Review Article

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Bibliometric analysis and review of auditory and non-auditory health impact due to road traffic noise exposure

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Abstract: This paper presents a bibliometric and critical review of auditory and non-auditory health impacts due to road traffic noise exposure. The paper discusses the general trends of studies conducted in the research domain using the bibliometric network approach. These networks are based on citation, bibliographic coupling, and co-authorship relationships. Further, a critical review is conducted to summarise the auditory and non-auditory impacts due to traffic noise exposure. Auditory health impact issues such as noise-induced hearing loss (NIHL) and tinnitus are presented. Non-auditory impacts are categorised as physiology and performance-related impacts. Physiology related health impact includes a review of cardiovascular and sleep disturbance issues due to noise. Performance-related health impact includes annoyance and cognitive impairment issues. This paper discusses the severity level, different exposure-response relationships, techniques, and empirical models developed to assess the magnitude of these health impacts. Subjective and laboratory assessment techniques used to analyse the health impact through various modeling and statistical approaches are considered. Additionally, a scenario analysis of health impact due to heterogeneous transportation is performed. An assessment is done to find the applicability of health risk prediction models in heterogeneous traffic conditions.

Keywords: Road traffic noise exposure; Health impact assessment; Auditory health impact; non-Auditory health impact; bibliometric review; Heterogeneous traffic condition

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1 Introduction

Noise pollution is among the significant environmental issues which affect the health and quality of living in urban areas [1]. Road Traffic Noise (RTN) exposure ranks second among the nine environmental problems with significant health impacts. These impacts can be categorised into auditory and non-auditory health impacts. Auditory impacts due to noise exposure can be defined as the impacts on the hearing organ and effects due to masking of auditory information leading to speech interference and perception issues. The non-auditory impact due to noise is defined as an impact on human health at physiological and performance levels, impacting the mental health and wellbeing of humans [2, 3]. Auditory impact of noise includes noise-induced hearing loss (NIHL), tinnitus, hyperacusis, auditory fatigue, central auditory pathway damage, speech perception and interference issues [2]. Non-auditory impact of noise includes high blood pressure, cardiovascular diseases, sleep deprivation, annoyance, cognitive impairment etc. [4].

The World Health Organization (WHO) estimated that more than 2 billion citizens worldwide are exposed to noise levels of more than 55 decibels affecting 400-1500 healthy life lost because of ischemic heart diseases for every 1 million people in Europe [5, 6]. European directive 2002 [7] mandates policy-making agencies in Europe to forecast and map noise levels, estimate Disability-Adjusted Life Years (DALY), and create noise mitigation policies through ‘Noise Action Plans’. These Noise Action Plans include noise mapping, understanding people’s perception, quantifying health risk due to noise, and developing noise prediction models (NPM) and noise annoyance models (NAM). Research in environmental noise prediction and mitigation has significantly progressed in the last two decades [8, 9].

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However, studies related to health risks due to noise exposure and the resultant level of annoyance has not gained sufficient attention.

To identify the health risk of noise, it is crucial to determine the exposure-response relationship, which estimates the noise effect either at an individual or at population level. Many policymakers, authorities and public organisations are using this noise exposure-response relationship for health risk assessment (DALY) [10, 11] or to deduce effect-based noise indices [12]. Schultz [13], Kryter [14] and Fields are among the few authors who explored the relationship between traffic noise exposure and annoyance through exposure-response relationship. Miedema and Oudshoorn [15] developed a DENL (day-evening-night level) index to report the percentage of highly annoyed persons due to traffic noise. European Commission and WHO has accepted this relationship to predict disability-adjusted life years (DALY) and the Global Burden of Diseases (GBD) due to noise exposure [10]. Wolfgang Babisch [16], Martin Röösli [17] and other researchers have attempted to determine health impact due to noise exposure, and projects like SiRENE and TraNQuIL have contributed positively to support the hypothesis.

A WHO report estimates that DALYs from environmental noise are 61,000 years for ischaemic heart disease, 45,000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 22,000 years for tinnitus, 654,000 years for annoyance in the European Union Member States and other western European countries. Individual studies performed at the Athenian metropolis on RTN exposure and its health impact estimated 858.2 DALY lost due to cardiovascular diseases and 2197 due to sleep disturbance [18]. In another study in Sweden, 22218 DALY due to sleep disturbance, 12090 DALY due to annoyance, 6752 DALY due to the cardiovascular issue has been reported [19]. Considering the high impact of noise on humans (auditory and non-auditory), it is necessary to collate the work done by various researchers in this area and comprehend the gaps to identify future research roadmap.

The framework of this literature review is based on the following objectives. (a) To perform a bibliometric analysis of research articles published in the domain, and (b) To perform a critical review of the health risks associated with RTN exposure and various acoustical and non-acoustical factors associated with it. Further, various models that explain the risk rate due to long-term and short-term RTN exposure and their contextual application for heterogeneous RTN conditions are discussed. This paper primarily focuses on the health impact of road traffic noise exposure.

2 Review procedure

The database of research articles is prepared by searching for the keywords ‘noise annoyance’, ‘health impact’, ‘cardiovascular diseases’, ‘sleep’, ‘hypertension’, ‘myocardial infarction’, ‘ischemic diseases’, ‘stroke’, ‘blood pressure level’, ‘cognitive performance’, ‘hearing loss’, ‘tinnitus’, in conjunction with ‘road traffic noise’ and ‘Traffic Noise’. The search was done in the Web of Science, Scopus and PubMed databases from 1992 to 2021 November. A total of 1030 relevant papers were collected from the keyword search. Out of which 872 articles are considered after removing the duplicates. The review’s primary focus is to identify the health impact caused due to road traffic noise exposure. The workflow of article selection is presented in Figure 1.

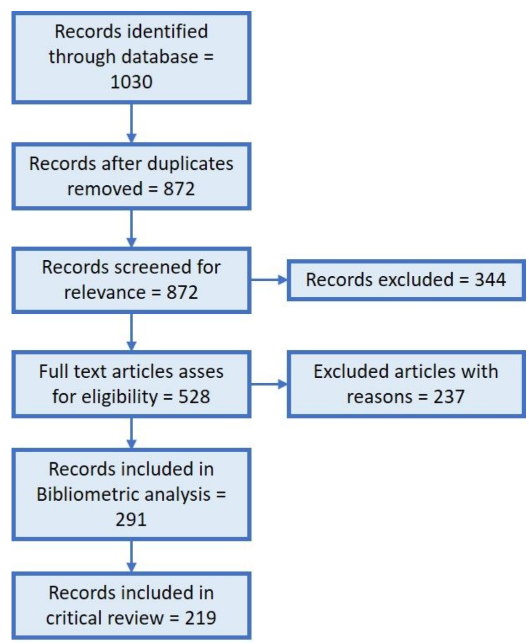

Figure 1: Workflow of dataset selection

The list includes original research articles, review papers, conference papers and book chapters from different journals. In this list of literature majority of papers are from the journals linked with publishers such as MDPI, Elsevier, Springer, Acoustical Society of America, BMC, Oxford University Press, US Dept Health Human Sciences Public Health Science, Wolters Kluwer Medknow Publications etc.

After extracting 872 articles, the list is manually checked to verify the paper’s relevance in the identified traffic noise exposure research domain, of which 344 articles are excluded. After excluding the not relevant records, a total of 528 records are assessed for eligibility in the bibliometric review, of which 237 articles are excluded with a reason. Finally, the list of 291 records is used for the bibliometric analysis and 219 articles are used for critical review. The research articles discussing the combined health impact of road, rail and aircraft noise are considered for the review. Articles exclusively discussing the health impact of rail, aircraft, windmill, occupational or construction noise exposure are excluded from the review process. In this extracted list, the papers deal with different health impacts such as cardiovascular diseases, sleep, hypertension, myocardial infarction, ischemic diseases, stroke, blood pressure level, cognitive performance, hearing loss, tinnitus and noise annoyance. It also includes articles dealing with the overall impact of road traffic noise pollution and a few relevant review papers.

Limitation

The study is limited to reviewing the impact of road traffic noise on human health. Few studies related to combined noise exposure, including road traffic noise, are considered in the review process. This paper does not focus on characterising traffic noise scenarios or reviewing noise emissions from different vehicles. The paper does not consider the evaluation of traffic noise models.

3 Bibliometric analysis

The bibliometric analysis is conducted using VOSviewer software [20]. It is a widely accepted software to conduct the literature study by analysing the network based on journals, researchers, citations, co-authorship relations. The co-occurrence maps are produced based on literature details which present the information by forming clusters into different groups. Clustering determines the highest frequency of occurrence and similarity of the keywords, and it provides indications of the most focused points in the research field [21]. Clustering helps determine the specific subgroups, which helps construct study frameworks and analyse the relationship between the clusters. The linkage between the clusters shows the strength of association between different subgroups.

The extracted list of 291 articles is used for the bibliometric analysis, termed ‘review records.’ The analysis includes building and analysing the network for scientific journals, organisations, countries and keywords.

The items in this network are connected by co-authorship, citations or co-citations links. The results of these analyses are presented in the following section.

3.1 Articles by research sub-domains

The review records are classified into different groups based on the health impact or the nature of the study. Figure 2 shows the number of papers describing RTN exposure and its association with particular health issues. Few papers in the records discuss the overall impact caused by RTN exposure. Apart from discussing health impact, few studies are related to developing exposure-response relationships, analysing the burden of diseases, assessing the quality of life and mortality rate. These areas are relevant to the research domain as they help identify the impact on the targeted population.

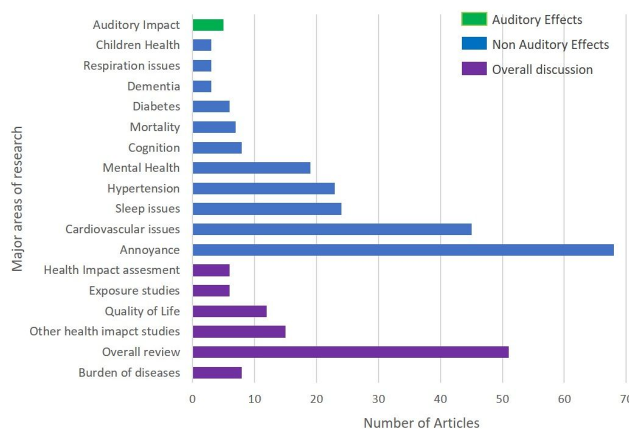

Figure 2: Number of papers describing different health impacts due to exposure to RTN

From the records, it is observed that maximum studies are related to noise annoyance, cardiovascular issues, sleep disturbance and hypertension issues. The studies dealing with cognition, dementia, diabetes have not yet gained relevance in the research domain, but the numbers are considerably increasing in recent years. It is also observed that the researchers widely discuss the non-auditory impact of noise, but the impact on auditory health is not discussed due to RTN exposure.

3.2 Authors keyword network

The keyword occurrence of the review records is checked to analyse the number of studies conducted in different areas and how they are linked with each other. For this analysis, the keywords provided by authors for each article are considered. The minimum number of occurrences is kept at 5; out of 578 unique keywords, 28 keywords meet the minimum occurrence threshold. To remove the various variant, keywords with similar meanings are merged before the analysis.

The analysis shows that the articles are based around the important keyword of 'Road Traffic Noise'. Along with it, other keywords such as environmental noise and annoyance seems to have significant importance. Total keywords are classified into 5 clusters based on association. The node's size shows the number of times the keyword is used (Figure 3).

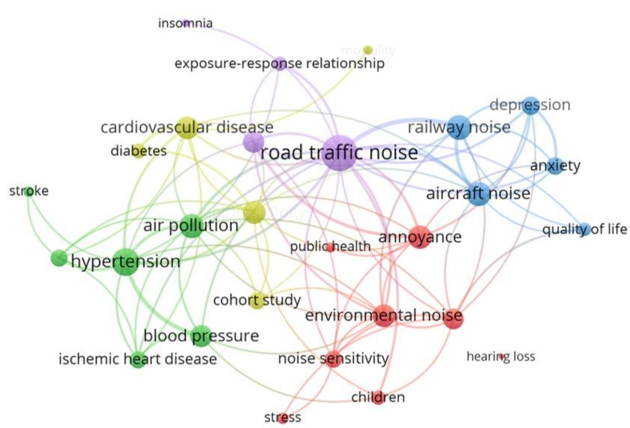

Figure 3: Keyword network analysis: Explaining relevant keywords and their association

Cluster 1: Annoyance, environmental noise, hearing loss, mental health, noise sensitivity, public health.

Cluster 2: Blood pressure, hypertension, ischemic heart diseases, myocardial infarction, stroke.

Cluster 3: Aircraft noise, railway noise, road traffic noise, anxiety, depression, quality of life.

Cluster 4: Cardiovascular diseases, Cohort studies, diabetes, epidemiology, mortality.

Cluster 5: Exposure-response relationship, Insomnia, road traffic noise, sleep disturbance.

The clusters show the different sub-domains formed in the health impact study due to RTN. Cluster 1 is the initial and most prominent cluster that deal with annoyance, environmental noise and public health, sensitivity, and hearing loss, a primary research area. This is followed by a discussion of cardiovascular issues and other related diseases in cluster 2. Cluster 3 is the area that mainly deals with the combined effect of transport noise, including air and rail transport and how it affects the quality of life and burden of diseases. Cluster 4 is a relatively new area in this research domain that deals with the in-depth study of health impacts caused due to RTN exposure. These studies are mainly classified as clinical studies. Cluster 5 explores noise exposure relationship models for various sleep disturbance and annoyance issues.

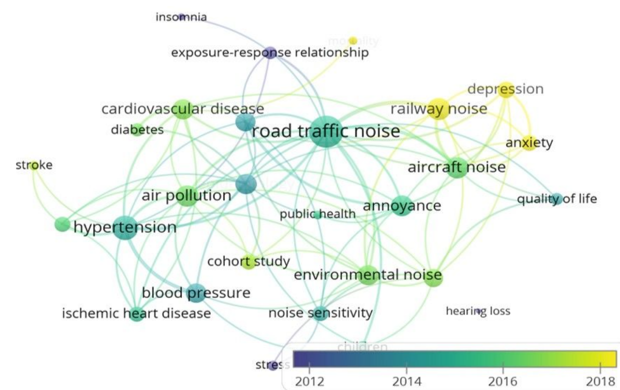

Figure 4: Keyword analysis explaining the use of different keywords in the research domain in the last two decades

Most of the studies were conducted between 2010 to 2020, where the initial work started with the development of exposure-response relationship for Sleep disturbance, annoyance and Insomnia. The period between 2014 to 2016 mainly discussed the road traffic noise and its impacts focusing on hypertension blood pressure noise annoyance. Cardiovascular issues due to traffic noise have been studied after 2016. In comparison, the studies discussing stroke, anxiety and depression caused due to road traffic noise exposure were completed in 2018 and later.

3.3 Articles by year of publication.

The total number of research papers published each year is shown in Figure 5. It is observed that the trend of research in the area of health impact associated with traffic noise pollution has gained importance among researchers. There are few studies from the initial years till 2002, but gradually, the trend increased to 12 studies in 2012. After that, there has been an upward trend in the number of research articles published, with maximum numbers reaching 25 articles in 2020. A slight drop is observed in 2015 and 2019 compared to articles published in the previous year.

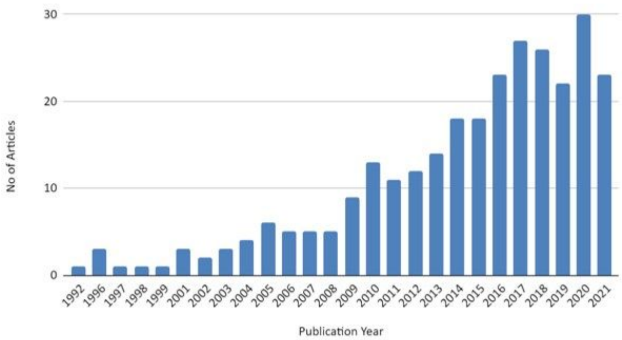

Figure 5: Total number of research articles published each year 1992 to 2021 November

3.4 The distribution by the journal.

The total number of papers published in different journals is presented in Figure 6. Total 105 journals are listed with at least one paper related to the domain. The 'International Journal of Environmental Research and Public Health is the most popular journal to publish 30 research papers in this area, contributing to about ten percent of total research articles from the review records. This is followed by 'Noise and Health' with 27 (9.27%) articles, 'Environmental Research' with 20 articles (6.87%) and 'Environment International' with 19 research articles contributing to 6.5% of total articles in the review list.

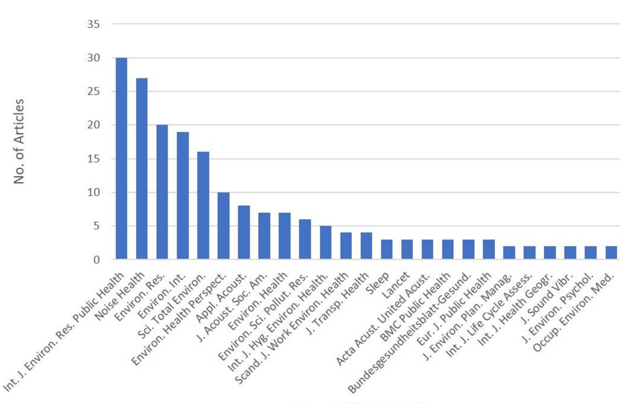

Figure 6: Total number of research articles published by different journals

Figure 7 shows the trend of publication of articles in different journals for the year of publications. It is observed that during the year 1992 to 2000, very few articles were published by the journals such as 'Sleep', 'Science of Total Environment' and 'Environment International'. After the year 2000 to 2010, two highly cited studies were published in 'Lancet' and 'Environment Health Perspective'. Also, few other journals published the articles, which include 'Journal of Acoustical Society of America', 'Noise and Health' and 'Applied Acoustics'. From 2010 till date, most articles have been published in 'International Journal of Environmental Research and Public Health', 'Noise and Health', 'Science of Total Environment, 'Environment International' and 'Environmental research'. At present, these are the journals that meet the aim and scope of the study, which deals with environmental studies and related health impacts.

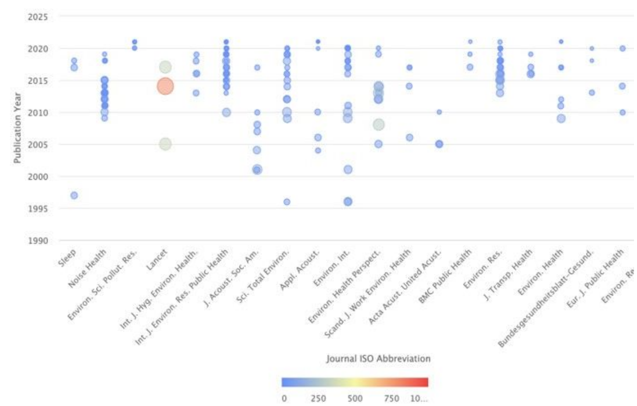

Figure 7: Trend of publication of articles in different journals from 1990 to 2021, Colour and Size of the node indicates the number of citations per paper

3.5 Institutes with major contributions

Co-authorship analysis is conducted on the basics of organisations considering the fractional counting method. The inclusion criteria of a minimum number of documents are kept at five documents from each organisation. Out of 486 unique organisations, 28 meets the criteria, and the results are presented in Figure 8. It is observed that 'The University of Basel' and 'The Swiss Tropical and Public Health Institute are the top leading institutes working on the impact of noise exposure on human health. In terms of citation, the 'Federal Environmental Agency (UBA)', 'University of Pennsylvania' and 'Queen Mary University of London' are the organisations that have received the highest number of citations for the published articles.

From these institutes, many authors have contributed substantially to the research domain. A co-authorship is analysed in the Vos viewer to know the link between different authors. The full counting method is used to analyse where each co-authorship, bibliographic coupling and co-occurrence link has the same weight. The inclusion criteria for the analysis were to have at least five documents for each

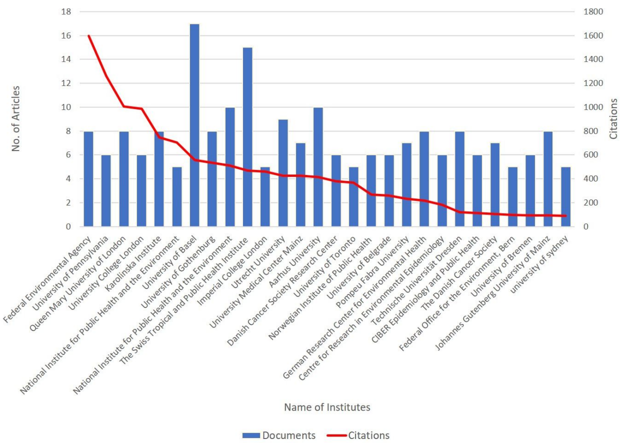

Figure 8: Total number of articles published by different research organisations with the total number of citations received

author. As per this criterion, out of 1052 authors, 36 qualify for the analysis. The results of co-authorship analysis are presented in the supplementary section.

3.6 The contribution of countries

Co-occurrence analysis is conducted by considering countries as a unit. Articles from 57 counties are detected in the review records. The fractional counting method is used for the analysis, and the minimum number of documents from each country is set at five. Out of 57 countries, a total of 23 countries meets the threshold level. Figure 9 shows different countries and their association based on co-occurrence. The node size shows the number of documents published by each country, and the links show the association between countries. It is observed that the majorly 5 clusters are observed along with a sixth cluster without any association.

The first five clusters are grouped as follows.

Cluster 1 consist of Austria, Belgium, France, Spain and Switzerland. Cluster 2 includes Canada, Finland, New Zealand, China and England; cluster 3 includes Austria, Denmark, Germany and Serbia. Whereas cluster 4 consist of Greece, Italy, Netherland and Sweden. Moreover, cluster 5 includes Japan, Norway, South Korea and the USA.

Apart from these five clusters, the sixth cluster is formed, which only includes India. In the first five clusters, most of the counties are from Europe, followed by the USA and a few Asian countries.

Considering the number of documents published and the citations, Germany is the leading nation to work in health impact due to RTN, followed by USA and England. Other European countries have substantially worked in this area, including Spain, Netherland, Switzerland, Sweden, and Denmark (Figure 10).

India contributes many studies to the research area, but the association is not observed with any other nation. This may be due to the heterogeneous type of transportation observed in India. Several other countries with heterogeneous transportation have attempted to identify health impacts due to RTN. However, they have not substantially contributed to the research domain, including Pakistan, Egypt, Indonesia, Morocco, South Africa, Mexico and Columbia.

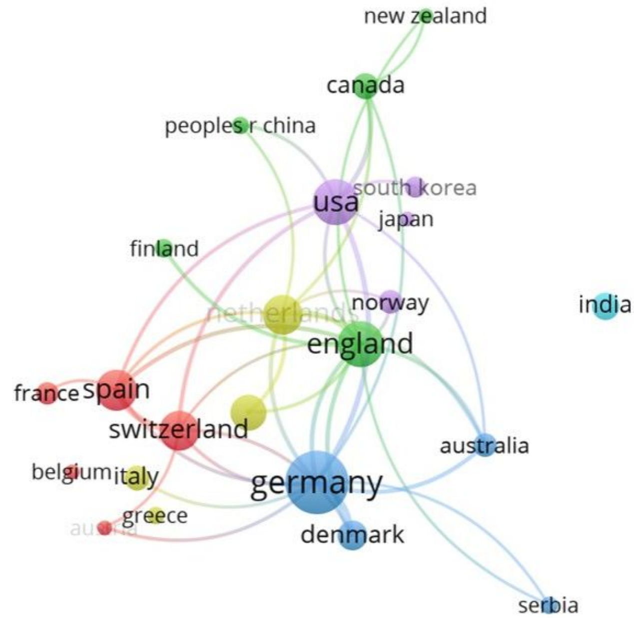

Figure 9: Network analysis explaining the contribution of the number of research articles from different countries and association among counties based on co-occurrence

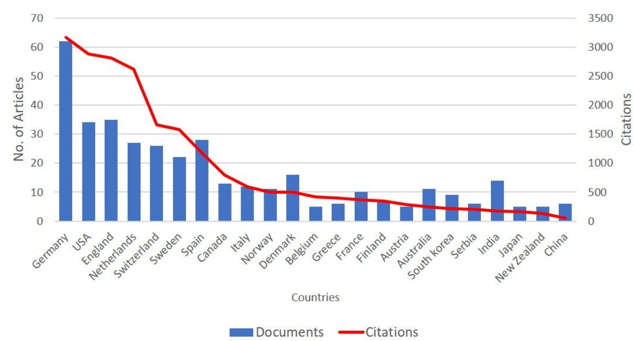

Figure 10: Figure showing the number of articles published from different countries and the total number of citations

4 Critical review

The bibliometric analysis has provided an understanding of the workflow in health impact due to RTN. To get an insight into these health impacts, the categorisation of review records is done based on health issues caused due to RTN. A critical review is conducted to review the impact of road traffic noise on humans, including identifying the health impact caused, adopted methods and different parameters considered the risk identification.

Section 4.1 focuses on traffic noise exposure and human health impact. The section is broadly divided into auditory and non-auditory health issues. Auditory health effects such as noise-induced hearing loss and tinnitus are discussed in section 4.2. It is observed that the non-Auditory health impacts are majorly discussed due to RTN; very few studies are based on auditory impact. There is limited literature on the auditory health impact of RTN. Hence, we attempted to infer the auditory impact of RTN based on similar noise exposure characteristics from other sources. Non-Auditory health impacts of road traffic noise are reported in section 4.3, including cardiovascular, sleep disturbance, noise annoyance and cognitive impairment issues.

4.1 Traffic noise and health impact

Environmental noise includes noise from multiple sources like transportation, industries, and neighbourhood. Often, noise is responsible for changes in emotions, social behaviour, and annoyance. Adverse effects, including the physical and psychological impact of continuous noise exposure, have been reported by various researchers. Noise exposure and sleeping issues are well discussed in studies done in controlled conditions. However, it has been challenging to establish this impact in field conditions. Studies performed in the area of road traffic noise exposure reveal increased stress levels, hypertension, cardiovascular issues and sleep deprivation. It is noted that RTN is not associated with psychiatric complaints but is responsible for physiological disorders. Multiple studies about noise exposure and health impact assessment confirm non-auditory impacts like cardiovascular diseases, stress, sleep disturbance, and auditory impacts such as hearing loss and tinnitus estimates that more than 20% of the EU population is vulnerable to traffic noise levels above 65 dBA during the day, and 30% are subject to more than 55 dBA at night, resulting in 61,000 DALY [10, 22]. A study conducted in Madrid (Spain) has reported that 1 dB noise reduction amounted to a reduction of 200 and 300 deaths due to cardiovascular and respiratory problems [23]. Often, the exposed population

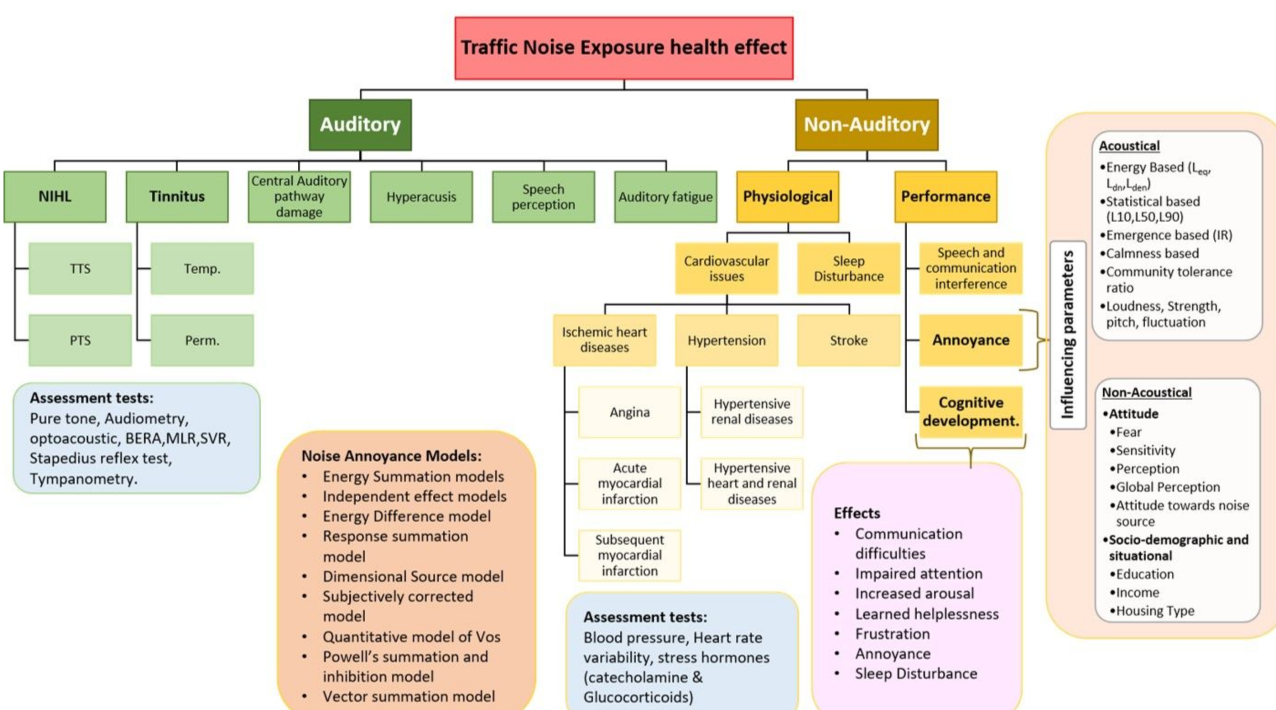

Figure 11: Traffic noise exposure and its auditory and non-auditory health impact on human health, describing health impacts, assessment tests, influencing parameters and available risk prediction model

tends to adapt to the slightly high level of noise exposure, but this degree of habituation is not specific and differs with many social, economic and demographic parameters [24].

Müller [25] established a methodology to quantify the health loss due to traffic noise exposure. This health loss was recorded in case of sleep disturbance and communication disturbance aggregated into DALY to quantify the health risk. Environmental Burden of diseases (EBD) is a method established using DALY for health risk assessment [26]. It quantifies potential years of life lost due to premature death and equivalent years of healthy life lost because of the same health and disability [27]. EBD considers the distribution of noise exposure among citizens, exposure-response relationship and estimate of disability weight for a particular outcome. According to the European Environment Agency [26], environmental noise alone has caused 10,000 premature deaths in Europe, with high annoyance affecting 20 million adults and sleep disturbance affecting 8 million. Nine hundred thousand hypertension cases are also caused by noise, and nearly 43,000 hospital admissions in Europe are caused by noise [28]. Brink M. [29] stated that using active health indices is required to estimate correct health impact than subjective assessment. The acoustical parameters (Spectral distribution of energy, type of source, type of traffic condition, etc.) alone are not sufficient to predict the exposure level and associated health risk both physically and mentally [30]. It is necessary to identify Non-Acoustical Parameters, such as noise sensitivity, attitude, social and demographic variables, that are significant in predicting these health risks [31]. Figure 11 presents different effects of traffic noise pollution, assessment tests, influencing parameters and available risk prediction model.

4.2 Auditory health effects

According to WHO, around 104 million people are exposed to noise levels that cause Noise-Induced Hearing Loss (NIHL) [32]. According to an audiometric study performed on the population living in urban areas, the hearing capacity of people from urban areas is reduced compared with people from suburban areas. Multiple types of noise sources contribute to the increase in ambient noise levels in urban areas, which includes traffic noise, construction noise, community noise, industrial noise etc. The road traffic noise exceeding 70 dB is majorly responsible for NIHL [33, 34]. Majority of the population associated with the urban transport system and industrial sector experience a high level of noise exposure and associated health issues. The vulnerable group includes drivers, police personnel and hawkers for whom traffic noise exposure can be treated as occupational noise. Hearing impairment due to industrial noise is extensively acknowledged in the present context, but another exposure like traffic noise or military and police personnel [35, 36] is overlooked.

Apart from these noise sources bursting of firecrackers, loud music etc leads to NIHL [37] and other issues, which can be permanent or temporary. During festival season, the study conducted in India shows that ambient noise levels increase beyond the threshold due to the bursting of firecrackers leading to NIHL [38, 39].

4.2.1 Noise-induced hearing loss (NIHL)

The leading cause of NIHL is the loss of outer hair cells in the organ of Corti because of the high level of noise exposure. Cochlear damage happens due to more than 115 to 125 dB noise exposure. The findings in NIHL include the destruction of outer hair cells, floppy stereocilia, fusion and loss of stereocilia, loss of adjacent supporting cells, complete disruption of the Corti, progressive Wallerian degeneration, and loss of primary auditory nerve fibres [40]. This occurs in bilateral, sensorineural hearing loss, often with a pathognomonic knot with a reduced hearing on an audiogram at 4,000 Hz. Continuous exposures to sound above 85 dB over 8 hours have been shown to induce NIHL [41]. Continuous noise exposure has a higher risk of NIHL than Intermittent noise exposure.

NIHL has two types: temporary threshold shift (TTS) and permanent threshold shift (PTS). TTS is caused due to short term noise exposure of high noise levels where subjects can detect ringing or buzzing sounds. Similar exposure for an extended period leads to PTS. In a few cases, patients are more vulnerable to permanent threshold shifts (PTS) based on threshold measures of auditory brainstem response (ABR) when subject to similar noise exposure [42, 43].

The working population associated with the transportation sector, including drivers [44] and traffic police personnel, are at the highest risk of NIHL [45–47]. The study conducted on shopkeepers along the street shows a high level of hearing loss due to long term exposure to road traffic noise levels [48]. Traffic police officers reported delayed conduction in the peripheral part of the auditory pathway. However, no impairment was observed in the subcortical, cortical, or association areas [49]. NIHL was reported among 84% of traffic police personnel. The occurrence of hearing loss explained as an average threshold above 25 dBA hearing level was 80%, 70% and 46% for low, mid and high frequency average respectively for traffic police personnel [50].

NIHL is the most frequent but avoidable occupational disease in many Asian countries. One of the significant sources responsible is RTN [33], resulting in the highest attributable cases of hearing loss in the world [51]. Barbosa and Cardoso [34] report that 28% of the Brazilian population deals with NIHL and other health issues due to RTN exposure.

4.2.2 Tinnitus

Tinnitus is a sensation and perception of sound without any presence of an external noise source. Recent studies show that hyperactivity in the Dorsal Cochlear Nucleus (DCN) is a potential tinnitus generator [52]. Tinnitus is of two types, objective and subjective. Objective tinnitus is a case in which a person can hear internal acoustic stimuli, such as turbulent blood flow in an artery close to the ear. It is detectable by physicians. Subjective tinnitus is a sensation of ringing or buzzing sound, which is non-detectable. Subjective Tinnitus and hearing loss have not been convincingly associated with each other [53]. Subjects affected by tinnitus face difficulty in concentration, emotional problems, speech perception and sleep disturbance [54].

Many times, tinnitus is misinterpreted as hearing loss. As per Lewis *et al.* [55] tinnitus, in an extreme scenario, leads to suicidal tendencies. Tinnitus suffering is subjective to the patient's reaction (irritation, coping, adjustment level); hence it has not been significantly correlated with tinnitus sensation when measured using a matching test [56]. Hyperacusis is unusual tolerance to ordinary environmental sounds [57], which is not detectable by any audiological or medical test. Before the advent of hyperacusis, most of these patients required psychological treatment.

Clinical research correlates excessive exposure of noise impacts like central and peripheral auditory pathway damage [58] with Hyperacusis, difficulty in speech perception and auditory fatigue. Psychological symptoms were associated with aircraft and road traffic noise. Besides, difficulty in reading comprehension and increased blood pressure issues were noted in children [4].

Traffic police and bus drivers with high traffic noise exposure have reported hearing issues and tinnitus [59]. WHO estimates 22,000 DALYs for tinnitus [10]. Temporary noise-induced tinnitus is reported to be the most common issue due to loud music among adolescents [60]. Most of these experiments have been administered only for general noise exposure and not specifically for traffic noise. Since noise equivalent levels and total exposure levels are similar in these experiments, it can be assumed that such auditory impacts may result from a similar level of traffic noise exposure. Hence further studies for establishing such auditory impact due to traffic noise exposure and its spectral characteristic are strongly recommended.

4.3 Non-auditory health impact

The investigation by various authors on non-auditory health impacts due to RTN can be divided into two categories, physiological impact and performance-related impact, as shown in Figure 12. These impacts are based on various changes in the human body. Performance level changes lead to issues like hypertension, stress, behavioural changes, and cognitive impairment, whereas physiological changes lead to myocardial infarction, high blood pressure, muscle tension, etc.

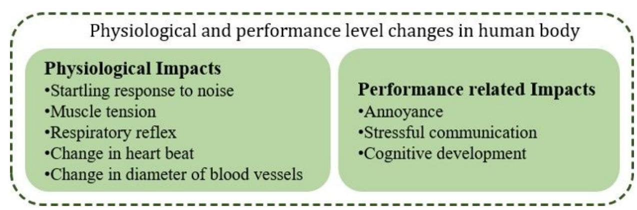

Figure 12: Physiological and performance-related changes due to RTN exposure

This review summarises the noise impact on cardiovascular issues, sleep deprivation, annoyance level, and cognitive impairment. Apart from these issues, there are many other health impacts due to noise exposure (e.g., Stroke, dementia). Due to the lack of sufficient literature in the area of traffic noise exposure and these health impacts, the review of these studies has been excluded.

4.3.1 Physiological impacts

A. Cardiovascular issues and noise

Over the past two decades, researchers have extensively studied the association between traffic noise exposure and cardiovascular diseases. It mainly includes hypertension, ischemic heart diseases, blood pressure and stroke. As per the WHO Global Burden of Disease (GBD) report, ischemic heart diseases are a vital cause of fatalities in developing and underdeveloped nations. Exposure to traffic noise increases cardiovascular disease incidence [61]. In the human auditory system, cortical and subcortical brain structures are responsible for interpreting and filtration of acoustic

Table 1: Details of time domain and frequency domain parameters employed for HRV analysis

Heart rate variability parameters		Used for relevance
Time-domain parameters	Mean RR	
	SDNN (ms)	The standard deviation of normal to normal (NN).
	RMSSD	Root mean square of successive RR interval differences
	NN50	The number of adjacent NN cycles that are more than 50 ms (NN50) apart from each other includes an epoch of 2 minutes.
	pNN50 (%)	Percentage of more than 50 ms of consecutive RR cycles.
Frequency domain parameters	LF	low-frequency power.
	HF	High-frequency power.

signals. The autonomic nervous and endocrine systems' excitement is linked to repeated temporal modifications in biological responses [10, 62–65]. Continuous exposure to a high noise level acts as a nonspecific stressor that impacts human health. Epidemiological research has estimated the high risk of cardiovascular diseases among the subjects exposed to the high noise level.

A subjective study in Oslo, Norway, revealed a strong relationship between exposure to noise, chest pain and hypertension [66]. An evaluation in school environments found that the systolic pressure of school children was at an average high of 2 beats/min in a noisy environment compared to quiet spaces [67].

In a long-term scenario, the relationship between insufficient sleep, metabolic, endocrine changes and cardiovascular diseases (CVD), and hypertension is well established [68]. This long-term cause of sleep disturbance and change in metabolic activities is attributed to continuous or intermittent traffic noise during night hours. Permanent vascular effects, hypertension and ischemic diseases can result from a high noise exposure level [69, 70]. Research shows an increased risk of myocardial infarction with raised noise levels, acute noise sensitivity that stimulates the sympathetic and endocrine system, increased blood pressure, heart rate and stress hormone levels [71, 72]. Angiotensin (AGT) gene polymorphisms are used to Identify workers ' risk of hypertension dealing with occupational noise. Workers with TT genotype are more vulnerable to the risk of hypertension due to noise exposure [73]. Long-term RTN exposure increases the risk for all-cause mortality and cardiovascular mortality and morbidity in the population at large, especially for older people with stroke [74]. Reports have shown increases in systolic blood pressure (not diastolic pressure), total cholesterol, total triglycerides, blood viscosity, platelet count, and blood glucose level of the studied population.

Heart rate variability (HRV) and blood pressure are the basic parameters used to identify CVD risk because of noise exposure. The medical-grade electrocardiographic machines and IoT based health monitoring systems are typically used for this analysis in the reported literature. Many laboratory experiments have established the association between change in Heart rate and blood pressure due to noise exposure. Heart rate variability analysis includes time-domain analysis parameters (Mean RR, SDNN, RMSSD, NN50 and pNN50) and frequency domain analysis parameters (low-frequency power-LF and high-frequency power HF) [75].

The impact of RTN is analysed subjectively by investigating the medical history and noise exposure history. In controlled experimental conditions, noise stimuli are provided to subjects through headphones or loudspeakers in supine or seated conditions. The experiment time interval varies from 5 minutes to one hour. Apart from the above parameters, various sociodemographic parameters which have an association with noise exposure are considered. Muzet [76] reports that people with angry, helpless and hostile aggressive behaviour and lower-income group population are more vulnerable to noise exposure resulting in different health consequences.

Multiple cross-sectional and longitudinal subjective surveys, laboratory measurements and several meta-analysis reports have helped researchers establish a dose-response relationship for quantification of CVD risk due to noise level exposure. Noise indicators such as L_{dn}, L_{den}, L_{night} are used for finding the association, which is widely accepted by WHO and other policy-making organizations. Following Table 2 summarizes different studies performed to identify cardiovascular risk due to road traffic noise exposure.

B. Sleep disturbance

According to the WHO report, sleep disturbance due to traffic noise constitutes the maximum level of 903,000 DALYs [10]. Noise exposure and sleep disturbance are closely re-

Table 2: Different studies are showing the association between traffic noise and cardiovascular issues

Study type	Reference	Inference
Long term noise exposure	[77]	Increased risk of diabetes due to excess cortisol and sleep disturbance, with an improved incidence rate range of confirmed diabetes 1,14 (1,06-1,22) to 10 dB in L_{den}.
	[78]	Per 10 dB increase in L_{den} can cause myocardial infarction.
	[79]	A strong association between arrhythmia atrial fibrillation and noise annoyance considering ECG based diagnosis and physician-diagnosed history.
	[80]	Noise levels (Leq) during 6-22 hrs. above 65 dBA is correlated with increased risk of CVD.
	[81]	Annoyance due to traffic noise serves as a regulator of the relationship between the noise level and hypertension.
	[82]	Risk of hypertension among reproductive aged women due to road traffic noise exposure
	[83]	Impact of long-term noise exposure on BP and hypertension is not convincingly reported.
	[84, 85]	Non-significant risk of cardiovascular issues.
	[86]	Rate of risk is low for noise level below 60 dB, but increases for noise levels above 60 dB considerably, complimenting the suggested dose-response relationship.
Short term exposure	[87]	The correlation between rate of noise exposure and cardiovascular mortality indicates a combined impact of levels of diurnal and night-time noise.
Cross-sectional studies	[88–91]	Positive association observed between RTN and blood pressure change among children and pregnant women.
laboratory study	[92]	Increases in blood pressure and hemodynamic factors associated with RTN.
	[93]	No significant association with change in blood pressure due to RTN exposure
	[94]	Increased heart rate was observed due to noise exposure
	[95]	Risk of respiratory illness among children by the effect of emotional stress-induced through the noisy neighbourhood as compared to air pollution
Meta-analysis	[96]	Traffic noise and hypertension, and cardiovascular diseases positive association
	[97]	A meta-analysis done on literature (hypertension and traffic noise) for the year 2011-17 has reported risk but was on the lower side as compared to a meta-analysis done previously
	[98]	Contribute to evidence on traffic noise as a risk factor for cardiovascular disease
	[99]	Updated exposure-response relationship for RTN and coronary heart disease (CHD)
	[86]	Dose-response relationship developed for traffic noise and myocardial infarction and are widely recognized.
	[100]	Dose-response relationship developed for aircraft noise and hypertension
	[96]	Dose-response relationship developed for traffic noise and hypertension
	[101]	Direct association between RTN, annoyance, and arterial hypertension, with risk of ischemic heart diseases.
Combined effect of air and noise pollution	[102–106]	Attempt to identify combined effect of air pollution and noise pollution from traffic.
	[104, 106]	Calculated share of noise pollution in these studies.
	[107]	Self-reported study showing hypertension issues due top combined pollution level.
	[108]	Long-term exposures to RTN and ambient air pollution were associated with blood biochemistry.
	[62]	Study of short term interventions like headphones and respirator for prevention from air and noise pollution has shown significant drop in risk of cardiovascular diseases.
Statistical Modeling	[109]	**SEM analysis**: Higher noise annoyance is associated with less social cohesion, which in turns has increased risk of mental health issues.
	[67]	**SEM analysis**: Hypertension and chest pain are only related to sensitivity to noise. Relationship not established between other health issues and noise pollution.
	[110]	**System dynamics model**: Predictions based on annual changes in traffic volume, at-risk population, technological advances and behaviours related to motor vehicles, and strategies for urban planning.
	[23]	**Integrative model proposed**: RTN's long-term and short-term associations with health outcomes.
	[111]	**Univariate and multifactorial logistic regression**: This study suggests epidemiological evidence that exposure to road traffic noise of L_{den}>65 dB(A) may be associated with occurrence of CHD in adult subjects.

Table 3: Clinical and laboratory assessment related to traffic noise exposure and sleep disturbance

Study Type	Reference	Inference
Catecholamine excretion and sleep disturbance	[121]	Sleep quality is associated with catecholamine excretion and concentration of adrenaline and noradrenaline in urine in women aged between 30 to 45 years.
Cardiovascular reactivity and sleep disturbance.	[122, 123]	Night-time sleep disturbance impacts on physiological and psychological functions of a person with cardiovascular reactivity, leading to reduced productivity in following day.
ICBEN review	[69]	"Acute and chronic sleep restriction or fragmentation have been shown to affect waking psychomotor performance, memory consolidation, creativity, risk-taking behaviour, signal-detection performance, and risks of accidents."
Pre-ejection (PEP) period and respiratory arrhythmia (RSA) during sleep	[124]	Indicates the cardiac sympathetic and parasympathetic nervous system tone, which shows that high traffic noise exposure during sleep has caused cardiac parasympathetic withdrawal during sleep.
Gender-based study	[125]	Younger girls are majorly affected as compared to younger boys because of sleep disturbance by traffic noise.
Decreased performance level	[126]	Noise caused sleep disturbance, and inhibitory brain processes reflected a change in the performance of an individual.
change in children's behaviour	[127]	RTN exposure and change in children behaviour due to sleep disturbance is analysed.
Quite façade and noise exposure	[128]	Nocturnal noise was significantly associated with sleeping problems on the least visible façade. The existence of a quiet facade in a house will eliminate noise disturbance and sleep disturbance

lated to each other. With a proportional increase in noise levels, a change in sleep pattern occurs and the number of awakenings increases. Various sleep studies performed using polysomnography, self-reporting epidemiological studies, EEG and Actigraphy techniques have established a strong association between sleep quality and level of noise exposure. The impact of traffic noise on sleep quality was evaluated using sleep logs, and wrist Actigraphy showed a positive relationship [112]. Sleep disturbance occurs when more than 50 noise events occur with noise levels more than 50dBA in indoor conditions. However, intermittency of noise in outdoor conditions has a low association with sleep disturbance [4]. In these studies, sleep-induced parameters like total sleep time (TST), sleep efficiency (SE), wake after sleep onset (WASO), hormonal parameters (e.g., cortisol secretion) are used for analysis. People between 35-55 years of age were more susceptible to sleep disturbance, followed by older people [113]. Studies related to subjective evaluation of sleep disturbance show some data discrepancies since the subject is not aware of surrounding during sleep. However, this process is affordable compared to physiological measurements for large scale sampling.

The sound pressure level of more than 42 dB affects sleep quality and causes self-reported sleep disorder leading to the use of sleeping drugs by subjects [114]. The noise from ventilation was reported to be less annoying than traffic noise. Hence, measures such as placement of bedroom towards quiet side instead of roadside have been recommended [115].

The dose-response relationship for various transport modes and multiple health impact assessments have been conducted by various authors, describing the level of noise exposure and associated health impact. Miedema and Vos [116] developed a curve to predict the percentage of annoyance and self-reported sleep disturbance. Recent studies have revealed that in last decade annoyance concerning aircraft noise has increased and is now more than forecasted by European standard curve [117–120]. The percent highly sleep disturbed (HSD) using a function Lnight (L_n) i$_s$ calculated with the Eq. (1):

$$\%HSD = 20.8 - 1.05L_n + 0.01486L_n^2 \tag{1}$$

Apart from RTN, various other sources of traffic like railways, aircraft and wind turbines were found be responsible for sleep disturbance. Various studies are being done to identify the effect of railway noise and vibrations generated combined on sleep quality, the effect of aircraft noise exposure on probability of awakening. A threshold level identifying number of awakenings and cardiovascular arousal is required to prevent negative impacts on human health.

Such threshold values for traffic noise need to assess the impact of temporal variations on such sleep parameters. Few projects are currently dealing with Traffic noise impact on sleep. For instance, NORAH [129] deals with traffic noise impact on different health parameters. SiRENE [17] deals with short term and long-term noise exposure levels, mainly working on exposure patterns and describes its effect on sleep and cardio-metabolic risks.

4.3.2 Performance related impacts

A. Annoyance

Noise annoyance is the most widely explored research area in the field of environmental noise. Generally, noise-induced annoyance is responsible for multiple negative responses such as anger, anxiety, distraction, agitation etc. WHO reports 587,000 DALYs lost from noise-induced annoyance for the EU population living in cities of more than 50,000 people [10].

Several large-scale epidemiological studies have formulated the relationship between noise levels, exposure and annoyance. Few studies have attempted to explore various factors responsible for annoyance and have derived empirical relationships. Both acoustical and non-acoustical factors are responsible for the assessment of total noise annoyance caused. Acoustical parameters like time, energy and spectral configuration of signals are explained in Table 4 [130, 131]. Non-acoustical parameters include personality, attitude, socio-physical and demographic variables are described in Table S1 (Supplementary Materials). Fields *et al.* [114] have extensively described demographic attitudinal and situational behaviour. Objective acoustical parameters influencing human health are easy to measure, but the challenge lies in determining the non-acoustical and attitudinal parameters affecting annoyance levels [132]. In 2001 ICBEN recommended a five-point verbal scale and a 10-point numeric scale for community noise annoyance surveys, which is being used by ISO/TS 15666:2003 [133]. It has been more than two decades, research on noise and its impact is in progress. Ambiguity still exists about the impact and weight of various acoustical and non-acoustical factors and their effect on human health both mentally and physically.

Acoustical parameters

To describe the dynamics of noise exposure, statistical and emergence-based indicators are adopted. Table 4 describes Various indicators describing noise characteristics. These include L_{Aeq}, L_{dn}, L_{den} and L_{night} for the study of noise exposure [134, 135]. Initially, Kryter [136] and Schultz [12] analyzed the relationship between average day-night noise exposure level (L_{dn}) and annoyance. Using L_{eq} as an acoustical parameter, it was concluded that noise levels in the evening are at maximum level on highways and cause high level of annoyance [137]. Miedema and Oudshoorn [15] developed a separate noise exposure relationship for rail, road and aircraft noise and presented curves for highly annoyed persons using DNL (Day night level) and day-evening-night level (DENL) as functions. Typically, annoyance caused by road and rail noise is lower compared with aircraft noise. While few Asian countries' studies reveal, aircraft noise was not that annoying [138]. DNL and DENL were considered as noise indices by [15]. In 2002 European directive introduced Noise action planning, and since then, these parameters have been used widely. L_{10} describes the peaks from noise exposure, L_{50} and L_{90} describe average noise and background noise levels, respectively. To characterize the eventfulness of a noise exposure, which is independent of an overall energetic dose, an Intermittency ratio (IR) is used [139].

Lambert *et al.* [140] have provided a noise threshold value of 55 dB(A) for slightly annoyed people and 60 dB(A) for severely annoyed people for the daytime (8.00 to 22.00 hrs.). Fields [141] have pointed out that even low-level noise and the addition of new sound source to existing soundscape can be annoying. The "community tolerance level" is used to define tolerance towards noise level for a community using sociodemographic variables [142–145]. The qualitative dimension of noise, such as loudness, sharpness, tonality, roughness, fluctuation power, periodicity and impulsiveness, has been thoroughly represented in various studies [146–148]. These indices are contributing to increased annoyance levels [148, 149]. A social survey conducted to find the spatial distribution of noise revealed that a location with more than 65 dBA L_{dn} value is closely associated with a high level of annoyance [150].

Non-acoustical parameters

Non-acoustic variables play a crucial role in determining the level of annoyance [141, 151–153]. There is a lack of robust theoretical and empirical models considering non-acoustical parameters such as attitudinal and socio-demographic factors.

In a study on non-acoustical parameters affecting noise annoyance, James M. Fields in 1993 [141] proposed that factors like total time spent at residence and demographic parameters hardly have any impact on noise annoyance. Indeed, factors like respondents' attitude and sensitivity towards noise source and sociodemographic factors are majorly responsible. Table S2 (Supplementary Materials) presents an overview of different non-acoustical parameters contributing to noise annoyance levels.

Attitudinal parameters have a significant role in noise annoyance. In a study done by [154] on the identification of factors linked with the annoyance caused due to noisy streets, noise sensitivity among people has emerged as an influencing factor. Whereas [155] suggested that sensitivity, attitude towards noise source and perceived quality of living environment have less impact compared to perceived loudness and noise disturbance in determining noise annoyance.

In a laboratory experiment on annoyance due to outdoor traffic noise in residences, noise sensitivity was found to be an influential factor [156]. Another sensitivity analysis revealed that visible noise sources cause more annoyance compared to invisible noise sources [157]. Age of the receiver is found to be an influential parameter for noise annoyance, and analysis on the influence of age group concluded that the level of annoyance is more in older people, especially for traffic noise [158]. The level of annoyance increases with increased traffic noise pollution [159, 160]. Studies related to noise sensitivity conducted in south Korea shows cognitive development issues in children [161]. Night-time exposure and increased sensitivity are known to cause suicidal tendencies [162].

Various studies have established the effect of socioeconomic parameters such as occupation, income and education on perceived noise annoyance. Culture and nationality have emerged as a point of discussion. For instance, the noise annoyance level among respondents of a few Asian countries is less than European countries at the same noise exposure level. A study performed by Koushki *et al.* [163] found a strong association between socioeconomic parameters such as level of education, income and level of noise annoyance caused. It was concluded that people with high income and higher education are highly annoyed.

Few authors point out that the location of a house, type of dwelling unit, location of bedroom in residence, and quality of insulation have a role in determining noise annoyance. A constructive relationship was observed between annoyance and housing condition, placement of bedroom and duration of stay in residence [164]. Research by [165] indicates that apart from socioeconomic and demographic parameters character of a neighbourhood, perception towards greenery, gardens and parks also changes the level of annoyance caused. 'Few authors have attempted to assess the impact of noise on the quality of life (QOL). Through subjective surveys, these studies have concluded a positive relationship between traffic noise and QOL [166–169].

Different mathematical models are available for the quantification of the Noise annoyance model (NAM) due to RTN exposure. These models are developed through clinical and subjective surveys. Various authors have investigated annoyance levels through survey and experimental methods in conjunction with statistical techniques for the development of NAM and exposure-response relationship.

Models developed for assessment of noise annoyance

Noise mapping is one of the techniques to analyse the exposure of noise levels using L_{den} as an exposure parameter. But noise mapping only considers exposure level, while other non-acoustical parameters and annoyance caused are difficult to describe accurately. To overcome this, NAM is developed to analyse the effect of noise exposure physically and psychologically. A questionnaire developed by ICBEN for Community noise response is commonly used to detect subjective noise annoyance.

A multi-item annoyance scale is suggested by ICBEN for better predictability of annoyance over a single item annoyance scale [133, 170]. Energy Summation Model, Independent Effect Model, Energy Response Summation Model, Summation and Inhibition Model, and Exposure Response Relationship by Miedema and Vos are few models developed for the estimation of annoyance caused due to RTN [171, 172]. The detailed summary of noise annoyance models developed is presented in the supplementary material.

People may typically be exposed to multiple sources of noise in an urban environment, which complicates the analysis of exposure-response from individual sources. A variety of models have been developed to determine the impact of combined noise exposures over the years. Many models have been evaluated using in situ or laboratory data [173–175], but none of them has been conclusive [176]. Hence there is a necessity to improve noise prediction accuracy. Multiple studies have attempted to develop a combined noise annoyance model; the summary of these models is presented in the supplementary material Table S3.

4.3.3 Cognitive impairment

Environmental noise has a significant impact on children's cognitive development. Stansfeld *et al.* found a linear relationship between reading comprehension, recognizing memory, episodic memory, and recalling information and annoyance. A non-linear relationship between socioeconomic status, longstanding illness and annoyance has been reported [177]. Children exposed to high noise levels show poor auditory discrimination and speech perception [179–183].

Cognitive control and auditory distraction have been the topic of discussion for last decade. Studies have dealt with the effect of noise on the difficulty in task performance and the relation between noise and cognitive controls in which factors such as types of noise signal and intermittence character have been considered. The effect of air and noise pollution combined on cognitive functions is widely studied. It was reported that air pollution and road noise impair cognitive function in adults. Participants exposed to high noise levels showed a stronger link between air pollution and cognitive function [183]. Long term noise exposure has shown positive association with mild cognitive impairment (MCI) for every 10 dB increase in L_{den} levels [184].

5 Discussion

In this paper, an attempt is made to explore the studies conducted in the area of road traffic noise and its impact on human health. To understand the structure of the research area, a bibliometric review is conducted. From the review, it is observed that traffic noise pollution and its impact on human health is a leading topic of discussion among the research fraternity. The major allied areas are rail, air traffic noise and its auditory and non-auditory effects on humans. The effects are assessed using subjective and laboratory surveys using a clinical research approach. The majority of studies are conducted related to the level of annoyance caused, hypertension, cardiovascular issues, sleep deprivation, and mental health Figure 2. It is noted that the auditory impact due to road traffic noise is not yet analysed. Few studies are conducted in the area of occupational noise hazards, where traffic police personnel are assessed for traffic noise exposure, and it is observed that a high level of traffic noise pollution has a more considerable impact on the human auditory system. The review process noted that there is a need to perform studies to identify the auditory impact of road traffic noise on other categories of listeners (bus drivers, hawkers and nearby residents). Considering the timeline of the research area, the majority of studies are from 2010 to the present, and multiple studies are being added up to the area. Research studies are published in a variety of journals, broadly in environmental research, public health, and acoustics domains.

Due to rapid economic growth and urbanisation, developing nations face the issue of heterogeneous traffic conditions [186]. Many developing nations in Asia, Africa and South America represent heterogeneous transportation systems. The difference between homogenous and heterogeneous traffic systems is based on differences in operational and performance characteristics of vehicles as well as vehicle mix [186]. This leads to a distinct noise climate on urban street networks. The disturbing nature of traffic is responsible for noise pollution of higher order. The traffic composition in countries like India, China, Brazil involves a combination of motorised and non-motorised, slow and fast-moving vehicles using the same right of way, lateral movement of small vehicles and in some instances, non-adherence to lane rules. The vehicle types in such traffic conditions range from cars, buses, trucks, autorickshaws, scooters, cycle rickshaws, bicycles and animal-drawn carts [186].

The diversity of noise sources and their spectral characteristics has made the prediction of noise climate, annoyance levels, and other health impacts challenging [187]. Frequent use of horns as a warning device increases the average noise level [188]. In a study, over 68% of drivers in Vietnam use horns, while only 7% of drivers in Japan use horns while driving a car [189]. Studies by Ali and Tamura [190] showed a decrease of 7-10 dB in background noise levels when regulated honking. Few authors have stated that honking is the primary reason for noise pollution in India, leading to increased annoyance [191].

It is observed that the majority of work carried out in the field is from the European context, followed by USA and China. Not much contribution from the Asian, African and South American context is noted. It is noticeable that the transportation system in these countries is very different and majorly leads to the high level of noise pollution. But no attempt has been made to associate with these countries to develop global scales and models to estimate health impact due to RTN. Since most of these studies in the field are carried out with reference to the homogeneous traffic system, these studies are not directly applicable in these countries with heterogenous traffic systems. In one instance, the contribution of Indian studies in analysing the health impact is considerable, but no research association with other counties was observed.

Although many fragmented initiatives, regulations and regional policies have been developed still, the problem of noise pollution remains unaddressed in developing nations [192]. Several studies related to traffic noise assessment, prediction and modeling have been reported in heterogeneous traffic conditions like India and Brazil. Studies based on the impact of traffic noise on human health using subjective surveys have been performed. The average noise level recorded in Ho Chi Minh City is 78.8 dBA, which led to 4758 DALY in 2007 [193, 194]. Due to high noise levels, 60% of sampled pollution was annoyed in Malaysia [195], 50% in Beijing, China [196] and 48.4% in São Paulo, Brazil [197]. Association between poor mental health and level of annoyance due to traffic noise has also been reported [198].

Considering the above scenario, it is vital to analyse traffic noise pollution and its effects on humans holistically, with global participation. It is required to understand the effect of heterogeneous noise on human health and well-being in underrepresented nations. The health impact of noise on people established in a homogeneous noise environment needs ground validation before their applications to the heterogeneous traffic noise conditions. International research network

The health impact of noise on humans established in homogeneous noise environment needs ground validation before their applications to the heterogeneous traffic noise conditions. International research networks need to be fostered in order to establish global standards for auditory and non-auditory and health impacts due to road traffic noise.

6 Conclusion

This paper presented a bibliometric and critical review of different auditory and non-auditory health impacts due to road traffic noise exposure.

- From the Bibliometric analysis, it is observed that the impact of RTN on health studies is a relatively new and challenging domain of research. The specific impact of road traffic noise on human health is not yet explored individually. The epidemiological studies conducted in this area are minimal. Most of the studies are based on subjective surveys. There is a need to conduct studies in a controlled environment, where the specific impact of RTN can be assessed on human health.
- Most articles are from developed countries, which have homogenous nature of transportation systems. The representation of studies exploring the impact of the heterogeneous nature of transport is very limited.
- Health impacts such as NIHL, Tinnitus, cardiovascular issues, sleep disturbance and annoyance are widely addressed in the literature. However, quantitative data is still insufficient to build a relation between noise exposure and health, especially in the case of traffic noise. The auditory health impact of RTN exposure is not examined broadly. Evidence for impacts such as NIHL and Tinnitus is available at a minor level. However, evidence for impacts such as central auditory pathway damage, Hyperacusis, difficulty in speech perception and auditory fatigue need further investigation for traffic noise exposure.
- Limited literature is available on non-auditory impact due to RTN exposure such as stroke, speech and communication interference. The RTN exposure is responsible for the difficulty in reading, recognising memory, episodic memory and recalling information. The cognitive load and noise exposure is mainly studied for younger children with a positive relationship, whereas the middle and older age group are not studied inclusively. The impact of occupational noise on workers is a trending area in auditory research. Still, studies related to the impact of RTN on people living in the vicinity of the road or workers from the transportation section are not yet assessed.
- Traffic noise exposure leads to different non-auditory impacts like cardiovascular issues, sleep disturbance, cognitive impairment and annoyance, classified as physiological and performance-related impacts. These health impacts are discussed with multiple self-reported subjective surveys and experimental analyses. It is required to establish a standardised laboratory assessment technique to assess such impacts. The risk of cardiovascular issues such as Angina, acute myocardial infarction, subsequent myocardial infarction, hypertensive renal diseases and stroke are studied due to traffic noise exposure. These include long term and short-term noise exposure surveys meta-analyses confirming the risk of cardiovascular issues.
- Few statistical analyses are conducted to quantify the risk and identify the combined effect of air and noise pollution on cardiovascular issues, sleep disturbance and level of annoyance caused. For further assessment dose-response relationship is developed using noise levels at night-time (L_n); also, multiple clinical assessments are conducted based on gender, age and hormonal changes. Due to a lack of consideration of different traffic noise scenarios, the developed relationships are not widely applicable in different scenarios.
  It is required to analyse the cross-cultural differences in noise climate, the level of sensitivity towards noise and perception of noise pollution by people to develop international noise exposure and health impact relationship.
- Different acoustical parameters have been analysed to quantify the level of annoyance caused. However, non-acoustical parameters need further emphasis in noise annoyance models. Factors such as level of heterogeneity in traffic and intermittency pattern of noise have an essential role in the annoyance caused. Further research is essential in this context. The existing annoyance models do not sufficiently account for the traffic heterogeneity. Parameters such as in-

termittency of noise signals and sensitivity towards noise signals have an essential role in the level of annoyance caused, which needs further analysis. There is a need to consider traffic heterogeneity while developing new annoyance models. Also, the level of sensitivity of respondents is different across countries, creating a need to develop new models or correction factors to the existing ones.

- Few studies have attempted to estimate noise exposure and health impact caused by heterogeneous traffic conditions. The majority of studies are self-reported and restricted to some causes such as headache, sleep disturbance, hearing issues and irritation. Studies dealing with an in-depth understanding of physiological and psychological changes are limited. It is required to quantify the noise exposure and rate of cardiovascular issues, sleep deprivation caused, and hearing loss. Noise annoyance models need to be developed considering the traffic scenarios.

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