

# STUDYING THE EFFECTS OF AIRCRAFT NOISE AROUND ABU DHABI INTERNATIONAL AIRPORT, UAE ON THE SURROUNDING RESIDENTIAL AND WORK PLACES

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## **ABSTRACT**

*The aim of this study is to investigate the impact of aircraft noise pollution on community and workers' health near Abu Dhabi International Airport. This study was conducted in residential neighborhoods and employment areas living and working within a 25-km radius of the airport with high exposure to aircraft noise and in matched control areas far from the airport (outside the 25-km radius) and are unaffected by aircraft noise. Data was collected by conducting a revealed-preference face-to-face interview surveys among the residents and the workers near and far from Abu Dhabi International Airport during the months of September and December 2014. A total of 5,070 residents in both areas (2,579 near the airport and 2,492 far from the airport) and 1,995 workers in both areas (995 near the airport and 1,000 far from the airport) were interviewed and completed the questionnaire. Binomial Logit Regression Model was used to determine the impact of aircraft noise on community and workers' health. After controlling for confounders, the health of the residents adjacent to the airport who have been chronically exposed to high aircraft noise level are found to be worse than the control group. The results show that residents from the noise exposure area have a high level of noise stress, hypertension, headache, general disturbance, loss of sleep/insomnia, and hearing problems than the matched control area. On the other hand, aircraft noise pollution near Abu Dhabi Airport has no negative impact on workers adjacent to the airport. The impact of aircraft noise on community health should not restrain the growth of air travel industry in the city as this growth is essential and beneficial to the whole nation's economy. The reduction of aircraft noise level in the exposed area could be achieved by imposing policies, codes of practices, and action noise plans to assess and evaluate land use management as an effective tool for mitigating aircraft noise. Future research should assess community health based on self-reported physician diagnosed blood pressure; and hearing, stress, headache diagnostic examination.*

## **KEYWORDS**

*Noise Pollution, Abu Dhabi International Airport, Binomial Logit Regression Model, Aircraft Noise, Health*

## **1. INTRODUCTION**

Aircraft noise pollution is considered an important environmental problem at airports and a significant issue affecting the operation and development of airports and hence the capacity of airports around the globe [1],[2]. It is one of the important factors that is considered a great barrier to airport development, expansions, or airport construction around the world. Therefore, challenges are facing air transportation stakeholders to balance air traffic growth against both local and global environmental concerns. Aircraft noise causes more annoyance compared to noise from road and railway traffic as a consequence of its intermittent and unpredictable character [3]. Aircraft noise modifies social behavior, hinders in complex task performance, and causes annoyance. Short-term exposure to noise may cause neuroendocrine arousal as noise is a stressor resulting in different hemodynamic and metabolic changes [4],[5], [6]. On the other side,

long-term exposure to noise pollution may cause cardiovascular effects [7]. An association have been found between aircraft noise and use of cardiovascular drugs, acute increase in heart rate and blood pressure, and higher risk of hypertension [8], [9],[10],[11],[12], [13], [14]. On the other side, [15] found that people living near the airports are at no risk of suffering hearing damage from aircraft noise.

People who live or work in places that are close to airports agonize more mere annoyance from descending and ascending aircraft. The mental and physical health of those people, particularly those who live or work below the flight paths of private and commercial airplanes, maybe significantly affected by aircraft noise pollution. On the other side, Airport managers, government's institutions, and traffic controllers aim to minimize community exposure to aircraft noise pollution due to the impact of aircraft noise on the health of the community members. When formulating environmental management plans and policies at airports, these policies ignore the health effects of exposing to aircraft noise and hence underestimate the social impact of aircraft noise. According to the World Health Organization (WHO), "good health is a state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity."<sup>1</sup>

High levels of aircraft noise as a result from aircraft take-offs, landings, over flight, and ground operations threaten the health of the members of the community and workers who are exposed to it. Therefore, governments, traffic controllers aim to minimize this threat through the enactment of policies and regulations. Many of these policies are based on an empirical relationship between annoyance, stress, elevated blood pressure and noise exposure [16],[17],[18],[19],[20],[21],[22],[23], [24]. Different mitigation programs and policies have been introduced and implemented at different USA, UK, Canadian and Australian major airports. These mitigation programs include sound insulation programs, noise and flight track-system, land-use compatibility, community programs, curfew, and preferred runways and flight path usage [16].

This paper aims to study the impact of aircraft noise pollution on community health near Abu Dhabi International airport. Furthermore, the paper evaluates the impact of aircraft noise pollution on workers near the Airport. This study is the first of its kind in the United Arab Emirate. In particular, this paper investigates the correlation between aircraft noise pollution and headache, disturbance, hypertension, insomnia, stress, hearing problems, and colitis. The paper seeks to answer a core question: "Is the health of the community members and workers worse in a community chronically exposed to aircraft noise around Abu Dhabi International Airport than in a community not exposed?" As such, a cross-sectional study of community health was conducted in residential districts and working areas adjacent to airport with potential high level of exposure to aircraft noise and in a matched control districts unaffected by aircraft noise pollution. The aim is to develop a better understanding of the impacts of aircraft noise pollution on community health by examining if the health related quality of life worse in a community chronically exposed to aircraft noise than in a community not exposed in the Emirates of Abu Dhabi. Aircraft noise is considered an important source of noise pollution that negatively impact people living adjacent to airports vicinity. However, the impact of aircraft noise on the health of the employees who are working in areas adjacent to the airports is not address.

## **2. LITERATURE REVIEW**

A comprehensive literature review was conducted by different scholars since the 1970s to examine the impact of aircraft noise pollution on the community health and retrieved information despite of its disciplinary base(see for example, [16] (Chapter 2),[25],[26],[27],[28],

[29],[30],[31],[32], [33], [34], [35], [36], [14]. These studies found strong correlation between aircraft noise pollution and stress, blood pressure, sleep disturbance, learning and academic performance, work-related performance, and annoyance. For example, [31] found that long-term exposure to aircraft noise was significantly associated with chronic noise stress and that chronic noise stress was significantly associated with hypertension. [37] found that exposing to aircraft noise pollution have immediate consequences on hearing and blood pressure and stress. [38] and [12] found a negative correlation between noise on subjective sleep quality and blood pressure. [31] and [14] found positive correlations between aircraft noise and hypertension. On the other side, [39] and [40] found no significant effect on self-reported health and myocardial infarction and strokes.[41] examined the association between sleep quality and the number of aircraft noise events. They concluded that only the number of high noise level events may have additional effects on sleep quality. [42] compared the hypertension data of women living adjacent to the Fukuoka Airport with women living in areas that are far from the airport and hence are not exposed to aircraft noise. They concluded that there was no evidence that aircraft noise is a risk factor in elevating blood pressure in women in Fukuoka, Japan. On the other side,[13] concluded that there is a marginally significant association between aircraft noise and high blood pressure when he studied two randomly groups one is exposure to aircraft noise and the other is not. [43] concluded that residents who are more likely to complain of sleep difficulties and to have poor health are those who were bothered by aircraft noise. [44] used multiple analysis of co-variance to measure general health outcomes, noise sensitivity and annoyance, and perceived stress and concluded that all health measures (mental health, sense of vitality, and general health) as well as stress and noise annoyance were significantly worse in areas adjacent to the airport and exposed to aircraft noise pollution.

The impact of aircraft noise on the health of the workers who are working in areas adjacent to the airports is not address. However, Studies of occupational and environmental noise exposure concluded that there is an association between noise and cardiovascular systems and blood pressure [45],[46], [47],[48],[49],[50],[51],[52],[53], [37],[54],[55]. These studies have found that workers exposed to noise levels exceeds 80 dBA have higher risk of hypertension or to other factors that also associated with hypertension than those who are not exposed to noise. These epidemiological studies explain the biological mechanism between noise exposure and hypertension based on an assumption that noise activates the sympathetic and endocrine systems to induce a release of stress hormones producing a transient elevation of blood pressure. Chronic and repetitive noise stimuli results in baroreceptors and lead to hypertension [5],[56], [33]. [57] showed that those doing complex but not simple jobs noise levels are more vulnerable to higher possibility of raising systolic and diastolic pressure and an increase in mortality risk. [58] found that exposure to occupational noise exposure has been linked to greater risk of death from motor vehicle injury. [59] explains that by stating that the effect of noise on hypertension are mediated through an intermediate psychological response such as noise annoyances.

Occupational noise is the most frequently studied type of noise exposure. It can cause both auditory and non-auditory health effects [60]. Several studies showed that negative health outcomes can be seen if chronic exposure to noise in occupational places exceeds certain levels [61]. In occupational settings, noise-induced hearing loss remains highly prevalent. The non-auditory impact of noise leads to annoyance, affect staff performance in occupational places, and increase the probability of cardiovascular and hypertension occurrence [3], [62], [63], [64], [65]. Noise annoyance might be accompanied by negative responses such as displeasure, stress-related symptoms, anger, and exhaustion and can result from noise interfering with thoughts, daily activities, rest or sleep, and feelings [66]. Studies of occupational and environmental epidemiology have found that the exposure to environmental noise causes mortality in highly noise-exposed groups and affects the cardiovascular system and causes different diseases such as ischaemic heart diseases, release of stress hormones, arousals in endocrine system and autonomic

nervous system, blood lipid concentrations, systolic and diastolic blood pressure, blood glucose concentrations, and stroke [67], [6], [68], [40], [69], [65], [70], [71].

General health and safety legislation that are intended to protect workers in the occupational places from excessive noise exposure are enforced in many countries. These legislations include specifying maximum exposure levels and requirements for action, regular audiometric testing, monitoring, including noise assessment, and protective equipment. For example, to guard against the risk of hearing loss, the Occupational Safety and Health Administration (OSHA) in the USA has established standards and regulations for permissible noise exposure in the work place and stated that hearing protection is required when the noise levels exceed the legal limits. Based on these standards, hearing conservation programs should be established when the noise levels exceed 85 Leq during the eight hours workday. This also includes the testing of employees' hearing, the monitoring of work place noise, and the establishment of a training program. The purpose of these standards is to inform employees about the effects of noise from the workplace on hearing and the effectiveness of hearing protection devices.

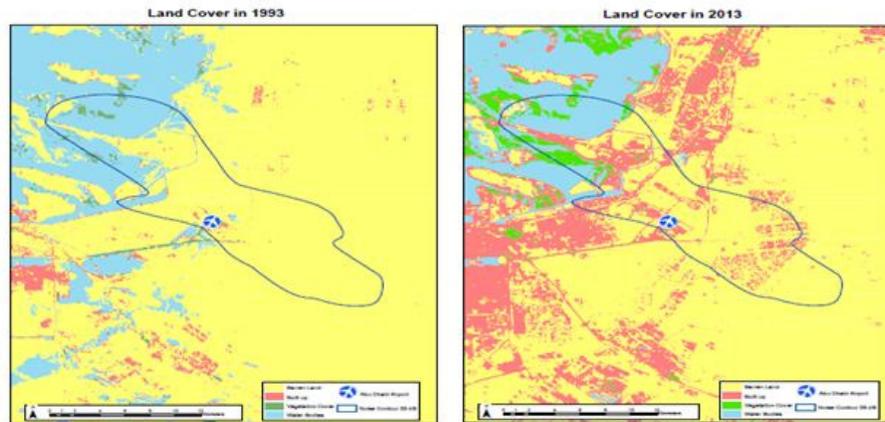
### **3. STUDY AREA**

Abu Dhabi city is the capital of the UAE with a population of about 2.33 million in the year 2012, [72] of whom 1.76 million are males and 0.90 are females. According to the Surface Transport Master Plan (STMP) published by [73], the DoT predicts a population size of 3.1 million by the year 2030. Abu Dhabi International Airport is located east of Abu Dhabi City the capital of the Emirate of Abu Dhabi and the United Arab Emirates. The airport was created in 1982 to lead the redevelopment in the aviation sector in the Emirate. The airport is owned by Abu Dhabi Government and plays an important role in its economic vision 2030. The airport is growing rapidly and in 2014 was servicing 93 destinations to 54 countries. In 2015, the airport witnessed growth in both passenger movement and handling cargo compared to 2014. During this year, passengers traveling through the airport increased by 17.2% with more than 23 million passengers traveled through the airport. In addition, the airport handled 827,456 metric tonnes of cargo with an increase of 3.8%. Aircraft movement through the airport also increase in 2015 by 11.6% compared to 2014 with Etihad Airways, the national airline of the UAE, carried 116 passenger and cargo destinations around the world, and 17.4 million passengers with 18.4% increase compared with 2014-time period [74]. The airport is spread over 8,500 acres and has three operational terminals. The airport has witnessed several stages of development during the last five years. In 2009, terminal 3 and the north runway was completed providing the airport with the ability to increase its handling capacity by 5 million passengers per year. In 2010, terminal 1 was refurbished to align with the service and look of terminal 3. In 2012, the construction works of Midfield Terminal Building was launched including cargo and catering facilities, utilities and related infrastructure aiming to reach to serve 30 million passengers.

The government of Abu Dhabi is aiming to achieve sustainable communities and provide them with highest quality of life style and standards. The area around the airport witnessed a rapid development during the last two decades as shown in Figure (1). This rapid development highlights the significant of studying the impact of aircraft noise pollution on community and workers' health.

Abu Dhabi aviation and airport development benefit the Emirates economic through different distinct types such as benefits to the industry, and creating new jobs in the city and the country as a whole. The economic value created by the industry includes the benefits for the customer, using the air transport service, and benefits to the passenger or shipper. Through connectivity to different parts of the world, Abu Dhabi aviation sector can be considered an essential infrastructure asset that generates more benefits to the Emirate and the country by enabling foreign investment, business clusters, and other impacts on the economy's productive capacity.

The contribution of the aviation sector to UAE GDP in general and Abu Dhabi in particular is significant. Improved connectivity gives Abu Dhabi-based businesses better access to various markets around the globe, and at the same time encourages exports. The aviation sector in the Emirate enable of opening up foreign markets to UAE exports, and encouraging to increase competition because the exports can be distributed in a wider area and at the same time reduce average costs by lowering transport costs. In addition, the aviation sector in the Emirates posts the economy by increasing job availability and reducing unemployment. This leads to speeding the adoption of new business practices.



**Figure 1:** Urban development around Abu Dhabi Airport between 2003 and 2013- time period

#### 4. DATA COLLECTION AND SURVEY DESIGN

Primary data were collected through self-administered questionnaire survey, which was selected as the most proper method for this research because of its suitability for examining and investigating the phenomena in question. In addition, the research purpose could be satisfied by getting first-hand information from a sample of residents and workers in Abu Dhabi. The self-administered questionnaire surveys enable the researcher to reach a large number of people in a short period of time. Other studies were reported in the literature that used the same type of survey (see for example [43], [31], [44]).

In order to understand the impact of noise pollution on the community and workers' health near Abu Dhabi International Airport, a two-revealed preference (RP) face-to-face interview surveys were designed and conducted by the author exclusively for this research. The aim of the stated-revealed survey is to collect detailed revealed preference information on the current perception of resident and workers of the impact of aircraft noise on their health. The first survey explores the impact of aircraft noise pollution on community health, and the second survey explore the impact of aircraft noise pollution on workers' health. The surveys are design to be completely anonymous, and requires less than 15 minutes to be completed. Core survey questions ask respondents to what extent they are annoyed from aircraft noise and if they suffer from any health related issues such as high blood pressure, headache, stress, or hearing problems.

The purpose of the surveys is to collect data to analyze the impact of aircraft noise pollution on the health of the residents and workers of the city. This purpose was introduced to respondents prior to questioning. A significant portion of the surveys was dedicated to acquiring data on the impacts of aircraft noise pollution on the health of the residents and workers who live or work adjacent to the airport. In addition, the survey includes different socio-demographic questions to provide data for a series of statistical tests of difference that assess the impact of aircraft noise between different groups. For assessing the health impact, a set of closed-end question as scaled and multiple-choice questions has been designed and included in the surveys in order to prevent

the distortion effects from socio-economic variables when assessing the health impact of noise pollution. The survey also tracks the medical (related to hypertension) history of the parents, as it is evident that the history of hypertension of parent(s) is related to hypertension.

The sampling and distribution method chosen for this study reflects the survey's purpose and target population. The target population was residents and workers of Abu Dhabi City who live or work near the airport. Those people are compared to other people who reside or work far from the airport. Therefore, the survey was distributed randomly into two areas in the city of Abu Dhabi. The first area is adjacent to the airport and is highly exposed to aircraft noise as shown in Figure 2. This area near the airport was identified in this paper as the area that is located within 25-km radius of the airport. Other studies used the same distance to identify the area near the airport (see for example [30], [10]). This area is selected as the study population for the impact of noise pollution on community and workers' health. The control area, the second area, is selected in locations not exposed to aircraft noise and are scattered around Abu Dhabi City far from the airport (outside the 25-km radius). The two areas were matched in terms of population density, socio-economic characteristics. This helps to control the confounding variables and hence reach to the correct results. The power to detect a statistically significant difference in health status measures was the main factor of estimating the sample size in each area. The sample sites in each area were selected based on its proximity to the airport and the population size and density. More emphasis was given to the areas that are located below the flight paths (i.e., Shamkhah, Al Falah, Airport District, Yas Island) as residents and workers of these areas are more exposed to aircraft noise than the other areas near the airport. A total of 5070 residents in both areas (2579 near the airport and 2492 far from the airport) and 1995 workers in both areas (995 near the airport and 1000 far from the airport) were interviewed and completed the questionnaire. The survey questionnaire was conducted during the months of September and December, 2014. The survey was designed to satisfy the requirements for the assessment of the impact of aircraft noise pollution on community health. Since the residence of the City of Abu Dhabi are from different nationalities, the questionnaire was designed and written in both English and Arabic languages.

In both surveys, the annoyance measurement consists of two sections. The first section assesses annoyance from aircraft noise. This section asks respondents to rate their overall annoyance from aircraft noise by using opinion scale (0-10) where 10 means extremely annoyed and 0 means not at all annoyed. In addition, it asks people to identify the time during the day, evening, and night that they feel they are extremely annoyed. The second section measures annoyance of subjects from daily activity disturbance such as from traffic, TV, or other means. The questionnaire was designed to consider all potential confounders. The confounder questions have been designed specifically for this research. The confounder questions include mainly the socio-economic status such as age, gender, income, nationality, and number of persons in a household in addition to smoking status and exercise activities. Other set of questions included to capture potential confounders are the time length that respondents lived or work in their house or their place of employment and if they insulated their house or working place from noise to access if the long-term aircraft noise exposure has negative impact on human health and to investigate if they took some measures to eliminate the effect from acoustic insulation.

## **5. MODEL DEVELOPMENT**

Research investigating the impact of aircraft noise pollution on residential and workers' health focused on contextual variables relating to physical conditions of surroundings and objective attributes of respondents related variables such as income, education, occupation, age, gender, duration of residence or work, and the presence of children, have been found to significantly correlated with the level of noise pollution impact on community and workers' health. Therefore, in the analyses of self-rated health, the association between the aircraft noise exposure and health indicators was assessed using a Binary Logit regression model, controlling for potential



Table 1. Comparing the socio-economic characteristics between the two samples

|                                       | Residents             |         | Employees             |         |
|---------------------------------------|-----------------------|---------|-----------------------|---------|
|                                       | X <sup>2</sup> -value | P-value | X <sup>2</sup> -value | P-value |
| Gender                                | 5.919                 | 0.432   | 4.835                 | 0.305   |
| Nationality                           | 40.505                | 0.941   | 89.935                | 0.482   |
| Age                                   | 27.069                | 0.514   | 23.216                | 0.806   |
| Income                                | 13.240                | 0.152   | 72.278                | 0.198   |
| Occupation                            | 19.211                | 0.258   | 58.326                | 0.599   |
| Number of persons in household        | 4.835                 | 0.305   | 285.561               | 0.793   |
| Number of children under 12 years old | 20.474                | 0.200   | 37.671                | 0.661   |

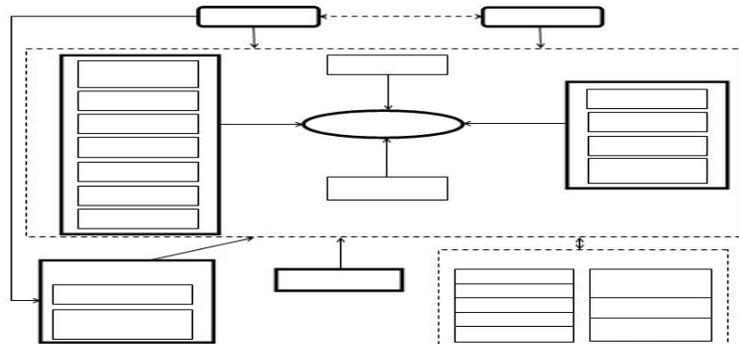


Figure 3: Theoretical model of the effects of aircraft noise exposure on community health

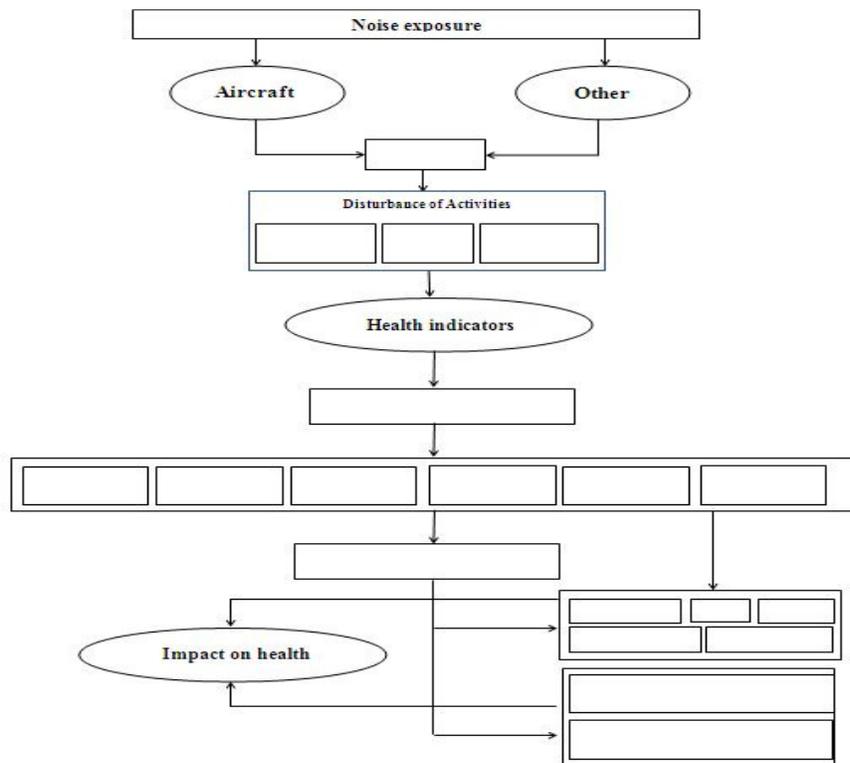


Figure 4: Theoretical model of the effects of aircraft noise exposure on employees' health

Figures 5 and 6 show that both samples of residents and workers near and far from the airport are almost similar in the distribution of different categories. Figure 5 shows that the majority of the respondents in both groups are in the age between 25 and 44 years old. Although there are some differences in the percentage between both samples but chi-square test reveals no significant differences (p-value = .514). The survey was distributed on residents from different nationalities. The chi-square test reveals no significant difference between the noise exposed group and the control group (p-value = .941) in terms of nationality in the sample. More than 95% of the respondents are Arab residents distributed between United Arab Emirates nationals, Gulf Cooperation Council (GCC) nationals, and Arabs from different Arabic countries other than the UAE and the GCC area. However, it is worth mentioning that United Arab Emirates nationals comprise 41% of the total respondents that are exposed to aircraft noise compared to 24% of respondents in the control group. In the exposure area, 67% of the sample are males, which is 5% higher than in the control group. On the other hand, the percentage of female in the exposed group is 5% lower than in the control group. The chi-square test revealed that this difference is not significant (p-value = .432). In terms of socioeconomic status, respondents from both groups were similar in average monthly income (p-value = .152), occupation (p-value = .258), number of persons in household (p-value = .305), and number of children under 12 years old (p-value = .200).

Figures 6 show that both samples of employees are almost similar in the distribution of different socio-economic categories. The figures show that the majority of the respondents in both groups are in the age between 25 and 34 years old. Although there are some differences in the percentage between both samples but chi-square test reveals no significant differences (p-value = .806). The survey was distributed on employees from different nationalities. The chi-square test reveals no significant difference between the noise exposed group and the control group (p-value = .482) in terms of nationality in the sample. The Asian workers comprise 37% of the total respondents followed by UAE and Arab employees. In the exposed area, around 86% of the respondents are males compared to 90% in the control area. About 60% of the respondents in both areas earns less than AED 10,000 per month. The employees in both areas have similar occupational status, the number of persons in the household, and the number of children younger than 12 years old. On the other hand, the percentage of male in the exposed group is higher than in the control group. The chi-square test revealed that this difference is not significant (p-value = .305). In terms of income status, respondents from both groups were similar in average monthly income (p-value = .198), occupation (p-value = .599), and number of persons in household (p-value = .793).

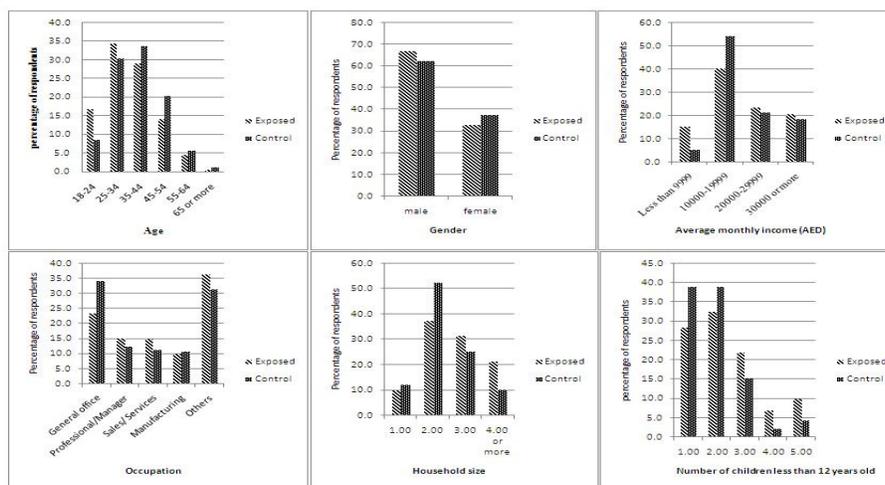


Figure 5: Comparison between the socioeconomic characteristics between the exposed and control population areas

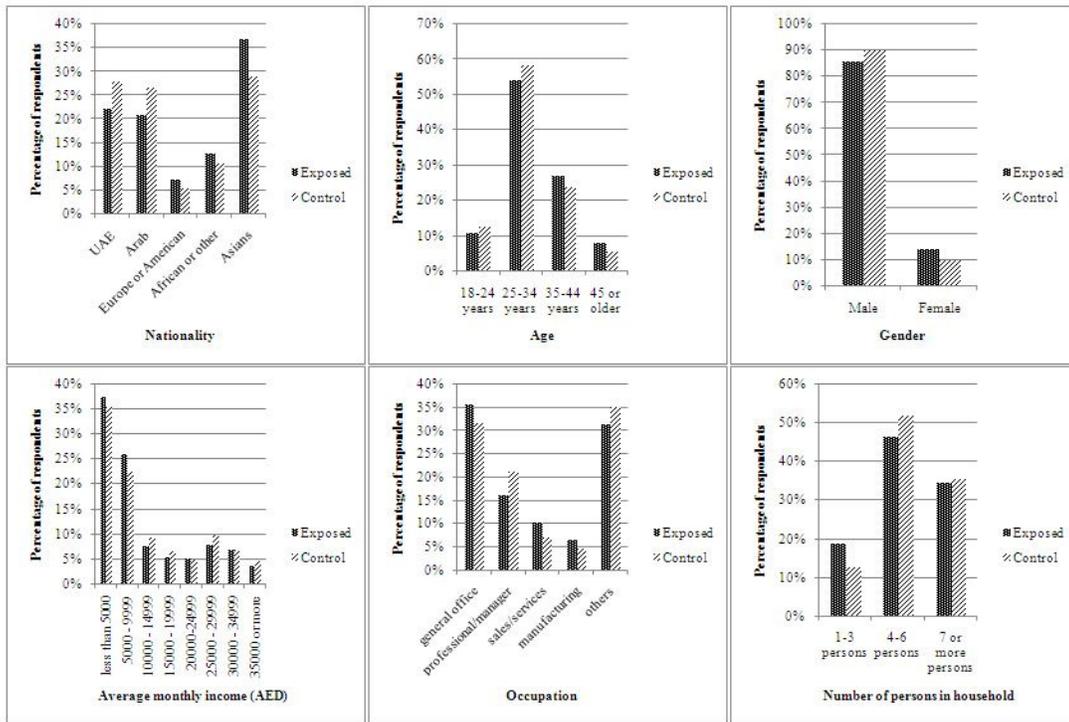


Figure 6: Comparison between the socioeconomic characteristics between the exposed and control population areas

Figure 7 shows that most of the employees from the exposed and control areas are working in the same place for one to six years and most of them are working in the day time. The figure clearly demonstrates that the employees in both areas work almost similar number of days and number of hours.

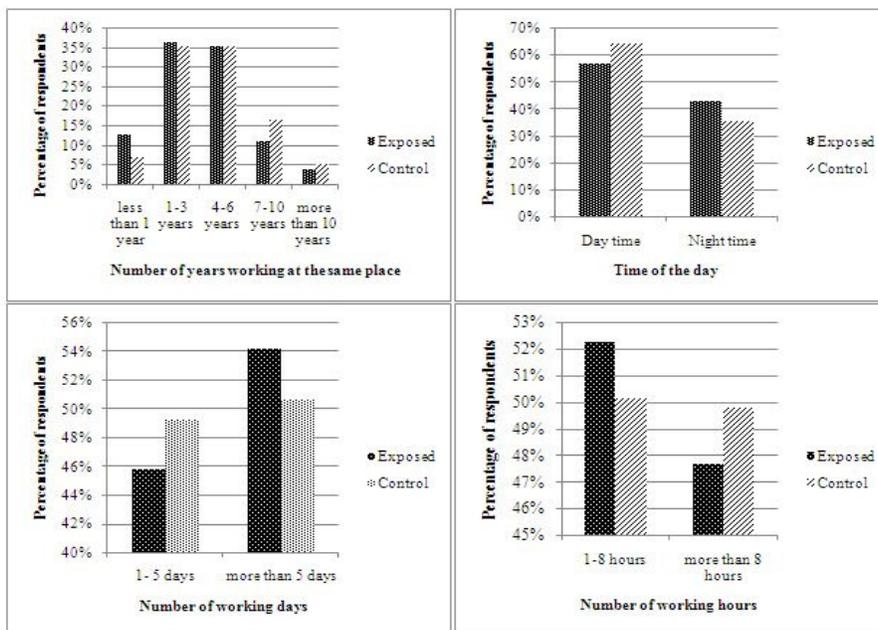


Figure 7: comparison between employees from the exposed and control areas

## **7. DESCRIPTIVE RESULTS OF THE SAMPLE NEAR THE AIRPORT**

The survey asked respondents to rate the degree of aircraft annoyance level. The results show that 36.4 % of the respondents who reported that they are annoyed from the aircraft noise rated this noise as high and only 17.7% of them reported it as low and the rest reported it as moderate. On the other hand, 53.6% of respondents who reported that they are not annoyed from the aircraft noise rated it as low and only 27.7% of them reported it as high and the rest reported it as moderate. The survey asked respondents if aircraft noise annoy them and to what extent. From the total sample only 31.4% reported that aircraft noise does not disturb them and they can tolerate with this noise compared to 27% reported that they cannot tolerate this noise and the noise disturb them, while the rest reported that they don't know. Of those who said they are annoyed from the aircraft noise, only 36.4% reported that they can tolerate the noise and that the noise does not disturb them and 24.2% reported that they cannot tolerate the noise, while the rest don't know. The survey also asked if the aircraft noise may cause general disturbance (irritation); 25.3% of the total respondents reported that aircraft noise pollution results in general disturbance and 33.4% reported that it do not disturb them, while the rest don't know. Among those who aircraft noise annoys them 37.5% reported that the noise result in general disturbance compared to 27.8% who said it do not disturb them and the rest reported that it may disturb them.

The result shows that 52.3% of those who are annoyed by the aircraft stated that they get used to aircraft noise without difficulty while 48.9% of those who are not annoyed get used to the aircraft noise. In addition, 64% of the respondents who are annoyed by aircraft noise find it hard to relax in a place that is noisy, while the others can tolerate and relax despite the aircraft noise. On the other hand, 71.1% of those who are not annoyed find it hard to relax in a place that is noisy, while the rest can relax despite of the aircraft noise. In terms of health, 92.3% of the respondents who are annoyed from aircraft noise described their health to be good, very good, or excellent and the rest described their health to be fair or poor. On the other hand, 97% of those who are not annoyed by aircraft noise described their health to be good, very good, or excellent. The exposure to aircraft noise leads sometimes to use medication to mitigate the noise impact; however, 85.5% of the respondents who are annoyed by the noise do not use any type of medicine, and 88.3% of those who are not annoyed do not use any type of medicine. Exposing to aircraft noise on a regular basis may cause hearing problems; however, 90.3% of those who are annoyed by the noise do not use any hearing aid and the same for those who are not annoyed as 91.4% of them do not use a hearing aid. Residents who are annoyed from the noise tend to use different strategies to mitigate the impact of the noise on their health. About 30% of them close the windows and doors to reduce the noise exposure and 12.6% are thinking of moving from their neighbourhood to other places that are not affected by aircraft noise.

The survey asked respondents if aircraft noise cause them a headache. In general, only 12.8% of the respondents said yes compared to 53.7% said no, while 33.5% of them indicated that they do not know. Among those who are annoyed by the noise, only 15.4% of them reported that aircraft noise causes them a headache compared to 53.2% said no, and the rest (31.4%) said they do not know. On the other hand, only 8.7% of those who reported that they are not annoyed by aircraft noise have a headache as a result compared to 49.6% who said no, and 41.7% said that they do not know. In terms of hypertension, only 9.1% of the respondents reported that aircraft noise causes them hypertension compared to 58.2% who said it will not cause them this disease, while the rest they do not know. From those who reported that they are annoyed, only 12% of them reported that the noise causes them hypertension compared to 52.2% who said no, while the rest do not know. On the other hand, only 7.2% of those who are not annoyed by aircraft noise reported that the noise will cause them hypertension compared to 64.8% who said no, and the rest do not know.

In terms of employees, the survey asked respondents to rate the degree of aircraft annoyance level. The results show that 52% of the respondents in the area adjacent to the airport rated aircraft noise as low, 21% of them rated it as moderate, and 27% as high. Most of the respondents who work during the day time are annoyed by the aircraft noise between 12:00 pm and 4:00 pm time period, while those who are working during night time are annoyed between 8:00 pm and 12:00 am. One of the reasons that encourages respondents to work in their current companies is that their jobs in general are good where 69% of the respondent stated that they do not mind working in companies near the airport if their jobs are good. On the other hand, only 7% of the respondent working adjacent to the airport are willing to move even their jobs are good. Respondents also were asked if they still work in areas near the airport if they have good salaries, positions, and specialties. In response to that, 59% of the respondents agreed or strongly agreed that they are willing to stay in a noisy area if they have these incentives. About 81% of the respondents indicated that they get used to aircraft noise without difficulties.

### 7.1 Health related measures

To examine the impact of aircraft noise on the exposed residential group, a chi-square test was conducted to determine if there is any statistical significant difference between the exposed and the control groups. The statistical differences in the health status may clearly indicate that this difference is due to aircraft noise. Table 2 summarizes the chi-square test and shows that there is significant difference in health status between both groups. This implies that the health of the exposed group was worse than the control group. The proportion of people that can tolerate the noise in the exposed group was slightly higher than in the control group. This difference is statistically significant and this may due to that more subjects in the exposed group install sound isolation in their house walls and ceilings. The acoustic insulation in Abu Dhabi buildings is based on Abu Dhabi Building Codes, which are developed by the Department of Municipal Affairs to protect the public health and safety in all communities through a set of regulations. The proportion of respondents with hypertension in the exposure group was higher than in the control group, it was also statistically significant (p-value = .001) as shown in the table. Obviously, respondents from the noise exposure area have a high level of noise stress (p-value = .000), headache (p-value = .001), general disturbance (p-value = .041), loss of sleep/insomnia (p-value = .001), and hearing problems (p-value = .024) than the matched control area.

**Table 2:** Comparing the impact of noise pollution among the two groups

|                                  | Residents             |         | employees             |         |
|----------------------------------|-----------------------|---------|-----------------------|---------|
|                                  | X <sup>2</sup> -value | P-value | X <sup>2</sup> -value | P-value |
| No disturbance (can tolerate)    | 9.051                 | 0.060   | 12.706                | 0.176   |
| General disturbance (irritation) | 9.991                 | 0.041   | 11.234                | 0.509   |
| Headache                         | 33.173                | 0.000   | 7.944                 | 0.789   |
| Hypertension                     | 18.287                | 0.001   | 5.754                 | 0.928   |
| Loss of sleep/insomnia           | 17.918                | 0.001   | 9.763                 | 0.637   |
| Stress                           | 21.017                | 0.000   | 15.608                | 0.111   |
| Hearing problems                 | 11.274                | 0.024   | 9.998                 | 0.867   |

Table 2 summarizes the chi-square test results of the impact of aircraft noise on employees' health, and clearly shows that there are no significant differences in health status between both groups either for those who work at daytime or nighttime. This implies that aircraft noise has no impact on workers' health. About 98% of the respondents described their health as good, very good, or excellent. In addition, 93% and 98% of the respondents do not take any type of medicine or use hearing aids respectively. This also indicates that aircraft noise have no negative impact on respondents.

High blood pressure is a genetic disease and therefore the respondents were also asked if either of their parents ever been told by a doctor that they have a high blood pressure. In response to this question 31.5% of the respondents indicated that one of their parents have a high blood pressure

compared to 42.5% who said that none of their parents have a high blood pressure and the rest (26%) indicated that they do not know if either of their parents have a high blood pressure.

## 8. MODEL RESULTS AND DISCUSSION

The analysis was performed to assess prediction of presence/absence of chronic aircraft noise pollution related health issues on residents living near the airport based on: (a) the socioeconomic characteristics of the respondents; (b) the coping strategies that are considered by residents adjacent to the airport to mitigate the impact of the noise on their health; and (c) how long have they lived in adjacent to the airport. Table 3 shows the model results and clearly demonstrate that these variables are significant in examining the impact of aircraft noise pollution on residential health. The model shows an acceptable goodness-of-fit with a statistically significant improvement in log-likelihood. Overall, the model fits the data where the Hosmer and Lemeshow goodness-of-fit test revealed that the model fits the data as the significant value (p-value = 0.749) is greater than 0.05. The two R-Squared values indicated that the model have moderate explanatory power. The variables included in the model accounted for 43.3% of the variation for the Negelkerke and for 36.6% for the Cox and Snell. The literature suggests that values of 0.2 to 0.4 for  $R^2$  represent an excellent fit. In addition, the model was robust in terms of goodness-of-fit where the model is good in predicting the overall choice with 69.0% indicating that the 69.0% of the variation of the dependent variable can be explained by the explanatory variables.

In general, the model shows that socio-economic factors that include, nationality, age, monthly income, and gender, are significant factors at 0.05 level; and that occupation are significant factors at 0.1 level. On the other hand, the model results show that number of persons in household and number of children under 12 years old was not found to be statistically significant indicators in the model. Aircraft noise pollution is annoying residents from all nationalities. The model clearly shows the time that respondents lived near the airport is a significant factor that affect their health.

This study of self-assessed of the impact of aircraft noise pollution on community and workers near Abu Dhabi International Airport is the first of its kind in the United Arab Emirates and the Arab countries in the Middle East. However, numerous studies have been conducted around the world to assess and address this issue. The results of this study are consistence with the results of different studies found in the literature. For example, [31] conducted a study in residential neighborhoods near Sydney Airport to examine the impact of aircraft noise on resident’s stress and hypertension. They found the residents who are chronically exposed to a high level of aircraft noise are more likely to have stress and hypertension compared with the control group. [10] also found an association between aircraft noise pollution and sleep disturbance, tiredness, headache, and increased blood pressure.

**Table 3.** Binomial logit models for predicting the impact of aircraft noise pollution on residents’ and workers’ health based on workers’ socioeconomic characteristics

| Community                                 |         |            |        |    |      |                |
|---|---------|------------|--------|----|------|----------------|
|   | $\beta$ | Std. Error | Wald   | df | Sig. | Exp( $\beta$ ) |
| Intercept                                 | -.792   | .437       | 3.292  | 1  | .070 |                |
| Nationality                               | -.115   | .032       | 13.038 | 1  | .000 | .892           |
| Age                                       | .134    | .064       | 4.335  | 1  | .037 | 1.143          |
| Gender                                    | .302    | .134       | 5.106  | 1  | .024 | 1.353          |
| Income                                    | -.105   | .046       | 5.131  | 1  | .024 | .900           |
| Occupation                                | .065    | .039       | 2.819  | 1  | .093 | 1.068          |
| Number of persons in household            | -.072   | .113       | .407   | 1  | .523 | .930           |
| Number of children less than 12 years old | .002    | .053       | .002   | 1  | .965 | 1.002          |
| Time lived adjacent to the airport        | .481    | .079       | 37.371 | 1  | .000 | 1.618          |
| Workers                                   |         |            |        |    |      |                |

|   | $\beta$ | Std. Error | Wald   | df | Sig. | Exp( $\beta$ ) |
|---|---------|------------|--------|----|------|----------------|
| Intercept                                 | -.345   | .559       | .381   | 1  | .537 | .709           |
| Nationality                               | .140    | .037       | 14.307 | 1  | .000 | 1.150          |
| Age                                       | .179    | .099       | 3.259  | 1  | .071 | 1.196          |
| Gender                                    | -.127   | .219       | .336   | 1  | .562 | .881           |
| Income                                    | .088    | .050       | 3.119  | 1  | .077 | 1.092          |
| Occupation                                | .116    | .045       | 6.605  | 1  | .010 | 1.123          |
| Number of persons in household            | -.074   | .028       | 7.065  | 1  | .008 | .929           |
| Number of children less than 12 years old | .007    | .049       | .023   | 1  | .878 | 1.008          |
| Time worked adjacent to the airport       | -.125   | .083       | 2.254  | 1  | .133 | .883           |

Although there is no impact of aircraft noise on workers' health near the airport, yet they perceive the noise differently. Aircraft noise is annoying about 35% of the respondents who work in areas near the airport. Most of them are working between 1 and 5 days a week and are working from 1-6 years in the same place. Employees working during the day time are more annoyed by the aircraft noise than those who are working during the night time. Most of the employees working adjacent to the airport indicated that aircraft noise is not a source of disturbance and they can tolerate the noise.

In examining the impact of aircraft noise on employees working adjacent to the airport, the analysis is performed based on the socio-economic characteristics of the respondents, the time they worked adjacent to the airport, and the mitigation strategies that they, or their employers, take to protect themselves from the noise. Table 3 shows the model results and clearly demonstrate that these variables are significant in examining the impact of aircraft noise pollution on workers' health.

In general, the model shows that socio-economic factors that include, nationality, occupation, and the number of persons in the household are significant factors at 0.05 level; and that income and age are significant factors at 0.01 factors in preceding aircraft noise. On the other hand, the model results show that gender, number of children less than 12 years old, and time the employee worked adjacent to the airport were not found to be statistically significant indicators in the model. Emirates and Arab residents, are annoyed from the noise the most. In addition, the noise affect those who work as general office and those who have more children under 12 years old in the house.

In occupational settings employees are more exposed to occupational noise (i.e. noise from the workplace) than environmental noise (i.e. aircraft, traffic, music). In this study, respondents working in areas adjacent to the airport or far from it indicated that they experience noises other than aircraft noise in their workplace. Occupational noise level varies depending on the working activity and the occupational sector. For example, people working in manufacturing or construction may experience a high level of occupational noise due to dealing with different machines and equipment.

The findings of the study may indicate that many occupational places in Abu Dhabi are designed and built based on specifications to minimize the impact of external noise on the employees. Many factories in Abu Dhabi use soundproof materials to minimize the noise hazardous on the surrounding areas and to reduce complaints from neighboring buildings as well as to improve their work environment for their employees. The impact of the noise created by the airport on the employees of such factories will also be minimized. On the other hand, factories that typically have machines creating all types of noises such as hydraulic vats, elevator equipment, boilers, exhaust systems, drills, punch presses, engines, generators, and other machines. In many factories, the high ceilings with lots of hard reflective surfaces make machinery noise bounces off these hard surfaces and back into the space. Thus, any noises created by the airport during the working hours of the factory will add little impact to the machinery noise. In addition, Abu Dhabi Emirate Environment Health and Safety Management System (EHSMS) issued in 2012 a

regulatory framework and code of practice (CoP) for occupational noise. The CoP applies to all employers within the Emirate, and sets the requirements and standards to eliminate the negative affect of occupational noise on the health of the employees particularly if the noise levels in excess of 85 decibels (dB). The CoP stated that employers should provide training and protection tools to all employees exposed to noise exceeds the 85dB threshold. Hearing protection is one of the major that theCoP focused on and stated that employers shall eliminate noise hazards in the working place by following different procedures such as purchasing low noise vibrating production equipment or providing employees with protection tools. The CoP also states that employees should report any activity relating to noise exposure that may cause health issues, and at the same time they should use appropriate hearing protection or safety devices provided from the employers.

### 8.1 Coping Strategies

The survey asked respondents who are annoyed from the aircraft noise pollution if they take any medications or using hearing aids as a result of this noise. Only 8% indicated that they use medicine and 12% reported that they use a hearing aid device. Different strategies are adopted by the residents adjacent to the airport to manage\mitigate the noise. Many of the respondents (29.7%) close the windows and doors to reduce the noise exposure. Others 10.4% ignore the noise and pretend that itdoes not bother them. Another strategy of avoiding the noise is by moving to other parts of the city away from this noise where 12.6% of the respondents are thinking doing that. Few respondents (7.9%) try to make themselves feel better by exercising or using relaxation techniques and 3.9% try to escape the effects of the noise using cigarettes /sleeping tablets. On the other hand, 9.8% of the respondents reported that they are used to the noise and 5.4% of them are not annoyed by the noise. Another way of mitigating the impact of aircraft noise on residential health is by installing sound isolation in the house wall where only 14.4% of the respondents indicated that they did that while 49% of them did not installed sound isolation where the rest they don't know if there houses have sound isolation or not.

### 8.2 Geographical analysis of the impact of aircraft noise pollution

In this section, the impact of aircraft noise pollution on community health is compared based on respondents' area of residents(i.e., Shamkhah, Al Falah, Khalifa Citey A, Khalifa Citey B, Airport District, Capital District, Al Raha, and Yas Island) as shown in Table 4. The table shows that the areas of Shamkhah, Al Falah, Airport District, and Yas Island areas are more exposed to aircraft noise pollution than the other areas. This is mainly because these areas are located below the flight paths.The data revealsthat there are significant differences in health status between residents in these areas as a result of aircraft noise pollution.The percentage of respondents who indicated they have Headache, Hypertension, loss of sleep, stress, and hearing problems are higher in these areas than the other areas adjacent to the airport. On the other side, the percentage of respondents who can tolerate the aircraft noise is higher in the areas of Khalifa City B, Khalifa City A, Capital District, and Al Raha than the other cities.

**Table 4:** Binomial logit models for predicting the impact of aircraft noise pollution on community health based on geographical location

|                  | $\beta$ | Std. Error | Wald   | df | Sig. | Exp( $\beta$ ) |
|------------------|---------|------------|--------|----|------|----------------|
| Intercept        | .959    | .173       | 30.573 | 1  | .000 |                |
| Shamkhah         | -.454   | .218       | 4.365  | 1  | .037 | .635           |
| Al Falah         | .983    | .282       | 12.162 | 1  | .000 | 2.673          |
| Khalifa City B   | -.201   | .208       | .942   | 1  | .332 | .818           |
| Airport District | -1.481  | .207       | 51.095 | 1  | .000 | .227           |
| Capital District | .350    | .278       | 1.593  | 1  | .207 | 1.420          |
| Khalifa City A   | -.192   | .241       | .630   | 1  | .427 | .826           |
| Al Raha          | -.069   | .208       | .111   | 1  | .739 | .933           |
| Yas Island       | -1.447  | .276       | 27.465 | 1  | .000 | .235           |

### **8.3 Policy implication**

Mitigation strategies for aircraft noise suggested in this study are mainly adopted from other international airports such as those in the US, Japan, Taiwan, Australia, Germany, and the Netherlands. For example, Abu Dhabi Airport may adopt many noise-abatement measures such as curfews, noise-abatement flight procedures and preferential runways, mandatory phase-out of noisier aircraft, other operational restrictions, and non-aircraft noise-abatement programs. Some other policies that Abu Dhabi Airport can adopt include minimizing, as far as is practical, the population density in the most affected areas identified in this study where people in the community are exposed to high levels of aircraft noise from take-offs, landings, over-flights and ground operations such as taxiing and engine ground running. This could be done by reducing the total number of people living in these areas by providing compensations to move out and live away from the airport. On the other hand, other policies include funding soundproofing for homes in eligible neighborhoods. In addition to the more obvious noise policy instruments described above, other mitigation strategies that are suggested in this study for Abu Dhabi international airport is using Passenger Facility Charge (PFC) and Airport Improvement Program (AIP) funds similar to those adopted in the international airports in the United States. These programs include noise-abatement measures that do not directly include aircraft operations. Instead, they include the construction of noise barriers, the acquisition of property whose use is incompatible with airport operations, the conversion of such property to airport-compatible use, the soundproofing of residences and public buildings, the installation of noise-monitoring equipment to improve noise management, and the staffing of offices to handle and record community noise complaints [75]. Such measures, if adopted by Abu Dhabi Airport will improve its relationship with the neighboring communities. International airports of the United States currently are using such mitigation strategies. For example, Chicago's O'Hare and Atlanta's Hartsfield-Jackson airports have implemented all-embracing set of noise-mitigation measures using PFC and Airport Improvement Program (AIP) funds. Both have installed noise-monitoring systems connected to the radar system that enables the recording of noise from each aircraft movement, cross-referenced with relevant aircraft information such as its type, operator, and heading. Such data if collected by the authorities of Abu Dhabi Airport will assess and improve their noise-management programs; periodic data publication serves to inform the airport's neighboring communities as well as the airlines. Monitoring of the noise intensity level in the broader area of Abu Dhabi airport in addition to the instant relevance of the noise levels with particular aircraft traffic is attained with a relevant noise monitoring system. The implementation of a yearly noise monitoring system is significant in making the right decisions regarding sound insulation. On the other hand, a number of international airports in the world use economic instruments to mitigate aircraft noise impact that Abu Dhabi Airport may adopt. Such instruments include noise-related taxes or discounts, to embolden airlines to operate quieter aircraft. Commonly, the noise tax increases with aircraft noise, and with aircraft weight, as heavier aircraft are likely to be noisier. Abu Dhabi airport may define a maximum per-aircraft noise threshold above which aircraft should pay noise prices per operation. However, another measure that could be taken by Abu Dhabi airport is to establish aircraft noise categories each with its corresponding fee or discount. Noise charges could also be segregated by the time of operation. Moreover, noise tax may be imposed on departures only or on arrivals only. Most significantly, Abu Dhabi Airport authorities may use the collected taxes to fund the airport noise-mitigation measures discussed earlier.

### **9. CONCLUSION**

This study provided an overview into aircraft noise and the health of residents and workers surrounding a busy international airport. In this study, subjective health outcomes were measured by a revealed preference survey. The questionnaire was designed to measure the impact of noise pollution on health in terms of stress, hypertension condition, headache, loss of sleep/insomnia, and hearing problems. This study applied a cross-sectional technique to compare between an aircraft noise exposed group with a matched control group as a tool to explore the impact of

aircraft noise pollution on residential health. In addition, the study explored the long-term exposure to aircraft noise and the coping strategies that residents follow to manage/mitigate the noise affect. The study rejects the null hypotheses and concluded that chronic aircraft noise was significantly associated with pervasiveness of stress, hypertension, headache, loss of sleep/insomnia, and hearing problems on the residents adjacent to the airport. In addition, the study concluded that long-term aircraft noise exposure was a significant factor in the prevalence of the above health issues. The result of this study with regards of the impact of aircraft noise pollution on community health coincide with other international studies. The link between aircraft noise pollution and the health of residents living adjacent to the airport has been confirmed in several studies. Therefore, an appropriate measure should be taken to eliminate the impact of aircraft noise on community health such as issuing a code of practice that include installing sound insulation in residential buildings. The implementation of sound insulation measures in residential buildings nictitate the presence of an appropriate regulation framework. The aim of this framework is insuring that these buildings should be constructed so that their residents are protected from aircraft noise pollution or any other kind of noises beyond the acceptable level of acoustic comfort in the limits of the building. On the other hand, investigating the impact of aircraft noise on employees' health who are working in areas adjacent to Abu Dhabi International Airport revealed that there is no association between aircraft noise pollution exposure and the prevalence of headache, hypertension, insomnia, stress, and hearing problems. The study showed that there are no significant differences in the health between employees working in areas adjacent to the airport and other employees working far from the airport. The impact of aircraft noise on community health should not restrain the growth of air travel industry in the city as this growth is essential and beneficial to the whole nation's economy. The reduction of aircraft noise level in the exposed area could be achieved by imposing policies, codes of practices, and action noise plans to assess and evaluate land use management as an effective tool for mitigating aircraft noise. Further research is recommended to investigate the impact of aircraft noise on community health by establishing a strategic noise map and matric that measure the accumulation of real noise level at a given location around the airport over a period of time. In addition, future research should investigate land use planning around the airport using Geographic Information System (GIS) and Remote Sensing (SI) to determine the impact of aircraft noise pollution on community health near the airport based on the intensity of noise exposure at different time of day and night. This research is based on data gathered through stated-preference survey. Furthermore, future research should assess community health based on self-reported physician diagnosed blood pressure; and hearing, stress, headache diagnostic examination.

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