Modelling Airport Noise Pollution & Its Potential Impacts on Public Health: A Case Study of Tuguegarao Domestic Airport

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Abstract: Living near an airport can offer convenience, but for many residents around Tuguegarao Domestic Airport, it also means coping with constant noise from aircraft operations. With takeoffs and landings close to residential zones, concerns have grown about how this noise affects daily life and well-being. Using the Benetech GM1358 sound level meter, noise levels were measured during peak airport activity and analyzed through QGIS to create spatial noise maps. Affected areas were categorized into Safe, Borderline, Unsafe, and Highly Unsafe zones based on international health standards, providing a clearer picture of which communities are most exposed. To complement technical findings, a survey gathered residents' self-reported health experiences, revealing hearing issues, stress, headaches, and difficulty concentrating. However, results indicated no significant difference in reported health impacts between "unsafe" and "highly unsafe" zones. The findings challenge the sensitivity of current zoning frameworks, highlighting the need to better reflect human experiences in environmental planning.

Keywords: Airport Noise, Public Health, Noise Mapping

1. INTRODUCTION

1.1 Background of the Study

Airports are essential to the world economy, fueling activity and facilitating social and cultural interaction. They serve as critical parts of international transportation networks for efficiently moving passengers, freight, and trade, far beyond what other modes offer. Globally, airports drive trade, tourism, commerce, cultural exchanges, academic partnerships, and character building. They connect regions and promote diverse cultures and ideas.

Economically, airports generate employment, FDI, and attract multinational companies. Regions with well-operated airports often see strong growth. Airports also support tourism and local jobs. Air cargo enables global supply chains to operate efficiently and move high-value products quickly.

Culturally, airports support global travel, work, education, and leisure, strengthening family ties and fostering intercultural cooperation. In the Philippines, airports like NAIA and Mactan-Cebu are crucial for trade, tourism, and connecting its 7,000+ islands. Ferries complement air transport, aiding access and the movement of goods. Due to its archipelagic nature, the country relies on air travel for health, education, and economic activities. Airports also link the Filipino diaspora to home, enabling family reunions and cultural traditions.

However, airports pose environmental challenges, especially noise. Increased air traffic raises noise levels, impacting health and quality of life near airports. Long-term exposure can lead to sleep disturbance, hearing issues, and mental health problems. Communities near airports require mitigation strategies to protect their well-being.

In the Philippines, airplane noise pollution is worsening, especially in urban areas like Manila. Continuous air traffic causes constant disruption. The rise in flights and noise adds health and social concerns. Although CAAP oversees noise management, enforcement is inconsistent, leaving communities caught between economic benefits and health risks.

Tuguegarao Domestic Airport connects Cagayan to Manila and supports local tourism and business. However, nearby neighborhoods raise concerns about aircraft noise. This highlights the need for policies that balance environmental, economic, and social factors (Veng Kheang Phun et al., 2015). Cohen et al. (2018) also emphasize noise management's impact on residents.

The study aimed to model noise pollution from Tuguegarao Airport and assess its health effects. Tools like QGIS were used to map noise exposure, while surveys estimated health impacts. This data supports risk mitigation planning and helps identify noise-affected areas for targeted interventions, improving both community well-being and airport operations.

1.2 Statement of the Problem

Airports in the Philippines have taken steps to manage aircraft noise, but key areas need improvement. Adjusting flight routes helps reduce noise in some areas but increases it in others, frustrating newly affected residents. Despite promoting quieter aircraft, older noisy models remain in use, slowing progress.

Before COVID-19, air travel accounted for over 95% of tourist movement. Tuguegarao Domestic Airport was a vital link to Manila and Luzon, supporting tourism and local businesses. However, its proximity to homes caused disruptions. Noise-reduction measures were applied, but their effectiveness varied.

Concentrated flight paths led to higher noise in certain neighborhoods, underscoring the need to balance operations with resident well-being. With advances in noise monitoring and mapping, it's now easier to visualize noise impacts. This study aimed to model noise pollution from Tuguegarao Domestic Airport and assess related health risks

1.3 General Objective

The main objective of this study was to assess the level of aerodynamic noise on the residential areas around Tuguegarao Domestic Airport and identify its potential impacts on public health through a descriptive-inferential model.

1.3.1 Specific objective

1) To measure the level of aerodynamic noise generated by the airport using Benetech GM 1358
2) To model and classify the spatial distribution of noise intensity using QGIS and categorize affected areas as Safe, Borderline, Unsafe, or Highly Unsafe based on established standards.
3) To assign predicted health risk levels to each noise category based on recognized thresholds.
4) To validate the noise model by analyzing residents' self-reported health impacts and comparing them across the noise categories.

1.4 Significance of the Study

This study focused on modelling airport noise pollution and its potential impacts on public health near Tuguegarao Domestic Airport.

1) Tuguegarao Domestic Airport Residents: The residents of the vicinity of the airport benefited on the study because they became knowledgeable also about the noise pollution level they are exposed and what are the effects to their health.
2) Health Professionals: Health professionals learned about the public health
3) implications of airport noise for the community. The findings of the current study were practical to propose health policies or interventions for preserving residents against the noise-effects.
4) Urban Planners, Policymakers: Those working in the fields of urban development obtained data-driven insights for better urban planning. This
5) knowledge allowed local authorities to put in place more effective noise abatement measures, local zoning decisions, and future airport developments that balanced economic growth with the welfare of residents.
6) Airport Officials: Airport leaders were informed about the magnitude of noise and effect upon the community. This information informed prevention measures to
7) control noise levels, maintain tolerable levels of noise pollution, and increase the cooperation by the local residents.
8) Local Government Unit: LGUs with municipal zoning and planning and other planning functions were to gain from understanding how airports influence land
9) use and public health. This data helped inform decisions on zoning and development intended to minimize the impacts of noise pollution on residential properties.
10) Future Researcher: Researchers and academicians benefited from the research work which adds to the existing body of literature on noise pollution and public health. The approach and results formed the basis for future studies in similar areas.

1.5 Scope of the Study

This study assessed aircraft noise pollution from takeoffs and landings at Tuguegarao Domestic Airport. Noise levels were measured using the Benetech GM 1358 sound level meter, compliant with IEC 61672 Class 2 standards, with ±1.5 dB accuracy and a frequency range of 31.5 Hz to 8.5 kHz. Measurements at varying distances showed how noise spread into nearby residential areas.

Data were modeled using QGIS to create spatial noise maps, identifying zones with safe, borderline, or unsafe noise levels. These maps helped evaluate potential health risks like stress, hearing problems, and hypertension.

A short survey was conducted among residents to gather self-reported health concerns related to noise exposure. Their responses helped validate the model by comparing actual experiences with measured data.

Limitations included the sound meter's lower precision, reliance on perceived (not clinically diagnosed) health risks, and potential survey bias. Socioeconomic and environmental factors like air pollution weren't considered, and variations due to flight schedules or weather weren't fully captured.

2. REVIEW OF RELATED LITERATURE

2.1 Modelling Airport Noise

2.1.1 Airport Noise Mapping

Noise is nothing more than air pollution caused by increased vibration in the air. Environmental noise is the noise in the environment generated by several simultaneous sources, with the exception of occupational noise, with emphasis on roadway noise, construction noise, railway noise and aircraft noise. Aircraft noise is the noise generated mainly by aircraft operation at airports. Aircraft noise exposure causes considerable damage to life quality, health and well-being of the population near airports. As with all forms of pollution, noise must also be managed through the application of methodologies for identifying sources and receivers, highlighting, among the existing ones, the measurement of environmental noise and acoustic mapping of the area. The objective of this work was to verify the existence of aircraft noise in the area directly affected by Bacacheri Airport, in Curitiba, through the measurement of acoustic parameters and acoustic mapping held by Souza et al. (2020). For this purpose, the Bruel & Kjaer 2238 sound analyzer and the Soundplan 8.0 software were used to measure aircraft noise and acoustic mapping, respectively. The results indicate that there is intense to moderate aircraft noise in the area surrounding the airport, as well as quantify the population exposed by the noise pollution generated at the airport being affected by the negative impacts. It is concluded that there is a need for the airport to provide noise mitigation measures recommended by the International Civil Aviation Organization (ICAO).

The measurement of aircraft noise is very important for the industry of air transportation, for residents and for the municipality. The study of Rafanambinantsoa et al. (2024) shows that in the United States of America, the Federal Aviation Authority (FAA) has a managing tool for aircraft noise map called Aeronautical Environmental Design Tool (AEDT); in French Bruitparif is the tool which satisfies the European directive for noise map elaboration strategy. The noise map enables city authorities, residents, and the airport manager to control the noise produced by aeronautical activities in order to master, for instance, the building of infrastructures surrounding the airport zone - a dataset built with a relational database management system obtained from secondary radar detection. This data, after having gone through a data cleaning process, will be brought and tested with functions such as Naive Bayes, decision tree and random forest. Based on the confusion matrix as a metric, we assessed the provided result by the decision tree with metrics as “98% for precision, 97% for recall and 97% for f1-score”. This article emphasizes that on the one hand, the data used for machine learning have the same quality in terms of integrity and precision of the radar itself and on the other hand the performance resides on the confusion matrix.

Additionally, Vogiatzis & Remy (2014) highlights strategic noise mapping and action plans are important tools to define the main strategies to reduce noise exposure of residents and introduce and preserve "quiet zones". Within this framework and as a part of the Herakleion city Strategic Noise Mapping general a specific analysis was introduced in the urban area of Alikarnassos (east part of the city) adjacent to the International Airport “Nikos Kazantzakis”. The 2nd biggest airport in Greece, airport is proposed to be relocated in Kastelli area (some 37 km south of the Herakleion city centre, far away from densely populated areas), within the next decade but in the meantime, air traffic (take off, taxi and landing procedures, especially during the extended spring and summer period), are affecting the city. This paper analyzes the extended acoustic measurement monitoring program and the modelling of environmental noise levels within the city’s SNM introducing –state of the art - qualitative surveys on the sound perception and noise annoyance by the residents as well as in depth analysis of the urban and architectural tissue. All these results have been transcribed in several maps introducing a very comprehensive evaluation tool towards an efficient noise action plan leading to the eventual relocation of the airport. This paper presents the main results of this research aiming at the evaluation of the influence at the inhabitants’ sonic comfort from aircraft operation.

Meanwhile, Guangzhou Baiyun International Airport (BIA) is the core airport of Guangdong–Hong Kong–Macau Greater Bay Area. This study of Xie et al. (2022) produced the noise maps of BIA during summer and winter using a simplified calculation method for the weighted equivalent continuous perceived noise level. Particularly, this method used open-source flight data and short-term noise measurement to replace the traditional long-term noise measurement method. The accuracy of the developed noise map was verified by the field experimental data with an average error of 1.5 dB. The noise maps were analyzed in many aspects including the area and population under different noise levels, the spatial distribution of the aircraft noise, the distribution of noise sensitive points, and the land use condition around BIA. It was revealed that about 22.22% and 25.46% of the total population of the five administrative regions were exposed to > 70 dB during summer and winter, respectively. The total area within the noise-affected area that violated the noise limit were about 18.740 km2 and 18.109 km2 during summer and winter, respectively.

Aircraft noise pollution significantly affects the health and well-being of nearby residents, as highlighted by various studies that emphasize noise measurement and mapping to mitigate its impacts. Souza et al. (2020) identified moderate to intense noise near Bacacheri Airport using acoustic mapping, stressing the need for ICAO-recommended mitigation. Rafanambinantsoa et al. (2024) demonstrated the efficacy of tools like AEDT and Bruitparif in precise noise mapping, leveraging machine learning for high accuracy. Vogiatzis and Remy (2014) integrated strategic noise mapping and surveys in Herakleion, Greece, to support urban planning and airport relocation. Xie et al. (2022) innovatively used short-term noise measurements and open-source flight data to map noise around Guangzhou Baiyun Airport, revealing significant exposure to noise exceeding 70 dB. However, research gaps persist, including limited integration of health data, underutilization of real-time noise monitoring, inadequate evaluation of mitigation strategies, and challenges in generalizing findings across different regions.

2.1.2 Geographic Information System (GIS) in Airport Noise Modelling

The study of Wunderli et al. (2018) shows that the aircraft noise simulation model sonAIR has been designed to precisely predict single flights with the scope of investigating and optimising noise abatement procedures. With its current implementation it is also possible to do noise mapping for entire airports. The simulation process is based on a time-step approach in which single flights are represented in a high temporal resolution. Several sound emission models are available, from detailed models for turbofan powered aircraft, which describe airframe and engine noise separately with a three-dimensional sound directivity pattern, to simplified models for a wide variety of propeller driven aircraft and helicopters. A detailed sound propagation model is used, which for example pays particular attention to air attenuation through a stratified atmosphere. The whole simulation chain is formulated for one-third octave bands within a frequency range of 25 Hz to 5 kHz. The full implementation of the program in a geographic information system (GIS) allows for a user-friendly calculation process. In this contribution an overview of the model and the calculation process is given, and first results of model verifications as well as application examples are presented.

Wunderli et al. (2018) introduced the aircraft noise simulation model sonAIR, which accurately predicts noise from single flights and facilitates noise mapping for entire airports. The model employs a time-step approach, representing single flights with high temporal resolution and incorporating sound emission models for different aircraft types, including turbofan-powered and propeller-driven aircraft. It uses a detailed sound propagation model that accounts for air attenuation through stratified atmospheres and operates within a frequency range of 25 Hz to 5 kHz. The integration of sonAIR into a geographic information system (GIS) enhances its usability by streamlining the calculation process. However, research gaps include limited application to diverse operational scenarios, inadequate exploration of its potential for real-time noise monitoring, and the need for comprehensive validation across varying geographic and atmospheric conditions.

2.1.3 Noise Propagation Models

The effect of the atmosphere on sound propagation can impact the perceived noise on the ground significantly and therefore needs to be accounted for in aircraft noise modelling as mentioned in the study of Tunistra (2014). However, to be practical, propagation modelling cannot impose a limitation on calculation time. The aim is therefore to design a robust and computationally lean atmospheric propagation model for the prediction of aircraft noise. Foreseen applications are the evaluation of en-route noise, noise optimization studies and the evaluation of noise in airport scenarios. To achieve a computationally low demanding algorithm an analytical approach is pursued. When the wave front orientation is approximated to be perpendicular to the ray path, it follows from the Eikonal equation that a ray obeys to an adapted form of Snell's law. If the atmosphere is then discretized in layers of linearly varying sound speed and wind velocity, it allows the ray path and ray properties to be expressed analytically within a layer. Cross-validation against two independently developed ray tracing routines has shown the validity of the selected modelling approach. In conclusion, a robust and computationally low demanding method has been developed for atmospheric sound propagation that can be incorporated in aircraft noise modelling.

On the other hand, pollution is a big issue in the Philippines but the country has not focused its attention towards noise pollution. The study of Espenido et al. (2018) assessed the noise intensity of a hamlet located very near the airport, where aircraft takeoffs and landings occur daily. It compares the noise intensity (in decibels) between areas with tree cover and those without. The noise intensity data were derived from recording using a mobile application, Sound Meter Pro (by Mobile Essentials), installed in two Android phones, LG G3 and Asus Zenfone Max. To avoid any bias, both phones were calibrated against a laboratory sound meter before and after field samplings and against each other, since the phones were switched between two sublocations (i.e., with tree and without tree cover). Our results showed a significant difference between sound intensities recorded in areas with (mean ± S.D.: 83.94 ± 5.51, n = 10) and without tree cover (88.14 ± 6.76, n = 10). This suggests that tree cover does reduce the amount of noise generated from aircrafts in the vicinity.

Tunistra (2014) emphasized the importance of accounting for atmospheric effects on sound propagation in aircraft noise modeling, which significantly influences perceived ground noise. The study developed a computationally efficient atmospheric propagation model using an analytical approach based on the Eikonal equation and Snell's law. This model, validated through cross-checks with independent ray-tracing routines, offers robust predictions for en-route noise, airport noise evaluation, and optimization studies. Espenido et al. (2018), focusing on the Philippines, highlighted the issue of noise pollution near airports, particularly in areas without tree cover. Using calibrated mobile applications for noise measurement, the study found that tree cover significantly reduces noise intensity (83.94 ± 5.51 dB with trees vs. 88.14 ± 6.76 dB without trees). These studies highlight gaps such as the limited exploration of real-time atmospheric effects in diverse environments and the need for integrated noise mitigation strategies like tree coverage to complement technical modeling efforts.

2.1.4 Airport Noise Annoyance

Noise annoyance due to aircraft flyover noise was assessed under laboratory conditions. The main objectives of the study of Gille et al. (2017) were: (i) to identify influential acoustical features of noise annoyance, (ii) to propose noise indices to characterize these acoustical features and (iii) to enhance annoyance models including influential acoustical and non-acoustical variables. Therefore, a verbalization task was performed by the participants of the experiment to collect their whole impression concerning the aircraft flyover noises for which they rated annoyance. This verbalization task highlights that noise annoyance was influenced by three main acoustical features: (i) the spectral content, (ii) the temporal variation and (iii) the perceived sound intensity. Four combinations of noise indices were used to propose multilevel annoyance models, in combination with the individual noise sensitivity. Noise sensitivity was found to highly contribute to annoyance models and should therefore be considered in future studies dealing with noise annoyance due to aircraft noise. Different combinations of noise indices coupled with noise sensitivity were found to be promising for future studies that aim to enhance current annoyance models.

Meanwhile, in the study of Dekoninck (2020) highlights that noise annoyance due to aircraft operations extends well beyond the 55 Lden noise contours as calculated according to the Environmental Noise Directive (END). Noise mapping beyond these contours will improve the understanding of the perception, annoyance and health impact of aircraft operations. OpenSky data can provide the spatial data to create an aircraft noise exposure map for lower exposure levels. This work presents the first step of region-wide noise exposure methodology based on open-source data: detecting low LAmax aircraft events in ambient noise using spectral noise measurements and correlating the detected noise events to the matching flights retrieved from the OpenSky database. In ISO 20906:2009, the specifications of noise monitoring near airports is standardized, using LAeq,1sec values for event detection. This limits the detection potential due to masking by other noise sources in areas with low maximum levels of aircraft noise and in areas with medium maximum levels of high ambient exposure areas. The typical lower detection limit in airport-based monitoring systems ranges from 55 to 60 LAeq,max, depending on the ambient levels. Using a detection algorithm sensitive to third-octave band levels, aircrafts can be detected down to 40 LAmax in ambient noise levels of a similar magnitude. The measurement approach is opportunistic: aircraft events are detected in available environmental noise data series registered for other applications (e.g., road noise, industrial noise, etc.). Most of the measurement locations are not identified as high-exposure areas for aircraft noise. Detection settings can vary to match ambient noise levels to improve the correlation success.

Gille et al. (2017) examined noise annoyance caused by aircraft flyovers in laboratory conditions, focusing on identifying key acoustical features, proposing noise indices, and improving annoyance models by incorporating both acoustical and non-acoustical variables. The study found that noise annoyance is influenced by spectral content, temporal variation, and perceived sound intensity, with individual noise sensitivity playing a significant role in annoyance levels. These findings suggest that incorporating varied noise indices and sensitivity factors can enhance future annoyance models. Dekoninck (2020) extended the understanding of aircraft noise annoyance, demonstrating that its effects go beyond the 55 Lden contours defined by the Environmental Noise Directive (END). Using OpenSky data and a sensitive detection algorithm, the study created detailed noise exposure maps, detecting low LAmax events in ambient noise as low as 40 LAmax, even in high-exposure areas. However, gaps remain in addressing the variability of annoyance factors across diverse environmental and population settings, the limitations of standard detection algorithms in complex ambient conditions, and the integration of real-world noise impacts into broader health assessments.

2.2 Airport Noise Pollution

2.2.1 Community Annoyance

In the Philippines, airport noise pollution is a growing concern for residents living near urban airports. Noise pollution has emerged as a critical environmental issue, particularly in developing countries where rapid urbanization and industrialization have intensified exposure to various anthropogenic noise sources.

According to the study of Çoban, et al., (2015), the increasing prevalence of noise annoyance among the population not only affects individual well-being, but also has broader implications for community health and quality of life. As urban areas become more densely populated, understanding the factors that contribute to noise pollution and public sensitivity is essential for developing effective management and mitigation strategies. The study investigates the noise complaints received by a provincial directorate (Antalya) and correlates these complaints with research trends identified through bibliometric and content analyses within the field of noise pollution in Turkey, utilizing this as a case study. According to the results of noise annoyance (n=785) in 2014, the most frequently reported noise sources were music sound amplifiers (47.6%), mechanical equipment (35.2%), air conditioners (8.2%), and electric generators (4.7%). Within the scope of bibliometric and content analyses, research published in the Web of Science and Scopus databases was classified according to environmental noise sources. The distribution of the studies revealed that 24% focused on traffic noise, 13% on industrial facilities, 10% on mechanical equipment, and 8% on aircraft noise. In addition, the study shows the 48% of these studies concentrated on measuring and modeling sound levels, whereas approximately 20% examined noise exposure and its associated annoyance. Furthermore, it aims to contribute to the broader academic discourse on noise pollution, emphasizing the need for targeted interventions and policies to address this pressing concern in rapidly developing regions.

Meanwhile, as urban areas expand and airports are situated in close proximity to residential communities, the impact of aircraft noise on local populations has garnered significant attention from researchers and policymakers. According to the study of Phun, et al., (2015), it demonstrated that affluent status significantly contributes to the annoyance caused by aircraft noise (i.e., not other noise sources), thereby empirically supporting findings from the existing literature. Furthermore, the impact of noise sensitivity on aircraft noise annoyance was found to be approximately double that of affluent status. This suggests that prioritizing the implementation of aircraft noise mitigation strategies for individuals who are particularly sensitive to noise, followed by addressing the concerns of wealthier residents, would enable aviation authorities to alleviate noise-related tensions within communities located near airports. Such an approach could also enhance the overall management of aircraft noise in these regions. In response to the increasing demand for air transport services, aircraft noise continues to be the most significant impediment to airport expansion.

Furthermore, the impact of noise on human health, well-being, and productivity has been the subject of numerous recent studies. Understanding the perception and effects of noise in different settings is crucial for developing effective noise management strategies and improving quality of life in urban spaces. According to the study of de Paiva Vianna, et al., (2015), in the workplace scenario, individuals subjected to noise reported identifying noise sources, whereas those not exposed to noise sources were from social activities. The hypothesis emerged that, as both groups reported annoyance from perceived noise, no statistically significant correlation between exposure and annoyance was evident. This implies that noise-related irritation was experienced across both the exposed and non-exposed areas. Environmental noise can diminish work efficiency and engender social disadvantages, including absenteeism and workplace accidents. Traditional commercial areas represent distinctive facets of urban activity and vividly illustrate the rhythms of daily life. In the residential scenario, correlations were observed between noise exposure and perception of various noise sources. This was coupled with noise-related annoyance, particularly with a notable perception of heightened noise levels during the nighttime hours. In addition, the study's findings indicate that 53.3% of traders perceived their workplace as noisy, with 48.3% experiencing annoyance due to this noise. Thus, in the work and home scenarios, the probability of reporting annoyance increased compared to the leisure scenario. Home environment was identified as the primary context in which individuals became particularly cognizant of various noise sources. This awareness frequently results in reports of annoyance related to perceived noise levels and sleep disturbances. This soundscape is significant to acknowledge as it encompasses the context of leisure, familial bonding, and tranquility. Persistent urban development and industrialization in developing countries have compromised essential urban planning, which is crucial for ensuring the sustainability of large urban areas. This has detrimental effects on both public health and the overall quality of life of residents.

Airport noise pollution in the Philippines is an increasing concern, especially in urban areas where industrialization and urbanization intensify exposure. Çoban et al. (2015) emphasize that noise annoyance from sources like aircraft, music amplifiers, and mechanical equipment adversely affects community health and quality of life, with aircraft noise receiving limited research focus despite its significant impact. Phun et al. (2015) show that affluent status and noise sensitivity significantly influence annoyance, suggesting that mitigation strategies should prioritize sensitive individuals and affluent communities near airports. De Paiva Vianna et al. (2015) further highlight noise's pervasive effects on productivity and well-being, particularly in residential settings where nighttime disturbances lead to heightened annoyance and sleep issues. These studies reveal gaps in addressing aircraft noise impacts, proposing tailored mitigation strategies for vulnerable groups, and integrating noise management into sustainable urban planning to enhance public health and quality of life.

2.2.2 Cultural and social perspectives on airport noise

The manner in which individuals relate to their surroundings can significantly influence their interpretation of various acoustic stimuli, particularly those generated by anthropogenic activities, such as vehicular traffic, construction, and industrial operations. This relationship is frequently contextualized within the framework of sense of place theory, which emphasizes the emotional and cognitive connections individuals form with specific locations. These connections are deeply rooted in personal experiences, cultural backgrounds, and social interactions, all of which contribute to how one perceives and responds to environmental stimuli.

According to the study of Carson, et al., (2020), the perception of environmental stimuli plays a pivotal role in evaluating the effects of noise pollution. An individual's relationship with their surroundings can profoundly affect their interpretation of various acoustic phenomena, especially those originating from human-induced sources. This interaction is frequently examined through the lens of sense of place theory, which underscores the affective and cognitive bonds people form with particular environments. In addition of their study, the theoretical framework suggests that the significance individuals ascribe to their surroundings can influence their reactions to auditory input, including the mechanical noises characteristic of urban settings. This perspective is consistent with the proposed conceptual model grounded in sense of place theory, which posits that individuals who possess strong environmental place meanings are more inclined to categorize mechanical anthropogenic sounds as noise pollution. Conversely, those with robust socio-cultural place attachments may be less prone to perceive potentially detrimental sounds as noise (Carson et al., 2020). Understanding these dynamics is essential for developing effective strategies to mitigate noise pollution and to enhance the overall well-being of urban residents.

While, in densely populated urban areas, such as Puducherry, South India, where rapid development frequently coincides with an increase in vehicular traffic and construction projects, understanding how residents perceive and experience noise pollution is crucial for effective urban planning and public health initiatives. A recent study conducted in Puducherry revealed that a significant portion of the population considers noise pollution to be a major concern, with many residents identifying traffic noise as the primary source of disturbance in their daily lives Bhattacharya et al., (2023). The findings of this study underscore the importance of community awareness and engagement in addressing noise pollution because individuals' perceptions can vary widely based on their socioeconomic status, education level, and proximity to noise sources. The results indicate that two-thirds of the respondents were aware of noise pollution, and half of them experienced it in their local area. The majority of the participants reported feeling disturbed by the noise. More than half the participants were unaware of the rules and regulations regarding noise pollution. Employees tend to be more aware of noise pollution issues than those who are unemployed, as many of them work outdoors. Furthermore, individuals with formal education have a greater awareness of noise pollution problems than those who lack formal education. Residents located within 200 m of the road experience noise pollution issues at a much higher rate than those living more than 200 m away, with prevalence rates of 82.5% and 14.7%, respectively. Furthermore, according to the study of Bhattacharya, et al., (2023) it highlights the need for targeted interventions such as sound barriers, improved urban design, and stricter regulations on noise emissions to mitigate the impact of noise pollution on residents' health and well-being.

The perception of noise pollution is deeply influenced by individuals' emotional and cognitive connections to their surroundings, as explored through the framework of sense of place theory. Carson et al. (2020) suggest that people with strong environmental place meanings are more likely to perceive mechanical anthropogenic sounds, such as traffic or construction noise, as pollution, while those with socio-cultural place attachments may view such sounds less negatively. Similarly, Bhattacharya et al. (2023) highlight that noise perception varies widely based on factors like socioeconomic status, education, and proximity to noise sources, with urban residents in Puducherry reporting traffic as the primary source of disturbance. Notably, individuals with formal education and outdoor occupations tend to have greater awareness of noise pollution, but more than half of respondents were unaware of existing noise regulations. These findings emphasize the need for targeted interventions, such as sound barriers, urban planning improvements, and stricter regulations. However, gaps remain in understanding how cultural and social contexts shape noise perception across diverse populations and in implementing comprehensive, community-specific strategies to mitigate noise pollution's impact on health and well-being.

2.2.3 Economic and Social Impacts

The escalating concern regarding noise pollution in urban environments underscores its pervasive nature and frequently overlooked consequences on individuals and communities. This persistent exposure to elevated noise levels can disrupt tranquility that many individuals seek in their daily lives, potentially leading to a range of adverse outcomes.

According to the study of Karki et al., (2024), this can lead to social impairments, reduced productivity, and maladaptive social behavior. Noise can disrupt the enjoyment of domestic life and leisure activities, potentially leading to an increase in antisocial behavior. Similar to prolonged stress, exposure to noise can adversely affect overall health and wellbeing. The impact of noise on social interactions and behavior is complex, with both subtle and indirect effects. These complexities highlight the necessity to understand how noise pollution influences not only individual health but also community dynamics. Changes in everyday behavior (e.g., closing windows and doors to reduce outside noise; avoiding the use of balconies, patios, and yards; and increasing the volume of radio and television sets); changes in social behavior (e.g., aggressiveness, unfriendliness, nonparticipation, or disengagement); changes in social indicators (e.g., residential mobility, hospital admissions, drug consumption, and accident rates); and mood changes (increased reports of depression). In summary, it establishes the foundation for a more comprehensive exploration of the multifaceted effects of noise pollution, urging readers to consider its implications not only for individual health but also for the social fabric of communities.

On the otherhand, according to the study of Frufonga, & Sulleza, (2017), the development of Iloilo International Airport has initiated a new era of economic growth and transformation in the surrounding region. As a key infrastructure project, the airport has not only enhanced connectivity, but has also stimulated various sectors of the local economy. With the influx of travelers and businesses, the area has experienced a significant increase in demand for services and amenities, resulting in a dynamic economic landscape. This transformation has intensified competition among local enterprises as they endeavor to capitalize on the opportunities presented by increased air traffic and tourism. Iloilo International Airport's economic influence has intensified competition in the labor market, affecting various aspects such as employee compensation, income levels, savings rates, and living expenses. The value of land in the vicinity of airports has increased significantly. In addition, former agricultural areas have progressively been transformed into residential and commercial properties Frufonga, & Sulleza, (2017). The airport's establishment has spurred a significant proliferation of diverse business ventures in the surrounding area, as exemplified by the notable inception of the School of Aeronautics. This educational institution has not only enhanced the local academic landscape but has also generated numerous employment opportunities for residents and attracted job seekers from neighboring communities. These institutions contribute to the development of a skilled workforce, further bolstering the region's economic prospects. Furthermore, the surge in both domestic and international tourism has profoundly impacted the community's financial well-being. The influx of visitors has led to increased demand for local goods and services, stimulating the growth of small businesses and artisanal producers. This tourism boom not only enhances sales, but also promotes local cultural heritage, fostering a vibrant marketplace that benefits the entire community. The economic ripple effects of airport development are evident in the thriving job market and improved income opportunities for residents, contributing to a more prosperous and dynamic local economy Frufonga, & Sulleza, (2017).

Moreover, chronic exposure to elevated noise levels can result in stress, anxiety, and other health issues that may diminish an individual's capacity to perform effectively in the workplace. However, the economic ramifications of noise pollution are frequently underestimated despite their potential to influence the overall productivity and profitability of enterprises. In addition, in the study of Ukwu, (2024) the direct effects on employee health, noise pollution can impede communication and concentration, further diminishing workplace efficiency. Employees in acoustically challenging environments may experience difficulty in maintaining a focus on their tasks, potentially resulting in errors and reduced productivity. This decline in output can have cascading consequences on a company's financial performance, as project completion times may be extended, and customer satisfaction may decrease. Furthermore, organizations may encounter elevated turnover rates, as employees seek more acoustically favorable work environments, leading to additional expenses associated with the recruitment and training of new personnel. Understanding the relationship between noise pollution and economic performance is crucial for both policymakers and business leaders as it can guide efforts to foster healthier work environments and improve employee well-being. By implementing soundproofing measures, adopting flexible work arrangements, or relocating operations to less sonically disruptive areas, companies can mitigate the adverse effects of noise pollution. The economic ramifications of noise pollution are substantial. Companies situated in high-noise areas may face decreased productivity owing to adverse health effects on their employees, resulting in increased health-related expenses and diminished economic performance Ukwu, (2024). Addressing noise pollution not only benefits individual workers, but also contributes to a more resilient and sustainable economy as a whole.

Noise pollution in urban environments has far-reaching consequences for individuals and communities, disrupting tranquility, reducing productivity, and impairing social behavior. Karki et al. (2024) highlight its complex impacts, including increased antisocial behavior, mood changes, and adverse health outcomes, such as stress and depression, which collectively strain community dynamics and quality of life. Frufonga and Sulleza (2017) explore how airport development, as seen with Iloilo International Airport, stimulates regional economic growth but also transforms land use and intensifies competition for resources. While this growth creates employment opportunities and boosts tourism, it may exacerbate the noise pollution that disrupts daily life. Ukwu (2024) underscores the underestimated economic consequences of noise pollution, which impairs workplace efficiency, increases turnover rates, and raises operational costs, negatively affecting company productivity and profitability. Despite its pervasive effects, gaps remain in integrating noise pollution mitigation with urban planning, evaluating long-term economic impacts, and implementing strategies to balance economic benefits with health and social well-being.

2.2.4 Community Awareness

Chronic exposure to elevated noise levels can result in stress, anxiety, and other health issues that may diminish an individual's capacity to perform effectively in the workplace. However, the economic ramifications of noise pollution are frequently underestimated despite their potential to influence the overall productivity and profitability of enterprises. In addition, in the study of Ukwu, (2024) the direct effects on employee health, noise pollution can impede communication and concentration, further diminishing workplace efficiency. Employees in acoustically challenging environments may experience difficulty in maintaining a focus on their tasks, potentially resulting in errors and reduced productivity. This decline in output can have cascading consequences on a company's financial performance, as project completion times may be extended, and customer satisfaction may decrease. Furthermore, organizations may encounter elevated turnover rates, as employees seek more acoustically favorable work environments, leading to additional expenses associated with the recruitment and training of new personnel. Understanding the relationship between noise pollution and economic performance is crucial for both policymakers and business leaders as it can guide efforts to foster healthier work environments and improve employee well-being. By implementing soundproofing measures, adopting flexible work arrangements, or relocating operations to less sonically disruptive areas, companies can mitigate the adverse effects of noise pollution. The economic ramifications of noise pollution are substantial. Companies situated in high-noise areas may face decreased productivity owing to adverse health effects on their employees, resulting in increased health-related expenses and diminished economic performance Ukwu, (2024). Addressing noise pollution not only benefits individual workers, but also contributes to a more resilient and sustainable economy as a whole.

Moreover, in contemporary urban environments, the persistent cacophony of vehicular traffic, construction activities, and social interactions has transformed urban areas into acoustic landscapes that can be overwhelming. While many urban residents recognize the nuisance of excessive noise, a comprehensive understanding of its implications, ranging from psychological stress to economic consequences, remains limited for a substantial portion of the population. This knowledge gap is particularly evident when examining disparities between various demographic groups such as gender.

In the study of Bala, & Verma (2020), the findings of the study indicate that males exhibit a higher level of awareness regarding noise pollution than females. However, a substantial portion of the population, particularly in urban environments, remains uninformed about the nature of noise pollution and its detrimental effects on health and socioeconomic factors. This deficiency in understanding underscores a significant knowledge gap that requires attention. Insufficient comprehension of the adverse effects of noise pollution has impeded efforts to mitigate it. Consequently, it is imperative for individuals to recognize the negative ramifications of noise pollution on their well-being. Increasing public awareness of these consequences is essential to effectively address this issue. In addition to the study of Bala, & Verma (2020), this identified traffic and loudspeaker sounds as significant contributors to outdoor noise pollution. Specifically, the increase in "traffic volume" from road, rail, and air transportation has become increasingly recognized as a substantial threat to human health. Television and various household appliances significantly contribute to indoor noise pollution. The study determined that the proportion of females compared to males was nearly identical for each noise source. This observation suggests that both genders are equally affected by indoor pollutants. Consequently, the percentage variation in noise exposure between the male and female populations was minimal. Overall, the findings indicate that indoor noise affects both sexes in a similar manner. This study emphasizes that adolescents are significantly affected by noise pollution. It examines the various ways in which noise can affect human health and well-being. These findings indicate that both male and female populations are equally susceptible to the negative consequences of noise exposure. This suggests that the adverse effects of noise are not sex specific. Ultimately, the study Bala, & Verma (2020) highlights the widespread risk that noise pollution poses to individuals across all age groups. Noise pollution engenders a range of adverse outcomes, including annoyance, sleep disruption, auditory impairment, reduced work efficiency, and communication difficulties.

Ukwu (2024) highlights how noise pollution hampers communication and concentration, causing errors, reduced productivity, and higher turnover rates, which result in increased recruitment costs and diminished financial performance. Effective mitigation strategies, such as soundproofing and flexible work arrangements, can improve employee well-being and foster a more resilient economy. In urban environments, noise from traffic, construction, and social activities creates overwhelming acoustic landscapes. Bala and Verma (2020) found that both males and females are equally affected by indoor and outdoor noise pollution, with adolescents particularly vulnerable to its negative effects. Despite these widespread impacts, a lack of awareness persists, with many urban residents uninformed about noise pollution's detrimental health and socioeconomic consequences. This knowledge gap hampers mitigation efforts, emphasizing the need for targeted awareness campaigns and interventions.

2.3 Potential Impacts of Noise Pollution on Public Health

2.3.1 Physical Health Effects

On a worldwide scale, there is an increasing concern about noise pollution, particularly in urban areas where noise levels have risen due to rapid industrialization and urbanization. One of the key physical health effects of noise pollution is its association with cardiovascular issues. Münzel (2014) determined the cardiovascular effects of environmental noise exposure. The article underscores that exposure to environmental noise is not only associated with an increased incidence of cardiovascular diseases but also with a higher prevalence of arterial hypertension, a primary risk factor for cardiovascular morbidity. In addition to these effects, noise pollution has been linked to the exacerbation of pre-existing health conditions, disturbances in sleep patterns, and an overall decline in quality of life. This expanding body of evidence emphasizes the pervasive and detrimental impact of noise on both physical health and general well-being. Such claims are supported by a substantial body of research, including extensive epidemiological studies, controlled laboratory experiments, and observational field investigations. One key mechanism connecting long-term exposure to noise with adverse health outcomes is the disruption of sleep caused by noise. These findings highlight the pressing need for more concerted efforts to reduce environmental noise exposure, not only to safeguard public health but also to alleviate the growing burden of cardiovascular diseases and other related health conditions.

In the Philippines, noise pollution has a major negative impact on people's physical health, especially in urban areas and common learning environments. Abellana and Abellana (2021) assert that excessive noise pollution has a detrimental impact on cognitive development within educational settings, which can, in turn, affect their academic performance and long-term opportunities. This form of environmental stressor extends beyond educational environments and significantly influences the daily lives of residents, particularly in urban areas. In these regions, public transportation systems, especially trains, represent a major source of noise pollution. The persistent exposure to elevated noise levels has been shown to have adverse effects on both the mental and physical health of the community, contributing to conditions such as stress, hypertension, and sleep disturbances. In the context of the Philippines, where economic activities are concentrated in urban areas that are characterized by high levels of noise, the public health implications of this issue are especially troubling and warrant urgent attention.

Münzel (2014) emphasizes its detrimental effects on physical health, including associations with cardiovascular diseases, arterial hypertension, and sleep disturbances, which collectively degrade quality of life. Long-term exposure to noise disrupts sleep, a critical mechanism linking noise to adverse health outcomes, highlighting the urgent need for targeted interventions to reduce environmental noise and alleviate the burden of cardiovascular conditions. In the Philippines, noise pollution also impacts cognitive development, as Abellana and Abellana (2021) note that excessive noise in educational environments impairs academic performance and long-term opportunities. Moreover, persistent urban noise from transportation systems exacerbates stress, hypertension, and sleep disruptions in communities. These findings underscore the urgent need for public health interventions and urban planning strategies to mitigate the pervasive impacts of noise pollution on mental and physical well-being globally and locally. However, gaps remain in developing localized mitigation strategies, conducting longitudinal studies on cumulative noise effects, and integrating noise management into comprehensive urban planning efforts.

2.3.2 Mental and Psychological Health Impacts

Numerous psychological and physiological problems have been connected to noise pollution. Stress, anxiety, and depression are common in congested city areas and can be exacerbated by prolonged noise exposure. The study of (Floroian et al., 2022) indicates the significant link between noise-induced discomfort and an increased prevalence of anxiety and depression, with affected individuals experiencing twice the rate of these mental health issues compared to the general population. The research further demonstrates that noise exposure contributes to a range of health problems, including sleep disturbances, fatigue, the onset of cardiovascular disease, and, notably, hearing loss. A variety of negative emotional and psychological responses, such as anger, frustration, loneliness, feelings of helplessness, anxiety, sadness, difficulty concentrating, exhaustion, and agitation, have all been associated with noise pollution. These detrimental effects are often amplified when individuals perceive a lack of control over the noise they are exposed to. The sense of powerlessness in managing or escaping chronic noise can heighten stress levels, potentially leading to more severe mental health outcomes, including long-term anxiety and depression. Although noise pollution is widely recognized for exacerbating and accelerating the onset of latent mental health conditions, it is not considered a direct cause of mental illness. However, it can contribute to or intensify symptoms of anxiety, tension, irritability, headaches, mood swings, social friction, and in extreme cases, hysteria, neurosis, and psychosis. The pervasive nature of noise pollution poses a public health risk to the entire population, with its far-reaching impact on both mental and physical well-being. The difficulty in managing noise pollution underscores the urgent need for the implementation of targeted, effective measures aimed at reducing its prevalence. Addressing this issue requires not only regulatory policies and urban planning reforms but also a concerted effort to mitigate the broader social and psychological consequences associated with prolonged exposure to environmental noise.

Additionally, in the study of Camarillo et al. (2021), exposure to transportation noise has been shown to impair students' ability to recover from short-term memory loss. As transportation noise is a significant contributor to disruptions in students' well-being and attentional capacities in the classroom, it is imperative to address these noise sources immediately. Extensive research on noise pollution indicates that environmental noise adversely affects communication and concentration, particularly in educational settings. Campuses, as the common center of various noise sources, including sounds from electrical equipment, laboratories, and recreational activities, are frequently impacted by these disruptions. Such noise disturbances are often perceived as significant impediments to students' ability to focus, engage with course material, and perform academically. Prolonged exposure to these environmental stressors can lead to cognitive impairments, reduced academic achievement, and increased levels of psychological stress. Consequently, effective management of noise on educational campuses is essential for fostering an optimal learning environment and supporting students' overall well-being and academic success.

Mesene et al. (2022) emphasize that unwanted noise degrades living conditions, hinders verbal communication, and erodes social connections, leading to isolation and emotional distress. Persistent noise exposure reduces productivity, job satisfaction, and overall life quality. However, limited public awareness and recognition of noise pollution as a serious issue hinder effective mitigation strategies. Kumar and Naik (2022) highlight societal consequences, including stress, anxiety, irritability, and behavioral abnormalities like aggression and social withdrawal, which diminish social engagement and community cohesion. Chronic noise exposure impairs cognitive functions, such as attention and memory, exacerbating psychological dysfunctions and undermining social capital. These findings reveal gaps in addressing the societal effects of noise pollution, fostering public awareness, and developing policies to protect social bonds and community resilience. Targeted interventions and educational initiatives are essential to mitigate these widespread impacts and preserve social well-being.

2.3.3 Social and Behavioral Consequences

Noise pollution affects social relations and the quality of living environments, disturbing spoken communication and work performance (Mesene et al., 2022). The study highlights that unwanted and disruptive noises can significantly degrade living conditions, hinder verbal communication, and disturb social relationships. These disruptions not only affect daily interactions but may also have a cumulative impact on mental health, contributing to heightened levels of stress and anxiety. Over time, chronic exposure to noise can erode the quality of social connections, potentially leading to isolation and a decline in emotional well-being. Persistent noise pollution negatively affects productivity and concentration, thereby reducing work performance and job satisfaction. Consequently, the long-term effects of noise extend beyond immediate discomfort, potentially diminishing both individual and collective life satisfaction. Notably, despite the clear social and psychological issues associated with noise pollution, the general public often demonstrates a limited understanding of its causes and consequences. Government officials and the public may fail to recognize noise pollution as a serious problem, highlighting the need for enhanced awareness and public engagement to effectively address this issue (Mesene et al., 2022). This gap between the perceived and actual severity of noise pollution complicates the implementation of effective mitigation strategies, underscoring the importance of targeted policy interventions and educational initiatives.

In addition, noise pollution has numerous societal consequences, such as effects on mental health, sleep problems, and psychological dysfunctions that may show up as poor social behavior. (Kumar & Naik, 2022). Individuals who are regularly exposed to environmental noise tend to experience higher levels of stress, anxiety, and irritability, often exhibiting exaggerated emotional responses to minor stimuli. This persistent state of heightened physiological arousal can disrupt social interactions, increasing the likelihood of conflict and diminishing the ability to cultivate meaningful and supportive relationships. Furthermore, chronic exposure to noise and the associated sleep disturbances can impair cognitive functions such as attention, memory recall, and decision-making, thereby negatively affecting both personal and professional performance. Psychological dysfunctions induced by noise pollution can manifest in various behavioral abnormalities, including aggression, social withdrawal, and a general decline in social engagement. As these detrimental behaviors become more prevalent, communities may experience a erosion of social capital—defined as the trust, cooperation, and shared norms that underpin social cohesion. This degradation of social bonds further exacerbates the negative mental health impacts of noise, creating a cycle that is difficult to break. The broader societal implications of noise pollution thus extend beyond individual well-being, potentially undermining the social fabric and community resilience.

Noise pollution significantly impacts social relations and living environments by disrupting communication, work performance, and overall mental well-being. Persistent exposure to disruptive noise contributes to stress, anxiety, and sleep disturbances, which can degrade social bonds, impair cognitive functions, and hinder emotional well-being. The cumulative effects of noise pollution manifest as aggression, social withdrawal, and diminished social engagement, eroding social capital and community cohesion over time. Despite these issues, public awareness of the causes and consequences of noise pollution remains limited, complicating efforts to implement effective mitigation strategies. Research gaps include the lack of comprehensive public engagement, inadequate policy interventions tailored to community-specific needs, and insufficient understanding of the long-term societal consequences of chronic noise exposure.

2.3.4 Vulnerable Population

Noise pollution poses a significant threat to public health, with particularly pronounced effects on vulnerable populations. The study by Kumar and Naik (2022) suggests that exposure to high levels of noise (≥ 80 dB) during pregnancy is significantly associated with an increased risk of adverse outcomes, such as congenital abnormalities, gestational hypertension, and the birth of small-for-gestational-age infants. While noise pollution was linked to a higher incidence of preterm delivery, spontaneous abortion, perinatal death, and preeclampsia, these associations did not reach statistical significance. Residents, in particular, are highly vulnerable to the effects of noise pollution, with various health conditions and dysfunctions identified as being linked to prolonged noise exposure. These include hearing loss, cognitive impairments, psychological disturbances, and difficulties with learning and comprehension. Additionally, noise pollution has been implicated in exacerbating age-related conditions such as dementia, suggesting that its long-term effects may extend well beyond early childhood into later life.

Similarly, the study by Millar (2020) further emphasizes that residents are particularly susceptible to the adverse health effects of noise pollution. In environments characterized by persistent unwanted or loud noise, such as homes or schools, learners may experience significant challenges in learning, as such noise disrupts their ability to concentrate, develop communication skills, and perform cognitively. These disruptions can also impact a child's self-confidence, behavior, and social interactions, potentially hindering their emotional and social development. Chronic exposure to environmental noise has been associated with increased risks of physiological issues, including elevated blood pressure, which can compound the negative effects on overall health. Moreover, sustained exposure to noisy environments over time may lead to long-term developmental difficulties, highlighting the urgent need for effective noise management strategies in spaces where residents spend considerable amounts of time.

While, the article published in The Indian Journal of Pediatrics underscores that noise pollution can adversely affect a child's development at various stages, from fetal development through to adolescence. Due to their heightened developmental sensitivity, these populations should be prioritized in the implementation of noise pollution mitigation strategies to ensure the preservation of their physical and psychological well-being. Such targeted interventions are essential in minimizing the long-term detrimental effects of noise on early childhood development and overall health outcomes.

Furthermore, Hassan (2024) highlights that noise pollution is a pervasive environmental issue with significant and detrimental effects on public health. It exerts a considerable impact on both mental and physical health, particularly through its association with increased risks of cardiovascular diseases, hearing impairment, sleep disturbances, and cognitive deficits. These health consequences can hinder cognitive development, especially among vulnerable populations such as the young and the elderly. Given the heightened sensitivity of these groups to noise exposure, the cumulative effects of chronic noise pollution are of particular concern, necessitating targeted interventions and more stringent noise regulation policies to safeguard public health.

Noise pollution significantly threatens public health, with its effects being particularly severe for vulnerable populations. Kumar and Naik (2022) associate high noise exposure during pregnancy with congenital abnormalities, gestational hypertension, and other adverse outcomes, learning difficulties, and psychological disturbances due to chronic noise. Millar (2020) highlights that noise in homes and schools disrupts concentration and emotional development, increasing risks of elevated blood pressure and long-term developmental challenges. Hassan (2024) underscores the broader impacts of noise pollution, including cardiovascular diseases, sleep disturbances, and cognitive deficits. Despite these findings, gaps remain in understanding the cumulative long-term effects of noise pollution across life stages, developing tailored mitigation strategies for vulnerable groups, and implementing robust regulatory measures to manage environmental noise effectively.

3. RESEARCH METHODOLOGY

3.1 Study Area

This study focused on Tuguegarao Domestic Airport in Cagayan, Philippines. As a key transportation hub, it supports domestic flights and boosts the local economy. However, rapid population growth and urbanization have led to noise pollution issues. With the airport near residential areas, assessing its health impact is highly relevant.

3.2 Research Design

This study used a descriptive-inferential research design to assess noise pollution from Tuguegarao Domestic Airport and its health impacts. The descriptive part involved measuring noise levels with a Benetech GM1358 sound level meter and modeling the data in QGIS to create spatial noise maps, categorized as safe to highly unsafe.

The inferential part involved surveying residents in noise-affected areas to compare reported health issues with measured noise levels. This integration of objective data and subjective responses supported data-driven recommendations for noise mitigation and public health action.

3.3 Sample Population

The sample population consisted of residents living in areas affected by noise pollution from Tuguegarao Domestic Airport. These zones were identified through noise intensity modeling, highlighting areas exposed to borderline and unsafe levels based on health standards. The study focused on individuals who regularly reside or spend significant time in these areas, including a range of age groups

3.4 Sample Technique and Sample Size

This study used purposive sampling to intentionally select residents living near Tuguegarao Domestic Airport who were directly exposed to noise pollution. While the target was 30–50 respondents per zone, actual numbers varied by availability, leading to unequal distribution. However, data were collected from all noise levels to allow valid comparisons. Efforts were made to ensure sufficient sample sizes per zone to maintain statistical relevance and reflect real-world conditions.

3.5 Data Collection

3.5.1 Identifying Points for Data Collection

Noise measurement points were strategically selected within and around Tuguegarao Domestic Airport based on expected impact areas. Measurements were taken above 2 meters in open spaces using a Benetech GM 1358 sound level meter during aircraft operations. Noise modeling defined the spatial extent of the affected area, which became the study area.

3.5.2 Categorizing Noise Levels and Health Risks

After noise intensity was gathered and modeled, it was categorized as safe, borderline, unsafe, or highly unsafe based on health noise standards, often aligned with WHO guidelines. These thresholds help identify potential health risks at each noise level. The table below summarizes the associated health risks.

Category	Noise Level (dB)	WHO Guideline Basis	Potential Health Impacts
Safe	Below 60 dB	Below recommended levels for community environments	No risk of hearing damage Supports cognitive function and relaxation Healthy sleep
Borderline	60 - 75 dB	Exceeds optimal levels; approaching risk thresholds	May cause difficulty concentrating Mild stress Reduced productivity over long exposure
Unsafe *(Risky)*	75 – 85 dB	Above health-based limits; considered harmful	Hearing fatigue Speech perception difficulties Increased stress Reduced cognitive performance
Highly Unsafe	Above 85 dB	Significantly above WHO thresholds	Risk permanent hearing loss Tinnitus (ringing in ears) Cardiovascular strain Increased anxiety Sleep disturbance

Table 1

3.5.3 Conducting a Survey to Assess Vulnerability

A survey was conducted among residents in noise-affected areas to assess reported concerns and determine if predicted health impacts matched actual experiences. This provided empirical validation of the model and a clearer understanding of noise-related health effects in the community.

3.6 Study Variable

3.6.1 Dependent Variables

Public Health Impacts: This included health issues (e.g., hearing problems, stress, or other health effects) caused by prolonged exposure to aircraft noise. The study assessed how noise pollution affects the well-being of residents near Tuguegarao Domestic Airport.

Noise Exposure Levels: The study measured the noise levels experienced by communities around the airport using decibel meters. Noise mapping helped identify high-exposure areas and categorize noise levels as safe, borderline, unsafe, or highly unsafe.

3.6.2 Independent Variables

Proximity to the Airport: The study analyzed how distance from the airport affects noise exposure.

Frequency of Aircraft Operations: The number of aircraft takeoffs and landings during the measurement period was expected to impact the noise intensity.

Time of Day: Noise levels varied depending on the time of measurement, influenced by operational schedules.

3.7 Data Processing Analysis

To do detailed data processing and analysis, the following steps will be followed:

Step 1. Measure Noise Intensity

Noise levels were measured at selected points around the Tuguegarao Domestic Airport, capturing sound intensities during aircraft operations using the Benetech GM 1358 sound level meter. This device provided accurate readings of aerodynamic noise generated by the airport.

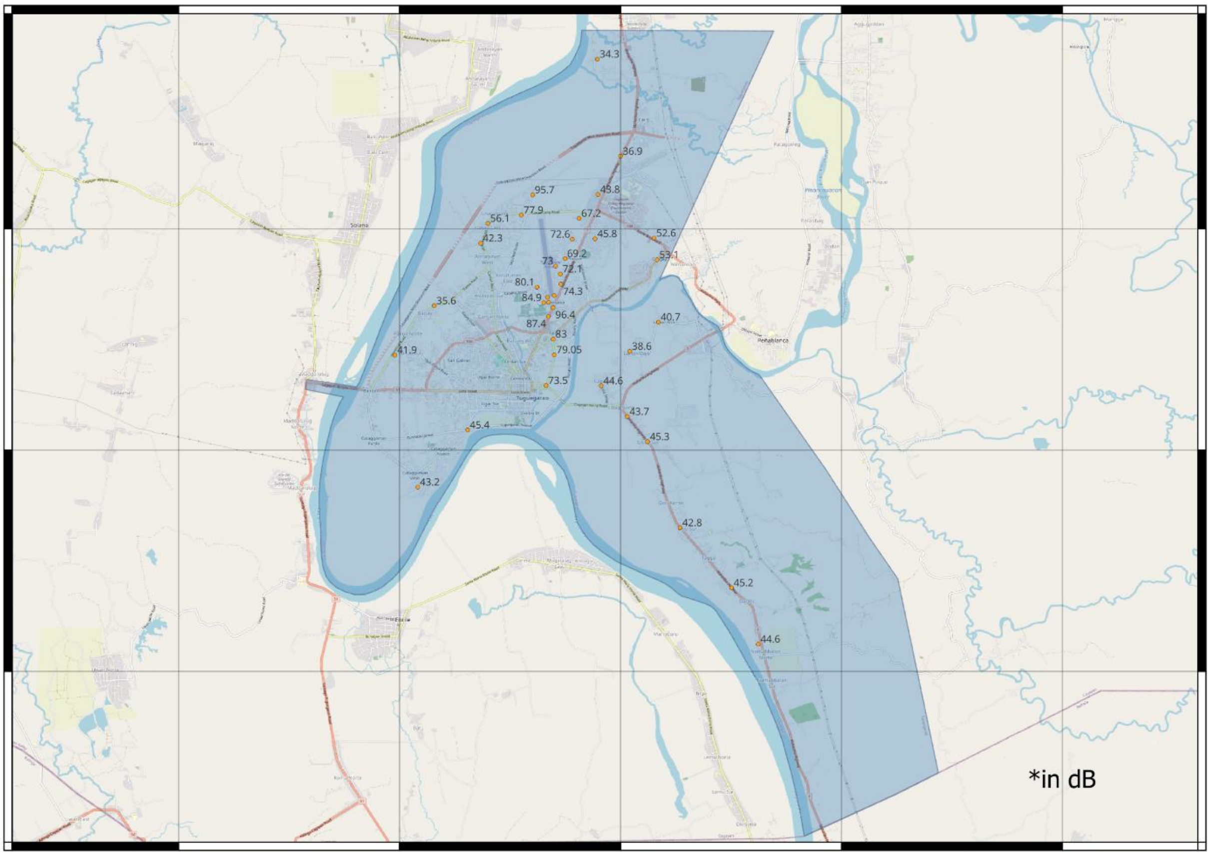

Figure 1

Step 2: Noise Modelling

The collected noise data were analyzed in QGIS to model spatial noise distribution around the airport. Noise levels were categorized as Safe, Borderline, Unsafe, and Highly Unsafe based on environmental noise standards. The procedure included:

1) Importing Data: Noise readings with coordinates were imported into QGIS via the Delimited Text Layer tool, mapping them as point features.
2) Interpolating Data: IDW interpolation was used to generate a continuous raster surface of noise intensity.
3) Clipping Raster: The interpolated raster was clipped to the study area boundary to focus analysis on the airport and surroundings.
4) Classifying Noise: The Raster Calculator classified noise into the four categories based on health standards.
5) Classifying Noise: The Raster Calculator classified noise into the four categories based on health standards.

This structured approach enabled a clear visualization and assessment of noise impact zones around the airport.

Step 3: Health Risk Assignment

Each noise intensity category will be assigned a predicted health risk level according to recognized noise exposure thresholds. These risk levels will range from minimal or low risk in Safe zones to high risk in Highly Unsafe zones, reflecting potential adverse health effects such as hearing impairment, stress, and cardiovascular problems.

Step 4: Model Validation with Health Impact Data

To validate the noise model, residents from different noise zones were surveyed on self-reported health impacts. The prevalence and severity of symptoms were compared across Safe, Borderline, Unsafe, and Highly Unsafe zones using one-way ANOVA. Data were analyzed in SPSS to assess whether predicted impacts aligned with actual experiences, validating the model and enhancing understanding of noise-related health effects. Conclusions were drawn based on the results.

4. RESULTS AND DISCUSSION

4.1 Measured Aerodynamic Noise

The study measured aircraft noise during both take-off and landing at 39 distinct locations around Tuguegarao. The raw data presented below were obtained using the Benetech GM 1358 sound level meter.

Baranggay	Latitude	Longitude	Landing (dB)	Take-off (dB)	AVG (dB)	Total AVG (dB)
Leonarda	17.632202	121.734732	104.1	88.6	96.35	91.875
	17.6302	121.73365	92.2	82.6	87.4	
Tanza	17.626506	121.735196	91.1	81.5	86.3	84.65
	17.625105	121.734758	89.3	76.7	83	
Diversion	17.621561	121.734979	84.6	73.5	79.05	79.05
Pengue	17.63341	121.73373	96.9	96.9	96.9	77.82
	17.63333	121.73263	85.6	84.2	84.9	
	17.63751	121.73647	86.4	62.9	74.65	
	17.63981	121.73637	55.6	63	59.3	
	17.64329	121.73743	63.4	57.4	60.4	
	17.64159	121.73531	78.4	67.6	73	
	17.64766	121.73908	75.3	72.6	73.95	
	17.63495	121.73496	89.7	85.3	87.5	

	17.63683	121.73107	83.1	77.1	80.1	
	17.63455	121.73347	90.5	84.5	87.5	
Linao	17.65768	121.7301	98.7	92.7	95.7	76.57
	17.65312	121.72754	80.9	74.9	77.9	
	17.65124	121.72000	59.1	53.1	56.1	
Centro 11	17.61461	121.73314	78.8	72.8	75.8	75.8
Carig	17.64776	121.74423	48.8	42.8	45.8	49.26
	17.65238	121.7406	70.2	64.2	67.2	
	17.65777	121.74487	46.8	40.8	43.8	
	17.66644	121.74998	39.9	33.9	36.9	
	17.64791	121.75758	55.6	49.6	52.6	
Cataggaman Nuevo	17.60458	121.71537	48.4	42.4	45.4	45.4
Dadda	17.56892	121.77512	48.2	42.2	45.2	45.2
Capatan	17.61456	121.7456	47.6	41.6	44.6	44.6
Nambbalan Norte	17.55616	121.78115	47.6	41.6	44.6	44.6
Libag	17.60761	121.7515	46.7	40.7	43.7	44.5
	17.60191	121.75611	48.3	42.3	45.3	
Cataggaman Viejo	17.59164	121.70412	46.2	40.2	43.2	43.2
Gosi	17.5825	121.76346	45.8	39.8	42.8	42.8
Annafunan	17.64676	121.71833	45.3	39.3	42.3	42.3
Pallua	17.62149	121.69895	44.9	38.9	41.9	41.9
Larion Bajo	17.62234	121.7521	41.6	35.6	38.6	38.6
Bagay	17.63266	121.70781	38.6	32.6	35.6	35.6
Larion Alto	17.62893	121.75856	43.7	37.7	40.7	40.7

Table 2

The highest average noise level was recorded in Barangay Leonarda at 91.875 dB, followed by Pengue (77.82 dB) and Linao (76.57 dB), indicating high aircraft noise exposure. The peak value was 104.1 dB during a landing in Leonarda. Moderate levels were observed in Tanza (84.65 dB), Diversion (79.05 dB), and Centro 11 (75.8 dB), suggesting potential impacts depending on exposure frequency. The lowest levels were in Bagay (35.6 dB), Larion Bajo (38.6 dB), and Pallua (41.9 dB), all below the 50 dB safety threshold.

4.2 Model and Categorization of Spatial Distribution

The study utilized QGIS to model the measured noise levels through interpolation and categorized the affected areas into four zones: Highly Unsafe (above 85 dB), Unsafe (70–85 dB), Borderline (60–70 dB), and Safe (below 60 dB).

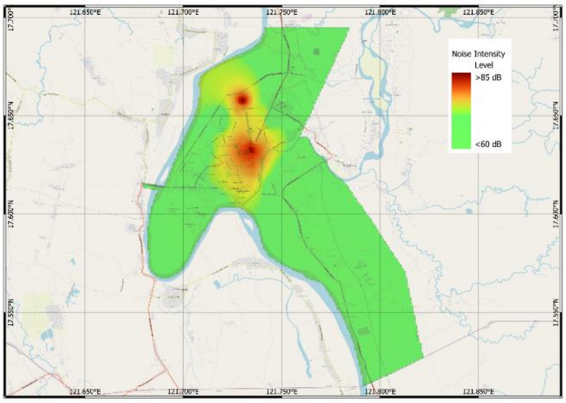

Figure 2

The map shows that central Tuguegarao barangays—Leonarda, Pengue, and Tanza—fall within the Highly Unsafe and Unsafe zones, experiencing high noise levels, especially during landings and takeoffs. Leonarda, for instance, averaged 96.35 dB, far above the safe threshold. In contrast, farther barangays like Gosi, Capatan, Dadda, and Cataggaman Viejo remain within the Safe zone, with levels below 60 dB. Noise intensity decreases with distance from the airport, emphasizing the need for proper planning and mitigation in high-exposure areas.

4.3 Assigned Predicted Health Risk Levels to Noise Categories Based on Threshold

The study delineated boundaries between noise exposure zones and assigned corresponding health risk levels. The zones were color-coded as follows: green for low risk, yellow for moderate risk, orange for high risk, and red for very high risk.

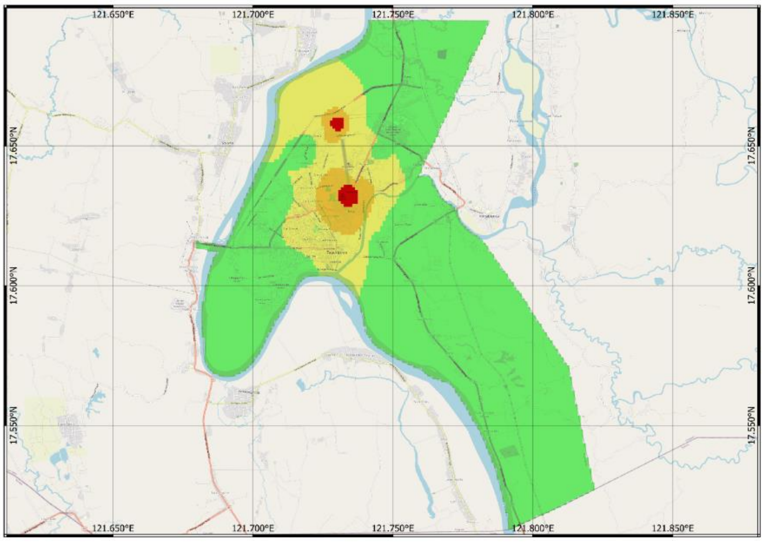

Figure 3

Barangay	Latitude	Longitude	AVG (dB)	Noise Category	Predicted Health Risk
Leonarda	17.632202	121.734732	96.35	Highly Unsafe	Very High
	17.6302	121.73365	87.4	Highly Unsafe	Very High
Tanza	17.626506	121.735196	86.3	Highly Unsafe	Very High
	17.625105	121.734758	83	Unsafe	High
Diversion	17.621561	121.734979	79.05	Unsafe	High
Pengue	17.63341	121.73373	96.9	Highly Unsafe	Very High
	17.63333	121.73263	84.9	Unsafe	High
	17.63751	121.73647	74.65	Borderline	Moderate
	17.63981	121.73637	59.3	Safe	Low
	17.64329	121.73743	60.4	Borderline	Moderate
	17.64159	121.73531	73	Borderline	Moderate
	17.64766	121.73908	73.95	Borderline	Moderate
	17.63495	121.73496	87.5	Highly Unsafe	Very High
	17.63683	121.73107	80.1	Unsafe	High
	17.63455	121.73347	87.5	Highly Unsafe	Very High
Linao	17.65768	121.7301	95.7	Highly Unsafe	Very High
	17.65312	121.72754	77.9	Unsafe	High
	17.65124	121.72000	56.1	Safe	Low
Centro 11	17.61461	121.73314	75.8	Unsafe	High
Carig	17.64776	121.74423	45.8	Safe	Low
	17.65238	121.7406	67.2	Borderline	Moderate
	17.65777	121.74487	43.8	Safe	Low
	17.66644	121.74998	36.9	Safe	Low
	17.64791	121.75758	52.6	Safe	Low
Cataggaman Nuevo	17.60458	121.71537	45.4	Safe	Low
Dadda	17.56892	121.77512	45.2	Safe	Low
Capatan	17.61456	121.7456	44.6	Safe	Low
Nambbalan Norte	17.55616	121.78115	44.6	Safe	Low

Libag	17.60761	121.7515	43.7	Safe	Low
	17.60191	121.75611	45.3	Safe	Low
Cataggaman Viejo	17.59164	121.70412	43.2	Safe	Low
Gosi	17.5825	121.76346	42.8	Safe	Low
Annafunan	17.64676	121.71833	42.3	Safe	Low
Pallua	17.62149	121.69895	41.9	Safe	Low
Larion Bajo	17.62234	121.7521	38.6	Safe	Low
Bagay	17.63266	121.70781	35.6	Safe	Low
Larion Alto	17.62893	121.75856	40.7	Safe	Low

Table 3

Barangays like Leonarda, Pengue, and parts of Tanza fall within the high-risk red zones, with noise levels above 85 dB posing serious health risks. Nearby areas in orange and yellow face moderate to high risks from 60–85 dB exposure. Outer barangays in green remain low-risk, with levels below 60 dB. This spatial analysis shows how airport noise disrupts daily life and poses significant health risks, especially for those near flight paths or airport infrastructure.

4.4 Validation of Noise Model by Analyzing Self-Reported Health Impact

4.4.1 Interpretation of Ratings on Reported Health Impacts

Table 4.4.1a Interpretation of Ratings on Reported Health Impacts in the Safe Zone

Descriptive Statistics		
	Mean	**Verbal Interpretation**
S1. The respondent tends to feel calm and mentally at ease when aircraft noise is minimal.	**4.33**	**Strongly Agree**
S2. The respondent is confident that the noise levels in their current environment pose no risk to their hearing.	**4.55**	**Strongly Agree**
S3. The respondent usually reports restful sleep, uninterrupted by airplane noise.	**4.38**	**Strongly Agree**
S4. The respondent does not associate physical symptoms such as headaches or fatigue with aircraft noise.	**4.55**	**Strongly Agree**
S5. Low aircraft noise appears to have no effect on the health or comfort of the respondent.	**4.67**	**Strongly Agree**

Table 4.4.1a showed that respondents in the safe zone strongly agreed that they experienced minimal to no health impacts due to noise exposure, with all mean values greater than 4.21 and interpreted as Strongly Agree.

Table 4.4.1b Interpretation of Ratings on Reported Health Impacts in the Borderline Zone

	Mean	Verbal Interpretation
B1. The respondent sometimes finds it harder to focus due to frequent but moderate aircraft noise	**3.12**	**Neutral**
B2. The respondent may feel mild stress or irritation during times of regular airplane activity	**2.65**	**Neutral**
B3. The respondent occasionally reports headaches, tiredness, or mood changes linked to aircraft noise.	**2.94**	**Neutral**
B4. Tasks that require concentration—like studying or working—may be more difficult for the respondent.	**3.79**	**Agree**

Table 4.4.1b showed that while the respondents in the borderline zone neither agreed nor disagreed on most of the potential health impacts of being exposed to the aircraft noise, there is an agreement that doing tasks that require concentration might be more difficult

Table 4.4.1c Interpretation of Ratings on Reported Health Impacts in the Unsafe Zone

Descriptive Statistics		
	Mean	**Verbal Interpretation**
U1. The respondent experiences hearing fatigue or tiredness after long periods of aircraft noise.	**3.76**	**Agree**
U2. Communication, such as talking on the phone or chatting indoors, often becomes challenging.	**4.49**	**Strongly Agree**
U3. Reports of stress, anxiety, or tension increase during periods of heavy aircraft activity.	**3.76**	**Agree**
U4. The respondent may notice a decline in their ability to think clearly or retain information.	**4.19**	**Agree**

Table 4.4.1c presented the reported health impacts by the respondents in the unsafe zone. The respondents generally agreed that aircraft noise could cause hearing fatigue or tiredness after prolonged exposure, increase stress, anxiety, or tension during periods of heavy aircraft activity, and negatively affect their ability to think clearly or retain information. Meanwhile, they strongly agreed that aircraft noise makes communication challenging.

Table 4.4.1d Interpretation of Ratings on Reported Health Impacts in the Highly Unsafe Zone

	Mean	Verbal Interpretation

HU1. The respondent reports hearing issues or loss due to loud aircraft noise.	**3.21**	**Neutral**
HU2. The respondent reports ringing in the ears following loud aircraft flyovers.	**4.33**	**Strongly Agree**
HU3. Sleep quality is often negatively affected, especially during early morning takeoffs.	**3.33**	**Neutral**
HU4. The respondent experiences physical symptoms such as headaches, faster heart rate, or body tension due to noise.	**4.27**	**Strongly Agree**
HU5. There is a general sense of unease or emotional discomfort of the respondent during periods of intense aircraft noise.	**4.24**	**Strongly Agree**
HU6. The respondent believes their long-term health may be at risk due to continuous exposure to very high noise levels.	**4.24**	**Strongly Agree**

Table 4.4.1d presented that respondents in the highly unsafe zone strongly agreed that health impacts such as ringing in the ears, headaches, faster heart rate, body tension, and emotional discomfort were experienced due to aircraft noise. Meanwhile, they reported neutral feelings regarding potential impacts such as hearing loss and sleep problems

4.4.2 Validation of Noise Model through Health Impact Comparison Across Noise Zones

To statistically validate the noise exposure model and its relationship to health outcomes, a comparison of self-reported health impacts was conducted across the different noise zones using one-way ANOVA. The hypotheses tested are as follows:

- Null Hypothesis (H_0): There is no significant difference in self-reported health impact scores among residents in different noise exposure zones (Safe, Borderline, Unsafe, and Highly Unsafe)
- Alternative Hypothesis (H_1): There is at least one significant difference in self-reported health impact scores among the noise exposure zones.

Table 3.4.2a Comparison of Health Impacts Across Noise Zones: (a) One-Way ANOVA and (b) Post Hoc Tukey HSD Test Results

ANOVA

Save

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	159.920	3	53.307	298.070	.000
Within Groups	25.395	142	.179		

Total	185.315	145			

A one-way ANOVA was explored to compare the self-reported health impacts across respondents living in different noise zones (safe, borderline, unsafe, and highly unsafe). The results revealed that there was a significant difference among at least two groups of respondents based on noise exposure (p-value = 0.000).

Table 4.4.2b Comparison of Health Impacts Across Noise Zones: (b) Post Hoc Tukey HSD Test Results

Multiple Comparisons						
Dependent Variable: Save						
Tukey HSD						
(I) Noise Category	(J) Noise Category	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Safe	Border line	-1.6202*	.0976	.000	-1.874	-1.367
	Unsafe	-2.5425*	.0953	.000	-2.790	-2.295
	Highly Unsafe	-2.3740*	.0984	.000	-2.630	-2.118
Border line	Unsafe	-.9223*	.1005	.000	-1.183	-.661
	Highly Unsafe	-.7538*	.1033	.000	-1.022	-.485
Unsafe	Highly Unsafe	.1685	.1013	.347	-.095	.432
*. The mean difference is significant at the 0.05 level.						

Post hoc analysis showed significant differences in reported health impacts between the Safe zone and the Borderline, Unsafe, and Highly Unsafe zones ($p < 0.05$), with Safe zone respondents reporting the least effects. Borderline zone responses also significantly differed from Unsafe and Highly Unsafe zones ($p < 0.05$), with lower reported impacts. However, no significant difference was found between Unsafe and Highly Unsafe zones ($p = 0.347$), indicating similar health impacts. Overall, the results suggest that as noise levels increase or proximity to the airport decreases, health impacts worsen

4.4.3 Summary of Data

This study examined self-reported health impacts of aircraft noise among 146 residents across four zones: Safe (42), Borderline (34), Unsafe (37), and Highly Unsafe (33).

In the Safe zone, respondents reported minimal health effects, with all indicators rated "Strongly Agree" (mean > 4.21), reflecting calmness, uninterrupted sleep, and no perceived risk to hearing or physical health.

In the Borderline zone, most responses were "Neutral" (mean 2.65–3.12), though one item—difficulty concentrating—scored 3.79 ("Agree"), suggesting mild cognitive disruption despite few physical symptoms.

In the Unsafe zone, scores ranged from 3.76 to 4.49, indicating increased stress, fatigue, and communication difficulties due to noise. Communication disruption had the highest score (4.49, "Strongly Agree").

In the Highly Unsafe zone, several symptoms such as headaches, anxiety, and emotional discomfort scored between 4.24–4.33 ("Strongly Agree"). However, hearing loss and sleep disturbance received lower scores (3.21–3.33, "Neutral"), showing variability in symptom perception.

A one-way ANOVA showed significant differences in health impacts across zones ($p = 0.000$). Tukey HSD tests found the Safe zone significantly differed from all others, and Borderline differed from Unsafe and Highly Unsafe. No significant difference was found between Unsafe and Highly Unsafe zones ($p = 0.347$), indicating similarly high health effects.

In conclusion, health impacts increased with proximity to the airport. Residents in high-exposure zones reported more severe physical and psychological effects, underscoring the need for targeted noise mitigation strategies.

4.5 Discussions

This chapter presents the results of the study on aircraft noise pollution in Tuguegarao City, based on four objectives: measuring noise levels, modeling spatial distribution, categorizing health risks, and validating the model through resident feedback. Noise measurements at 39 locations using a Benetech GM1358 sound level meter showed Barangay Leonarda had the highest average at 91.875 dB, with a peak of 104.1 dB during landing. Nearby barangays—Pengue (77.82 dB), Linao (76.57 dB), and Tanza (84.65 dB)—also exceeded the 50 dB safety threshold. In contrast, distant barangays like Bagay, Larion Bajo, and Pallua recorded safer levels from 35.6 to 41.9 dB.

A spatial noise map was developed using QGIS, classifying noise into: Highly Unsafe (above 85 dB), Unsafe (70–85 dB), Borderline (60–70 dB), and Safe (below 60 dB). Barangays closest to the airport fell in Highly Unsafe and Unsafe zones; farther areas like Gosi and Cataggaman Viejo were in the Safe zone, showing a clear decrease in noise with distance.

Barangays were also categorized by health risk: red (very high), orange (high), yellow (moderate), green (low). Leonarda and Pengue were high-risk.

A survey of 146 residents showed minimal symptoms in Safe zones, neutral responses in Borderline zones, and strong agreement with symptoms like stress, fatigue, and communication difficulty in Unsafe and Highly Unsafe zones. ANOVA confirmed significant differences across zones ($p = 0.000$), except between Unsafe and Highly Unsafe zones.

In conclusion, proximity to the airport correlates with higher noise exposure and health effects, highlighting the need for mitigation strategies.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the above-mentioned findings of the study, the following conclusions were drawn.

1) The study successfully modeled the spatial distribution and intensity of noise pollution around Tuguegarao Domestic Airport using QGIS and field data.
2) The measured noise levels, using the Benetech GM1358 sound level meter, revealed that several residential zones were exposed to noise intensities exceeding safe limits set by WHO.
3) The spatial distribution of noise, modeled using QGIS, clearly identified areas categorized as Safe, Borderline, Unsafe, and Highly Unsafe, providing a visual representation of risk zones.
4) The predicted health risks—such as stress, sleep disturbances, and hearing fatigue—were validated through resident surveys, confirming the real-world impacts of noise exposure.
5) The integration of spatial modeling and community feedback proved to be a reliable method for assessing environmental noise and its public health implications.
6) The findings highlight the need for urgent interventions, as current noise mitigation measures are either lacking or inconsistently enforced, posing ongoing health risks to nearby communities.

5.2 Recommendations

Based on the facts and findings gathered, the following recommendations are hereby given:

1) Support further research to improve noise modeling tools using Class 1 meters and real-time monitoring. Airports should regularly monitor noise, especially during peak hours
2) Share research with policymakers and planners to guide zoning and infrastructure. Consider physical noise barriers or green buffer zones near residential areas.
3) Conduct awareness campaigns on noise-related health risks. Integrate health risk levels into local health and safety guidelines.
4) Future researchers should explore the community's perceptions and lived experiences of noise exposure more deeply, particularly in "Unsafe" and "Highly Unsafe" zones where no significant statistical difference was found. This will help ensure that noise classifications accurately reflect the actual experiences and conditions faced by affected residents.
5) Evaluate current noise mitigation strategies to identify what works and improve or replace ineffective measures.

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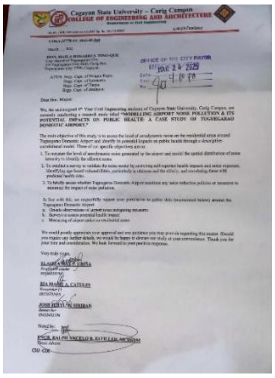
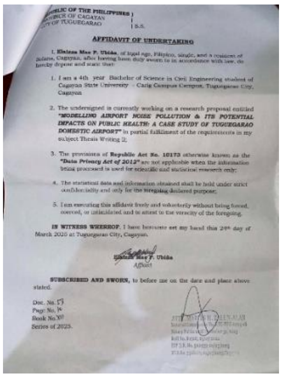
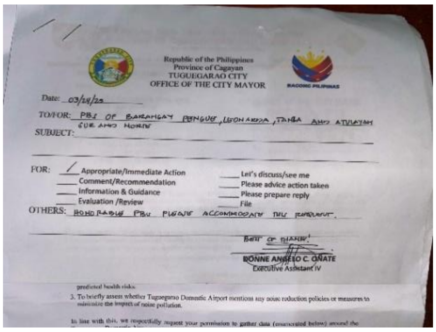
APPENDICES

Appenndix E_ Permission Letters







Appenndix F_ Documentation

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