, from https://adse.eu/sleeping-in-economy-class-has-never-been-so-easy.

da Silva Menegon, L., Vincenzi, S. L., de Andrade, D. F., Barbetta, P. A., Vink, P. and Merino, E. A. D. (2019). An aircraft seat discomfort scale using item response theory. Applied Ergonomics, 77, pp. 1–8.

Guida, M., Lamanna, G., Marulo, F. and Caputo, F. (2022). Review on the design of an aircraft crashworthy passenger seat. Progress in Aerospace Sciences, 129, p. 100785.

Krause, L., van de Par, S. and Töpken, S. (2023). Pleasantness ratings for vertical whole-body vibration on an aircraft seat and relevant body parts involved. Applied Acoustics, 207, p. 109330.

Kuo, C. W. (2022). Taiwan Passengers' Willingness to Pay for Air Sleeper Seats. Journal of Advanced Transportation, 2022(1), p. 5294377.

Liu, J., Yu, S. and Chu, J. (2019). The passengers' comfort improvement by sitting activity and posture analysis in civil aircraft cabin. Mathematical Problems in Engineering, 2019(1), p. 3278215.

Ma, Y., Yuan, J., Tan, L., Liu, Q. and Li, M. (2024). A model for aircraft cabin evacuation considering passenger type. Journal of Safety Science and Resilience, 5(1), pp. 83–90.

Moraes, A. D. O. and Ciaccia, F. R. D. A. S. (2023). Smart cabin design concept for regional aircraft: Technologies, applications & architecture. Journal of Aerospace technology and Management, 15, p. e2023.

Ministry of Transport of China. (2016). Airworthiness standards for transport aircraft (Order No. 19).

Porta, J., Saco-Ledo, G. and Cabañas, M. D. (2019). The ergonomics of airplane seats: The problem with economy class. International Journal of Industrial Ergonomics, 69, pp. 90–95.

Russo, P., Guida, M., Marulo, F. and Vitolo, B. (2019). Analysis of integrated fuselage composite seat for small aircraft in crashworthiness applications. Journal of Materials Engineering and Performance, 28, pp. 4856–4862.

Vanacore, A., Lanzotti, A., Percuoco, C., Capasso, A. and Vitolo, B. (2019). Design and analysis of comparative experiments to assess the (dis-) comfort of aircraft seating. Applied ergonomics, 76, pp. 155–163.

Wang, J., Zhi, J. Y., Zhang, X. W., Wei, F. and Zhang, L. L. (2023). A method of aircraft seat dimension design for long-term use by passengers with different body types. International Journal of Industrial Ergonomics, 98, p. 103520.

Wang, J., Xiang, Z. R., Zhi, J. Y., Chen, J. P., He, S. J. and Du, Y. (2021). Assessment method for civil aircraft cabin comfort: contributing factors, dissatisfaction indicators, and degrees of influence. International Journal of Industrial Ergonomics, 81, p. 103045.

Wang, J., Zhi, J. Y., Du, Y., Xiang, Z. R., Feng, S. and Chen, J. P. (2021). A method identifying key optimisation points for aircraft seat comfort. Ergonomics, 64(3), pp. 287–304.

Yao, X., Ping, Y., Song, Y. W. and Vink, P. (2023). Sitting comfort in an aircraft seat with different seat inclination angles. International Journal of Industrial Ergonomics, 96, p. 103470.