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CASE STUDY

Effects of railway noise and vibrations on dissatisfaction of residents: case study of Iran

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Abstract
In this study, the effects of noise and vibrations caused by railways on the lives of residents around the railways in districts 17 and 18 of Tehran, the capital of Iran which amounts to about 700,000 people, are investigated. In the first stage the actual level of noise was measured at various points which showed above standard levels. Afterward, the authors developed a questionnaire and the survey was conducted from 376 residents. The findings of this study show that the most important factor for the residents adjacent to the railway line is the need for action by the country's railway authorities to reduce and control the adverse effects of noise and vibration. Also, the analysis of inferential statistics performed by chi-square test shows that the variables of gender and proximity of residence or workplace or both to the railway do not affect any of the railway noise or vibration dissatisfaction. The age variable also has no effect on noise dissatisfaction but does impact on vibration. Finally, distance from the railway affects both disaffection from noise and vibration.

Keywords Noise pollution · Railways · Vibrations · Urban areas · Resident satisfaction · Tehran · Iran

1 Introduction and literature review

Noise pollution has been associated with human life for decades and it is common knowledge that it is one of the factors that reduce the quality of life (Fiorini, 2022). Noise pollution, which is generally referred to unwanted noise that can disrupt the life of humans or even animals, has existed in various forms in the world for a long time but in today's world, its nature and characteristics are very different from the past, due to changes

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in the structure of human life, such as urbanization and the advancement of technology (Murphy & King, 2014a). What is meant by noise pollution in this study, is environmental noise pollution, which means any unwanted sound created by human activities such as transportation and industrial activities which are considered harmful to the physical and mental health of humans (Murphy et al., 2009).

Noise pollution has many destructive effects on human and animal life (Hadi Hassan Al-Taai, 2021; Mohamed et al., 2021). The most common harms that noise pollution can cause to the human body and mind are dysfunction of the mind and loss of concentration, sleep disorders, and causing stress that can lead to cardiovascular disease and mental disorders (Jacyna et al., 2017, Hadi Hassan Al-Taai, 2021, Auger et al., 2018). Apart from the annoyance that noise pollution, especially noise pollution caused by transportation (Miedema & Oudshoorn, 2001), creates for the residents of urban areas (Licitra et al., 2016), one of the significant problems caused by noise pollution is sleep disturbances (Kawada, 2011). Sleep is a physiological state that is sensitive to environmental factors, and environmental noise is one of the types of external stimuli that cause sleep problems (Muzet, 2007). Learning impairment (Klatte et al., 2013) and reduction in working performance (Rossi et al., 2018; Vukić et al., 2021) are other problems caused by noise pollution. The effects of noise especially on the learning of students and children are one of the issues of interest (Minichilli et al., 2018) because babies (Zacarías et al., 2013) and young children are more sensitive to noise (Erickson & Newman, 2017). Physical disorders such as heart diseases (Dzhambov et al., 2016; Münzel et al., 2021) and blood pressure (Dratva et al., 2012; Petri et al., 2021), and mental diseases (Ma et al., 2018; Tortorella et al., 2022) are also other harmful effects of noise pollution on human life.

As mentioned earlier, one of the main causes of environmental noise pollution is transportation. Population growth and increase in urbanization have long led to increased transportation demand, therefore, there is a need to develop transportation systems and their structures to meet the need for mobility in society (Murphy, 2012). But this increase in transportation systems, in addition to the benefits it has brought to human life, has always caused destructive environmental effects and problems.

Meanwhile, noise pollution is one of the most important environmental problems caused by transportation, and transportation policies and planning have long sought solutions to control and reduce transportation noise (Murphy & King, 2014b). One of the most common forms of environmental noise pollution in the world is the noise of transportation systems. Road traffic is the main source of this noise (Korzhenevych et al., 2014) and one of the foremost imperative environmental impacts caused by transportation systems is road traffic noise (Ruiz-Padillo et al., 2016).

Road traffic noise, like other forms of noise pollution, has destructive effects on human physical and mental health (Ouis, 2001), therefore measures such as noise maps (Fredianelli et al., 2022a), use of vegetation (Ow & Ghosh, 2017), use of more efficient road transportation systems, especially in urban transportation, such as city bus services (Cueto et al., 2017), should be taken to reduce this noise is essential.

Other modes of transportation, such as air (Gagliardi et al., 2018), maritime (Abowei et al., 2011), and rail transportation (Bunn & Zannin, 2016), also cause noise pollution. Along with the rapid development of the aviation industry, noise pollution caused by air transportation has also become one of the common problems of countries (Xie et al., 2014), which has a destructive effect on human life and wildlife (Iglesias-Merchan et al., 2015; Pepper et al., 2003). Maritime transportation, which is constantly increasing in today's world for both passengers and freight, although it has various advantages, it can cause noise pollution (Fredianelli et al., 2022b), especially in ports and for residents of areas near ports (Nastasi et al., 2020).

Rail transport and consequently the construction of railways have made significant progress over the decades in many countries and cities all around the world due to its ability to reduce road traffic and its lesser environmental impact compared to other modes of transportation such as road or air transport. The main feature of rail transport is its high capacity for both passengers and freights, so it is one of the most economical ways of transportation for large flows of passenger traffic and heavy and bulky freights. The main markets for rail passenger transport are long-distance passenger services and urban or suburban services in large cities (Nash & Fowkes, 2021). It can be said that rail transport is generally considered one of the most environmentally friendly types of transport (Tumavičė et al., 2016), especially in the field of air pollution and emissions (Murphy & King, 2014b; Travaini et al., 2013).

However, despite the numerous benefits rail transportation entails, it cannot be said that rail transport does not cause any pollution, and one of the most common environmental problems posed by rail transportation is noise pollution (Murphy & King, 2014b). In the European Union, after the noise caused by road traffic, the railway is considered the second main source of noise pollution (Michali et al., 2021; Murphy & King, 2014b; Wosniacki & Zannin, 2021). An increase in the use of rail transportation systems is likely to lead to an increase in noise emissions from railways (Gidlöf-Gunnarsson et al., 2012).

Railway noise pollution is usually due to noise from the interaction between the train wheels and the surface of the railroad tracks as the train crosses the tracks, which is known as rolling noise. (De Vos, 2012; Michali et al., 2021; Wosniacki & Zannin, 2021). Rolling noise is the foremost noticeable source of railway noise pollution for speeds of 50 to 300 km/h and above (Chen et al., 2009). The rolling sound generation mechanism comprises two primary basic components: wheel and rail (Babici & Tudor, 2019). This noise can be divided into three main categories, Rolling noise in a straight line is caused by waves within the wheel and rail surfaces, extreme rolling noise is caused by discontinuities within the wheel or rail surface, shrieking noise, which happens in sharp radius curves (Thompson & Jones, 2000). Also, the noise made by the city railways is caused by the use of various electric vehicles, locomotives, danger signals, maintenance equipment, as well as construction equipment, which causes harassment to the residents of those areas.

In the case of railways, another issue that needs to be addressed is the vibrations emitted on the ground when the train is moving on the railways and it may cause annoyance to people living near the tracks or interfere with the operation of sensitive equipment inside buildings (Bahrekazemi, 2004).

The destructive effects of railway vibrations include sensible vibrations on the floor of buildings, shaking of windows, shaking of objects on shelves or hangings on the wall, and the sound of roaring caused by vibration, which has annoyed residents. When the train passes over the rails, very intense vibrations are generated which will be transmitted through the ground to nearby structures and as a result of subsidence, cracking and even collapse of buildings may occur (Nerişanu & Drăgan, 2017). Rail vibrations can also negatively affect sleep disturbances (Smith et al., 2013, 2017).

In general, a good number of researches have been done that examine the issue of noise pollution and vibrations caused by railways. Some of this research has only focused on noise pollution caused by railways (Grubliauskas et al., 2014; Zhang & Ma, 2021), and some other only deals with rail vibrations (Connolly et al., 2016; Peris et al., 2012, 2014; Sharp et al., 2014) and there is a limited number of papers which investigated as a novel approach, the efficiency of combining railway vibration and noise barriers (Maigrot et al., 2020; Nering et al., 2020; Peplow et al., 2021).

As mentioned in the previous section, noise from railways has long been a problem for human life (Sahu et al., 2020). A good amount of research has long been conducted to examine the human response to sound and vibration from transportation and railway from decades ago (Miedema & Vos, 2007; Waddington et al., 2014, 2015; Walker & Chan, 1996).

One of the factors that affect the annoyance caused by noise and vibrations of the railway is the individual sensitivity to noise (Pennig & Schady, 2014). Therefore, it can be found that paying attention to people's opinions and individual characteristics in studying the effects of railway noise is important. Previous research has also shown that there is a relationship between the level of dissatisfaction with railway noise and population density, the length of the existing railway infrastructure, and the type of areas through which the railway passes (Wrótny & Bohatkiewicz, 2020). Therefore, studying the characteristics of the study area can also be useful. Another thing that has been explored by past research is that one of the most important factors that have contributed to the difference in people's reactions to disturbances caused by road noise is the distance between railway residences (Lim et al., 2006). Therefore, it is important to study the characteristics of the residential building as well. Also, one of the most important problems of noise and vibrations caused by railways is sleep disorders, which many studies have emphasized (Aasvang et al., 2011; Elmenhorst et al., 2012; Smith et al., 2016; Tassi et al., 2010). So, the importance of examining, it is obvious.

There is another group of studies that have studied the issue of railway noise and vibration more from the perspective of infrastructure and specifications of railways and trains than the study of human characteristics and reactions (Aleknaite & Grubliauskas, 2018; Tang et al., 2019). And some studies have looked at both the human response and the infrastructure together (Michali et al., 2021).

The most important results that can be concluded from this type of research is that train noise depends on the types of trains, type of track, driving speed, and driving mode. Noise levels also depend on the rotation of the wheels on the track and the short track wheel beats connections (Grubliauskas et al., 2014). Also, about the Railway vibrations, it can be stated that they are generated primarily at the wheel-rail interface, and then propagate into the supporting soil. These vibrations are known as 'ground-borne vibrations', and may also result in ground-borne noise (aka 're-radiated noise'), if they reach nearby buildings and cause the walls and floors to shake (Connolly et al., 2016). Good foundations reduce vibration transmission from ground soil up into the building and lead to a lower level of structure-radiated noise (Zou et al., 2020).

But it is noteworthy that most of this research has been done in developed countries and is less focused on developing countries (Fukushima et al., 2011; Morihara et al., 2013). Therefore, due to the importance of the subject and the lack of relevant research in developing countries, this study has tried to examine the community response to noise and vibrations of railways in the developing country of Iran.

In our study the effects of noise pollution and vibrations on dissatisfaction of residents of areas adjacent to the railway in the city of Tehran are studied. The objective of this research was to assess overall dissatisfaction of residents and factors that affect it such as floor of the building which the respondent resides, type of building frame, the age of the building as well as the age and gender of respondents. For this purpose, the present research was done in six main sections. The first section includes the introduction and structure of the research. The following section presents a literature review and analysis of previous research. The third section introduces and expresses the characteristics of the case study area. The fourth section clarifies the research methodology, and the last two sections, respectively include the results, discussions, and suggestions of the research.

2 Location and characteristics of the case study

The history of using rail transport and railways in Iran dates back to the nineteenth century (Koyagi, 2021). For many years rail transport has been used as one of the main types of intercity and in-town transportation for both freight and passengers. And even now, rail travel in Iran is increasing day by day due to the benefits it has for both freight and passenger transportation (Mirabadi & Sharifian, 2010). According to the International Union of Railways (UIC), the Iranian railway carried 11.1 million passengers and 50.6 million tons of freight in 2021 on its 9454 km of railway lines which was severely affected by the Covid-19 pandemic (UIC, 2021).

Meanwhile, the city of Tehran, as the capital of Iran, accounts for a large part of the total transport volume of the country, including rail transport. According to the rail transport statistical yearbook of Iran published by Islamic Republic of Iran Railways (RAI) in 2019, 735 km of all Iranian railways are located in the province of Tehran, and also in 2021, the amount of passengers transported by rail in Tehran is close to 5 million people (RAI, 2021).

As mentioned earlier, the noise and vibrations caused by the railways affect the residents around the railways more than anyone else in the community. Therefore, when researching the effects of the mentioned cases in urban areas, this group of people should be considered a priority.

In this study, which was conducted in Tehran, the capital of Iran, the group that was studied were people from Tehran whose place of work or residence is adjacent to the railways and is constantly exposed to the effects of noise pollution and railway vibrations.

Figure 1 shows the map of the city of Tehran, in which dark black lines represent railway lines that are located in the city. This figure also shows several more important and densely populated districts in the 22 districts of Tehran (GoogleMap, 2021). As shown in the figure, the main concentration of railway lines is in areas 17 to 19, and the Tehran railway station is located in the same area. Therefore, districts 17 and 18 have been selected for a case study in this research, and the total population of these two districts, according to the Statistical Center of Iran (SCI) is a little over 693 000 (SCI, 2016).

3 Methodology

So far, the basics and literature on the subject was discussed. Also, the characteristics of the study area were described. In this section, the research methodology is introduced. In this study, a questionnaire-based survey was used to collect data, and then the collected data were examined by descriptive and inferential statistics for better understanding. Also, the noise level in the study areas has been measured by the relevant tools to compare it with the standards.

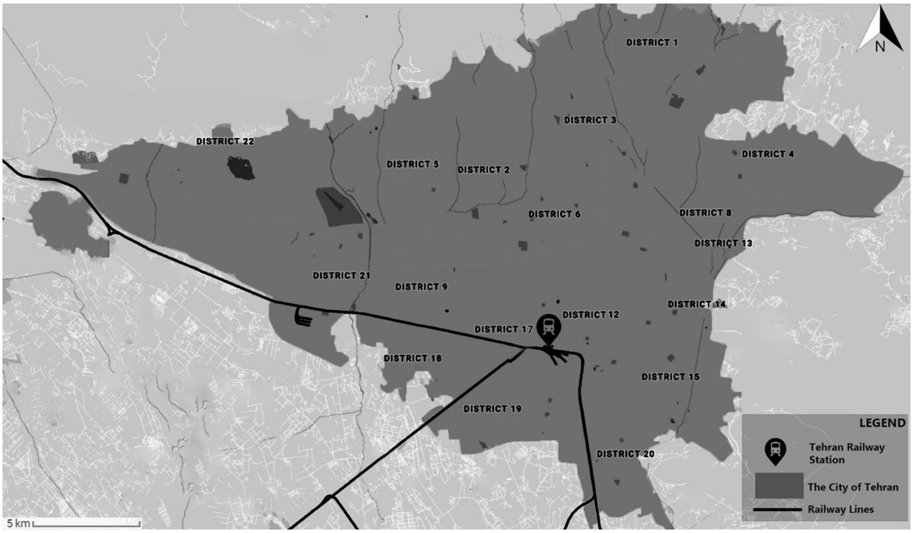

Fig. 1 The City of Tehran and Railway Lines

3.1 Noise level measurement

Noise measurement can be taken for various purposes such as surveying the number of individuals exposed to noise, evaluating environmental impacts, taking measures and adjustments, and in case necessary. Moreover, the measurement process, measuring location, and other related matters ought to be suitable for the measurement (Berglund et al., 2000).

To determine the number of fundamental measurements and analyze the results in this research, measurement stations were decided based on the distance of the residential area from the railway line, and the amount of noise due to the movement of trains at the A-weighted sound level has been measured using a sound meter level device.[1] A total of six measuring stations were selected, which include three stations in each of the 17 or 18 districts of Tehran, at distances below 100, 100 to 500, and more than 500 m from the railway line. The exact distance of each measurement station from the railway line can be seen in Figs. 2, 3, 4, 5, 6and 7. In each of the measurements, the measurement length was 2 min. Sampling was performed both when there was no train on the lines and when the train was passing to compare the sound level in these two modes. Also, all measurements were taken during daylight. Equivalent Continuous Sound Pressure Level (Leq/LAeq) is used in this study as the exposure indicator of the railway noise. Measurements were repeated 3 times per each of the stations, in each measurement, the maximum, minimum and average data are recorded, and Table 1 shows the average number of 3 times of measurements for each of these three modes (min, max, avg) in each of stations.

In this research, the sound measurement was taken locally and the purpose of doing it was to outline the general level of noise pollution in the conditions of passing and

[1] The measuring tool was a WINTACT WT1357 sound lever meter.

Fig. 2 Measurement Station in district 17, distances below 100 m from the railway line

not passing the train in the case study locations, and compare it with domestic and international standards.

There are several standards for acceptable noise levels developed by different organizations based on criteria such as sleep disturbance, hearing impairment, and so on. Some of these guidelines address land use (King et al., 2019). According to the WHO guidelines, the acceptable noise level outside the building in residential areas so as not to annoy is 50–55 dB (A) during the day, and at night it is 5–10 dB(A) less(Berglund et al., 2000). In Iran, according to the outdoor sound standard, the permissible sound level in residential areas is 55 dB(A) per day and in residential-commercial areas is equal to 60 dB (A) per day (Maleki & Hosseini, 2011).

After measuring and comparing the sound with the sound standard of Iran, the results show:

- According to the measurements obtained in this study, all values obtained were above the standard.
- In the study area, 700,000 people live within 1000 m of the railway track, which is exposed to the noise pollution of more than 70 decibels.

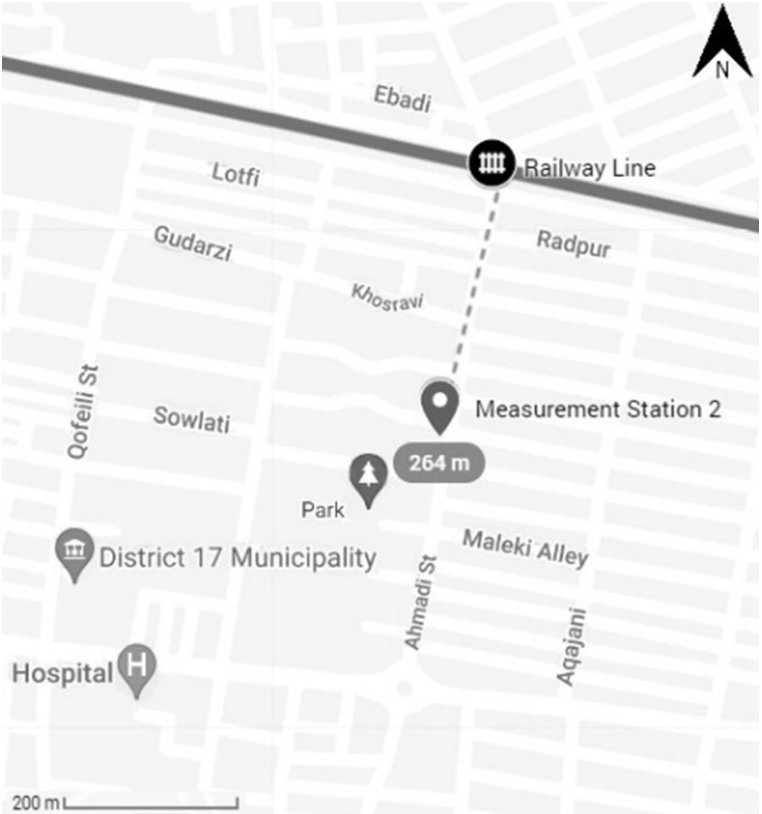

Fig. 3 Measurement Station in district 17, distances between 100 and 500 m from the railway line

Figure 8 shows the difference in average sound level measured in the study areas with the Iranian sound standard.

3.2 A questionnaire-based survey

Basically, in studies that study a specific group of people and try to create an in-depth understanding of the socioeconomic characteristics of people and their attitudes and opinions, a questionnaire-based survey is one of the best tools (Preston, 2009).

To prepare the questionnaire for this study, in the first step similar research has been studied in Iran and abroad. Afterward, the initial version of the questionnaire has been developed and after applying the opinions of the experts in Tehran Municipality, the final version of the questionnaire has been compiled and distributed. The survey was conducted in July 2021, and the questionnaires were distributed in paper form in the above-mentioned districts of Tehran especially very close to railway lines mostly at shops and bakeries. A voluntary sampling method has been used in this research.

In this study, Cochran's formula has been used to determine the sample size which is one of the most widely used methods to calculate the statistical sample size. In which n and N represent sample size and population size in respect. Z score is 1.96 with a 95%

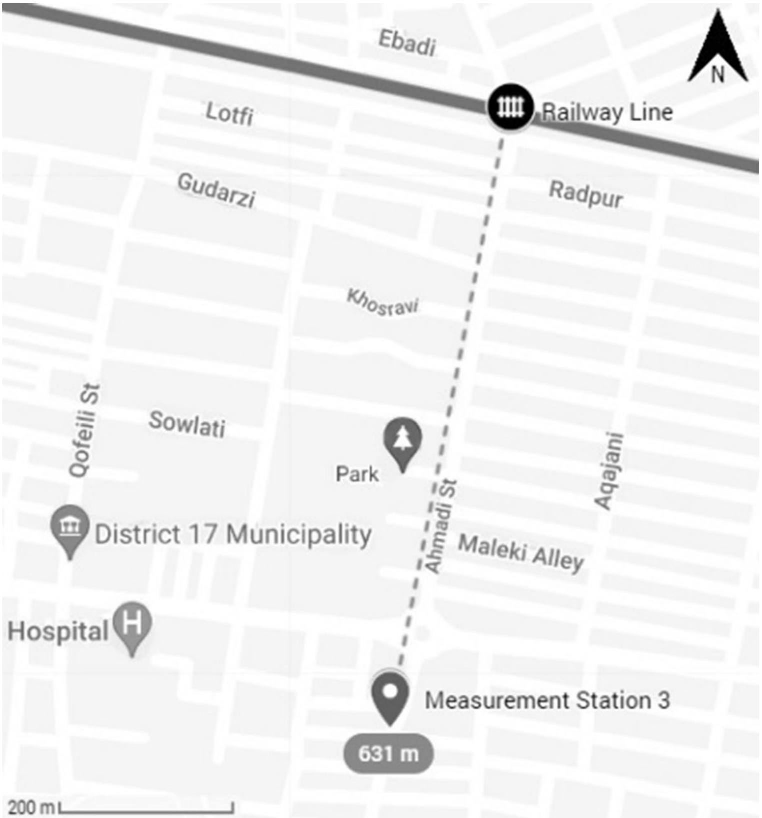

Fig. 4 Measurement Station in district 17, distances over 500 m from the railway line

confidence level, P is the proportion of the population ($q = 1 - \mathrm{p}$) and d is the error rate which is 5% in this study (Formula 1) (Shokouhibidhendi & Kalmarzi, 2022).

$$n = \frac{\frac{Z^2 pq}{d^2}}{1 + \frac{1}{N}\left(\frac{Z^2 pq}{d^2} - 1\right)} \tag{1}$$

Since the population of the regions mentioned in the third section, i.e., the volume of the statistical population has been equal to 693,113 people in total, the required statistical sample size according to Cochran's formula with an error rate of 5% is estimated at 384 people. A total of 390 answers were received, and after the final correction and elimination of incomplete and unusable answers, a total of 376 questionnaires were used.

The questionnaire used in this research consists of three main parts. The first part includes socio-demographic variables such as age, gender, level of education, occupation, and living district (17 or 18) to gain a better understanding of the sample under study. This part of the questionnaire also clarifies whether the people's place of residence or work is adjacent to the railways. The results of the analysis of socio-demographic variables show that the number of residents studied from districts 17 and 18 is almost equal. The

Fig. 5 Measurement Station in district 18, distances below 100 m from the railway line

population of men in the statistical sample is slightly higher than women (60% vs. 40%). Most people are middle-aged, i.e., in the age range of 30 to 50 years (68%) and generally have a diploma level. More than 50% of the statistical sample are employed (employee or self-employed) and finally, about 60% of the people have their home near the railway, 30% of their workplace, and 11% of people both (Table 2).

The second part includes questions regarding characteristics of people's living spaces which includes the following questions: the type of residential house; distance from the railway line; the age of the building; the type of frame of the building; the floor of the building which they live; length of residence and whether the windows of their place of residence or occupation are double-glazed or not. The results of this section show that the distance from a residential home or workplace to more than 45% of the statistical sample is a distance of 500 m or more from the railways. About 77% of people have been living in their current place of residence for more than 2 years. In the statistical sample, people live on different floors of buildings with a relatively uniform distribution, and the largest number belong to the ground floor with 28% of the total population. The building where more than 50% of people live is between 5 and 20 years old and is mostly made of metal structures. 56% of the statistical sample stated that the windows of their home or workplace are normal and not double-glazed (Table 3).

Fig. 6 Measurement Station in district 18, distances between 100 and 500 m from the railway line

Finally, in the third part, the respondents were asked to express their views on the effect of noise and vibrations caused by the railways on their quality of life. About this part of the questionnaire, it should be noted that when it comes to exploring the exposure–response relationship between noise and vibration, one of the common methods that can be used is standard questions and scales proposed by the International Commission on Biological Effects of Noise (ICBEN). This method, presents a 5-point scale including Not at all, slightly, moderately, very, and extremely, to cover the whole range of opinions (Gjestland, 2017). Also, there are a good number of former studies that used this method to study noise or vibration effects on humans (Fields et el. 2001; Hammersen et al., 2016; Jeon et al., 2003; Woodcock et al., 2011). Another scale that is frequently used in research questionnaires is the Likert scale. The Likert scale is generally used to measure the point of view, feeling, opinion, and such things that are not visible but can affect the audience's behavior. The 5-point scale generally includes: very low, low, average, high, and very high (Albaum, 1997; Joshi et al., 2015). Some of the previous studies that have investigated noise pollution have used this scale (Connolly et al., 2015; Croy et al., 2013; Gilles et al., 2012).

Fig. 7 Measurement Station in district 18, distances over 500 m from the railway line

The reason for using the Likert scale instead of the ICBEN scale in this research is that, firstly, the questions of this research do not only include the level of annoyance from noise pollution caused by the railway, but in general, people are asked to express their opinion about the presence of the railway line in their place of residence or work, for example, the effect of the railway on the beauty of the environment, the necessity of the relevant action by the government authorities, etc., and the second reason is that the ICBEN scale is rarely used in questionnaires and researches in Iran, and the Likert scale method is more common and people are more familiar with this scale and was used in former studies about noise in Iran (Abbasi et al., 2016; Ahmadi & Dianat, 2019; Hamidi et al., 2014).

In this section, the following issues were investigated: the need for action by railway officials; degree of sleep disturbance; concerns about damage to property and objects inside the house; the possibility of migration from the current residence due to problems caused by railways; the impact of railways on the quality of life, price of residential house and on the attractiveness of the living environment. The results of which are analyzed using descriptive statistics and are presented in the fifth section.

Data collection tools should have the Reliability feature, which means that if it is used at several different times in a population, not much difference will be seen as a result (Taherdoost, 2016). From a content validity perspective, the following questions are expected to

Table 1 Results of noise level measurement

District		When the train is not passing		
		Less than 100 m	Between 100 and 500 m	More than 500 m
District 17	Minimum sound level dB (A)	59.2	61.4	67.5
	Maximum sound level dB (A)	67.4	70.9	73.6
	Average sound level dB (A)	61.7	72.3	71.2
District 18	Minimum sound level dB (A)	61.7	60.8	59.4
	Maximum sound level dB (A)	70.5	69.2	72.4
	Average sound level dB (A)	67.8	64.5	65.1
		When the train is passing		
		Less than 100 m	Between 100 and 500 m	More than 500 m
District 17	Minimum sound level dB (A)	83.2	80.6	78.5
	Maximum sound level dB (A)	87.7	87.2	83.2
	Average sound level dB (A)	84.9	84.1	80.9
District 18	Minimum sound level dB (A)	82.2	79.3	77.8
	Maximum sound level dB (A)	90	85.2	81.4
	Average sound level dB (A)	85.4	81.2	79.3

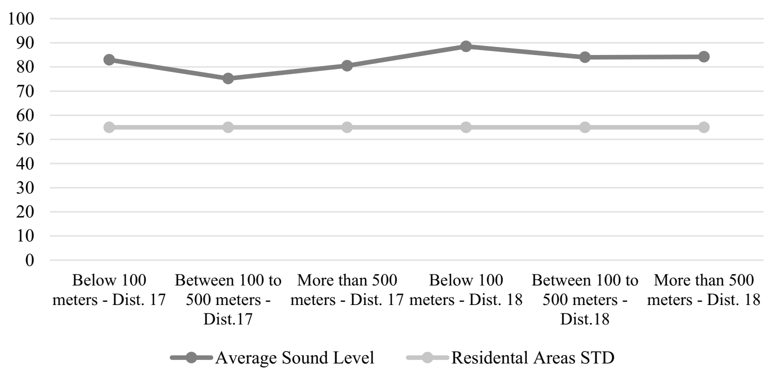

Fig. 8 Comparison of average measured sound with standard

be answered: Does the designed tool cover all the important aspects of the concept being measured? Do the structures of this tool do what they should (YAGHMAEI, 2003)?

Accordingly, in this research, to assess the validity, the questions have been tried to be as simple and understandable as possible. Also, research experiences have been used and finally, the questionnaire has been presented to some experts and their views on the accuracy of the questionnaire were examined. To measure reliability, an indicator called the reliability coefficient is used. The range of the reliability coefficient is from zero to + 1, which means that if the coefficient is zero, it shows unreliability, and if this coefficient is one, it shows complete reliability (Gliem & Gliem, 2003). To calculate the reliability

Table 2 Descriptive Statistics of Socio-demographic variables

			District 17			District 18
District						
Frequency			198			178
Percent			52.7			47.3
			Male			Female
Gender						
Frequency			225			151
Percent			59.8			40.2
	Under 20	20–30	30–40	40–50	50–60	More than 60
Age						
Frequency	9	44	139	117	31	36
Percent	2.4	11.7	37	31.1	8.2	9.6
	Less than diploma		Diploma	Bachelor's degree		Master's degree or Higher
Level of education						
Frequency	46		250	70		10
Percent	12.3		66.5	18.6		2.7
	Employed	Freelance	Retired	House Keeper	Student	Other
Occupation						
Frequency	51	160	57	85	11	12
Percent	13.6	42.6	15.2	22.6	2.9	3.2
		Workplace		Residence		Both
Workplace or residence near railway						
Frequency		114		220		42
Percent		30.3		58.5		11.2

coefficient, there are different methods in this research to measure the reliability Cronbach's alpha method is used. Cronbach's alpha was calculated as 0.81, which can be said that this questionnaire is good and the results obtained from this research can be trusted.

4 Results

In this section, the results of the questionnaires are examined by descriptive statistics and inferential statistics by SPSS software. In the first part, the results of people's opinions are examined using the 5-point Likert scale by calculating the mean and standard deviation, and in the second part, the effects of several variables on each other, for example, the effect of distance from the railway track on noise and vibration will be checked by the chi-square test.

Table 3 Descriptive Statistics of the characteristics of people's living/working space

	Too close (Less than 500 m)	Close (500–1000 m)	Far (more than 1000 m)
Distance from the railway			
Frequency	62	138	173
Percent	17.3	38.7	46

	Less than 1 year	1 to 2 Years	More than 2 years
Duration of residence			
Frequency	28	58	290
Percent	7.5	15.4	77.1

	Ground floor	One	Two	Three	Four	Five	Six
Floor number							
Frequency	106	82	78	55	33	13	5
Percent	28.2	21.8	20.7	14.6	8.9	3.5	1.6

	New	5–20 years old	More than 20 years old
Age of building			
Frequency	36	200	139
Percent	9.6	53.2	37.2

	Metal	Concrete	No skeleton	Incognizant
Type of building				
Frequency	174	65	10	127
Percent	46.3	17.3	2.7	33.8

	Yes	No
Double-glazed windows		
Frequency	164	212
Percent	43.6	56.4

4.1 Descriptive statistics

As mentioned before, in this section, with the SPSS software, the mean and standard deviation have been used to analyze items such as the amount of harassment caused by noise pollution and railway vibrations and other items mentioned in the previous section. In this section, people's opinions are expressed with a 5-point Likert scale, in which the number 5 represents very high and the number 1 means very low. Therefore, the closer the average is to 5, it means that the mentioned case has the highest value in the eyes of most people. The standard deviation has also been used, which is a measure of the scatter of data about the mean. A low standard deviation means that the data is grouped around the mean, and a high standard deviation indicates that the data is more scattered (Yu et al., 2016). The results of descriptive statistics in this section show that the first case, which has the highest average, the closest number to 5, and the lowest standard deviation, is a general belief (3.97 out of 5) that the railway company needs to take effective measures to reduce the effects of noise pollution and railway vibrations. The results show that many people consider the impact of the railway on house prices and the beauty of the environment to be relatively high (3.54 and 3.44, respectively), Also, the lowest average is related to the amount of noise sensation caused by the railway (Table 4).

4.2 Inferential statistics

Inferential statistics conclude the sample information about the population (King & Eckersley, 2019). In this section, the effect of variables of gender, age, the distance of residence from the railway line, which floor of the building people live in, type and age of the building, and whether or not there are double-glazed windows, on the noise sensation and vibrations caused by the railway is examined. Since the mentioned variables are two groups or more and the samples are taken from different people that means they are independent and unpaired, and the type of case variables and also the level of measurement, are nominal, the chi-square comparison test is used (Simpson, 2015).

The chi-square test is one of the most useful inferential statistics tools for testing hypotheses when variables are nominal which is a nonparametric statistic and a distribution-free test (McHugh, 2013). In the chi-square test, the initial assumption, or the null hypothesis, is that there is no significant relationship between the variables. To test this hypothesis, the *p*-value is used and compared with the significance level which is equal to 0.05. If the *p*-value is less than or equal to the significance level, the null hypothesis will be rejected and it is determined that there is a significant relationship between the variables under study and if the value of p is greater than 0.05, the null hypothesis, no significant relationship between variables, will be accepted (Pandis, 2016). ANOVA has also been used to compare the effects of auditory and non-auditory factors on residents' dissatisfaction level of noise and vibration. In the following section, with SPSS software and using crosstabulation, *P*-value is calculated to check the presence or absence of a significant relationship between variables.

4.2.1 The relationship of variables with railway noise pollution

In this section, the existence of a significant relationship between the following variables and the level of dissatisfaction with railway noise is examined by the chi-square test: gender, age, floor number of the building, the distance of from the railway, double-glazed windows, and proximity of residence or workplace or both to the railway.

Statistical analysis of SPSS software shows the P-value to examine the relationship between gender and the level of dissatisfaction with railway noise equal to 0.03, and thus the null hypothesis is accepted and it is stated that there is no relationship between gender and the level of dissatisfaction with railway noise. Also, regarding the effect of age on the mentioned factor, *P*-value has been calculated equal to 0.068, so it can be said that age does not effect the level of dissatisfaction with railway noise as well.

The issue of the floor on which the respondent live affects the level of noise dissatisfaction because the *P*-value was calculated as 0, which is less than 0.05. The most dissatisfaction is for the people who live on the first floor, so that 32% of the total people living on the first floor, are equally or more than average annoyed by the noise caused by the railway and the least dissatisfaction belongs to people living on the fourth and fifth floors, and only

Table 4 People's opinions about the existence of railways in their place of residence

	Mean	Standard deviation	Percentage				
			Very low	Low	Average	High	Very high
Feeling the noise from the railway	2.11	1.017	29.3	44.4	15.2	7.7	3.2
Feeling the vibration from the railway	2.18	1.041	26.1	45.7	15.2	9	3.7
Concerns about the impact of noise pollution and railway vibration on health	3.07	1.66	10.1	19.1	27.7	39.4	3.7
Concerns about damage to property and equipment due to rail vibrations	2.56	1.176	16.5	44.7	11.4	21	6.4
Sleep disorders due to noise and vibration of the railways	2.24	1.023	20.7	51.9	15.2	7.2	5.1
Possibility of moving from current the residence due to vibrations and railway noise	2.34	1.091	18.4	52.1	13.6	9	6.9
The effect of railway noise and vibrations on reducing the quality of life	3.12	0.956	8	29	36.2	25	8.8
The effect of railway noise and vibrations on reducing the price of a residential house	3.54	0.792	1.3	4.3	44.1	39.6	10.6
The impact of the existence of railways on reducing the beauty of the environment	3.44	0.853	0.8	6.1	56.9	20.5	15.4
The necessity of the railway company to eliminate noise pollution and vibration caused by the railway	3.97	0.733	5	3.5	14.6	60.9	20.5

15% of the population in each of them are above-average of being dissatisfied with railway noise (Table 5).

The statistical analysis of SPSS software also shows that there is a significant relationship between the distance of residence or work from the railway and the level of residents' dissatisfaction with the noise caused by the railway because the *p*-value is less than the significant level of 0.05. So that 48% of people who live less than 500 m from the railway are above-average being dissatisfied with railway noise, while this number for those who live between 500 and 1000 m from railways is equal to 31% and for residents at a distance of more than 1000 m is equal to 13% (Table 6).

Table 5 The results for which floor of the building and Railway noise pollution

Variable	Very low	Low	Average	High	Very high	Total	*P*-Value
Number of the floor							
Ground Floor	28	57	13	6	2	106	0.000
First Floor	22	33	13	10	4	82	
Second Floor	29	29	13	6	1	78	
Third Floor	20	18	6	4	4	55	
Fourth Floor	10	17	4	1	1	33	
Fifth Floor	0	11	2	0	0	13	
Sixth Floor	1	0	3	1	0	5	
Total	109	166	57	28	12	372	

Table 6 The results for the distance from the railway and Railway noise pollution

Variable	Very low	Low	Average	High	Very high	Total	*P*-Value
Distance from the railway							
Too Close (500 m or less)	10	22	14	11	5	62	0.000
Close (500–1000 m)	30	64	25	15	4	138	
Far (1000 m or more)	69	80	18	3	3	173	
Total	109	166	57	29	12	373	

Regarding the relationship between double-glazed windows at home or workplace and the degree of dissatisfaction of people with the railway noise, the *p*-value is equal to 0.34, so the null hypothesis is not rejected and it can be said that there is no significant relationship between the double-glazed windows of buildings and dissatisfaction with railway noise.

4.2.2 The relationship of variables with railway vibration

In this section, as in the previous section, the chi-square test is used to examine the existence of a significant difference between the sensation of vibration caused by the railway and the variables that are thought to affect this issue. The variables on which the chi-square test is performed in this section to examine their effect on the degree of dissatisfaction with the vibrations caused by the railways are: gender, age, floor number of the building, the distance from the railway, age of the building and proximity of residence or workplace or both to the railway.

Like noise pollution, the chi-square test shows that the variables of the proximity of residence or workplace or both to railway and gender does not affect the dissatisfaction with railway vibrations. Because their *p*-value, which is calculated by SPSS software, is equal to 0.4 and 0.73, respectively, and therefore there is no significant relationship between either of these two variables and the dissatisfaction with railway vibrations.

However, the results of the chi-square test show that the age of people affects their dissatisfaction with the vibration caused by the train. Contrary to popular belief that older

Table 7 The results for age and railway vibrations

Variable	Very low	Low	Average	High	Very high	Total	*P*-value
Age							
Less than 20	2	3	2	2	0	9	0.015
20–30	7	15	10	9	3	44	
30–40	32	71	23	9	4	139	
40–50	29	58	16	10	4	117	
50–60	9	12	6	2	2	31	
More than 60	19	13	0	2	2	36	
Total	98	172	57	34	15	376	

Table 8 The results for which floor of the building and Railway vibrations

Variable	Very low	Low	Average	High	Very high	Total	*P*-value
Number of the floor							
Ground Floor	22	62	10	9	3	106	0.034
First Floor	22	30	13	10	4	82	
Second Floor	29	31	13	6	2	78	
Third Floor	20	20	9	5	4	55	
Fourth Floor	10	20	3	2	0	33	
Fifth Floor	0	6	6	1	0	13	
Sixth Floor	1	0	3	1	0sss	5	
Total	97	170	57	34	14	372	

people are more likely than young people to suffer from rail vibrations, the results of this study show that the greatest dissatisfaction is among people between the ages of 20 and 30, with 48% of them reporting they feel equal to or greater than the average vibration caused by the railway. The least dissatisfaction is for people over 60 years old and only 11% of them have chosen average, high, and very high options in response to the question of dissatisfaction with railway vibrations (Table 7).

Like noise pollution, being on which floor of a building affects the sensation of vibrations from the railway. The results of the chi-square test show that due to the p-value = 0.034, it can be said that there is a significant relationship between building floor number and vibrations caused by rail. In this case, the residents of the fifth and sixth floors feel the vibrations above average more than other classes (61% of the total residents of the fifth and sixth floors) and the residents of the fourth floor have the least dissatisfaction and 15% of the total population of the residents of the fourth floor feel equal to or more than the average vibrations (Table 8).

The results of the chi-square test also show that another factor influencing the sensation of vibrations is the distance house or workplace to and from railway. Just like noise pollution, people who live less than 500 m from the railway are the most dissatisfied with vibrations, and 53% of them, in response to a question about the degree of dissatisfaction with rail vibrations, have chosen average, high, and very high options and people whose workplace or residence is located more than 1000 m away from railway have the least dissatisfaction (12%) (Table 9).

Table 9 The results for the distance from the railway and Railway vibrations

Variable	Very low	Low	Average	High	Very high	Total	*P*-value
Distance of from the railway							
Too Close (500 m or less)	11	18	16	9	9	63	0.000
Close (500–1000 m)	24	64	26	20	4	138	
Far (1000 m or more)	62	89	15	5	1	173	
Total	97	171	57	34	14	373	

Table 10 The results for age of the building and Railway vibrations

Variable	Very low	Low	Average	High	Very high	Total	*P*-value
Age of the building							
New	8	8	13	6	1	36	0.000
5–20 years old	59	94	26	16	8	200	
More than 20 years old	31	73	18	12	5	139	
Total	98	172	57	34	14	375	

Finally, the last variable examined by the chi-square test to find out whether there is a significant relationship between it and dissatisfaction with the railway is the age of the residential building. *P*-value, in this case, is calculated at 0.005 by SPSS software, which means that the age of the building is effective in sensing the vibrations of the railway. Contrary to popular belief that older buildings are more vibrant, the results of this questionnaire indicate that 55% of people living in new buildings feel equal or more than average vibrations caused by railway, while for buildings 5 to 20 years old and over 20 years old, this number is equal to 25% (Table 10). This can be due to potential decrease in the quality of buildings that are constructed in recent years.

In short, the variables of gender, age, double-glazed windows, and proximity of residence or workplace or both to the railway have no effect on the level of dissatisfaction with railway noise but floor number of the building and distance of from the railway affect it. Regarding the vibrations caused by the railway, again the variables of gender and proximity of residence or workplace or both to railway do not affect the dissatisfaction with it, but the variables of age, the floor number of the building, the distance from the railway and age of the building influence the dissatisfaction with railway vibrations.

4.2.3 ANOVA

In this section, to compare the different influences of auditory and non-auditory factors on residents' responses to noise and vibration, the existence of a significant relationship between these factors and the level of dissatisfaction with railway noise and the vibration is examined using ANOVA. For this purpose, the variables are divided into two groups. Non-auditory variables are: District, Gender, Age, Level of education, Occupation, Workplace

Table 11 ANOVA for non-auditory factors and Railway noise pollution

		Sum of squares	df	Mean square	F	Sig
District	Between Groups	10.099	4	2.525	11.200	0.000
	Within Groups	83.410	370	0.225		
	Total	93.509	374			
Gender	Between Groups	0.739	4	0.185	0.788	0.533
	Within Groups	82.317	351	0.235		
	Total	83.056	355			
Age	Between Groups	9.981	4	2.945	1.846	0.119
	Within Groups	500.217	370	1.352		
	Total	510.197	374			
Level of education	Between Groups	1.452	4	0.363	0.904	0.461
	Within Groups	148.113	369	0.401		
	Total	149.586	373			
Occupation	Between Groups	17.727	4	4.432	2.642	0.034
	Within Groups	620.673	370	1.677		
	Total	638.400	374			
Workplace or Residence near Railway	Between Groups	1.605	4	0.401	1.061	0.376
	Within Groups	139.952	370	0.378		
	Total	141.557	374			

or Residence near Railway, and auditory variables are: Distance from the railway, Duration of residence, Floor number, Age of Building, Type of Building, Double-glazed windows.

First, a one-way ANOVA test was performed for each of the non-auditory variables and the level of dissatisfaction with railway noise (Table 11), then the same test was performed for each of these variables and the level of dissatisfaction with railway vibrations (Table 12). In the same way, it has been done to discover a significant relationship between auditory variables and the level of dissatisfaction with railway noise (Table 13), and auditory variables and the level of dissatisfaction with railway vibrations (Table 14).

In the one-way ANOVA test, just like the chi-square test, the null hypothesis, is that there is no significant relationship between the variables and the level of dissatisfaction with railway noise and vibrations. To test this hypothesis, the Sig. is used and compared with the significance level which is equal to 0.05. If it is less than or equal to the significance level, the null hypothesis will be rejected.

The results of the one-way ANOVA test show that there is a significant relationship between non-auditory variables and the level of dissatisfaction with railway noise, only between the variables of the place of residence and work, and the level of dissatisfaction with noise. And also, among the variables inaudibility and level of dissatisfaction with railway vibrations, there is a significant relationship between the variables of the place of residence and age, and the level of dissatisfaction with vibrations. But in the case of auditory variables, there is a significant relationship between the variables of Distance from the railway, floor number, Type of Building and the level of dissatisfaction with noise. And also, among the auditory variables and the level of dissatisfaction with railway vibrations, there is a significant relationship. Between all the variables, and level of dissatisfaction with vibrations. So, in general, it can be concluded that auditory variables have a greater

Table 12 ANOVA for non-auditory factors and Railway vibration

		Sum of squares	df	Mean square	*F*	Sig
District	Between Groups	13.014	4	3.254	14.965	0.000
	Within Groups	80.442	370	0.217		
	Total	93.456	374			
Gender	Between Groups	0.420	4	0.105	0.446	0.776
	Within Groups	82.637	351	0.235		
	Total	83.056	355			
Age	Between Groups	25.357	4	6.339	4.862	0.001
	Within Groups	482.440	370	1.304		
	Total	507.797	374			
Level of education	Between Groups	3.008	4	0.752	1.893	0.111
	Within Groups	146.577	369	0.397		
	Total	149.586	373			
Occupation	Between Groups	13.616	4	3.404	2.008	0.093
	Within Groups	427.062	370	1.695		
	Total	440.677	374			
Workplace or Residence near Railway	Between Groups	1.894	4	0.473	1.261	0.285
	Within Groups	138.896	370	0.375		
	Total	140.789	374			

Table 13 ANOVA for auditory factors and Railway noise pollution

		Sum of squares	df	Mean square	*F*	Sig
Distance from the railway	Between Groups	21.990	4	5.497	11.240	0.000
	Within Groups	179.978	368	0.489		
	Total	201.968	372			
Duration of residence	Between Groups	24.674	4	6.168	21.197	0.412
	Within Groups	107.382	369	0.291		
	Total	132.056	373			
Floor number	Between Groups	10.748	4	2.687	0.991	0.000
	Within Groups	994.959	367	2.711		
	Total	1005.707	371			
Age of Building	Between Groups	3.600	4	0.900	2.327	0.356
	Within Groups	143.109	370	0.387		
	Total	146.709	374			
Type of Building	Between Groups	93.435	4	23.359	114.993	0.000
	Within Groups	574.907	369	1.558		
	Total	668.342	373			
Double-glazed windows	Between Groups	1.102	4	0.275	1.118	0.348
	Within Groups	91.176	370	0.246		
	Total	92.277	374			

Table 14 ANOVA for auditory factors and Railway vibration

		Sum of squares	df	Mean square	*F*	Sig
Distance from the railway	Between Groups	29.501	4	7.375	15.630	0.000
	Within Groups	173.646	368	0.472		
	Total	203.147	372			
Duration of residence	Between Groups	21.426	4	5.357	17.801	0.000
	Within Groups	111.034	369	0.301		
	Total	132.460	373			
Floor number	Between Groups	17.454	4	4.363	1.620	0.001
	Within Groups	988.253	367	2.693		
	Total	1005.707	371			
Age of Building	Between Groups	4.312	4	1.078	2.801	0.026
	Within Groups	142.398	370	0.385		
	Total	146.709	374			
Type of Building	Between Groups	81.076	4	20.269	12.736	0.000
	Within Groups	587.266	369	1.592		
	Total	668.342	373			
Double-glazed windows	Between Groups	5.181	4	1.295	5.511	0.000
	Within Groups	86.968	370	0.235		
	Total	92.149	374			

impact on the level of people's dissatisfaction with railway noise and vibrations than auditory variables.

5 Summary and conclusion

In this section, first a summary of all stages and results of the research is presented and then practical suggestions for controlling the effects of noise and vibrations of the railway are presented according to the research findings. In this research, a relatively comprehensive introduction to the issue of noise pollution and vibration caused by railways is first given. In the introduction of this research, it is stated that although rail transportation is generally known as environmentally friendly transportation, it is not free pollution free and noise pollution caused by railways is the second main source of environmental noise pollution. Also, the passage of the train over the railway lines leads to vibrations that are transmitted to the buildings through the ground and can cause damage to the building and dissatisfaction for the residents around the railway lines. Therefore, due to the increasing expansion of urbanization and increase in transportation demand, and due to the lack of studies about the noise and vibrations caused by railways in developing countries, conducting this research is necessary.

In the next section of the study, a literature review of the subject of the study is given, which reviews the issue of noise pollution and vibrations caused by railways separately or together. Past research has shown that noise from railroads depends on the type and speed of the train and the type of rails, and depending on the distance from the railway line and individual and social factors, can cause dissatisfaction and harassment such as sleep disorders for people. Also, the vibrations caused by the railway are mostly due to the interaction between the train wheels and the rails, and in addition to the dissatisfaction of the residents, it can cause problems for the buildings, such as falling and cracking.

In the third part, the characteristics of the case study were introduced, namely the city of Tehran, the capital of Iran, and after stating the characteristics of rail transportation in Tehran and Iran, the 17 and 18 districts of Tehran, due to the higher density of railways in it, was chosen a case study.

After that the research methodology is stated, which includes measuring the noise level in the study area in six measuring stations and a questionnaire-based survey and then the analysis of collected data by descriptive and inferential statistics. Finally, in this chapter, a summary, conclusion and expression of suggestions are given.

In this study, to collect research data, after calculating the statistical sample size with Cochran's formula, a questionnaire was collected voluntarily from 376 residents of districts 17 and 18. At first, the data of the questionnaire were analyzed using descriptive statistics and the results show that 60% of the statistical sample are men and 40% are women and most people are in the age range of 30 to 50 years. More than half of them are employed. Nearly 50% of the statistical population lives more than 500 m away from the railways, and more than half of the people live in buildings 5 to 20 years old, and 56% of the workplace or residential buildings have double-glazed windows.

Initially, the results of the measurements showed that when the train passing during the day, the noise level in the areas close to the railway was above the standard (55 dB). Nearly 700,000 people were exposed to noise pollution of more than 70 dB, which can cause severe dissatisfaction among the residents of these areas and even in the long run can cause hearing damage.

The analysis of the opinions of the statistical sample by a 5-point Likert scale showed that the most important issue from the people's point of view is the need for the railway authorities to take action to control and reduce noise pollution and the destructive effects of railway vibrations.

After the initial analysis of the data, inferential statistics were used to examine whether the results obtained from the statistical sample were generalized to the statistical comprehensive. To test the hypothesis of a significant relationship between variables such as age, gender, distance from the rail, building floor number, double-glazed windows, age and type of building and the dissatisfaction with noise and vibrations of the railway, the chi-square test was used. Table 10 shows the summary and the results of the total of ten tests that have been performed (Table 15).

The results of this research show that the dissatisfaction of people in these districts needs close collaboration of Railway Company and Tehran municipality to overcome the existing challenges. Moreover, quality of construction of new buildings at these areas which are among the most deprived parts of the city is under question that needs more strict control and supervision. Even the quality of double-glazed windows does not seem good enough to make a considerable change.

Future research is suggested to quantify the noise and vibration of railways and associate it with dissatisfaction results. Moreover, on the parameters that were found to be effective on noise or vibration more detailed research can be useful. For instance, from civil engineering aspect, it should be investigated why people who live at newly constructed buildings are more dissatisfied from vibration. Also, more psychological surveys are suggested to address soft aspects of noise and vibration on people's lives in these areas.

Table 15 Summary of inferential statistics results

		Railway noise pollution	
Null hypothesis	*P*-value	Conclusion	Description
No significant relationship between gender and Railway Noise pollution	0.53	Null hypothesis accepted	–
No significant relationship between age and Railway Noise pollution	0.068	Null hypothesis accepted	–
No significant relationship between the floor number of the building and Railway Noise pollution	0.00	Null hypothesis rejected	People living on the first floor of the building are more dissatisfied with the noise from the railways than others
No significant relationship between the distance from the railway and Railway Noise pollution	0.00	Null hypothesis rejected	People who live less than 500 m from the railways are more dissatisfied with the noise from the railways than others
No significant relationship between double-glazed windows and Railway Noise pollution	0.34	Null hypothesis accepted	–
No significant relationship between the proximity of residence or workplace or both to railway and Railway Noise pollution	0.40	Null hypothesis accepted	–
		Railway Vibrations	
Null hypothesis	*P*-value	Conclusion	Description
No significant relationship between gender and Railway Vibrations	0.73	Null hypothesis accepted	–
No significant relationship between age and Railway Vibrations	0.015	Null hypothesis rejected	People between the ages of 20 and 30 are more dissatisfied with rail vibrations than others
No significant relationship between the floor number of the building and Railway Vibrations	0.034	Null hypothesis rejected	People living on the fifth and sixth floors of the building are more dissatisfied with the noise from the railways than others
No significant relationship between the distance of from the railway and Railway Vibrations	0.00	Null hypothesis rejected	People who live less than 500 m from the railways are more dissatisfied with railway vibrations than others
No significant relationship between the age of the building and Railway Vibrations	0.00	Null hypothesis rejected	People who live in new buildings are more dissatisfied with railway vibrations than others
No significant relationship between the proximity of residence or workplace or both to railway and Railway Vibrations	0.40	Null hypothesis accepted	–

Appendix

The full text of the questionnaire is as follows:

This questionnaire is designed to investigates the effects of railway noise and vibrations on dissatisfaction of residents in the city of Tehran. If you live in any of the 17 or 18 districts of Tehran, please answer the following questions. It is hoped that the results of this project will cause improvement in the city of Tehran. Thank you in advance for your cooperation.

1. Which one of the 17 or 18 districts of Tehran is your place of residence or work? □ District 17 □ District 18

2. Gender? □ Male □ Female

3. Age? □ Under 20 □ 20-30 years □ 30-40 years □ 40-50 years □ 50-60 years □ 60 years and up

3. Level of education? □Less Than Diploma □Diploma □Bachelor's degree □Master's degree or Higher

4.Occupation? □Employed □Freelance □Retired □House Keeper □Student □Other

5. For you, which of the places of work or residence is located near the railway line? □Workplace □Residence □Both

6. What is the distance of your place of residence/work from the railway line??

□Too Close (Less than 500m) □Close (500-1000m) □Far (More than 1000m)

7. How long is the duration of your stay in your current place of residence/work?

□Less than 1 year □1 to 2 Years □More than 2 years

8. On which floor of your residence/ workplace do you live/work?

□Ground Floor □One □Two □Three □Four □Five □Six or more

9. In which classification is the age of the building of your place of residence/work?

□New (Less than 5 years) □5-20 years old □More than 20 years old

10. What is the type of building frame of your place of residence/work?

□Metal □Concrete □No skeleton □incognizant

11. Are the doors and windows of your place of residence/work double glazed?

□Yes □No

12. Indicate your opinion about having a railway line near the place of your residence/work in relation to each of the following, from least to most.

	Very Low	Low	average	High	Very High
Feeling the noise from the railway	□	□	□	□	□
Feeling the vibration from the railway	□	□	□	□	□
Concerns about the impact of noise pollution and railway vibration on health	□	□	□	□	□
Concerns about damage to property and equipment due to rail vibrations	□	□	□	□	□
Sleep disorders due to noise and vibration of the railways	□	□	□	□	□
Possibility of moving from current residence due to vibrations and railway noise	□	□	□	□	□
The effect of railway noise and vibrations on reducing the quality of life	□	□	□	□	□
The effect of railway noise and vibrations on reducing the price of a residential house	□	□	□	□	□
The impact of the existence of railways on reducing the beauty of the environment	□	□	□	□	□
The necessity of the railway company to eliminate noise pollution and vibration caused by the railway	□	□	□	□	□

13.Please list your suggestions and criticisms below:

Data availability The datasets gathered and analyzed during the current study are available from the corresponding author on reasonable request.

References

Aasvang, G. M., Øverland, B., Ursin, R., & Moum, T. (2011). A field study of effects of road traffic and railway noise on polysomnographic sleep parameters. *The Journal of the Acoustical Society of America, 129*, 3716–3726.

Abbasi, M., Monazzam, M. R., Ebrahimi, M. H., Zakerian, S. A., Dehghan, S. F., & Akbarzadeh, A. (2016). Assessment of noise effects of wind turbine on the general health of staff at wind farm of Manjil. *Iran. Journal of Low Frequency Noise, Vibration and Active Control, 35*, 91–98.

Abowei, J., Akaso, A., & Bariweni, P. (2011). Aspects of environmental pollution from maritime transportation in Nigeria. *Nig J Agric Food Environment, 7*, 54–67.

Ahmadi, O., & Dianat, I. (2019). Qualitative aspects of traffic noise in Tabriz city, Iran: Effects, habituation, and possible improvements. *International Journal of Environmental Science and Technology, 16*, 2009–2016.

Albaum, G. (1997). The Likert scale revisited. *Market Research Society Journal, 39*, 1–21.

Aleknaite, M., & Grubliauskas, R. (2018). Assessment and evaluation of railway noise spread dependence on different types of sleepers. *Energy Procedia, 147*, 249–257.

Auger, N., Duplaix, M., Bilodeau-Bertrand, M., Lo, E., & Smargiassi, A. (2018). Environmental noise pollution and risk of preeclampsia. *Environmental Pollution, 239*, 599–606.

Babici, L., & Tudor, A. (2019). Some aspects regarding the roughness of the railway surface and rolling noise at locomotives. *IOP Conference Series: Materials Science and Engineering, 514*, 012010.

Bahrekazemi, M. (2004) Train-induced ground vibration and its prediction. Byggvetenskap.

Berglund, B., Lindvall, T., & Schwela, D. H. (2000). New WHO guidelines for community noise. *Noise & Vibration Worldwide, 31*, 24–29.

Bunn, F., & Zannin, P. H. T. (2016). Assessment of railway noise in an urban setting. *Applied Acoustics, 104*, 16–23.

Chen, R., Wang, P. & Chen, X. (2009) Wheel/rail noise generation mechanisms and its control in high speed railway.

Connolly, D. M., Dockrell, J. E., Shield, B. M., Conetta, R., & Cox, T. J. (2015). Students' perceptions of school acoustics and the impact of noise on teaching and learning in secondary schools: Findings of a questionnaire survey. *Energy Procedia, 78*, 3114–3119.

Connolly, D. P., Marecki, G. P., Kouroussis, G., Thalassinakis, I., & Woodward, P. K. (2016). The growth of railway ground vibration problems—a review. *Science of the Total Environment, 568*, 1276–1282.

Croy, I., Smith, M. G., & Waye, K. P. (2013). Effects of train noise and vibration on human heart rate during sleep: An experimental study. *British Medical Journal Open, 3*, e002655.

Cueto, J. L., Petrovici, A. M., Hernández, R., & Fernández, F. (2017). Analysis of the impact of bus signal priority on urban noise. *Acta Acustica United with Acustica, 103*, 561–573.

De Vos, P. (2012) Railway noise. Noise Mapping in the EU: Models and Procedures**,** 81.

Dratva, J., Phuleria, H. C., Foraster, M., Gaspoz, J.-M., Keidel, D., Künzli, N., Liu, L.-J.S., Pons, M., Zemp, E., & Gerbase, M. W. (2012). Transportation noise and blood pressure in a population-based sample of adults. *Environmental Health Perspectives, 120*, 50–55.

Dzhambov, A. M., Dimitrova, D. D., & Dzhambov, A. (2016). Association between noise pollution and prevalent ischemic heart disease. *Folia Med (Plovdiv), 58*, 273–281.

Elmenhorst, E.-M., Pennig, S., Rolny, V., Quehl, J., Mueller, U., Maaß, H., & Basner, M. (2012). Examining nocturnal railway noise and aircraft noise in the field: Sleep, psychomotor performance, and annoyance. *Science of the Total Environment, 424*, 48–56.

Erickson, L. C., & Newman, R. S. (2017). Influences of background noise on infants and children. *Current Directions in Psychological Science, 26*, 451–457.

Fields, J. M., De Jong, R. G., Gjestland, T., Flindell, I. H., Job, R. F. S., Kurra, S., Lercher, P., Vallet, M., Yano, T., Guski, R., Felscher-Suhr, U., Schumer, R. (2001). Standardized general-purpose noise reaction questions for community noise surveys: Research and a recommendation. *Journal of Sound and Vibration, 242*(4), 641–679. https://doi.org/10.1006/jsvi.2000.3384

Fiorini, C. V. (2022). Railway noise in urban areas: Assessment and prediction on infrastructure improvement combined with settlement development and regeneration in central Italy. *Applied Acoustics, 185*, 108413.

Fredianelli, L., Carpita, S., Bernardini, M., del Pizzo, L. G., Brocchi, F., Bianco, F., & Licitra, G. (2022a). Traffic flow detection using camera images and machine learning methods in ITS for noise map and action plan optimization. *Sensors, 22*, 1929.

Fredianelli, L., Gaggero, T., Bolognese, M., Borelli, D., Fidecaro, F., Schenone, C., & Licitra, G. (2022b). Source characterization guidelines for noise mapping of port areas. *Heliyon, 8*, e09021.

Fukushima, H., Yano, T., Kawai, K., Nguyen, T. L., Nguyen, H. Q., Nishimura, T., Hashimoto, Y., Morihara, T. & Sato, T., (2011) Social Survey on community response to railway noise and vibration Hanoi. In 40th international congress and exposition on noise control engineering 2011 (pp. 3818–3825)

Gagliardi, P., Teti, L., & Licitra, G. (2018). A statistical evaluation on flight operational characteristics affecting aircraft noise during take-off. *Applied Acoustics, 134*, 8–15.

Gidlöf-Gunnarsson, A., Ögren, M., Jerson, T., & Öhrström, E. (2012). Railway noise annoyance and the importance of number of trains, ground vibration, and building situational factors. *Noise and Health, 14*, 190–201.

Gilles, A., de Ridder, D., van Hal, G., Wouters, K., Punte, A. K., & van de Heyning, P. (2012). Prevalence of leisure noise-induced tinnitus and the attitude toward noise in university students. *Otology & Neurotology, 33*, 899–906.

Gjestland, T. (2017) Standardized general–purpose noise reaction questions. Proceedings of the 12th ICBEN Congress, Zurich, Switzerland. 18–22.

Gliem, J. A. & Gliem, R. R. (2003) Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. Midwest Research-to-Practice Conference in Adult, Continuing, and Community ….

Googlemap. (2021). Tehran [Online]. Available: https://goo.gl/maps/GTVz4ZNpN44VmtabA [Accessed].

Grubliauskas, R., Strukčinskienė, B., Raistenskis, J., Strukčinskaitė, V., Buckus, R., & JanuševičiusDa Silva pereira, T. P. A. (2014). Effects of urban rail noise level in a residential area. *Journal of Vibroengineering, 16*, 987–996.

Hadi Hassan Al-Taai, S. (2021) Noise and its impact on environmental pollution. Materials Today: Proceedings.

Hamidi, M., Kavousi, A., Zaheri, S., Hamadani, A., & Mirkazemi, R. (2014). Assessment of the noise annoyance among subway train conductors in Tehran. *Iran. Noise and Health, 16*, 177.

Hammersen, F., Niemann, H., & Hoebel, J. (2016). Environmental noise annoyance and mental health in adults: Findings from the cross-sectional German Health Update (GEDA) Study 2012. *International Journal of Environmental Research and Public Health, 13*, 954.

Iglesias-Merchan, C., Diaz-Balteiro, L., & Soliño, M. (2015). Transportation planning and quiet natural areas preservation: Aircraft overflights noise assessment in a national park. *Transportation Research Part d: Transport and Environment, 41*, 1–12.

Jacyna, M., Wasiak, M., Lewczuk, K., & Karoń, G. (2017). Noise and environmental pollution from transport: Decisive problems in developing ecologically efficient transport systems. *Journal of Vibroengineering, 19*, 5639–5655.

Jeon, J.-Y., Kim, K.-H., & Yano, T. (2003). Standardized noise annoyance modifiers in Korean according to the ICBEN method. *The Journal of the Acoustical Society of Korea, 22*, 56–61.

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *British Journal of Applied Science & Technology, 7*, 396.

Kawada., T. (2011). Noise and health—Sleep disturbance in adults. *Journal of Occupational Health, 53*, 413–416.

King, A. P., & Eckersley, R. J. (2019). Chapter 4-inferential statistics I: basic concepts. In A. P. King & R. J. Eckersley (Eds.), *Statistics for Biomedical Engineers and Scientists*. Academic Press.

Klatte, M., Bergström, K., & Lachmann, T. (2013). Does noise affect learning? A short review on noise effects on cognitive performance in children. *Frontiers in Psychology, 2013*, 578.

Korzhenevych, A., Dehnen, N., Bröcker, J., Holtkamp, M., Meier, H., Gibson, G., Varma, A. & Cox, V. (2014) Update of the handbook on external costs of transport: Final report for the European Commission: DG-MOVE.

Koyagi, M. (2021). *Iran in Motion: Mobility, Space, and the Trans-Iranian Railway*. Stanford University Press.

Licitra, G., Fredianelli, L., Petri, D., & Vigotti, M. A. (2016). Annoyance evaluation due to overall railway noise and vibration in Pisa urban areas. *Science of the Total Environment, 568*, 1315–1325.

Lim, C., Kim, J., Hong, J., & Lee, S. (2006). The relationship between railway noise and community annoyance in Korea. *The Journal of the Acoustical Society of America, 120*, 2037–2042.

Ma, J., Li, C., Kwan, M.-P., & Chai, Y. (2018). A multilevel analysis of perceived noise pollution, geographic contexts and mental health in Beijing. *International Journal of Environmental Research and Public Health, 15*, 1479.

Maigrot, P., Parizet, É., & Marquis-Favre, C. (2020). Annoyance due to combined railway noise and vibration: Comparison and testing of results from the literature. *Applied Acoustics, 165*, 107324.

Maleki, K. & Hosseini, S. M. (2011) Investigation of the effects of leaves, branches and canopies of trees on noise pollution reduction. 5.

Mchugh, M. L. (2013). The chi-square test of independence. *Biochemia Medica, 23*, 143–149.

Michali, M., Emrouznejad, A., Dehnokhalaji, A., & Clegg, B. (2021). Noise-pollution efficiency analysis of European railways: A network DEA model. *Transportation Research Part d: Transport and Environment, 98*, 102980.

Miedema, H., & Oudshoorn, C. (2001). Annoyance from transportation noise: Relationships with exposure metrics DNL and DENL and their confidence intervals. *Environmental Health Perspectives, 109*, 409–416.

Miedema, H. M., & Vos, H. (2007). Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies. *Behavioral Sleep Medicine, 5*, 1–20.

Minichilli, F., Gorini, F., Ascari, E., Bianchi, F., Coi, A., Fredianelli, L., Licitra, G., Manzoli, F., Mezzasalma, L., & Cori, L. (2018). Annoyance judgment and measurements of environmental noise: a focus on Italian secondary schools. *International Journal of Environmental Research and Public Health, 15*, 208.

Mirabadi, A., & Sharifian, S. (2010). Application of association rules in Iranian Railways (RAI) accident data analysis. *Safety Science, 48*, 1427–1435.

Mohamed, A.-M. O., Paleologos, E. K. & Howari, F. M. (2021) Chapter 19 - Noise pollution and its impact on human health and the environment. In: Mohamed, A.-M. O., Paleologos, E. K. & Howari, F. M. (eds.) Pollution assessment for sustainable practices in applied sciences and engineering. Butterworth-Heinemann.

Morihara, T., Shimoyama, K., Nguyen, T. L., Nguyen, H. Q., Yano, T. & Kawai, K. (2013) A study on community response to road traffic and railway noises and vibrations in Hue, Vietnam. 42nd International Congress and Exposition on Noise Control Engineering 2013, INTER-NOISE 2013: Noise Control for Quality of Life,. 4662–4668.

Münzel, T., Sørensen, M., & Daiber, A. (2021). Transportation noise pollution and cardiovascular disease. *Nature Reviews Cardiology, 18*, 619–636.

MURPHY, E. (2012). Urban spatial location advantage: The dual of the transportation problem and its implications for land-use and transport planning. *Transportation Research Part a: Policy and Practice, 46*, 91–101.

Murphy, E., & King, E. A. (2014a). Chapter 1-noise pollution. In E. Murphy & E. A. King (Eds.), *Environmental Noise Pollution.* Elsevier.

Murphy, E., & King, E. A. (2014b). Chapter 5-transportation Noise. In E. Murphy & E. A. King (Eds.), *Environmental Noise Pollution.* Elsevier.

Murphy, E., King, E. A., & Rice, H. J. (2009). Estimating human exposure to transport noise in central Dublin, Ireland. *Environment International, 35*, 298–302.

Muzet, A. (2007). Environmental noise, sleep and health. *Sleep Medicine Reviews, 11*, 135–142.

Nash, C., & Fowkes, T. (2021). Introduction to Rail Transport. In R. Vickerman (Ed.), *International Encyclopedia of Transportation.* Oxford: Elsevier.

Nastasi, M., Fredianelli, L., Bernardini, M., Teti, L., Fidecaro, F., & Licitra, G. (2020). Parameters affecting noise emitted by ships moving in port areas. *Sustainability, 12*, 8742.

Nering, K., Kowalska-Koczwara, A., & Stypuła, K. (2020). Annoyance based vibro-acoustic comfort evaluation of as summation of stimuli annoyance in the context of human exposure to noise and vibration in buildings. *Sustainability, 12*, 9876.

Nerişanu, R., & Drăgan, D. (2017). Study of the Negative Effects of Railway Transport Systems upon Constructions. *Advanced Engineering Forum Trans Tech Publ, 1*, 94–101.

OUIS, D. (2001). Annoyance from road traffic noise: A review. *Journal of Environmental Psychology, 21*, 101–120.

Ow, L. F., & Ghosh, S. (2017). Urban cities and road traffic noise: Reduction through vegetation. *Applied Acoustics, 120*, 15–20.

PANDIS, N. (2016). The chi-square test. *American Journal of Orthodontics and Dentofacial Orthopedics, 150*, 898–899.

Pennig, S., & Schady, A. (2014). Railway noise annoyance: Exposure-response relationships and testing a theoretical model by structural equation analysis. *Noise and Health, 16*, 388–399.

Peplow, A., Persson, P., & Andersen, L. V. (2021). Evaluating annoyance mitigation in the screening of train-induced noise and ground vibrations using a single-leaf traffic barrier. *Science of the Total Environment, 790*, 1–47877.

Pepper, C. B., Nascarella, M. A., & Kendall, R. J. (2003). A Review of the effects of aircraft noise on wildlife and humans, current control mechanisms, and the need for further study. *Environmental Management, 32*, 418–432.

Peris, E., Woodcock, J., Sica, G., Moorhouse, A. T., & Waddington, D. C. (2012). Annoyance due to railway vibration at different times of the day. *The Journal of the Acoustical Society of America, 131*, 191–196.

Peris, E., Woodcock, J., Sica, G., Sharp, C., Moorhouse, A. T., & Waddington, D. C. (2014). Effect of situational, attitudinal and demographic factors on railway vibration annoyance in residential areas. *The Journal of the Acoustical Society of America, 135*, 194–204.

Petri, D., Licitra, G., Vigotti, M. A., & Fredianelli, L. (2021). Effects of exposure to road, railway, airport and recreational noise on blood pressure and hypertension. *International Journal of Environmental Research and Public Health, 18*, 9145.

Preston, V. (2009). Questionnaire Survey. In R. Kitchin & N. Thrift (Eds.), *International encyclopedia of human geography*. Oxford: Elsevier.

Rai. (2021) Statistical Yearbook of Iran Rail Transportation in 1399 [Online]. Available: https://www.rai.ir/page-karshenasan/fa/0 [Accessed].

Rossi, L., Prato, A., Lesina, L., & Schiavi, A. (2018). Effects of low-frequency noise on human cognitive performances in laboratory. *Building Acoustics, 25*, 17–33.

Ruiz-Padillo, A., Ruiz, D. P., Torija, A. J., & Ramos-Ridao, Á. (2016). Selection of suitable alternatives to reduce the environmental impact of road traffic noise using a fuzzy multi-criteria decision model. *Environmental Impact Assessment Review, 61*, 8–18.

Sahu, P., Galhotra, A., Raj, U., & Ranjan, R. V. (2020). A study of self-reported health problems of the people living near railway tracks in Raipur city. *Journal of Family Medicine and Primary Care, 9*, 740.

SCI. (2016) population of 22 districts of tehran in 2016 [Online]. Available: https://www.amar.org.ir/ [Accessed].

Sharp, C., Woodcock, J., Sica, G., Peris, E., Moorhouse, A. T., & Waddington, D. C. (2014). Exposure-response relationships for annoyance due to freight and passenger railway vibration exposure in residential environments. *The Journal of the Acoustical Society of America, 135*, 205–212.

Shokouhibidhendi, M., & Kalmarzi, M. A. (2022). Spatial justice perceptions in high-income and low-income quarters of Tehran, Iran: Case study of niavaran and nematabad quarters. *Journal of Urban Planning and Development, 148*, 05021059.

SIMPSON, S. H. (2015). Creating a data analysis plan: What to consider when choosing statistics for a study. *The Canadian Journal of Hospital Pharmacy, 68*, 311.

Smith, M. G., Croy, I., Hammar, O., & PerssonWaye, K. (2016). Vibration from freight trains fragments sleep: A polysomnographic study. *Scientific Reports, 6*, 24717.

Smith, M. G., Croy, I., Ogren, M., Hammar, O., Lindberg, E., & PerssonWaye, K. (2017). Physiological effects of railway vibration and noise on sleep. *The Journal of the Acoustical SOciety of America, 141*, 3262–3269.

Smith, M. G., Croy, I., Ogren, M., & Perssonwaye, K. (2013). On the influence of freight trains on humans: A laboratory investigation of the impact of nocturnal low frequency vibration and noise on sleep and heart rate. *PLoS ONE, 8*, e55829.

Taherdoost, H. (2016) Validity and reliability of the research instrument; how to test the validation of a questionnaire/survey in a research. How to test the validation of a questionnaire/survey in a research (August 10, 2016).

Tang, B., Mo, J. L., Xu, J. W., Wu, Y. K., Zhu, M. H., & Zhou, Z. R. (2019). Effect of perforated structure of friction block on the wear, thermal distribution and noise characteristics of railway brake systems. *Wear, 426–427*, 1176–1186.

Tassi, P., Saremi, M., Schimchowitsch, S., Eschenlauer, A., Rohmer, O., & Muzet, A. (2010). Cardiovascular responses to railway noise during sleep in young and middle-aged adults. *European Journal of Applied Physiology, 108*, 671–680.

Thompson, D. J., & Jones, C. J. C. (2000). A Review of the modelling of wheel/rail noise generation. *Journal of Sound and Vibration, 231*, 519–536.

Tortorella, A., Menculini, G., Moretti, P., Attademo, L., Balducci, P. M., Bernardini, F., Cirimbilli, F., Chieppa, A. G., Ghiandai, N. & Erfurth, A. (2022) New determinants of mental health: The role of noise pollution. A narrative review. International Review of Psychiatry**,** 1–14.

Travaini, G., Schut, D. & Mcnaughton, A. (2013) Rail route 2050: The sustainable backbone of the single European transport area. ERRAC, Paris, France, Tech. Rep.

Tumavičė, A., Laurinavičius, A., Jagniatinskis, A., & Vaitkus, A. (2016). Environmental noise mitigation measures for lithuanian railway network. *Transportation Research Procedia, 14*, 2704–2713.

Uic. (2021) UIC railway statistics synopsis 2021 [Online]. Available: https://uic.org/support-activities/statistics/ [Accessed].

Vukić, L., Mihanović, V., Fredianelli, L., & Plazibat, V. (2021). Seafarers' perception and attitudes towards noise emission on board ships. *International Journal of Environmental Research and Public Health, 18*, 6671.

Waddington, D., Woodcock, J., Smith, M. G., Janssen, S., & PerssonWaye, K. (2015). CargoVibes: Human response to vibration due to freight rail traffic. *International Journal of Rail Transportation, 3*, 233–248.

Waddington, D. C., Woodcock, J., Peris, E., Condie, J., Sica, G., Moorhouse, A. T., & Steele, A. (2014). Human response to vibration in residential environments. *The Journal of the Acoustical Society of America, 135*, 182–193.

Walker, J. G., & Chan, M. F. K. (1996). Human response to structurally radiated noise due to underground railway operations. *Journal of Sound and Vibration, 193*, 49–63.

Woodcock, J., Peris, E., Sica, G., Koziel, Z., moorhouse, A. T. & Waddington, D. C. (2011) Human response to vibration in residential environments: Establishing exposure-response relationships.

Wosniacki, G. G., & Zannin, P. H. T. (2021). Framework to manage railway noise exposure in Brazil based on field measurements and strategic noise mapping at the local level. *Science of the Total Environment, 757*, 143721.

Wrótny, M., & Bohatkiewicz, J. (2020). Impact of railway noise on people based on strategic acoustic maps. *Sustainability, 12*, 5637.

Xie, H., Li, H., & Kang, J. (2014). The characteristics and control strategies of aircraft noise in China. *Applied Acoustics, 84*, 47–57.

Yaghmaei, F. (2003) Content validity and its estimation.

Yu, C.-S., Shao, T.-T., & Li, D.-M. (2016). Distribution of standard deviation of an observable among superposed states. *Annals of Physics, 373*, 43–51.

Zacarías, F. F., Molina, R. H., Ancela, J. L. C., López, S. L., & Ojembarrena, A. A. (2013). Noise exposure in preterm infants treated with respiratory support using neonatal helmets. *Acta Acustica United with Acustica, 99*, 590–597.

Zhang, L., & Ma, H. (2021). Investigation of Chinese residents' community response to high-speed railway noise. *Applied Acoustics, 172*, 107615.

Zou, C., Wang, Y., & Tao, Z. (2020). Train-induced building vibration and radiated noise by considering soil properties. *Sustainability, 12*, 937.