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Noise-Induced Stress and Sleep Disturbance Among Urban Bus Drivers: A Comprehensive Review of Evidence from India and Global Studies (2010–2025): *A Systematic Narrative Review*

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***Abstract:** Urban bus drivers constitute a high-risk occupational group chronically exposed to elevated noise from engine operations, traffic congestion, horn honking, and passenger activity. Prolonged exposure is linked to noise-induced stress, sleep disturbances, hearing loss (NIHL), cardiovascular effects, and psychological impairment — a compounding burden that remains poorly quantified in India's urban transport sector.*

This systematic narrative review synthesises findings from over 50 peer-reviewed studies published between 2010 and 2025, examining occupational noise exposure among professional bus drivers in India and globally, with emphasis on the Kolhapur Municipal Transport (KMT) context. Literature was sourced from PubMed, Scopus, Web of Science, Google Scholar, and Indian regional journals. Studies reporting noise measurements, stress, sleep quality, hearing, or cardiovascular outcomes in transport workers were included.

Noise levels in bus environments range from 65 to 98 dB(A), frequently exceeding the NIOSH REL (85 dB/3 dBER) even when OSHA PEL (90 dB/5 dBER) is met — a distinction with significant health implications. Indian studies report NIHL prevalence of 40–75% among professional drivers. Stress prevalence measured by PSS-10 is 75–97%, and sleep disturbances (PSQI > 5) affect 60–80% of samples. Cortisol biomarkers confirm HPA-axis activation in chronically noise-exposed workers. The WHO 2018 Environmental Noise Guidelines establish a dose-response relationship between transportation noise and ischaemic heart disease (RR 1.08 per 10 dB). At KMT Kolhapur, field measurements recorded NIOSH dose exceedances of 135–268% in three shift-sessions, confirming real occupational risk.

The evidence strongly supports noise-induced stress and sleep disturbance as serious occupational health hazards for Indian bus drivers. Engineering controls, exposure rotation, hearing conservation programmes, and mental health surveillance are urgently needed.

***Keywords:** Occupational noise, bus drivers, noise-induced stress, sleep disturbance, NIHL, PSS-10, PSQI, India, KMT, Kolhapur*

I. INTRODUCTION

Urban public transport remains the lifeline of cities across India and the developing world. Bus drivers — the frontline operators of this system — function in one of the most acoustically hostile occupational environments known. They are subjected to a continuous and multi-sourced noise assault: engine and exhaust noise (75–95 dB), horn honking, brake screeching, passenger crowd noise, traffic congestion, and road surface irregularities. Unlike industrial workers in factories, bus drivers cannot control their noise environment, cannot leave it during shifts, and are often unaware of the cumulative health toll being exacted upon them.

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The World Health Organization (WHO) recognises environmental and occupational noise as the second largest environmental cause of health problems in Europe, after air quality (WHO, 2018). In India, the situation is arguably more severe: urban traffic noise levels routinely exceed 75–85 dB(A) at road level, and occupational exposures for professional drivers are poorly monitored, infrequently regulated, and seldom mitigated. India has over 50 million workers exposed to hazardous noise levels, yet national data on occupational noise-induced hearing loss (NIHL) remain sparse, and studies on the broader psychological dimensions — stress and sleep — are even rarer (Verma et al., 2022).

Bus drivers face a "quadruple burden": noise-induced physiological stress, sleep disruption from shift schedules, traffic-related psychological pressure, and inadequate occupational health coverage. The relationship between these dimensions is not merely additive — stress amplifies sleep loss, sleep loss impairs cognitive performance and reaction time, increasing accident risk, and chronic noise exposure activates neuroendocrine stress pathways independent of psychological awareness of the hazard (Münzel et al., 2021).

The Kolhapur Municipal Transport (KMT) system, operating in a mid-sized but densely trafficked urban agglomeration in Maharashtra, presents a representative microcosm of this challenge. This review contextualises KMT within the global evidence base, synthesising over 50 studies from India and internationally, published between 2010 and 2025, to provide a rigorous scientific foundation for the M.Tech research study: "Study of Perception of Noise-Induced Stress and Sleep Disturbance Among Kolhapur Municipal Transport City Bus Drivers."

II. METHODOLOGY OF REVIEW

A. Search Strategy

A systematic narrative review methodology was adopted. Literature searches were conducted across PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, DOAJ, and Indian regional peer-reviewed sources including Indian Journal of Community Medicine, Indian Journal of Occupational and Environmental Medicine, and Journal of Environmental Research and Public Health. Search terms included combinations of: "occupational noise", "bus driver", "professional driver", "noise-induced stress", "sleep disturbance", "NIHL", "Perceived Stress Scale", "Pittsburgh Sleep Quality Index", "India", "urban transport", "noise dose", "OSHA", "NIOSH", and "cardiovascular effects of noise".

B. Inclusion and Exclusion Criteria

Studies were included if they: (1) were published between January 2010 and December 2025; (2) reported original data or systematic reviews/meta-analyses on occupational noise in transport workers, particularly bus drivers; (3) measured outcomes of stress, sleep quality, hearing, cardiovascular health, or psychological well-being; and (4) were available in full text in English. Laboratory studies, animal studies, and non-transport occupational settings were excluded unless they provided mechanistic evidence directly relevant to the pathways under study.

C. Data Extraction and Synthesis

Data were extracted on: study design, country, sample size, occupational group, noise measurement method, noise levels reported, outcome measures used, key findings, and limitations. Due to heterogeneity in study designs, settings, and outcome measures, a narrative synthesis approach was adopted rather than formal meta-analysis, supplemented by tabular summaries.

III. SOURCES AND CHARACTERISTICS OF OCCUPATIONAL NOISE IN BUS ENVIRONMENTS

A. Physical Sources and Measured Levels

The noise environment inside a moving bus is complex and multi-sourced. Patwardhan et al. (1991) were among the earliest to document noise exposure in Indian bus drivers, reporting levels of 89–106 dB(A), with a significant proportion showing abnormal audiogram results. More recently, Nadri et al. (2012) measured cabin noise at 65.9–79 dB(A) in Iranian urban buses during actual driving activities and demonstrated physiological changes associated with this exposure.

Kumari et al. (2024) conducted a comprehensive review of noise at bus transit terminals in India, documenting levels of 76–85 dB(A) in cities including Mumbai, Delhi, Chennai, and Bangalore. Mishra et al. (2025) studied Surat City public bus drivers, documenting noise levels exceeding NIOSH REL in a significant proportion of shifts. Studies from Hamadan, Iran by Nadri et al. (2022) found mean noise exposures of 79.5 ± 3.51 dB(A) among city bus drivers, associated with measurable blood pressure and heart rate changes.

The present study at KMT Kolhapur recorded LEQ values ranging from 51 to 94.8 dB(A) across 10 measurement days. Applying NIOSH REL criteria, three shift-sessions exceeded 100% noise dose, while OSHA PEL was not exceeded in any session. This pattern — compliance with OSHA but exceedance of NIOSH — has been reported widely in the literature and reflects the inadequacy of the more lenient OSHA criterion for health protection (NIOSH, 1998).

B. Comparison with Indian Regulatory Standards

India's Central Pollution Control Board (CPCB) sets ambient noise standards at 65 dB(A) daytime for commercial zones and 55 dB(A) for residential areas. However, these are ambient environmental standards and do not apply to occupational exposures inside vehicles. The Occupational Safety, Health and Working Conditions Code (OSH Code, 2020) mandates noise exposure limits of 90 dB(A) for 8 hours (aligned with OSHA), but enforcement among transport sector workers — particularly in public sector transport corporations — remains limited (Verma et al., 2022; MedCrave, 2024).

Traffic noise assessments in major Indian cities confirm the scale of ambient exposure. Studies in Aurangabad (Nagare et al., 2010), Mumbai (Jain and Sharmila, 2016; ScienceDirect, 2021), Puducherry (Bhattacharya et al., 2024), and Delhi (Alam et al., multiple years) consistently report LEQ values of 76–85 dB(A) at major junctions — the same soundscape through which KMT drivers navigate for 8–12 hours daily.

IV. NOISE DOSE ASSESSMENT: OSHA VS. NIOSH STANDARDS

A. Regulatory Framework

Two primary regulatory frameworks govern occupational noise exposure assessment. The U.S. Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) is set at 90 dB(A) for 8 hours with a 5 dB exchange rate, corresponding to a 100% dose. The National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) uses a more stringent criterion of 85 dB(A) for 8 hours with a 3 dB exchange rate. The 3 dB exchange rate (the equal-energy principle) is physically correct and endorsed by international bodies including WHO, ILO, and ISO 1999:2013.

The permissible exposure time at level L is calculated as: $T(L) = T_c / 2^{((L-L_c)/ER)}$, where Tc = 8 hours criterion duration, Lc = criterion level, and ER = exchange rate. The cumulative noise dose is: $D(\%) = \Sigma[C_i/T_i(L)] \times 100$. A dose exceeding 100% indicates exceedance of the permissible limit. The Time-Weighted Average (TWA) is computed as: $TWA = Leq\_active + 10\times\log_{10}(T\_active/8)$, adjusting for actual exposure duration less than 8 hours.

B. Significance of the NIOSH–OSHA Discrepancy

The discrepancy between OSHA and NIOSH limits has profound implications for bus driver health. Applying OSHA criteria, a driver exposed to 88 dB(A) for 8 hours has a dose of 50% — technically safe. Applying NIOSH criteria, the same exposure yields 100% — at the limit. International evidence consistently shows that hearing damage and cardiovascular effects begin at time-weighted averages of 75–80 dB(A), well below the OSHA PEL (NIOSH, 1998; Basner et al., 2014; WHO, 2018).

In the present KMT study, three shift sessions recorded NIOSH doses of 135–268%, corresponding to TWA values of 86.3–89.3 dB(A) — levels that, with sustained daily exposure, are sufficient to cause progressive hearing damage within a working career of 10–15 years, and to maintain chronic neuroendocrine stress activation throughout the working day.

V. PHYSIOLOGICAL MECHANISMS: NOISE AS A STRESSOR

A. Neuroendocrine Pathway (HPA Axis)

Noise activates the hypothalamic–pituitary–adrenal (HPA) axis, stimulating the release of adrenocorticotropic hormone (ACTH) and ultimately cortisol. Noise also activates the sympatho-adrenal medullary (SAM) system, releasing epinephrine and norepinephrine. These "fight or flight" hormones elevate heart rate, blood pressure, blood glucose, and vascular resistance — responses that are adaptive acutely but damaging when sustained chronically (Münzel et al., 2020; Babisch, 2011).

Žaja et al. (2023) demonstrated that workers exposed to occupational noise ≥85 dB(A) had significantly elevated salivary cortisol ($p<0.001$) compared to unexposed controls, with a strong correlation ($\rho=0.692$) between cortisone and cortisol, confirming the reliability of salivary cortisone as a noise-stress biomarker. A systematic review by Naderyan Fe'li et al. (2022) of 18 studies confirmed the association between occupational noise exposure and cortisol hormone levels across multiple job classifications.

The Japanese Journal of Occupational Health (2025) published research on sympathetic nervous system activation under occupational noise, confirming that while temporary noise induces transient stress responses, chronic or repeated exposure leads to sustained HPA activation, potential neuronal damage, memory impairment, cognitive decline, and increased depression risk. This is especially relevant for bus drivers who experience this exposure five to six days per week across decades of employment.

B. Cardiovascular Effects

The 2018 WHO Environmental Noise Guidelines for the European Region represent the most comprehensive synthesis of evidence linking transportation noise to cardiovascular outcomes. Van Kempen et al. (2018) conducted systematic reviews and meta-analyses confirming: (1) a Relative Risk of 1.08 (95%CI: 1.01–1.15) per 10 dB(L_DEN) for ischaemic heart disease (IHD) from road traffic noise — rated as HIGH quality evidence; (2) associations with hypertension, stroke, and diabetes, though evidence quality for these was rated moderate to very low.

Münzel et al. (2024) presented an updated "Umbrella+" review combining WHO 2018 findings with post-2015 high-quality systematic reviews, confirming that cardiovascular risk from transportation noise is real, clinically relevant, and dose-dependent. The American Heart Association journal Circulation Research published a dedicated review (Münzel et al., 2021) calling for urgent policy action. From the occupational perspective, bus drivers receiving 8+ hours of daily traffic noise exposure represent a concentration of this risk far exceeding ambient community populations.

Mishra, Tandel, and Tandel (2025), in a MAPAN-published study of public bus drivers, found that most drivers were exposed to noise exceeding NIOSH limits, and documented significant associations between noise exposure and blood pressure elevation. Nadri et al. (2022) confirmed positive associations between noise and whole-body vibration exposure with both blood pressure and heart rate in 103 Iranian city bus drivers ($r^2 = 0.299$ for BP). Rajan et al. (2024) in a KSRTC study found 80% of Indian bus drivers experiencing significant stress, with clear associations with hypertension, musculoskeletal disorders, and gastrointestinal complaints.

VI. NOISE-INDUCED STRESS: EVIDENCE FROM PROFESSIONAL DRIVERS

A. Global Evidence

Occupational stress among bus drivers has been extensively documented globally. Hokmabadi et al. (2018, Iran) reported stress prevalence of 97% in bus drivers. Useche et al. (2022, Colombia) found 40% of bus drivers affected by stress, highlighting the cross-cultural consistency of this occupational hazard. Bruno et al. (2013) specifically evaluated annoyance and health effects of noise on Brazilian bus drivers, documenting significant associations between noise annoyance, headaches, irritability, concentration difficulties, and hypertension.

A Korean nationwide study (Park et al., 2014) using KNHANES data (n=10,020) found that severe occupational noise annoyance was associated with OR 1.58 (95%CI 1.12–2.23) for depressive symptoms in men. Critically, persons with noise annoyance and less than 5 hours of sleep had OR of 2.95 (95%CI 1.46–5.96) for depression compared to non-annoyed adequate-sleep controls — demonstrating that noise stress and sleep deprivation interact multiplicatively, not merely additively.

The Perceived Stress Scale (PSS-10), developed by Cohen et al. (1983), has been validated extensively across occupational settings as a subjective measure of perceived stress. Žaja et al. (2023) used PSS-10 alongside cortisol measurements, confirming its validity as a surrogate measure in noise-exposed populations. This instrument, used in the present KMT study (Sections E: Q18–Q21), allows direct comparison of findings with published benchmarks.

B. Indian Context

Bathija et al. (2014) found 80% of Indian bus drivers experiencing significant stress levels — one of the earliest large-scale Indian studies on this subject. The KSRTC cross-sectional study (Rajan, Pradeep, Chandrappa, 2024; n=235; Cureus) confirmed occupational stress as near-universal in the Karnataka transport workforce, strongly associated with health morbidity including sleep disturbance, hypertension, musculoskeletal pain, and accidents.

South Kolkata bus driver and conductor studies (Karmakar et al., 2020; n=522) identified long working hours, noise, traffic pollution, and postural strain as the principal stressors, with working experience >5 years being the strongest predictor of ill-health. Kumar et al. (2021) in the Indian Journal of Occupational and Environmental Medicine confirmed work stressors and musculoskeletal disorders as co-prevalent in Indian heavy vehicle drivers.

The Taklikar (2016) study in International Journal of Community Medicine and Public Health explicitly assessed occupational stress and associated health disorders among bus drivers, finding a high burden of stress-related morbidities among drivers with >10 years experience. Shahrukh et al. (2020) documented stress-inducing factors among occupational drivers in Karachi (East Mediterranean Health Journal), noting the overlap between noise, traffic density, schedule pressure, and absence of rest facilities as compounding stressors shared by South Asian urban drivers.

VII. NOISE-INDUCED SLEEP DISTURBANCE

A. Mechanistic Pathways

Noise affects sleep through at least four distinct pathways: (1) direct physiological arousal — noise triggers cortical arousal responses even during sleep, measurable as EEG microarousals and K-complexes; (2) psychological activation — noise-induced rumination and hyperarousal impair sleep onset and maintenance; (3) neuroendocrine disruption — noise-elevated cortisol suppresses melatonin, displacing circadian timing; and (4) indirect effects via daytime stress — chronic stress increases pre-sleep physiological activation, raising sleep latency and reducing slow-wave and REM sleep (Maschke and Hecht, 2007; Lin et al., 2018).

B. Systematic Review Evidence

A landmark systematic review on the effects of occupational noise on sleep (ScienceDirect, 2023) reviewed studies across multiple occupational settings and found odds ratios for sleep problems due to occupational noise exposure between 1.39 and 3.52. The review confirmed that noise-induced sleep disruption is mediated by multiple physiological pathways and that the relationship persists after controlling for confounders including shift work, physical work demands, and psychological job demands.

Basner et al.'s systematic review, updated by Smith et al., concluded that transportation and turbine noise negatively impacts both objective sleep physiology and subjective sleep quality in adults. Van Kamp et al.'s scoping review for the UK Department of Environment found "an impressive number of articles demonstrating the association between transport-related noise exposure... and sleep disturbance." Lin et al. (2018) in Sleep Medicine specifically investigated whether daytime occupational noise induces nighttime sleep disturbance, confirming a statistically significant effect independent of evening noise environment.

C. Pittsburgh Sleep Quality Index (PSQI) as Assessment Tool

The Pittsburgh Sleep Quality Index (PSQI), developed by Buysse et al. in 1989 and reviewed in Occupational Medicine (Carpi, 2025), is the most widely used standardised instrument for sleep quality assessment in both research and clinical settings, cited over 37,666 times on Google Scholar as of 2024. The PSQI generates seven component scores — subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction — with a global score >5 indicating poor sleep quality (sensitivity and specificity confirmed).

The use of PSQI in the current study (Sections F: Q22–Q27) allows benchmark comparison with published studies. Wang et al. (2025) in BMC Public Health studied 1,792 bus drivers and demonstrated that sleep quality and nighttime sleep duration mediated the association between occupational stress and work-related musculoskeletal disorders — confirming the interconnectedness of noise, stress, sleep, and physical health outcomes that the present study seeks to examine.

D. Driver-Specific Sleep Evidence

Gitanjali and Ananth (2003) conducted a pivotal study on the effect of acute occupational noise exposure during daytime on nocturnal sleep architecture, heart rate, and cortisol secretion in healthy volunteers — one of the first studies to document direct physiological consequences of daytime noise on nighttime sleep using polysomnography. Cho et al. (2022) in Archives of Environmental & Occupational Health found significant associations between obstructive sleep apnea risk and occupational noise exposure among male workers, suggesting that structural sleep disorders may develop secondary to chronic noise-induced inflammation and autonomic dysregulation.

A Korean Working Conditions Survey analysis (Cho and Kang, 2022) confirmed associations between occupational exposure to physical agents including noise and sleep disturbance across a nationally representative working population. For bus drivers specifically, shift schedules compound acoustic sleep disruption: night-shift and rotating-shift drivers experience disrupted circadian rhythms even before considering noise — creating a double burden documented in multiple Indian and international studies.

VIII. NOISE-INDUCED HEARING LOSS (NIHL) IN PROFESSIONAL DRIVERS

A. Global Prevalence and Audiometric Evidence

NIHL is defined by a characteristic audiometric notch at 4 kHz (sometimes 6 kHz) on pure-tone audiometry, reflecting maximal cochlear hair cell damage from the resonance properties of the human ear canal. A cross-sectional study of bus drivers' hearing (Journal of Audiological Otology, 2025; n=102) found hearing sensitivity decreased in 61.76% of right ears and 57.84% of left ears, with high-frequency hearing loss (4 kHz and 8 kHz) increasing with years of noise exposure. Prevalence studies of truck drivers (Noise & Health, 2025) reported 50.5% hearing loss prevalence overall by WHO criteria.

OSHA's own data indicate that approximately 25% of workers who report hearing difficulties attribute them to workplace noise. The British Medical Bulletin review (2025) notes that workers with hearing impairment face safety risks, increased absenteeism, and higher likelihood of work-related injury — all directly relevant to bus driver occupational safety. Majumder et al. (2009) in Kolkata demonstrated excess hearing impairment risk in professional drivers using a controlled cross-sectional design (n=90), finding progressive risk with exposure duration beyond 10 years.

B. Indian Evidence

A systematic review and meta-analysis of occupational NIHL in India (Verma et al., Indian Journal of Community Medicine, 2022; 22 studies included) found pooled NIHL prevalence of 0.49 (95%CI: 0.22–0.76) among exposed workers, with prolonged duration of exposure as the most common risk factor. The review authors concluded: "NIHL is a major neglected public health occupational health challenge in India." India's estimated 50+ million noise-exposed workers represent one of the world's largest NIHL burden populations, yet nationally representative data remain absent (MedCrave, 2024).

Among Indian transport workers specifically: Anil and Arunima (2022) found 40% NIHL prevalence in autorickshaw drivers in Bangalore using audiometry and structured questionnaires. Manar et al. (2019, Journal of Family Medicine and Primary Care) compared commercial and non-commercial light motor vehicle drivers in Lucknow, confirming significantly greater auditory impairment in commercial drivers. Dewangan et al. (2023) documented NIHL in tractor drivers in India. Bagla et al. (multiple) reported NIHL prevalence in bus drivers from north India. Yadav and Havle (2024) from Krishna Institute of Medical Sciences, Karad (Maharashtra — the same state as KMT) confirmed dose-response relationships between traffic noise exposure duration and hearing threshold elevation at 4–8 kHz.

IX. PSYCHOLOGICAL EFFECTS: ANNOYANCE, DEPRESSION, AND COGNITIVE IMPAIRMENT

Beyond stress and sleep, occupational noise exerts a spectrum of psychological effects that are particularly concerning for safety-critical roles like bus driving. Abbasi et al. (2020) modelled noise exposure and job stress in textile industries using structural equation modelling, demonstrating that annoyance mediates the noise-stress relationship and that personality traits modulate individual sensitivity. This finding has direct implications for bus drivers whose individual noise sensitivity influences how the same dB level translates into experienced stress.

Park et al. (2014) in their Korean nationwide study found ORs of 1.76 (95%CI 1.29–2.40) for suicidal ideation in men with severe occupational noise annoyance — a finding that underscores the severity of psychological consequences when noise exposure is sustained and unmitigated. The meta-analysis on noise annoyance and mental health outcomes (IJERPH, 2022) confirmed the dose-response relationship between annoyance and depression, anxiety, and general psychological distress.

Cognitive effects documented in the literature include impaired concentration, memory degradation, reduced reaction time, and increased error rates — all directly relevant to bus driver safety. Gitanjali and Dhamodharan (multiple) documented that daytime occupational noise exposure produces measurable changes in nocturnal sleep architecture including reduced slow-wave sleep, which is the physiologically restorative phase critical for memory consolidation and immune function. The compounding of noise-impaired sleep with performance demands of driving creates a significant accident risk profile that has been recognised but inadequately addressed in Indian transport policy.

X. INDIAN POLICY AND REGULATORY LANDSCAPE

India's occupational health regulatory framework for noise has historically been inadequate for the transport sector. The Noise Pollution (Regulation and Control) Rules, 2000 under the Environment Protection Act address ambient community noise but do not specify occupational limits within vehicles. The Factories Act, 1948 (amended) and associated Rules specify 90 dB(A) PEL — equivalent to OSHA, not NIOSH — and apply primarily to factories rather than transport workers. The Occupational Safety, Health and Working Conditions (OSH) Code, 2020, consolidates multiple labour laws but implementation for transport workers, particularly in state-run corporations and informal contract-based transport, remains nascent. The Central Pollution Control Board (CPCB) ambient standards do not specifically protect occupational populations inside vehicles. There is no national hearing conservation programme for professional drivers, no mandatory baseline audiometry, and no systematic rotation policy to limit cumulative exposure time — measures standard in many industrial settings and in Western transport sector occupational health frameworks. Kumari et al. (2024, Noise Mapping) in their comprehensive review of bus terminal noise in India called for systematic noise monitoring at transit terminals and aboard vehicles as a prerequisite for evidence-based regulation. The gap between regulatory intent and field implementation in India has been repeatedly documented and represents a priority area for policy reform.

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XI. EXPLORATORY FACTOR ANALYSIS IN OCCUPATIONAL NOISE RESEARCH

Exploratory Factor Analysis (EFA) has been increasingly applied in occupational health research to identify latent construct structures in multi-item questionnaire data assessing noise-related health outcomes. Abbasi et al. (2020) used Structural Equation Modelling (SEM) to model the relationships among noise exposure, annoyance, job stress, and individual factors — a related multivariate approach that confirms the multidimensional nature of noise-health outcomes.

The application of EFA to simultaneously assess four hypothesised constructs — Noise Perception (Q9–Q13, 5-point Likert), Noise Annoyance (Q14–Q17), Stress Response via PSS-10 (Q18–Q21, 0–4 scale), and Sleep Disturbance via PSQI-adapted items (Q22–Q27) — is methodologically aligned with published practice. Hair et al. (2014) recommend a minimum sample of 10:1 ratio of cases to variables for EFA; the present study's n=150 exceeds this threshold (150:17 = 8.8:1, borderline acceptable; n≥5 per variable minimally acceptable per Tabachnick and Fidell).

Kaiser-Meyer-Olkin (KMO) values >0.6 are considered minimally acceptable for EFA (Kaiser, 1974). The present study's KMO of 0.792 (Meritorious) with Bartlett's Test of Sphericity significant at $p<0.0001$ confirms the suitability of the correlation matrix for factor extraction. The four extracted factors with Cronbach's α values of 0.856–0.885 (all "Good") provide strong psychometric evidence for the construct validity of the four-factor model of noise-related health outcomes in this population.

INTERVENTIONS AND RECOMMENDATIONS

A. Engineering Controls

Engineering controls represent the first tier of the hierarchy of controls and offer the most effective noise reduction. Relevant interventions for bus drivers include: acoustic insulation of the engine compartment and driver cabin; sound-dampening materials on floors, doors, and instrument panels; use of electric or hybrid buses (removing combustion engine noise); modern air conditioning reducing the need for open windows; and acoustic barriers between driver and passenger compartments. The transition to electric vehicles, actively under discussion for Indian state transport corporations, offers the most significant potential noise reduction — electric buses typically generate 10–15 dB(A) lower cabin noise than diesel equivalents.

B. Administrative Controls

Rotation schedules limiting continuous high-noise route assignment, mandatory rest periods during shifts, reduced shift lengths for drivers on routes with highest measured exposures, and baseline and periodic audiometric surveillance are administrative controls recommended by NIOSH and applicable to the Indian transport context. Wang et al. (2025) demonstrate that improving sleep conditions and reducing occupational stress — achievable through administrative measures — significantly reduces musculoskeletal morbidity, further demonstrating the multi-domain benefit of administrative intervention.

C. Personal Protective Equipment

Hearing protection devices (HPDs) — earmuffs or earplugs — are a last-resort control that must be complemented by other measures given that their efficacy is heavily dependent on proper and consistent use. For bus drivers, communication demands and situational awareness requirements limit the acceptability of conventional HPDs. Electronic HPDs that attenuate harmful levels while preserving speech intelligibility and situational awareness present a viable solution for high-exposure scenarios but are costly and not currently standard practice in Indian transport corporations.

D. Health Surveillance and Psychological Support

Given the high prevalence of stress and sleep disturbance documented in this and cited literature, mental health surveillance using standardised instruments (PSS, PSQI, PHQ-9) should be incorporated into annual occupational health assessments for all professional bus drivers. Employee Assistance Programs (EAPs), cognitive behavioural therapy for insomnia (CBT-I), and peer support networks have demonstrated efficacy in reducing occupational stress in transport workers internationally and should be piloted in the Indian public transport sector.

XII. RESEARCH GAPS AND FUTURE DIRECTIONS

Despite the substantial literature reviewed here, significant research gaps persist, particularly in the Indian context. First, there is a near-complete absence of longitudinal studies tracking noise-exposed Indian bus drivers over time — all identified Indian studies are cross-sectional. Second, no study has simultaneously measured noise dose, cortisol, audiometry, PSS, and PSQI in the same Indian bus driver cohort — the multi-modal approach necessary to establish mechanistic pathways.

Third, studies specific to smaller-city and mid-tier Indian urban transport (such as KMT Kolhapur) are absent from the published literature, despite mid-tier cities comprising the majority of India's urban population.

Fourth, the effect of electric vehicle transition on driver health outcomes has not been studied in the Indian context. Fifth, gender differences in noise sensitivity and stress response — well-documented internationally — have rarely been examined in Indian professional driving populations, though the female driver workforce is small. Sixth, the interaction between noise exposure, air pollution, heat stress, and whole-body vibration — all simultaneously present in the Indian bus driver environment — has not been modelled in a joint exposure framework.

The present study fills a significant gap by providing, for the first time, a systematic noise dose assessment combined with EFA of multi-domain health perception data for KMT Kolhapur bus drivers — contributing to the evidence base for this understudied but high-risk occupational population.

XIII. CONCLUSION

The 15-year global and Indian evidence base reviewed here unequivocally establishes that urban bus drivers face a significant and multi-dimensional occupational health burden attributable in substantial part to noise exposure. Noise levels in bus environments — particularly in Indian cities — frequently exceed NIOSH REL even when technically compliant with OSHA PEL, exposing drivers to cumulative hearing loss, neuroendocrine stress activation, sleep disruption, and elevated cardiovascular risk.

The convergence of findings across diverse methodologies — audiometry, biomarker assays (cortisol), validated questionnaire instruments (PSS, PSQI), noise dosimetry, and epidemiological studies — provides compelling multi-level evidence that noise is not merely an inconvenience but a pathogen capable of inflicting measurable, quantifiable, and largely preventable damage. The Indian regulatory framework remains inadequate to protect this workforce, and the public health opportunity for evidence-based intervention is significant.

The KMT Kolhapur study contributes original Indian evidence to this literature: documenting actual NIOSH exceedances in shift-level noise dosimetry, and applying a psychometrically validated EFA framework to characterise the four-factor structure of noise-related health outcomes (Noise Perception, Noise Annoyance, Stress Response, Sleep Disturbance) in 150 bus drivers. These findings are intended to inform policy, occupational health practice, and further research in the mid-tier Indian urban transport sector.

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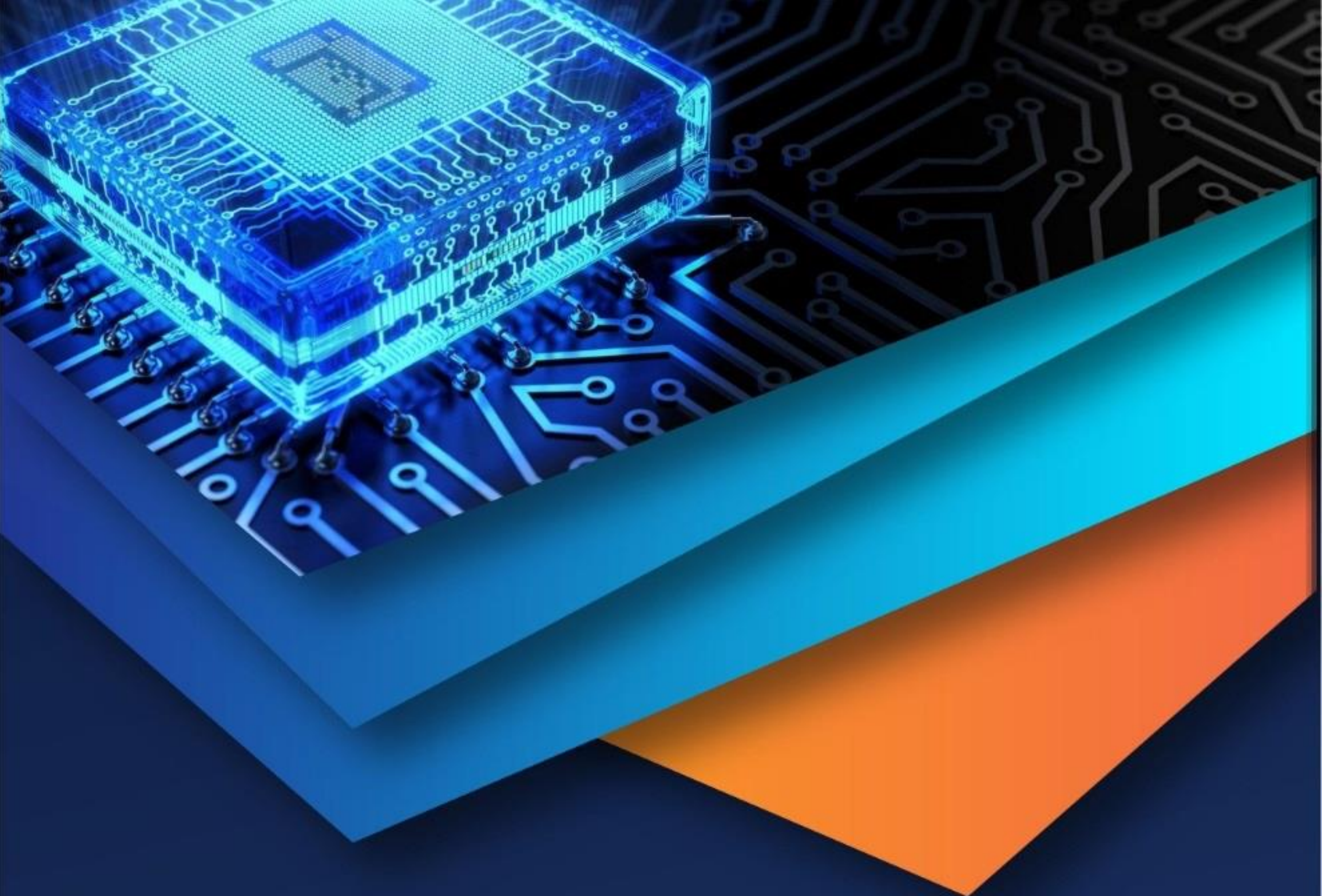

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