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NOISE EXPOSURE OF FLIGHT AND CABIN CREW: DIFFERENCES BETWEEN OLD (DASH 8–Q400) AND NEW (AIRBUS A220–300) GENERATION AIRCRAFT IN THE CONTEXT OF ACOUSTICS AND MATERIALS

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SUMMARY: Noise in commercial aviation is a significant stressor in the work environment and can adversely affect health, safety, and the performance of flight and cabin crew duties. The aim of this paper was to compare noise levels in the passenger cabins of older and newer aircraft generations and to analyse the subjective perception of noise exposure and related health complaints among crew members.The experimental part of this article involved measuring A-weighted sound levels in the passenger cabins of Dash 8–Q400 and Airbus A220–300 aircraft during five flight phases. Measurements were conducted as short-term phase assessments, with results presented as minimum and maximum noise level values. A survey was also conducted among cabin crew (n = 55) and flight crew (n = 24) to assess noise exposure, subjective noise level assessment, frequency of health complaints, and use of hearing protection measures. The measurement results indicate higher noise levels and more pronounced peak acoustic loads during key flight phases in the older-generation turboprop aircraft (Dash 8–Q400), especially during take-off and landing, while the newer-generation turbofan aircraft (Airbus A220–300) exhibited lower and more uniform noise levels in the passenger cabin. Survey results confirm greater exposure and more frequent reported disturbances among cabin crew compared to flight crew, as well as the perception that newer-generation aircraft are quieter. In addition, structural–material differences between the examined aircraft types, particularly regarding fuselage configuration and material selection, may represent an additional factor influencing the observed cabin noise characteristics. The results highlight the need for continued monitoring of noise exposure in aviation and emphasise the importance of combining technical, organizational, and personal protective measures to reduce the potential negative effects of noise on crew health.

Key words: *noise, noise measurement, occupational safety, commercial aviation, materials in aviation, aluminium–lithium alloys, cabin crew, flight crew*

INTRODUCTION

Noise is one of the most widespread harmful factors in the work environment and a significant risk factor that can lead to permanent health consequences, particularly hearing impairment. Prolonged occupational exposure to elevated noise levels is associated with the development of occupational noise-induced hearing loss (ONIHL), which typically develops gradually over years of exposure, as well as with non-auditory effects such as fatigue, concentration difficulties, cardiovascular disorders, impaired communication, and reduced work efficiency *(Chen et al., 2020, Chen et al., 2025, Clarke et al., 2025, Lie et al., 2016, Orikpete et al., 2024, Zeng et al., 2024)*. Occupational noise exposure remains one of the leading causes of occupational diseases despite existing preventive measures *(Bramati et al., 2024, Orikpete et al., 2024, Tikka et al., 2017)*.

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In commercial aviation, aside from noise sources related to propulsion and aerodynamics, it is also important to consider the role of the aircraft structure in transmitting vibrations and noise into the passenger cabin. From an engineering perspective, including metallurgy and materials science, a significant portion of cabin noise is transmitted through the structure – vibrational energy propagates through metallic fuselage components such as skins, frames, and stringers, as well as mechanical joints and interior panels, and is then radiated as sound inside the cabin *(Dewald et al., 2025, Feng et al., 2019, Mixson et al., 1991)*. Therefore, the acoustic characteristics of the cabin are determined not only by the noise source but also by the choice of materials, structural design concept (e.g., semi-monocoque versus sandwich structures), and damping capability, all of which influence vibration amplitudes and the efficiency of acoustic transmission *(Fink et al., 2023, Latsuzbaya et al., 2025)*.

From a materials engineering perspective, the dynamic response of aircraft fuselage structures is governed by mechanical properties such as elastic modulus, density, and specific stiffness (E/ρ), *(Prasad et al., 2021)*. Aluminium–lithium alloys have lower density and higher specific stiffness than conventional aluminium alloys *(Prasad et al., 2021, Ablakatov et al., 2022)*, which can affect structural vibration characteristics. Composite materials, by contrast, exhibit anisotropic stiffness and different sound transmission loss behaviour compared to metallic panels *(Peng et al., 2022)*. In aircraft exposed to turboprop-induced low-frequency excitation, structural vibration significantly contributes to cabin noise generation *(Feng et al., 2019, Lee et al., 2023)*. Therefore, differences in structural–material configuration between aircraft generations may represent an additional engineering parameter influencing measured cabin noise levels under comparable operational conditions.

In line with these material considerations, new-generation aircraft often use hybrid material solutions – a combination of aluminium alloys and composite materials – to reduce weight, increase stiffness, and improve overall performance *(Prasad et al., 2021, Safefly, 2026, The Airbus A220 – A Comprehensive Guide to History, Performance and Innovation.)*. For example, in the Airbus A220, the fuselage structure incorporates aluminium-lithium alloys, which offer reduced weight and enhanced mechanical properties compared to standard aluminium alloys *(Airbus, 2026, A220 Family – Purpose-Built Single-Aisle Aircraft., Ablakatov et al., 2022, Safefly, 2026, The Airbus A220 – A Comprehensive Guide to History, Performance and Innovation.)*. The Airbus A220 wing is predominantly made of composite materials, enabling further weight reduction and improved fatigue resistance *(Lobitz et al., 2025)*. Airbus technical documentation also highlights the use of advanced materials and technologies, including sound-insulated partitions and multilayer composites, aimed at mitigating noise and reducing the "noise footprint" *(Airbus, 2026, A220 Family – Purpose-Built Single-Aisle Aircraft, Safefly, 2026, The Airbus A220 – A Comprehensive Guide to History, Performance and Innovation)*. In contrast, turboprop aircraft such as the Dash 8–Q400 primarily use a traditional aluminium fuselage structure, with key structural elements and skin made of high-strength aluminium alloys, which contribute to specific mechanical responses and vibration transmission within the structure *(Gardonio et al., 2009)*. Furthermore, turboprop engines generate more pronounced low-frequency tonal components that are more easily transmitted through the structure, making vibration control particularly important in such aircraft *(Lee et al., 2023, Feng et al., 2019)*.

An effective method for mitigating such vibrations is constrained-layer damping (CLD), in which a viscoelastic material is placed between rigid structural layers to convert mechanical energy into heat *(Feng et al., 2019, Kudal et al., 2018)*. Studies show that integrated CLD technologies can significantly enhance vibration damping in sandwich and semi-monocoque structures, thereby reducing noise radiation into the cabin *(Fink et al., 2023, Zhou et al., 2016)*.

Systematic reviews of the scientific literature on occupational noise exposure and hearing loss emphasise that ONIHL is a preventable occupational disease, and that effective prevention is achievable through a combination of technical measures, work organization, health surveillance, and personal hearing protection *(Chen et al., 2020, Clarke et al., 2025, Lie et al., 2016, Mo-*

roe et al., 2020, Samelli et al., 2021). Research in aviation shows similar risk patterns, with high noise exposure among flight and cabin crew and pronounced health effects (*Lee et al., 2023, Orikpete et al., 2024)*.

In the European Union, minimum requirements for protecting workers from noise exposure at work are set by Directive 2003/10/EC, which obliges employers to assess and measure exposure, implement technical and organizational measures, inform workers, and ensure personal hearing protection and health surveillance *(Directive 2003/10/EC, 2003)*. In the Republic of Croatia, these requirements are implemented by the Regulation on the Protection of Workers from Noise Exposure at Work *(Official Gazette No. 148/2023)*, which prescribes lower action values ($L_{EX,8h}$ = 80 dB(A) i p_{peak} = 112 Pa or 135 dB(C)), upper action values ($L_{EX,8h}$ = 85 dB(A) i p_{peak} = 140 Pa or 137 dB(C)), and limit values ($LE_{X,8h}$ = 87 dB(A) i p_{peak} = 200 Pa or 140 dB(C)), *(Official Gazette No. 148/2023)*.

In professional practice, a preventive threshold is also often cited for hearing conservation programmes; for example, National Institute for Occupational Safety and Health (NIOSH) recommends limiting exposure to 85 dB(A) as an eight-hour time-weighted average (TWA), which represents the average exposure to a harmful substance over an 8-hour period *(Chen et al., 2020, Chen et al., 2025, Lee et al., 2022, Samelli et al., 2021)*. As the prescribed action and limit values refer to daily time-weighted exposure ($L_{EX,8h}$), in this study the phase measurements are used to characterize and identify flight segments that contribute most to the crew's overall noise burden.

In the aviation industry, flight and cabin crew are exposed to both continuous and intermittently impulsive noise during various phases of flight, making this work environment particularly demanding from an occupational health perspective *(Orikpete et al., 2024)*. The main sources of noise in an aircraft are the propulsion system, aerodynamic airflow around the fuselage and wings, auxiliary systems, and structural vibrations *(Lee et al., 2023, Ivošević et al., 2012, Shen et al., 2025)*. Elevated noise levels are especially pronounced during take-off and initial climb, while during cruise the levels are more stable but remain significant due to the duration of exposure *(Lee et al., 2022)*. Although noise levels in the passenger cabin during cruise often do not exceed regulatory limits, cumulative exposure over a long career can have adverse health consequences for the crew, which may affect flight safety *(Orikpete et al., 2024)*.

In-cabin measurements show that turboprop aircraft, due to the mechanical and aerodynamic characteristics of their propellers, are generally acoustically less favorable than jet aircraft, with predominant low-frequency components that can negatively affect the comfort, communication, and working efficiency of flight and cabin crew *(Ivošević et al., 2012, Ivošević et al., 2016, Vledder et al., 2025)*. Commercial pilots and cabin crew are at high risk of occupational noise exposure and an increased incidence of both auditory and non-auditory effects, such as reduced concentration, chronic fatigue, cardiovascular disorders, stress, hypertension, headaches, sleep problems, and more *(Bilan, 2024, Lie et al., 2016, Orikpete et al., 2024, Raphela, 2025)*. Experimental studies show that cockpit noise exposure above 70 dB(A) leads to changes in neurophysiological and cardiovascular indicators, which can affect pilots' alertness, cognitive functions, and decision-making *(Shen et al., 2025)*.

The development of new-generation aircraft aims to reduce noise through more efficient propulsion systems, aerodynamically optimized designs, and improved cabin sound insulation. However, available data on actual differences in occupational noise exposure between old and new-generation aircraft are limited *(Lee et al., 2022, Ivošević et al., 2012)*. Despite existing knowledge, analyses of current research indicate a lack of long-term and context-specific studies that would allow a clear assessment of the effectiveness of technical and organizational noise protection measures in complex work environments such as aviation. In particular, there is a pronounced lack of empirical data to enable a direct comparison of noise exposure for flight and cabin crew in aircraft of different generations under real operational conditions *(Orikpete et al., 2024, Shen et al., 2025)*.

In this study, field measurements of passenger cabin noise levels were conducted during regular flight operations on the Zagreb–Split route (Air-

bus A220–300) and the Split–Zagreb route (Dash 8–Q400). For the purposes of the research, the Airbus A220–300 represented the new-generation aircraft, while the Dash 8–Q400 represented the old-generation aircraft. Measurements were taken at defined locations during key flight phases (standing on the apron, taxiing, take-off, cruise, and landing) to compare noise levels in older and newer generation aircraft and to identify the flight phases with the highest acoustic load. In parallel, an anonymous survey titled "Impact of noise of old and new generation commercial aircraft on the health of flight and cabin crew" was conducted to gain insight into the experience of noise, frequency of exposure, and the most frequently reported disturbances and health issues related to working on an aircraft. The survey included 55 cabin crew members from the national airline and 24 flight crew members from various airlines. Although the measurement and survey results cannot be directly linked at the level of individual respondents, their parallel interpretation provides a more comprehensive insight into the objective noise levels in the cabin during various flight phases, as well as the subjective burden on the crew and the practice of using hearing protection. The present study builds upon and further develops the methodology and preliminary findings presented in the undergraduate thesis by Dobrenić *(2025)*.

METHODOLOGY

Tested aircraft and structural–material characteristics

In this study, noise levels in the passenger cabin (dB(A)) were measured to compare two commercial aircraft from different generations and with different propulsion concepts: the older-generation Dash 8–Q400 (turboprop) and the newer-generation Airbus A220–300 (turbofan).

In addition to the propulsion concept, the examined aircraft also differ in structural configuration. According to manufacturer technical documentation, the Airbus A220 incorporates advanced aluminium–lithium alloys in primary fuselage structures and composite materials in wing assemblies *(Airbus, 2026, A220 Family – Purpose-Built Single-Aisle Aircraft)*, whereas the Dash 8–Q400 features a conventional aluminium semi-monocoque fuselage design with aluminium skin panels riveted to frames and stringers *(Gardonio et al., 2009)*. These structural characteristics were considered contextual parameters in interpreting the measured cabin noise levels.

As the propulsion system, aerodynamic conditions, and structural vibrations can affect the cabin's acoustic environment, Table 1 presents the basic technical characteristics of the tested aircraft (engine type, maximum flight speed, maximum flight altitude, maximum take-off mass, and the dimensions of the fuselage and wings).

As the measurements were conducted on two different routes and under commercial conditions, the results should be interpreted with the limitation of potential variability in operational and meteorological conditions.

Table 1. Technical characteristics of the examined aircraft Dash 8–Q400 (Croatia Airlines (2025). Dash 8–Q400 – Fleet.) and Airbus A220–300 (Croatia Airlines (2025). Airbus A220-300 – Fleet.)

Tablica 1. Tehničke karakteristike ispitivanih zrakoplova Dash 8–Q400 (Croatia Airlines (2025). Dash 8–Q400 – Fleet.) i Airbus A220–300 (Croatia Airlines (2025). Airbus A220–300 – Fleet.)

Technical Characteristics	DASH 8–Q400	AIRBUS A220–300
Manufacturer	Bombardier	Airbus
Engine (Powerplant)	2 x Pratt & Whitney, PW 150A	2 x Pratt & Whitney, PurePower® PW1500G
Maximum flight speed (km/h)	667	840
Maximum flight altitude (m)	7 620	12 500
Maximum take-off mass (kg)	29 257	65 000
Fuselage length (m)	32.83	38.00
Wingspan (m)	28.42	35.10

Measuring equipment and method

Noise levels were measured using a handheld sound level meter, Habotest HT602B *(Habotest (2026). HT602B Sound Level Meter – Digital Handheld.).* According to the manufacturer's specifications, the device measures within a range of 30–130 dB(A) and a frequency range of 30 Hz–8 kHz, with a stated accuracy of ±1.5 dB(A) at 94 dB(A) and 1 kHz, and ±5 dB(A) at 94 dB(A) and 8 kHz (Figure 1). For each flight phase, two repetitions were conducted, with each measurement lasting 30 seconds. In this paper, noise was measured as short-term A-weighted sound levels, expressed in decibels (dB(A)), which is the standard measure of noise level for assessing exposure in the working environment.



Figure 1. Sound level meter - Habotest HT602B (Habotest (2026). Sound Level Meter Habotest HT602B)

Slika 1. Mjerač razine zvuka – Habotest HT602B (Habotest (2026). Sound Level Meter Habotest HT602B)

Measurement locations and flight phases

Measurements were taken during commercial flights on the Zagreb – Split route (Airbus A220–300) and the Split – Zagreb route (Dash 8–Q400). Due to restricted access to the cockpit, all measurements were carried out exclusively in the passenger cabin. One measurement location was chosen for each aircraft: seat 9A in the Dash 8–Q400 (Figure 2) and seat 15F in the Airbus A220–300 (Figure 3), with both points situated in the mid-section of the passenger cabins.



Figure 2. Seat map of the Dash 8–Q400 aircraft (Croatia Airlines (2025). Dash 8–Q400 – Fleet.)

Slika 2. Plan sjedala zrakoplova Dash 8– Q400 (Croatia Airlines (2025). Dash 8–Q400 – Fleet.)

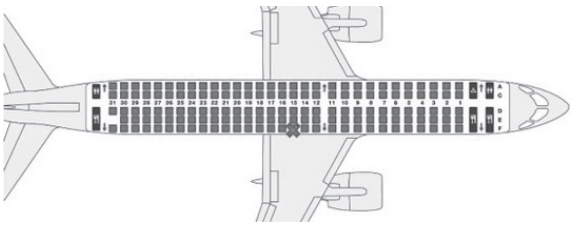


Figure 3. Seat map of the Airbus A220–300 aircraft (Croatia Airlines (2025). Airbus A220–300 – Fleet.)

Slika 3. Plan sjedala zrakoplova Airbus A220–300 (Croatia Airlines (2025). Airbus A220–300 – Fleet.)

The measurements were taken during five characteristic flight phases: apron (ground stand), taxiing to the runway, take-off, cruise, and landing.

Conducting the survey

An anonymous survey titled "Impact of noise of old and new generation commercial aircraft on the health of flight and cabin crew" was conducted to gain insight into the subjective experience of noise, frequency of exposure, and the most commonly reported disturbances and possible health issues related to working on an aircraft. The survey was administered online using Google Forms for both cabin crew and flight crew, with participation voluntary and anonymous. A total of 55 cabin crew members from the national airline and 24 flight crew members from various airlines participated. The questionnaire consisted of the following 15 questions:

1. Gender? (options: F, M)
2. Age? (options: <25, 25–34, 35–44, 45–54, 55+)
3. How long have you been working in the aviation industry? (options: <1 year, 1–5 years, 6–10 years, 11–20 years, ≥21 years)

4. What is your job position? (options: captain, co-pilot, cabin crew, other (please specify))
5. Which aircraft models have you flown or piloted? If multiple, how long on each? (answer: please specify)
6. How often are you exposed to noise during a flight? (options: never, occasionally, often, most of the time)
7. How many hours per day do you spend on work tasks in the aircraft (total)? (options: <1 h, 1–3 h, 4–6 h, 7 or more hours)
8. How would you rate the noise level in the cockpit (for pilots and co-pilots) or cabin (for cabin crew)? (options: very low, low, medium, high, very high)
9. Do you feel that noise in the aircraft has a negative impact on you? (options: yes, no, I cannot assess)
10. Do you notice differences in noise levels between older and newer aircraft types? (options: yes, the new generation is quieter; yes, the older generation is quieter; I do not notice any difference; I am not sure; other (please specify))
11. Which health issues do you consider to be associated with noise exposure in the aircraft? (you may select multiple answers) (options: headache, fatigue, reduced concentration, hearing damage, stress/anxiety, elevated blood pressure, sleep problems, other (please specify))
12. How often do you feel tired or exhausted after a flight due to noise exposure? (options: never, occasionally, often, almost always, other (please specify))
13. Do you have difficulty sleeping after being exposed to a high level of noise during a flight? (options: yes, no)
14. What type of hearing protection do you use during a flight, if any? (options: earplugs, noise-cancelling headphones, no protection, other (please specify))
15. Do you think airlines should be required to have regular medical examinations that include checks for hearing damage or other noise-related issues? (options: yes, no, I am not sure, other (please specify))

RESULTS AND DISCUSSION

Results of Noise Level Measurements

Table 2 and Figure 4 show the range of measured A-weighted sound levels in the passenger cabin (minimum–maximum) during the five flight phases for the Airbus A220–300 and the Dash 8–Q400. The values are the average of two repetitions (30 seconds each) per phase, with minimum and maximum indicating the lowest and highest readings during the measurements. The column ΔL shows the difference between the A-weighted noise levels (dB(A)) recorded in the passenger cabin for the Dash 8–Q400 and the Airbus A220–300 in the same flight phase.

Table 2. Results of the noise level measurements conducted on the Dash 8–Q400 and Airbus A220–300 aircraft

Tablica 2. Rezultati provedenih mjerenja razina buke zrakoplova Dash 8–Q400 i Airbus A220–300

Flight Phase		AIRBUS A220–300 (dB(A))	DASH 8–Q400 (dB(A))	Difference, ΔL (dB(A))
Apron	min	62.6	62.4	0.2
	max	75.5	74.2	1.3
Taxiing	min	67.4	68.9	1.5
	max	73.8	74.1	0.3
Take–off	min	70.0	70.3	0.3
	max	90.9	105.2	14.3
Cruising	min	79.2	86.7	7.5
	max	89.4	91.0	1.6
Landing	min	74.7	75.7	1.0
	max	79.9	88.1	8.2

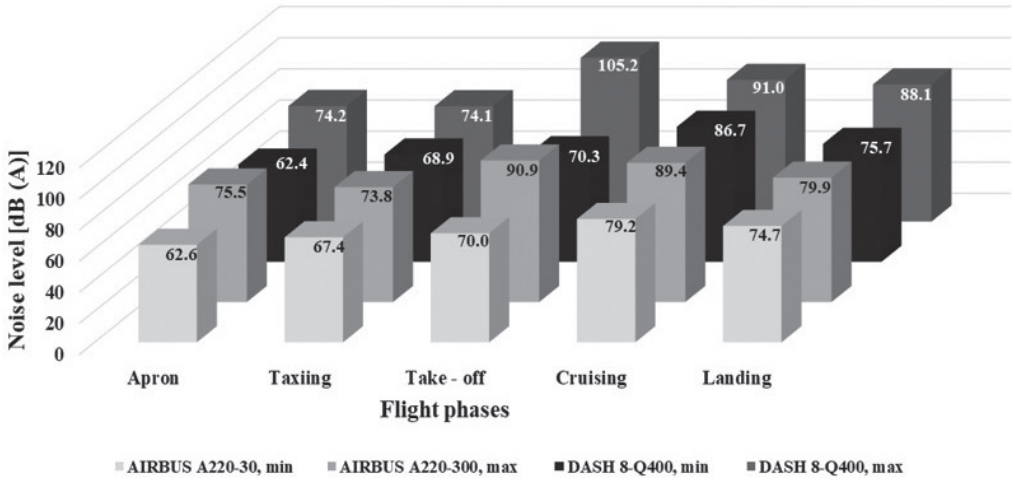


Figure 4. Graphical presentation of the noise level measurements for the Dash 8–Q400 and Airbus A220–300 aircraft
Slika 4. Grafički prikaz mjerenja razine buke za zrakoplove Dash 8–Q400 i Airbus A220–300

Table 2 presents the minimum (min) and maximum (max) A-weighted noise levels measured in the passenger cabin during the five flight phases for the Airbus A220–300 and Dash 8–Q400 aircraft. In the apron and taxiing phases, the differences are small (0.2–1.5 dB(A) for minimum values and 0.3–1.3 dB(A) for maximum values), indicating comparable acoustic conditions in these operational phases. The most pronounced difference was recorded during take-off, where the maximum noise level for the Dash 8–Q400 was 105.2 dB(A), while for the Airbus A220–300 it was 90.9 dB(A), a difference of 14.3 dB(A).

During cruise, the Dash 8–Q400 has a higher minimum noise level (86.7 dB(A)) compared to the Airbus A220–300 (79.2 dB(A)), while the maximum values are relatively similar. In the landing phase, a more pronounced difference in maximum noise levels is again observed, with higher values for the turboprop aircraft. Overall, the Dash 8–Q400 exhibits higher peak acoustic loads in the key flight phases, especially during take-off and landing, while differences in the quieter phases are less significant.

The observed differences can be attributed to the construction and propulsion features of the aircraft, as turboprop aircraft such as the Dash 8–Q400 generate more noise due to propeller operation and associated aerodynamic and structural vibrations, whereas newer jet aircraft are designed with an emphasis on reducing cabin noise.

In addition to propulsion-related factors, the measured differences may also reflect variations in structural design approaches between the two aircraft types. The Dash 8–Q400 uses a predominantly metallic, conventional fuselage configuration, which can facilitate the transmission of low-frequency structural excitation generated by turboprop operation. In contrast, the Airbus A220–300 incorporates more modern structural solutions, which may contribute to a different vibration behaviour of the airframe and consequently to the lower and more stable cabin noise levels observed in this study.

As the prescribed action and limit values for noise refer to daily time-weighted exposure ($L_{-EX,8h}$), the phase levels presented primarily serve to compare the acoustic conditions between different types of aircraft and to identify the noisiest flight segments.

Implementation of the Survey "Impact of Noise of Commercial Aircraft of Old and New Generations on the Health of Flight and Cabin Crew"

Table 3 presents a comparison of the responses from cabin crew (n = 55) and flight crew (n = 24) to the 15 survey questions, to provide insight into differences in noise exposure, noise level assessment, reported disturbances, and use of hearing protection.

Table 3. Comparison of the responses of cabin and flight crew to the 15 survey questions

Tablica 3. Usporedba odgovora kabinskog i letačkog osoblja na 15 anketnih pitanja

Question No.	Cabin Crew (n = 55)	Flight Crew (n = 24)
1.	Female (44 – 80%) Male (11 – 20%)	Male (23 – 95.8%) Female (1 – 4.2%)
2.	45-54 (23 – 41.8%) 35-44 (16 – 29.1%) 55+ (8 – 14.5%)	25-34 (15 – 62.5%) 45-54 (4 – 16.7%) 35-44 (2 – 8.3%) 55+ (2 – 8.3%) <25 (1 – 4.2%)
3.	21+ (32 – 58.2%) 6-10 (11 – 20%) 11-20 (9 – 16.4%) 1-5 (3 – 5.5%)	6-10 (8 – 33.3%) 1-5 (7 – 29.2%) 21+ (6 – 25%) 11-20 (3 – 12.5%)
4.	Cabin crew (55 – 100%)	Co-pilot (15 – 62.5%) Captain (9 – 37.5%)
5.	Dash 8–Q400 (55 – 100%) Airbus A220–300 (27 – 49.1%)	Dash 8–Q400 (6 – 25%) Airbus A220–300 (2 – 8.3%) Others (various)
6.	Most of the time (45 – 81.8%) Often (9 – 16.4%) Occasionally (1 – 1.8%)	Most of the time (14 – 58.3%) Occasionally (6 – 25%) Often (4 – 16.7%)
7.	7+ hours (37 – 67.3%) 4-6 hours (18 – 32.7%)	7+ hours (12 – 50%) 4-6 hours (7 – 29.2%) 1-3 hours (5 – 20.8%)
8.	High (35 – 63.6%) Very high (11 – 20%) Medium (9 – 16.4%)	Medium (12 – 50%) High (7 – 29.2%) Low (3 – 12.5%) Very low (2 – 8.3%)
9.	Yes (47 – 85.5%) No (1 – 1.8%) Indecisive (7 – 12.7%)	Yes (14 – 58.3%) No (6 – 25%) Indecisive (4 – 16.7%)
10.	New generation is quieter (43 – 78.2%) No difference (6 – 10.9%) Unsure (2 – 3.6%)	New generation is quieter (18 – 75%) Unsure (3 – 15.5%) No difference (2 – 8.3%)
11.	Fatigue (50 – 90.9%) Reduced concentration (39 – 70.9%) Hearing damage (37 – 67.3%) Headache (29 – 52.7%) Stress (22 – 40%) Sleep problems (20 – 36.4%) Elevated blood pressure (4 – 7.3%)	Fatigue (16 – 66.7%) Reduced concentration (15 – 62.5%) Hearing damage (14 – 58.3%) Stress (9 – 37.5%) Headache (4 – 16.7%) Sleep problems (4 – 16.7%)
12.	Often (26 – 47.3%) Almost always (21 – 38.2%) Occasionally (7 – 12.7%) Never (1 – 1.8%)	Occasionally (15 – 62.5%) Often (4 – 16.7%) Never (4 – 16.7%) Almost always (1 – 4.2%)
13.	Yes (33 – 60%) No (22 – 40%)	No (21 – 87.5%) Yes (3 – 12.5%)
14.	No protection (49 – 89.1%) Earplugs (4 – 7.3%) Noise-cancelling headphones (1 – 1.8%)	Noise-cancelling headphones (15 – 62.5%), No protection (8 – 33.3%) Earplugs (1 – 4.2%)
15.	Yes (44 – 80%) Indecisive (7 – 12.7%) Personal answers (4 – 7.3%)	Yes (13 – 54.2%) No (3 – 12.5%) Indecisive (2 – 8.3%) Personal answers (6 – 25%)

Table 3 presents a comparison of responses. The samples differ in basic characteristics. Among cabin crew, women predominate (80%) and the older age groups are most represented, typically 45–54 years, with a significant proportion having long work experience (58.2% have 21 years or more of service). In contrast, the flight crew sample is predominantly male (95.8%) and younger, mostly 25–34 years, with experience most often in the range of 6–10 years (33.3%). These differences are important to consider when interpreting subjective assessments of noise exposure and reported complaints.

Regarding exposure, cabin crew report being exposed to noise for most of their working time much more often (81.8%). The same response is given by 58.3% of flight crew. A larger proportion of cabin crew also spend seven or more hours per day in the aircraft on work tasks (67.3% compared to 50%). Accordingly, cabin crew rate the noise level as high or very high more frequently (63.6% and 20%, respectively). Among flight crew, the most common rating is medium (50%). A negative personal impact of noise is reported by 85.5% of cabin crew and 58.3% of flight crew.

Both groups generally observe that the new generation of aircraft is quieter (cabin crew 78.2%, flight crew 75%). This finding is consistent with respondents' comments about higher noise levels on turboprop aircraft. The most commonly reported disturbances in both groups are fatigue, reduced concentration, and hearing damage. These issues are generally more prevalent among cabin crew (fatigue 90.9% vs 66.7%; reduced concentration 70.9% vs 62.5%; hearing damage 67.3% vs 58.3%).

The difference is particularly marked regarding recovery after flight. Cabin crew more frequently report experiencing fatigue after a flight (47.3% "often" and 38.2% "almost always"). They also more often report sleep difficulties (60% "yes"). Among flight crew, the majority do not report sleep difficulties (87.5% "no").

A clear difference is also observed in the use of hearing protection. As many as 89.1% of cabin crew report not using hearing protection, while most flight crew use noise-cancelling headphones (62.5%). A majority of respondents in both groups support introducing or strengthening mandatory medical examinations with an emphasis on hearing and the consequences of noise exposure. Support is higher among cabin crew (80%) than among flight crew (54.2%). The higher proportion of "other" responses in the flight crew group suggests the existence of established procedures, such as audiometry as part of periodic examinations.

The observed differences in measured noise levels, as well as the more pronounced subjective disturbances among cabin crew, indicate the need for the systematic implementation of noise protection measures in commercial aviation. In addition to technical solutions and the gradual replacement of older aircraft types with new generations featuring lower cabin noise, appropriate personal hearing protection, especially during take-off and landing, also plays an important role. Such an integrated approach can help reduce both the short-term and long-term effects of noise on the health of flight and cabin crew.

Differences in the measured noise levels between the Dash 8–Q400 and Airbus A220–300 aircraft can be partially attributed not only to differences in propulsion systems but also to the structural and material characteristics of the aircraft. Although this study did not experimentally investigate the direct impact of materials on the acoustic properties of the cabin, numerous studies confirm that structural elements and materials play a key role in the transmission and radiation of noise in enclosed spaces such as aircraft cabins *(Peng et al., 2022)*. New-generation aircraft, such as the Airbus A220, use advanced aluminium-lithium alloys and composite materials that provide a more favourable strength-to-weight ratio and improved dynamic structural response, thereby reducing vibration transmission and, consequently, cabin noise levels *(Airbus (2026). A220 Family – Purpose-Built Single-Aisle Aircraft.)*.

In addition, the use of integrated damping technologies, such as constrained-layer damping (CLD), has proven effective in reducing vibrational transmission and acoustic radiation in aircraft structures, particularly in sandwich and semi-monocoque designs *(Fink et al., 2023)*.

The metallurgical and structural design of load-bearing fuselage elements therefore plays an indirect yet significant role in shaping the cabin noise environment through its influence on stiffness distribution and vibrational response.

These findings highlight the importance of an interdisciplinary approach that connects occupational safety, acoustics, and materials engineering with the aim of reducing occupational noise and vibration exposure in aviation.

CONCLUSION

Noise measurements were conducted across five flight phases for the Airbus A220–300 and Dash 8–Q400 aircraft. During the apron and taxiing phases, only minor differences in noise levels were observed. In cruise, the Dash 8–Q400 exhibited a higher minimum noise level compared to the Airbus A220–300, while the maximum values remained relatively similar. In the landing phase, a more pronounced difference in maximum noise levels was again identified, with higher values recorded for the turboprop aircraft. Overall, the Dash 8–Q400 demonstrated greater peak acoustic loads during key flight phases, particularly during take-off and landing.

Survey data confirm greater noise exposure and more frequent subjective disturbances among cabin crew, consistent with longer durations spent in noisy working environments. Most respondents perceive new-generation aircraft as quieter, further confirming the positive effects of modern technological solutions.

Beyond the propulsion system, the results also highlight the importance of material and structural characteristics in shaping the cabin's acoustic profile. The use of advanced materials such as aluminium–lithium alloys and the integration of damping systems into the fuselage structure may contribute to reduced vibration transmission and lower noise levels, as suggested by recent studies. An interdisciplinary approach – linking occupational safety, acoustics, and materials engineering – is therefore recommended in the development of aircraft and crew protection systems.

The findings emphasise the importance of continuous monitoring of occupational noise exposure and the implementation of technical, organizational, and personal protective measures to mitigate adverse health effects on cabin and flight crew.

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LITERATURE

Ablakatov, I. K., Baiserikov, B. M., Ismailov, M. B., Nurgozhin, M. R.: Aluminum–lithium alloys: types, properties, application, and production technologies. Overview, *Complex Use of Mineral Resources,* 323, 2022., 4, 5–14.

Airbus (2026). A220 Family – Purpose-Built Single-Aisle Aircraft, Available at: https://www.airbus.com/en/products-services/commercial-aircraft/passenger-aircraft/a220-family, Accessed: 16 January 2026.

Bilan, B. J.: Impact of noise pollution on aviation workers, *Research Invention Journal of Scientific and Experimental Sciences,* 3, 2024., 2, 52–56.

Bramati, L., Gondim, L. M. A., Schmidt, L., Lüders, D., Taveira, K. V. M., Néron, N., de Araujo, C. M., de Lacerda, A. B. M.: Effectiveness of educational programs in hearing health: A systematic review and meta-analysis, *International Journal of Audiology,* 63, 2024, 12, 936–947.

Chen, K.-H., Su, S.-B., Chen, K. T.: An overview of occupational noise-induced hearing loss among workers: Epidemiology, pathogenesis, and preventive measures, *Environmental Health and Preventive Medicine,* 25, 2020, 65.

Chen, K.-T., Su, S.-B.: A review of occupational noise-induced hearing loss: Focus on mechanisms and preventive measures, *British Medical Bulletin,* 156, 2025, 1–10.

Clarke, A. H. C., Zaidi, M., Kitila, A. T.: Preventing occupational noise-induced hearing loss: A systematic review of effective interventions and best practices, *New Zealand Journal of Health and Safety Practice,* 2, 2025, 1, Article 9681.

Croatia Airlines (2025). *Dash 8–Q400 – Fleet,* Available at: https://www.croatiaairlines.com/hr/flota/dash-8-q400, Accessed: 28 March 2025.

Croatia Airlines (2025). *Airbus A220–300 – Fleet,* Available at: https://www.croatiaairlines.com/hr/flota/a220/a220-300, Accessed: 28 March 2025.

Dewald, R. D., Klimmek, T., Hesse, C., Winter, R.: Parametric approach to primary structure modelling of aircraft for cabin noise analysis in FEM, *CEAS Aeronautical Journal, 16, 2025.*

Dobrenić, B.: *Influence of noise from old and new generation commercial aircraft on the health of flight and cabin crew. Bachelor's thesis,* University of Zagreb, Faculty of Metallurgy, Sisak, 2025.

European Parliament and Council (2003). *Directive 2003/10/EC on minimum health and safety requirements regarding workers' exposure to risks from noise,* Available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ%3AL%3A2003%3A042%3A0038%3A0044%3AEN%3APDF, Accessed: 10 January 2026.

Feng, Z., Han, F., Xu, J.: The effects on acoustic characteristics of aircraft with constrained layer damping, *Proceedings of the 9th International Workshop on Computer Science and Engineering (WCSE 2019 SUMMER),* Hong Kong, 1002–1009, 2019.

Fink, A., Schatz, R.: Structurally integrated constrained layer damping for noise reduction on sandwich and semi-monocoque helicopter structures, *Composite Structures,* 322, 2023., 117354.

Gardonio, P., González Díaz, C.: *Bombardier Dash–8–Q400 fuselage section with five decentralized velocity feedback control units, Institute of Sound and Vibration Research Technical Memorandum No. 983,* University of Southampton, 2009.

Habotest (2026). *HT602B Sound Level Meter – Digital Handheld,* Available at: https://www.habotest.com/sale-51801497-ht602a-sound-level-meter-digital-handheld-db-meter-sonometros-noise-audio-level-meter-30-130db-decib.html, Accessed: 15 January 2026.

Habotest (2026). *Sound Level Meter Habotest HT602B,* Available at: https://pepita.com/en/multimeters-c5103/sound-level-meter-habotest-ht602b-p6652437#ref, Accessed: 18 February 2026.

Ivošević, J., Miljković, D., Krajček, K.: Comparative interior noise measurements in a large transport aircraft – turboprops vs. turbofans. In: *Proceedings of the 5th Congress of the Alps-Adria Acoustics Association,* Acoustical Society of Croatia, Petrčane, 1-6, 2012.

Ivošević, J., Bucak, T., Sumpor, D.: Assessment methodology of interior aircraft noise influence on pilot performance and temporary threshold shift, *Promet – Traffic & Transportation,* 28, 2016, 5, 487–496.

Kudal, A. R., Cicirello, A.: Constrained layer damping treatment: Analysis of multi-strip application on thin plates, *Journal of Physics: Conference Series,* 1106, 2018, 012025.

Latsuzbaya, V., Middendorf, P., Völkle, D., Weber, C.: Acoustical properties of the new sandwich structures for aircraft cabin interiors with integrated vacuum insulation, *CEAS Aeronautical Journal,* 16, 2025, 1, 7–16.

Lee, H. P., Kumar, S., Garg, S., Lim, K. M.: Assessment of in-cabin noise of wide-body aircraft, *Applied Acoustics,* 194, 2022, No. 108809.

Lee, H. M., Garg, S., Lim, K. M., Lee, H. P.: Comparison of cabin noise of turboprop and tur-

bofan aircraft, *Applied Acoustics,* 214, 2023, No. 109651.

Lie, A., Skogstad, M., Johannessen, H. A., Tynes, T., Mehlum, I. S., Nordby, K.-C., Engdahl, B., Tambs, K.: Occupational noise exposure and hearing: A systematic review, *International Archives of Occupational and Environmental Health,* 89, 2016, 351–372.

Lobitz, L., Bülow, C., Heimbs, S., Horst, P.: Benefits from thin-ply composite materials in aircraft wing structures, *Aerospace,* 12, 2025, 12, 1078.

Mixson, J. S., Wilby, J. F.: Interior noise. In: Aeroacoustics of Flight Vehicles: Theory and Practice. Volume 2: Noise Control. *Proceedings of a Symposium on Aeroacoustics of Flight Vehicles, NASA Conference Publication 1258,* Langley Research Center, Hampton, Virginia, 271–355, 1991.

Moroe, N. F., Khoza-Shangase, K.: Recent advances in hearing conservation programmes: A systematic review, *South African Journal of Communication Disorders,* 67, 2020., 2, a675.

Official Gazette of the Republic of Croatia, No. 148/2023, Available at: https://narodne-novine.nn.hr/eli/sluzbeni/2023/148/2096, Accessed: 13 December 2023.

Orikpete, O. F., Dennis, N. M., Kikanme, K. N., Ewim, D. R. E.: Advancing noise management in aviation: Strategic approaches for preventing noise-induced hearing loss, *Journal of Environmental Management,* 363, 2024, 121413.

Peng, T., Dong, N., & Yan, Q.: Analysis of sound transmission loss characteristics of aircraft composite panel under variable temperature environment, *Journal of Low Frequency Noise, Vibration and Active Control,* 41, 2022, 3, 1044–1065.

Prasad, N. E., Gokhale, A. A., Wanhill, R. J. H.: *Aluminium–Lithium Alloys,* Elsevier, Oxford, 2021.

Raphela, F. S.: A systematic review of hearing loss and its associated factors among workers in the metal industry, *Journal of Otorhinolaryngology, Hearing and Balance Medicine,* 6, 2025., 18.

Safefly (2026). The Airbus A220 – A Comprehensive Guide to History, Performance and Innovation, Available at: https://safefly.aero/the-airbus-a220-a-comprehensive-guide-to-history-performance-and-innovation/, Accessed: 16 January 2026.

Samelli, A. G., Matas, C. G., Gomes, R. F., Morata, T. C.: Systematic review of interventions to prevent occupational noise-induced hearing loss – A follow-up, *CoDAS,* 33, 2021., 4, e20190189.

Shen, H., Hao, M., Ren, J., Chen, K., Gao, Y.: Experimental study on the effects of cockpit noise on physiological indicators of pilots, *Sensors,* 25, 2025, 4175.

Tikka, C., Verbeek, J. H., Kateman, E., Morata, T. C., Dreschler, W. A., Ferrite, S.: Interventions to prevent occupational noise-induced hearing loss, *Cochrane Database of Systematic Reviews,* 7, 2017, CD006396.

Vledder, G., Yao, X., Song, Y. (Wolf), Vink, P.: Effectiveness of earplugs and noise-cancelling headphones to improve turboprop acoustic comfort, *Work: A Journal of Prevention, Assessment and Rehabilitation,* 83, 2025, 1, 33–46.

Zeng, A., Huang, Y., Xin, J., Li, J., Qiu, W., Zhang, M.: Progress and recommendations of developing occupational exposure limits for noise – A systematic review, *Heliyon,* 10, 2024, e37878.

Zhou, X. Q., Yu, D. Y., Shao, X. Y., Zhang, S. Q., Wang, S.: Research and applications of viscoelastic vibration damping materials: A review, *Composite Structures,* 136, 2016, 460–480.

IZLOŽENOST BUCI ZRAKOPLOVNE POSADE: RAZLIKE IZMEĐU STARIH (DASH 8-Q400) I NOVIH GENERACIJA ZRAKOPLOVA (AIRBUS A220-300) U KONTEKSTU AKUSTIKE I MATERIJALA

SAŽETAK: Buka u komercijalnom zrakoplovstvu značajan je izvor stresa u radnom okruženju i može imati neželjen utjecaj na zdravlje, sigurnost i obavljanje radnih zadaća kod pilota i ostale posade. Cilj istraživanja bio je usporediti razinu buke u putničkom dijelu starijih i novijih zrakoplova i analizirati subjektivnu percepciju izloženosti buci i s time povezanim zdravstvenim teškoćama zrakoplovnog osoblja. Eksperimentalni dio članka bavio se je mjerenjem A-težine razine zvuka u kabinskom prostoru Dash 8-Q400 i Airbus-300 zrakoplovima tijekom pet faza leta. Mjerenja su provođena kao kratkotrajne fazne procjene s rezultatima iskazanim kao minimalne i maksimalne vrijednosti razine buke. Ispitano je kabinsko (n=55) i letačko (n=24) osoblje kako bi se procijenila izloženost buci, učestalost zdravstvenih teškoća i korištenje mjera za zaštitu sluha. Rezultati pokazuju višu razinu buke i izraženija vršna akustička opterećenja tijekom ključnih faza leta kod starijih zrakoplova (Dash 8-Q400), posebno pri polijetanju i spuštanju, dok je kod zrakoplova novije generacije (Airbus A220-300) razina buke niža i jednoličnija u putničkom prostoru. Rezultati istraživanja potvrđuju veću izloženost i učestalije teškoće (uznemirenost) kod kabinskog osoblja za razliku od pilota, kao i percepciju da su noviji zrakoplovi tiši. Pored ovoga, razlike u strukturi i materijalima između pojedinih tipova zrakoplova, naročito konfiguracije trupa i izbor materijala, mogu predstavljati dodatan čimbenik koji utječe na obilježju percipirane buke u kabinskom prostoru. Rezultati ističu potrebu trajnog praćenja izloženosti buci u zrakoplovstvu i ističu važnost kombiniranja tehničkih, organizacijskih i osobnih zaštitnih mjera kako bi se smanjili potencijalni negativni učinci buke na zdravlje zrakoplovnog osoblja.

Ključne riječi: *buka, mjerenje buke, sigurnost na radu, komercijalno zrakoplovstvo, materijali u zrakoplovstvu, slitine aluminija i litija, kabinsko osoblje, pilotsko osoblje*

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