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Field Measure of Noise Through Select Means of Transport

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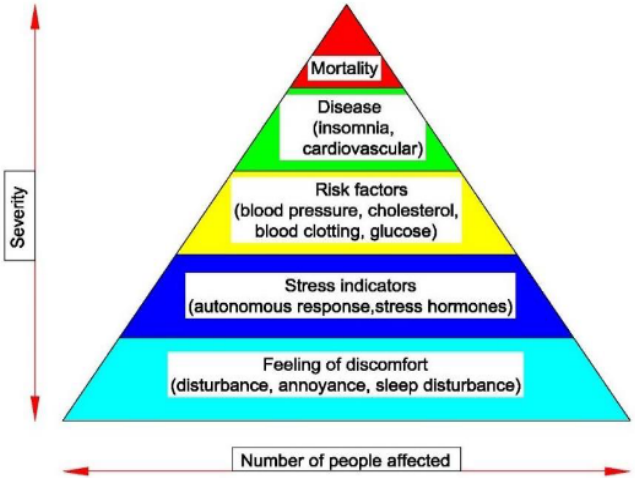
***Abstract* - Mobility of people has significantly increased. Daily and occasional trips consume a significant time in our whole life span. A comfortable and safe travel is prime need of any individual. Noise is an important parameter which defines the quality of life. Vehicular noise not only affects the outer environment of the vehicle but it also causes discomfort for the occupants travelling inside the vehicle. Noise reduction during journey is an important aspect for a comfortable travel. We are constantly exposed to various types of noise generated from vibrations. These vibrations produce longitudinal waves which are intercepted by our ear. Sensitivity of our auditory system depends on various factors, and age of individual is an important parameter. Apart from this the exposure of noise during lifetime is important criteria for long term auditory functions. Exposure of noise during travel is gaining significant importance as it decides our comfort level, and sleep duration. In this paper we examine the noise pressure level (dBA) during travel through filed data collection. The trips discussed are on road, rail and air.**
***Keywords:* Noise, Train Noise, Traffic Noise, Aeroplane Noise, Noise During Journey**

I. INTRODUCTION

Acoustic comfort is an important aspect for any journey. High noise is associated with fatigue, and dizziness. Noise is considered an "unpleasant sound". Noise can be described in terms of three variables: amplitude (loud or soft), frequency (pitch), and time pattern (variability). These combine to create the intensity of noise. Noise pollution is a severe issue now a days that impacts the quality of life negatively. The issue stands more in metropolitan cities because there is a lot of traffic related noise pollution. Among the noise sources trains, planes and road transport plays major role [1]. The noise perceived by a traveller is important because of constant exposure in a long journey. Long travel schedules add up to the problem. Noise is associated with sleep disruption and general fatigue.

Research Highlights

1. Noise perceived in a road journey by a car is highly variable because of varied external noises.
2. Journey inside LHB coaches is acoustically silent as compared to road, metro rail and air journey and is least annoying.
3. Journey by Metro Rail coaches are nosier than LHB coaches of Indian Railway
4. Noise inside Air Bus A320 has least variation in acoustic level (70.8 dBA to 73.8 dBA) but is noisiest among all transportation and most annoying.



Source: World Health Organization
Fig. 1 WHO pyramid of Health effect of noise

The ecology of urbanised areas and human health are sufficiently harmed by the noise pollution from vehicle transportation. It is evident that traffic related noise, that makes up to 10% of societal noise and accounts as the main source of noise in urban areas. Road traffic noise is most prevalent sort of noise in cities and as such, it is a major issue.

Vehicle produces noise only when road surfaces and tires come into contact so the noise depends on type of road surface, tire construction, speed and finally at driving style [2]. In rail vehicles, noise production is mainly caused by wheel-rail interaction that is directly influenced by the track's geometry and movement speed whereas, when travelling over straight rail sections, the noise is mainly produced by the friction between the roughness of the rail and wheel

surfaces. While navigating railway curves the wheel generate additional noise owing to rolling as well as metal wheel slippage which is audible as creaking along the railway track.

The WHO pyramid (Fig. 1) on ill effects of noise on health very well signifies how dangerous can noise pollution be if an individual is subjected to it for prolonged durations regularly. It starts with a feeling of discomfort initially and if taken proper care of the situation remains under control. Giving proper rest to ears can help increase concentration which can take a severe hit if the person is subjected to noise pollution frequently. However, if ignored for long, noise pollution can cause increase in blood pressure, cholesterol levels, etc. and may get severe with time to cause insomnia and other cardiovascular disorders that may even lead to mortality.

Noise pollution affects hormonal balance, releasing stress hormone like cortisol that influences metabolism as well as decreases relaxation level and disrupts cognitive function [3]. Children are adversely affected from noise pollution, they may suffer from attention, sleep disorder and memory decay [4]. Hearing loss, tinnitus, hypertension, vasoconstriction and other cardiovascular system have all been linked to noise exposure [5]. Many researchers concluded in their studies that, sound intensity puts adverse effect on the nearby community [6] [7] [8]. Industrial and traffic noise severely affects both auditory and non-auditory physiology in human including hearing loss [9], irregular pattern of heartbeat, psychology related problem and high blood pressure [10], stress and irritation, difficulty in sleeping, reduced work efficiency as well as difficulty in understanding the topic of conversation [11]

In a study conducted in Indonesia the noise recorded inside the Argo Parahyangan train was 67.5 - 74.2 dBA for executive class in daytime and for night-time it was 69.1 - 75.2 [12]. In a study conducted by [13] it was found that the noise inside an underground metro station is 5 dB higher than the open metro stations, because of reflective s It is surfaces and reverberations. Train noises are in the frequency of 400-4000 Hz [14].

II. RESEARCH METHODOLOGY

Noise emitted by all sources were measured using android mobile app 'Noise capture'. The mobile app was calibrated using sound level meter as per standard procedure laid in the manual of the app. It was verified using sound meter as per code [15]. Sound level instrument used for calibration was METRAVI *SL-4010 (IEC 651 TYPE II).* It was set to slow mode (response time of one second) for measuring sound. The reading was taken for a minimum of 15 minutes and data was tabulated for the journey. The recorded noise was the combined noise of the commuters and the vehicle.

A. Noise Inside Car (Toyota Etios)

Noise data inside car was recorded for Toyota Etios (2010 model), Petrol driven. Noise data was recorded for various speed when the window shutter was fully closed and no Air conditioning and fan was in working condition.

TABLE I NOISE LEVEL ASSOCIATED WITH SPEED (KM/HR) INSIDE CAR

Speed of Car km/hr	Min dBA	Avg dBA	LA90 (dBA)	LA50 (dBA)	LA10 (dBA)	Max (dBA)
25 (local)	49.3	67.5	52.9	59.7	71.5	79.0
40 (highway)	53.6	64.4	54.8	61.8	66.6	73.2
60(highway)	56.5	65.6	61.3	64.9	66.8	71.0
70(highway)	65.5	67.1	65.4	66.4	67.2	70.8
80(highway)	65.3	68.7	65.5	67.7	70.2	72.6

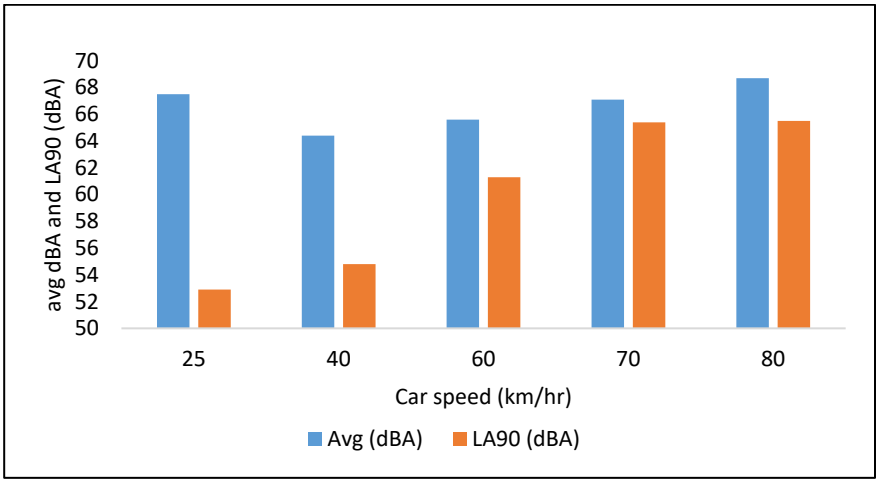


Fig. 2 Speed of car and Sound measured inside Car

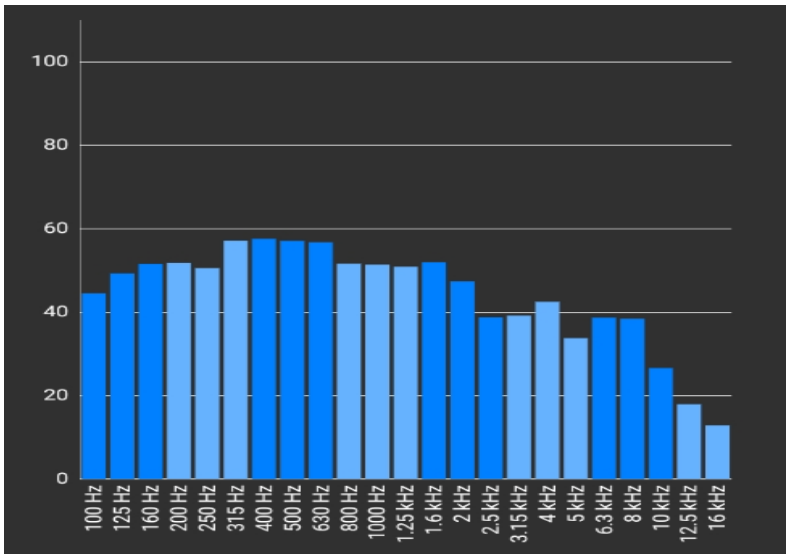


Fig. 3 Sound level for various frequencies for car travelling at speed of 60 km/hr

B. Noise in LHB Coach of Indian Railway

Indian Railway runs 13452 passenger trains daily and carry 23 million passengers per day[16]. It is the fourth largest railway network in the world after USA, China and Russia. In terms of passengers carried per year it is number one. It has a fleet of Integral Coach Factory (ICF) coaches and Link-Hoffmann-Busch (LHB) coaches. Indian Railway has discontinued the production of ICF coaches and its three coach manufacturing units at Kapurthala, Chennai and Rai Barely are upgraded to produce LHB coaches. Indian Railways entered into supply and technology transfer contracts with M/s. ALSTOM LHB a German company to initially supply 24 coaches consisting of 19 AC chair cars, 2 AC Executive Class Chair cars and 3 Generator cum Brake vans. The bogies for these coaches were manufactured by M/s. FIAT/SIG Switzerland. These coaches arrived in India and got commissioned in the year 2001 and put in service in Premier New Delhi- Lucknow Shatabdi Express train [17].

The benefits of LHB coaches are highlighted below.

1. Carrying capacity - LHB coaches are about 2 meters longer than ICF coaches. This extra length gave advantage of adding two additional rows of chairs in chair cars or one additional bay in sleeper coaches can be accommodated. In sleeper coaches additional pantry area is available. LHB coach can accommodate 72 passengers as compared to 64 in conventional AC III Tier Coach. Thus, giving better pay to tare ratio.
2. LHB coaches are lighter as compared to ICF design coaches.
3. Low corrosion due to usage of Stainless Steel and better design and manufacturing techniques.
4. Low Maintenance - Replacement and removal of sub-systems will be required only after one million kilometres.
5. These coaches are fitted with pneumatic disk braking system to slow down the speed of the train.
6. LHB Coaches have aesthetically superior interiors with FRP panels for side wall and roof. They can be removed easily for maintenance, resist water seepage and are resistant to wear and tear.
7. There are no visible screws inside the passenger compartment, improving the aesthetics.
8. Better passenger comfort: Better Riding Index has been specified as compared to conventional ICF coaches with low noise as compared to ICF manufactured coaches.
9. LHB coach offers better passenger safety due to:
   a. Use of fire retardant materials for furnishing.
   b. Provision of emergency openable windows.
   c. Vertically interlocked Centre Buffer Couplers.

LHB coaches are used by Indian Railways since 2001 and are slowly replacing their Integral Coach Factory (ICF) produced railway coaches. LHB coaches has several other advantages over the ICF coaches. They are fitted with anti-telescopic features which stop them rolling and flopping during an accident. They have an improved aesthetic and acoustically better performance. This process is smooth in operation and generates less noise as compared to traditional coaches. Better suspension gives a smooth ride to the passengers. The modular LHB coaches have wider windows and concealed light mechanism, individual reading lights, mobile charging point, air pressure toilet system and a thermostat based cooling/heating system. LHB coach was used for field study of noise inside the coach as perceived by the traveller. Single data may not be statistically appropriate, but it will give insight for further data collection and validation for the acoustic pressure data inside LHB coaches.

1. Data Collected: From Sampoorna Kranti Express 12393 fitted with LHB coaches.
2. Rajendra Nagar Stn. (Bihar) to New Delhi
3. Journey performed in AC3 coach at seat no 67 (Upper Berth) on intervening night of 02/2/2023 and 03/02/2023.

TABLE II NOISE LEVEL ASSOCIATED WITH TRAIN INSIDE LHB COACH OF AC3

Location	Min dBA	Avg dBA	LA90 (dBA)	LA50 (dBA)	LA10 (dBA)	Max (dBA)
RJPB_St_PF	51.2	60.9	53	56.3	62.6	76.1
PNBE_St_FC	51.1	67.1	55.2	63.9	70.6	76.3
LHB_full _run	52.1	60.2	56.1	58	62.2	68.9
NDLS_Plat 14/15	66.8	74.7	69.9	73.7	76.7	80

RJPB_St_PF: sound level at Rajendra Nagar Station, Patna, inside LHB coach (Stationary train with partially occupied seats) Date: 02/02/2023 (19:25)
PNBE_St_FC: sound level at Patna Jn inside LHB coach (Stationary train with fully occupied seats) Date: 02/02/2023 (19:40)
LHB_full_run: sound level inside 3AC LHB coach at speed of 110 km/hr (Date: 02/02/2023) (21:45)
NDLS_Plat 14/15: Sound level at Platform no 14/15 when Sampurna Kranti Exp (12393) reaches New Delhi Station and passenger gets down.(Date: 03/02/2023) (07:50)

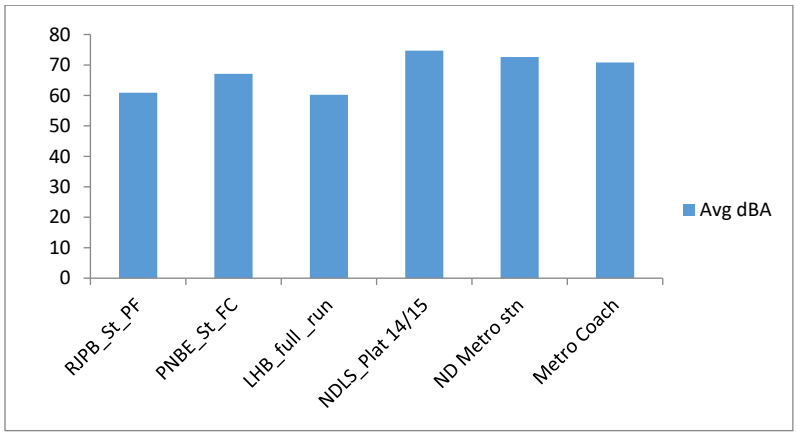


Fig. 4 Average dBA in a train journey

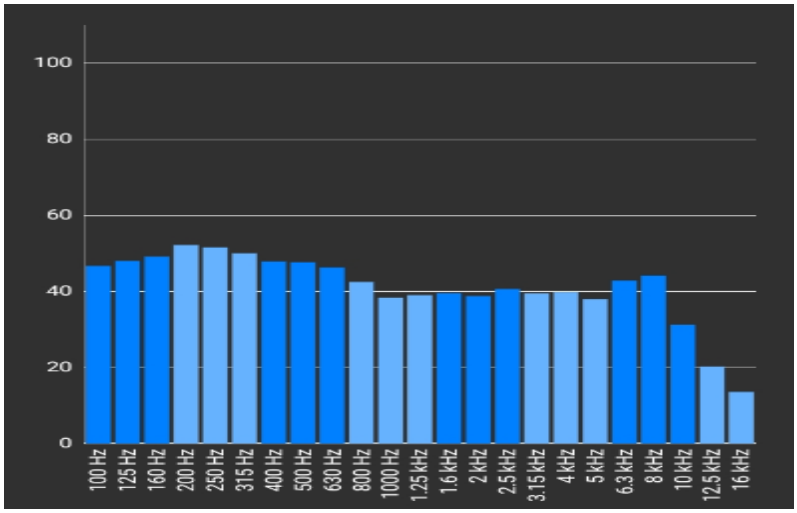


Fig. 5 Sound level for various frequencies for LHB coach travelling at full speed of 120 km/hr

TABLE III NOISE DATA OF TEJAS EXPRESS (12310) RUNNING FROM NEW DELHI TO RAJENDRA NAGAR STATION ON 10/2/2023 RECORDED IN COACH NO B11, SEAT NO 16 (SIDE UPPER BERTH)

Location	Min dBA	Avg dBA	LA90 (dBA)	LA50 (dBA)	LA10 (dBA)	Max (dBA)
AC3 coach	52.1	68.7	61.1	66.6	71.7	77.6

C. Noise in Delhi Metro Rail (Blue-Line)

Delhi metro rail is among the successful metro network of the world. The Delhi Metro of NCR consists of 390 km of network with 286 stations, out of which 29 are interchange stations. It includes 29.16 km of aqua line Noida Metro Rail Corporation (NMRC) and 12.85 km long Rapid Metro. Corridor of Haryana Mass Rapid Transport Corporation. The

daily passenger journeys stand at an average of approximately 2.52 million per day as compared to 6 million per day (pre-Covid)[18] Blue line connects East-West Delhi and city of Noida and Ghaziabad of Uttar Pradesh. It is one of the busiest routes which covers a distance of 56.61 km.

Source: DMRC

Fig. 6 Delhi Metro Blue-line

TABLE III NOISE LEVEL ASSOCIATED INSIDE METRO STN AND METRO COACH

Location	Min dBA	Avg dBA	LA90 (dBA)	LA50 (dBA)	LA10 (dBA)	Max (dBA)
New Delhi Metro stn.	60.5	72.6	65.4	69.8	76.1	83.4
Running Metro Rail Coach	56.2	70.8	60.5	69.4	73.7	76.1

ND Metro stn: Sound level at New Delhi Metro Station (Date: 03/02/2023)(08:00)

Running Metro Rail Coach: Sound level of Blue Line Metro (inside) coach when running underground (Date: 03/02/2023) (08:28)

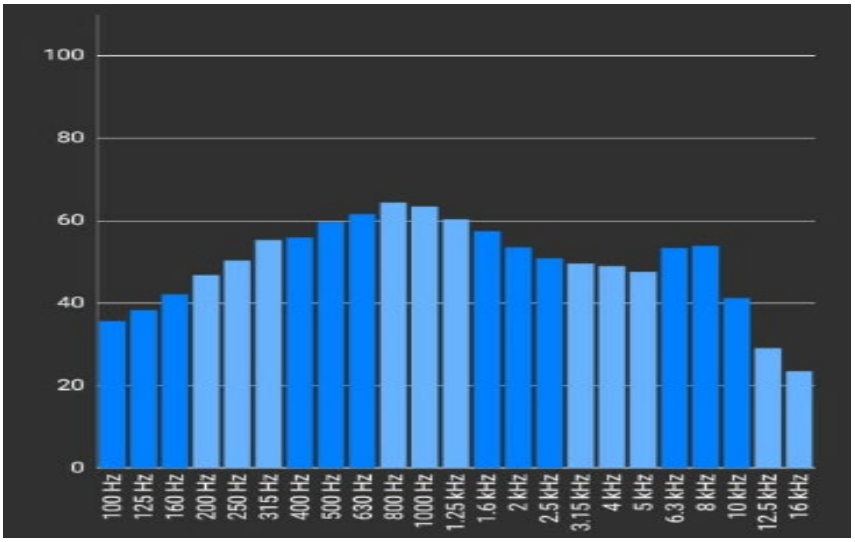


Fig. 7 Sound level for various frequencies for metro rail coach travelling at full speed

Average noise level recorded in running Delhi metro is 70.8 dBA when the coach is in full capacity.

D. Noise in Airbus A320 (Journey Performed on 04/02/2023)

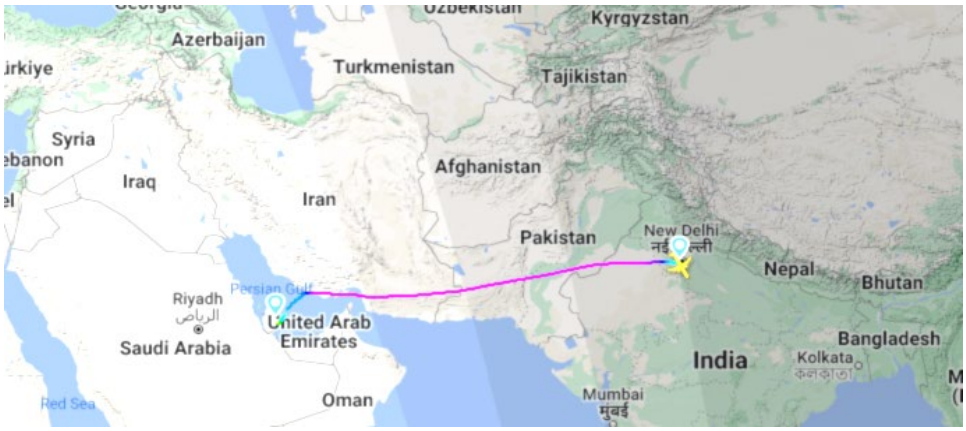
Airbus A320 is the largest selling passenger aircraft with narrow body and single aisle. It has a seating capacity of up to 220 passenger and has a range of 3100 to 12,000 km. Airbus A320 has a slogan of 'Unbeatable fuel efficiency" [19]. Noise sensed by a traveller inside an aircraft is both the noise of the aircraft and the noise by passenger. Ear pressure is adjusted to the ambient pressure by yawning and is frequently felt during air travel. Noise reduction is an important criterion for a comfortable travel especially when the flight duration is long through several time zones.

The noise data was collected from android based cell phone calibrated with Metravi Noise meter on 04 February 2023 during a flight from New Delhi to Doha (AI 971) in Air Bus A320 with almost full flight with an occasional crying kid at back seat. Seat No was 16(A).

The android based GPS reading in flight mode recorded a cruising speed of 650 km/hr which was verified from online flight tracker website, flight radar [20].

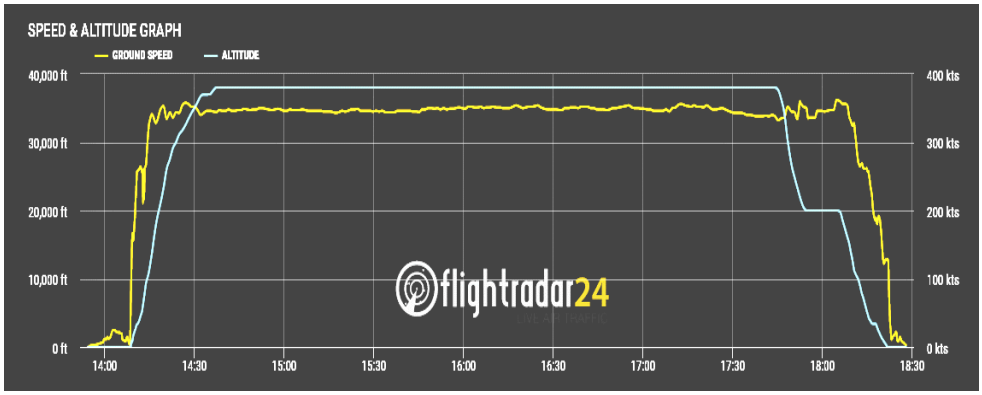
TABLE IV NOISE DATA COLLECTION DURING A FLIGHT JOURNEY IN AIR BUS A320

Particulars	Min dBA	Avg dBA	LA90 dBA	LA50 dBA	LA10 dBA	Max dBA
Grounded flight with full passenger	55.9	69.6	58.4	62.5	71.6	86.9
Take off	62.6	74.3	70.8	73.6	75.4	79.5
Mid-flight @ 650 km/hr and flying height of 38,000 ft from MSL	70.8	72.3	71.2	71.7	72.5	73.8



Source: flightradar24.com

Fig. 7 Route map of AI 971 (New Delhi to Doha) on 04/2/2023



Source: flightradar24.com

Fig. 8 Speed and Altitude graph of flight AI971 (04/2/2023)

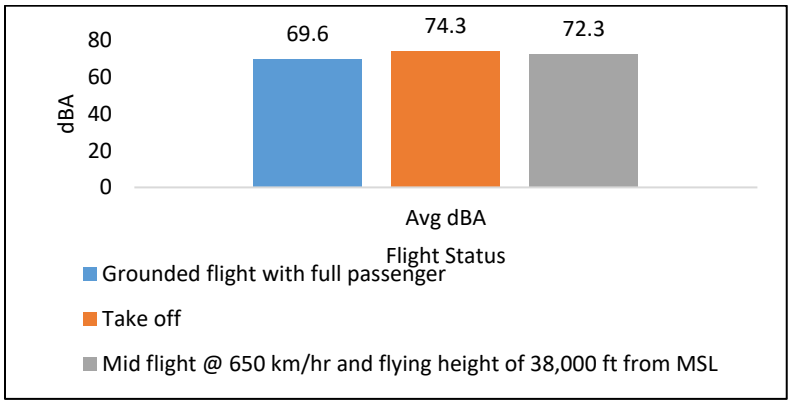


Fig. 9 Noise recorded during a flight journey in an Air bus A320

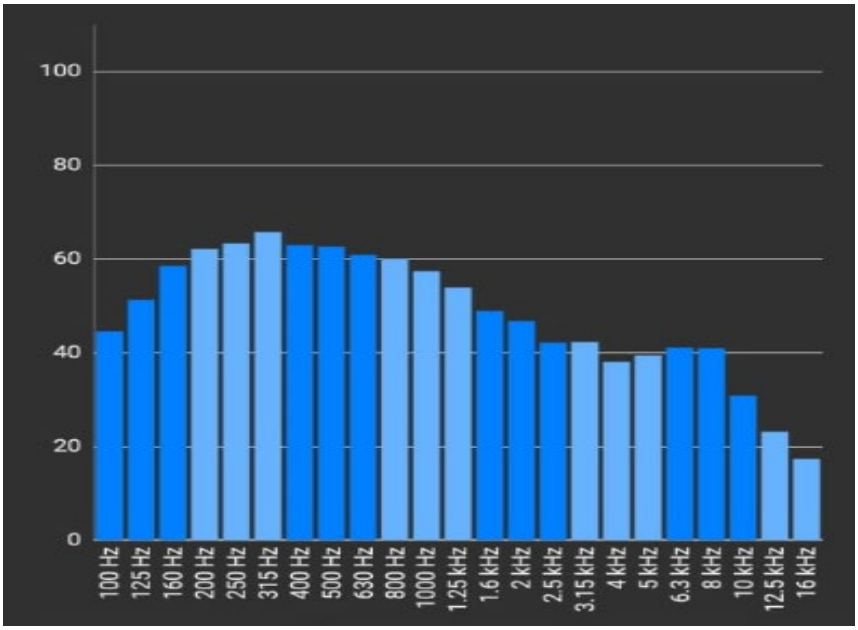


Fig. 10 Sound level for various frequencies for A320 airbus travelling at ground speed of 650 km/hr

E. Level of Annoyance

There is a correlation between noise and level of annoyance. It's not only the level of noise but also the duration of exposure of noise is important. Annoyance starts after 45 dBA and at 65 dBA forced behaviour starts like moving to a quitter location or shutting down the windows [21]. Level of annoyance is calculated for 24 hour period based on Equation 1 given below.

$$\text{HA (\%)} = \frac{100}{1+\exp(11.13-0.14\,DNL)} \qquad \text{(Equation 1)}$$

Where HA is level of annoyance in % and DNL (Day and Night Noise Level). DNL model is proposed by US air force as Equation 2 (Ouis, 2001).

$$\text{DNL} = 10 \log \frac{15 \times 10^{\frac{L_D}{10}} + 9 \times 10^{\frac{L_N+10}{10}}}{24} \qquad \text{(Equation 2)}$$

Where
L_D and L_N are average noise level during 15 hour day time and 9 hour night time.

Considering degree of annoyance is zero around the noise level of 40 dB to 45 dB, a simplified equation for Annoyance level is presented below as Equation 3[22]

$$\text{HA (\%)} = 0.24 \times (\text{DNL} - 42) + 0.0277 \times (\text{DNL} - 42)^2 \qquad \text{(Equation 3)}$$

Where HA(%) is annoyance in percentage and DNL is Day and Night noise level calculated in Equation 2.

Table IV shows the annoyance calculated based on observations form field data. It is assumed that $L_D = L_N = Avg\ noise\ emitted$ by the transport carrier.

TABLE IV CALCULATION OF ANNOYANCE HA (%)

Means of Transport	Avg dBA= $L_D = L_N$	DNL	HA (%)
Car @60 km/hr	65.6 dBA	72	31.5 %
Train (LHB Coach) @ 120 km/hr	60.2 dBA	66.5	22.5 %
Metro Rail	70.8 dBA	77.2	36.84 %
Air bus A320 @ cruising ground speed of 650 km/hr at 36500 ft from MSL	72.3 dBA	78.7	44.44%

III. RESULTS AND DISCUSSION

In the case of car, it is observed that on the local road the traffic noise and other noise accumulates with the engine noise and gives a higher level of average noise (67.5 dBA). On highway the noise level is positively correlated with the speed of the car. For the safe journey on Indian road condition (@ 60 km/hr) the sound generated is (65.6 dBA). LHB coaches are the silent vehicles with average sound of 60.2 dB when in full run at 110 km/hr and the passengers in sleeping condition. Here it is to be mentioned that the Tejas Train (New Rajdhani) which has a higher speed compared to Sampoorna Kranti Express recorded a higher noise of 68.7dBA, which needs a further investigation. Individual

Metro coaches are fitted with electric motors which makes it noisier as compared to Railways. Frequent breaking and acceleration makes it a noisier means of transportation. Air bus A320 is nosier during take-off, but at its optimum cruising speed the journey is maintained at 72.3 dBA. Journey in LHB coach is silent (60.2 dBA) as compared to other means of transportation. Journey in Metro coach is noisier (70.8 dBA) than the LHB coach of train.

IV. CONCLUSION

The average noise level recorded in car at 60 km/hr is 65.6 dBA with annoyance of 31.5%. The average noise level recorded in LHB coach is 60.2 dBA with annoyance of 22.5% which is least among all these four means of transport. The average noise level in metro coach is 70.8 dBA and annoyance of 36.84%. Air Bus A320 recorded 72.3 dBA during cruising ground speed of 650 km/hr and annoyance of 44.44% which is highest among all four.

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