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Study on impact of noise annoyance from highway traffic in Singapore City

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This study uses traffic noise mapping and structural equation model to evaluate the impact of noise annoyance from highway traffic noise. The indices generated in noise maps by CityMap have verified the actual field measurements obtained from the site. Structural Equation Model addresses the relationship between noise annoyance and psychological factors. The results show that the noise annoyance is mainly shaped by the subject's concern and noise disturbance including the negativity on perceived disturbance and noise sensitivity. The noise levels are affected by the type of vehicles in the road, mainly on the heavy truck with more axles instead of the count of vehicles only. The traffic noise level can exceed the permissible limit established by a local government agency at a particular time of the day and on an overhead bridge situated near the vicinity of the residential area.

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1. INTRODUCTION

In urban context with rapid development, upgrading of the road to accommodate the rise of traffic flow is inevitable. It was found that traffic noise emission contributed to more than half of the total urban noise [1]. In Singapore, accommodation of a dense population is required with scarce land resources. Efficient land development and construction strategy have to be deployed to maximize land usage. As a result, more construction of a highway along the residential area, exposing more residents to traffic noise causes growing concern of adverse impacts of traffic noise on the quality of life[2-4] in a residential area.

In recognition of the potential threats posed to the residents at the expense of urbanization, efforts have been made to study the noise situation. However, such studies were often carried out with the consideration of combined noise sources as mixed road traffic noise. For example, combined road traffic and industrial noise [5], mixed noise from public bus and tram transportation [6], railway and road traffic [7], wind turbine and combined road traffic noise [8] and combined road traffic noise [4, 9-10] were studied. It is therefore essential to understand the noise annoyance from different sources such as different types of vehicles such as a car, motorcycle, and truck with a different number of axles.

According to the report published by National Environment Agency (NEA) [11] in Singapore, approaches such as emission regulation, noise barrier installation, building location strategy and building design strategy are taken to reduce traffic noise exposure to residents. Recently, more studies and analysis of the environmental noise had been conducted due to the overgrowing concern from the public. Due to the challenges faced by NEA to establish precise sound pressure level produced by congested traffic noise, an equivalent sound pressure level of 67 dB(A) averaged over an hour measured at the façade of any residential building throughout the day was set as the maximum value. The microphone should be at a height of 1.2 - 1.5m above the floor. Surprisingly, in the study conducted by National University of Singapore [12], Singapore means outdoor noise level was 69.4 dB(A), according to the study averaged from more than 18,000 sound readings taken over a 2½-month period.

The results also indicated the following observations in various cities around the world. For example, in Hong Kong [7], noise exposure was not more than 70 dB(A). In Chennai city of India [13], the noise levels were observed not more than 88.4 dB(A) at peak hour in the day time. In Delhi city [14], the sound level measurements have been carried out during the working day and under ideal meteorological conditions. The equivalent noise levels measured at various locations ranged from 53 dB(A) to 83 dB(A). In the west of Lyon area in France [5], the noise level at day time was around 41.5 dB(A) to 68.5 dB(A). The equivalent continuous sound level measurements over 10 mins were conducted in three cities in the United States [10]: Atlanta, Los Angeles, and New York City with 65.17±7.4 dB(A), 66.47±4.6 dB(A), 69.27±4.1 dB(A), respectively. The equivalent noise levels for 15 mins interval for public transport in 118 streets at the city center of Belgrade in Serbia [6] were measured. The equivalent noise level was around 45 dB(A) to 70 dB(A) at daytime. At Oslo in Norway[4], approximately 33% people are exposed to sound levels above 55 dB(A). Around 82.3 percent of the number of selected individuals (exposed not more than 65 dB(A)) were annoyed by the combined traffic noise at night. In Egypt [15], the average noise level in Cairo near residential areas along a public road was around 76.5 dB(A) according to a 2010 report by the Egypt State of the Environment. Lastly, in China [16-17], the study showed that the average day-to-night noise level was 79.2 dB (A) in rooms facing main traffic in Beijing that had a non-stop constant exposure leading to noise-induced hearing loss [18].

The ref. [13] and [19] had illustrated the capability of utilizing noise map and contour map respectively to identify the area with high noise sound pressure level over the vast geological landscape. Applications of noise map have been used in the Dynamap project [20-23] in Milan and Rome that was a co-financed project by the European Commission to study the noise in the cities. As the noise maps are often created based on prior noise measurements, the noise map can be corrupted by another noise source that affects the precision of the maps. Past studies conducted to unravel the factors influential to annoyance under traffic noise had revealed different results [7] that identified noise disturbance and noise annoyance [24] have an adverse health effect. As the annoyance response to transportation noise can be a very complex phenomenon, the outcomes depend on the subjective responses from the survey conducted. This variation also shows the importance of conducting a study for both traffic noise and human annoyance simultaneously. Hence, this paper is to overcome these shortcomings from the previous studies [7-19] and provide a more comprehensive traffic noise visualization using noise and contour map, and structural equation model that is commonly used to analyze the structural relationship between latent constructs and measured variables will be applied to investigate the relationship between noise annoyance and psychological factors such as noise disturbance and sensitivity.

The paper is organized as follows. The methodology such as data measurement procedures, selection of study location, questionnaire and path model, and noise mapping approach are described in Section 2. It is followed by results and discussions of the traffic noise, verification of the results and structural equation model in Section 3. Lastly, Section 4 concludes the paper.

2. MATERIALS AND METHODS

Figure 1 summarizes the overview of the methodology in this study. The noise map is generated using acoustic software based on the traffic data while the evaluation of questionnaire responses is used to construct the Structural Equation Model. The detailed of the process are explained in the subsequent sections.

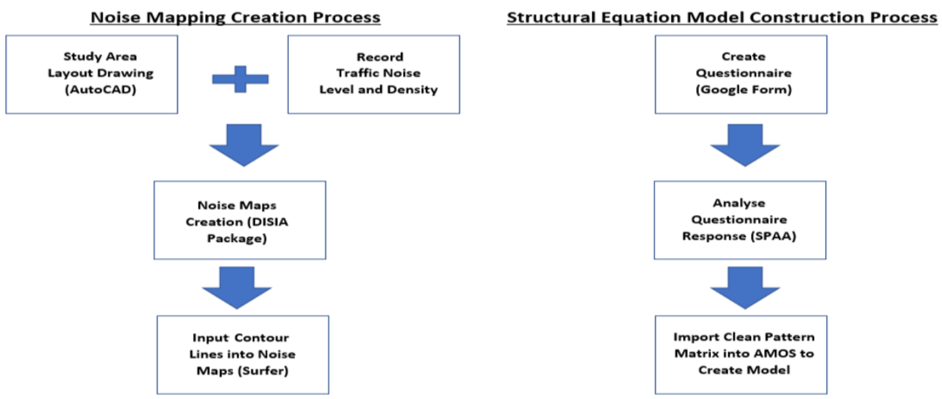

Figure 1. Flowchart for Noise Mapping and SEM

A. DATA MEASUREMENT PROCEDURES

Sound samples for the analysis were recorded using a sound level meter with the “BHS II” binaural headset. The differences between the left and right channel/signal for left and right ear, respectively are quite small (< 2 dB(A)). The equipment is capable of measuring frequency ranging from 0 Hz to 20 kHz and detect maximum sound pressure level up to 130 dB(A). All measurements recorded in this study are A-weighted. The measurement was performed in morning, afternoon and evening time of the working weekday. The sampling period for each measurement was standardized to 10 minute throughout the study due to the availability of the equipment and manpower for testing. The sound measurements are extrapolated to 60 minutes to analyze the traffic noise. The measurement was taken under optimal conditions for the consistency, abnormal environmental conditions such as the wind speed exceeded 5 m/s were avoided. The sound data are then used as the input to the acoustic software for creating the noise and contour map.

The measurement procedures and calculation follow the ISO 1996-2(1996) and IEC 61672-1:2003. In addition, the traffic counts are recorded and categorized into different types of vehicles (such as car, motorcycle, and truck of different axles) to examine the traffic noise contributions by each vehicle type. The commonly recorded indices used for assessing highway traffic noise are as follows.

- Leq: Equivalent continuous sound pressure level
- L10: Sound pressure level exceeded 10% of the time
- L90: Sound Pressure level exceeded 90% of the time
- Lpeak: Highest value obtained by the sound pressure level
- Lmax (via a Fast time constant): Highest sound pressure level measured

B. SELECTION OF STUDY AREA

The study location was between Ngee Ann Polytechnic Stadium and two blocks namely Block 92 and 94 in Singapore as shown in Figure. 2. The nearest and most affected area, the apartments (Blk 94 and Blk 90) are selected as the targeted location along with the overhead bridge. The location was selected based on the consideration of residential buildings near the highways with traffic noise. The overhead bridge provides a safe location to measure the traffic noise above incoming vehicles. The measurement took place on the eleventh floor of Blk 94 and Blk 90 instead of the roof that was not accessible to unauthorized personnel. As a result, the measurements were conducted at the open corridor (without window panels) near to the resident's house. The open corridor is facing the highway. The measurement of the traffic noise on the overhead bridge is located at the midway of the bridge to ensure that there is no obstruction or absorbing element that can affect the maximum sound pressure level measured. The wind speed is at the minimal, and the average distance from the apartments is around 70m away from the overhead bridge.

Figure 2. Targeted areas around highway

Table 1. Estimated height of each building in Figure. 2

Category	Label	Height (m)
Private Residential Building	Green	7
Ngee Ann Staff Apartments (BLK 90 and 94)	Yellow	33
High Rise Buildings	Purple	33
Ngee Ann Polytechnic Stadium	Orange	10
Ngee Ann Polytechnic Exterior	Black	14
Ngee Ann Polytechnic Interior	Gold	10
Ngee Ann Polytechnic Power Plant	White	3

C. QUESTIONNAIRE AND PATH MODEL

The questionnaire composed is adapted from[7, 20] to address traffic noise. The survey created from Google Form was sent through social media to students and the staff who are living in nearby buildings. A total of 150 responses was received. The questions used an International Commission on Biological Effects of Noise (ICBEN) of 5-point numeric scale (1-Not at all; 2-Slightly; 3-Moderate; 4-Very; 5-Extremely) on noise annoyance. The age group ranges from 24 to 40 years old. There are around 60 % male and 40% female participants. The online survey provides information on the annoyance response of people to the traffic noise.

The data samplings are analyzed using statistical software, SPSS. The pattern matrix generated is imported to AMOS Graphic to create the Structural Equation Model for traffic noise annoyance analysis [25]. The few variables used in structural equation model are namely: annoyance, attitude, noise sensitivity, perceived disturbance (PD), concern and noise disturbance (ND). Here, PD is defined as how noisy is the transportation noise that one can hear at home while ND expresses whether you are sensitive to noise.

The questionnaire consists of two sections. Section 1: enquiries personal information (Age, Gender, Education, Frequency, and Experience) that serves as moderators and controls in the Structural Equation Model, Section 2: to obtain subjective responses on the six latent variables through a 5-point scale. The selection of the latent variables are defined as an unmeasured variable that has some influence responses to one or more survey questions based on the findings of [24] on the adverse health impact due to noise and perceived disturbance as the most influential to human annoyance. In this study, an additional latent variable "noise disturbance," describing the effects of traffic noise on human cognitive performances is also included. Hence, a total of three latent variables along with two mediator variables (Attitude and Noise Sensitivity) were used to measure traffic noise annoyance as shown in Figure 3.

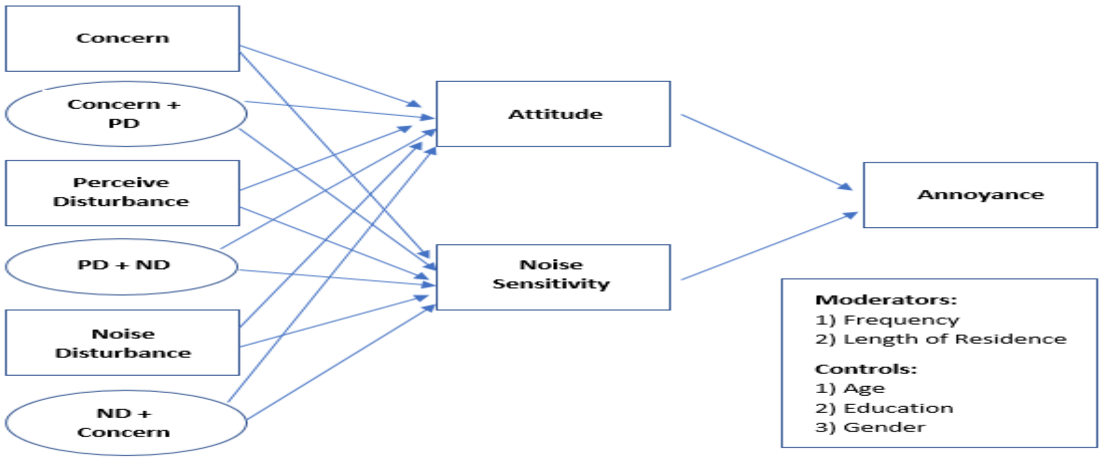

Figure 3. Overview of annoyance casual model layout.

The overall concept adopted in the statistical evaluation of the questionnaire responses is based on a review concluded by [26] that established conditions such as removal of low reliability (less than 0.7) variables and standardizing of the generated coefficients. The terms used adhered to the guidelines [27]. It states the use of maximum likelihood to estimate and determine the factors based on the conceptualized model.

D. DISIA NOISE MAPPING

DISIA[28] is an Italian Ministry of the Environment program that is quite accurate for the type of roads and vehicles for the Italian type of driving. The result obtained from the software has an error of around +/- 3 dB (A). It uses CityMap to perform noise simulation. The complete software can be downloaded from http://pcfarina.eng.unipr.it/Public/DISIA/Download. The study area layout needs to be created from an external program such as AutoCAD. The layout can be traced precisely by importing the study area image from Google Earth. For scaling the image to actual size, a specified object such as the overhead bridge is selected. The length of the overhead bridge obtained from the Google Earth is 97.4 meters that are quite close to the actual length of 98 m. The remaining of the buildings is drawn using the same scale. A few different layers were created for each geometrical entity. For example, the layers required are named in Italian with the CASE, PUNTI, STRADE and SEZIONI representing houses, point, roads, and sections, respectively. The purpose of each layer is to make an enclosed perimeter of the study area for noise mapping calculation in DISIA. The layer “point” can be used to specify the sound level at any location in the study area. All the drawings should be carried out in Polyline or 3DPoly entities. The DXF file from AutoCAD is then imported into CityMap in DISIA as shown in Figure 4. The noise mapping and sound pressure level uses the data from the actual traffic noise measurement. The traffic noise data input used in DISIA were grouped into daytime and nighttime traffic with the period of 16 hours and 8 hours, respectively and the data is upscaled to fit. The noise maps generated (.GRD) in the DISIA package can be employed in Surfer^{TM} to produce a detailed contour map to represent the sound pressure level map as shown in Figure 5.

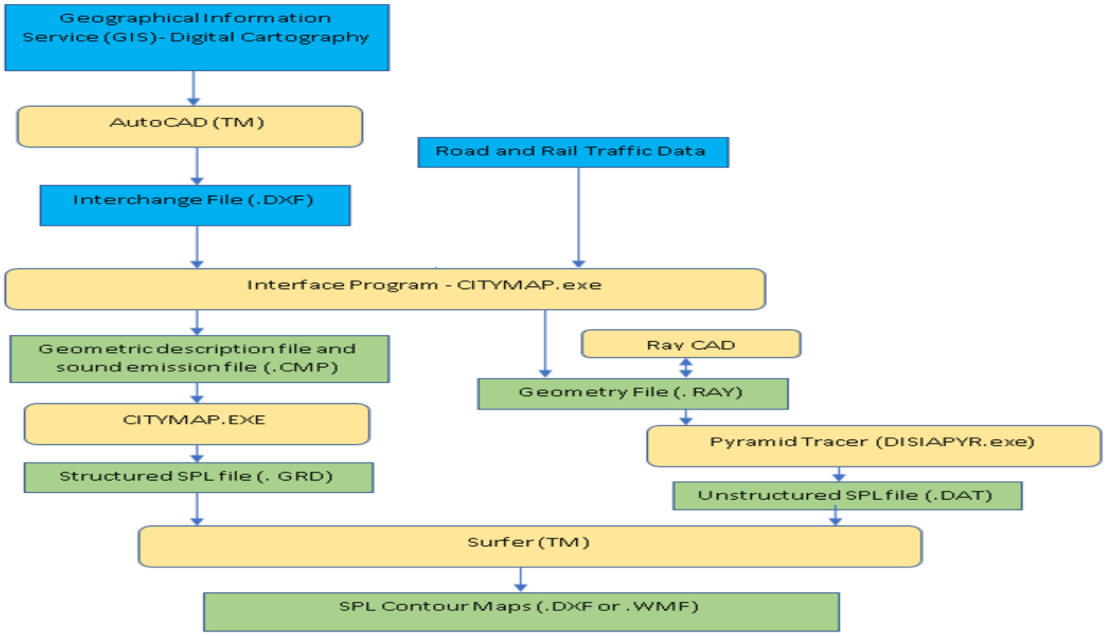

Figure 4. Progressive steps in noise mapping using DISIA [24]

3. RESULTS AND DISCUSSIONS

The recorded results of the site observations are shown in Table 2 and Table 3. As seen in Table 2a and Table 2b, the noise level varies from 66.1 dB(A) to 81.5 dB(A) and 58.3 dB(A) to 73.7 dB(A) at the overhead bridge and Ngee Ann staff apartments, respectively. The average of five field measurements consisting of more than 120 samples was tabulated. The readings were obtained from the sound measurement system. The readings obtained from 10 minutes can be tabulated in Table 2a. Since the equivalent sound exposure level is the steady sound pressure level in dB(A) that present in an environment for 10 min of a day, it would contain the same total energy as that generated by the actual and varying sound levels to which a person is exposed in 1 hour. The formula for 1-hour equivalent noise level can be written as: $L_{eq,1h} = 10\log_{10}(10/60\times10^{0.1(Leq,10min)})$. The 1-hour equivalent noise level can be tabulated in Table 2b. The computed levels are compared with the regulated equivalent sound pressure level limit of 67 dB(A). As shown in Table 2b, the 1-hour equivalent sound pressure levels are still within the limit of 67 dB(A) although, in some time, it exceeded 67 dB(A) (see Table 2a). The traffic noise-exposed at the overhead bridge situated near to the façade of the building has some concern as the noise exceeded the limit. However, it is a short term noise exposure as the pedestrians can cross the overhead bridge in less than 10 min. It is unlikely to cause permanent hearing damage or annoyance while walking along the overhead bridge. However, it still poses some concern as it is near to the vicinity of the residential area. Although the measurements (Leq for 10min) outside the apartment does not exceed the noise limit, it may pose some concern as the resident will stay in an enclosed space for most of their time, especially for older folks.

Table 2a. Recorded average field measurements of highway traffic noise (10 min)

Locations	L_{max}	L_{peak}	L_{eq}	L_{10}	L_{90}
Overhead Bridge	83.5	96.3	81.8	82.7	80.4
	89.4	101	83.5	85.7	80.6
	84.5	96.3	82.5	83.7	81.5
NP Staff Apartment Blk 90	70.4	82.8	67.2	68.5	66.1
NP Staff Apartment Blk 94	73.1	84.8	70.1	71.4	68.2

Table 2b. Extrapolate field measurements of highway traffic noise to 1 hour

Locations	L_{max}	L_{peak}	L_{eq}	L_{10}	L_{90}
Overhead Bridge	75.7	88.5	74.0	74.9	72.6
	81.6	93.2	75.7	77.9	72.8
	76.7	88.5	74.7	75.9	73.7
NP Staff Apartment Blk 90	62.6	75.0	59.4	60.7	58.3
NP Staff Apartment Blk 94	65.3	77.0	62.3	63.6	60.4

As shown in Table 3, the sound pressure level is not directly dependent on the overall traffic counts. Despite having a lower traffic count, the overall sound pressure level is still higher. The results show that the sound pressure level is determined by vehicle type, in particular, a truck with more than three axles. The increase of 5.9 dB(A) in both Lmax and Lpeak despite the number of vehicles remain quite similar, is mainly due to the two trucks (each from V3 and V4) generated a higher sound pressure level during the sound measurement. From the results, the sound pressure level depends on the noise generated by different vehicle category (in particular, the heavy trucks with more axles) although the traffic count is quite similar.

Table 3. On-site observations of highway traffic counts and weather conditions (V1= Car, V2= Motorcycle, V3= Truck with 2 or 3 axles, V4= Truck with more than three axles)

Location	Time Start	Time End	Traffic Count/hour					Wind Speed	Road Surface	Humidity	Ambient Temp
			V1	V2	V3	V4	Total				
Overhead Bridge	9:06	9:07	157	16	33	10	214	4.3 m/s	Dry	86%	26
	13:44	13:45	138	11	34	11	194	3.1 m/s	Wet	84%	27
	17:05	17:06	152	33	29	9	223	3.8 m/s	Wet	85%	26
NP Staff Apartment Blk 90	13:08	13:09	98	8	27	11	144	2.8 m/s	Dry	73%	30
NP Staff Apartment Blk 94	13:15	13:16	107	13	34	5	159	2.8 m/s	Dry	73%	30

A. TRAFFIC NOISE IMPACT ANALYSIS

Since the wet road surface will increase noise level [29], the noise map should reflect such condition. A few noise maps and contour maps at a different time in the morning were generated. The height of the noise map is at 4.5m above the road surface. Note that it rained in the late morning. As a result, the road was wet. The noise and contour map of the overhead bridge, Block 90 and 94 are shown in Figure 5 to 6. The contour map provides an alternate aerial view of the noise level on the map. There are four highway lanes marked with sound pressure level in dB(A) on the highway for the noise map. The exit of the highway is shown in the upper left-hand corner. The contour maps show the legend for different contour levels. The color scheme was auto-generated by the software. The point 1 and 2 in the noise map indicate the receiver points.

Figure 5 shows the first noise map with the sound pressure level for each lane (labeled from left to right as 71 dB(A), 84 dB(A), 85 dB(A) and 69 dB(A), respectively). The orange color in the middle of the road is significantly darker implying the expressway has a higher traffic noise level. The contour map in Figure 6 also shows around 10dB higher on the road traffic as compared to noise near the residential area. Despite having a higher sound pressure level, the signs of weaker noise and its propagation can be observed in the residential area. It can be noted that the sound pressure level at the individual contours can be quite similar. The sound pressure level at the exit of the expressway (top left-hand corner) is observed to be the lowest. It is due to the vehicles was reducing the speed while exiting the highway. Thus the vehicles created less noise.

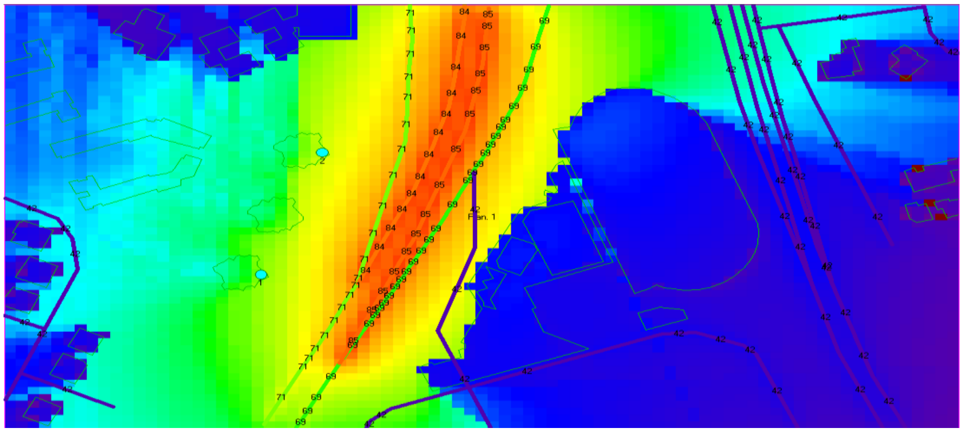

Figure 5. Noise map from traffic during morning period (first plot)

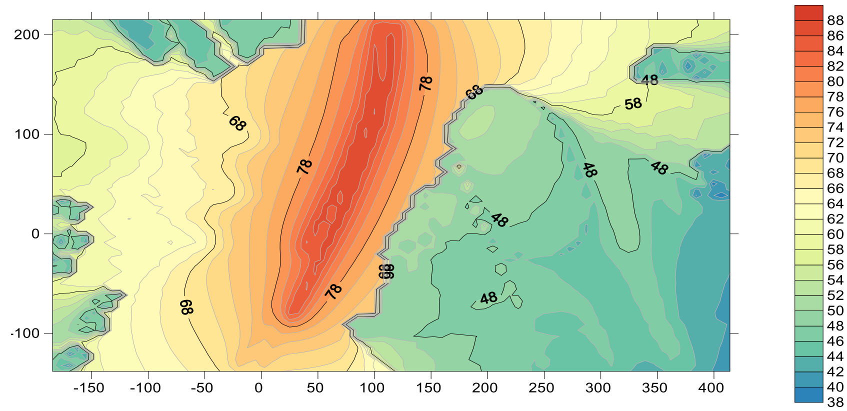

Figure 6. Sound pressure level contour map of traffic data during morning period (first plot)

B. VERIFICATION OF THE RESULTS

Although the noise maps generated are quite similar to the data collected, a comparison of the predicted and measured receiver points at Block 90, and 94 of Ngee Ann staff apartment is performed to verify with the results from DISIA. The only variation is mainly due to the exit of the expressway at the upper left corner of the highway. With the color varies from green to cyan to blue expressing the decrease in sound pressure level, the sound pressure level from the traffic along the lanes can reach 85 dB(A). As shown in Table 4a and Table 4b, the predicted values obtained through acoustic software (DISIA) are quite similar to with the measurement results obtained for 10 min and 1 hour, respectively. The results overestimate the recorded sound pressure level on average. But after considering the environmental noise, the results can be entirely accurate. As compared to the study[12], the noise level around this region known as Bukit Timah was 72.6 dB(A). The result is quite close to the values in Table 4b. Besides the noise mapping, the measurement shows that the sound pressure level can exceed the NEA's limit of 67 dB(A) averaged over an hour at the overhead bridge near to the vicinity of the residential area. The World Health Organization guidelines indicate 70 dB(A) is the sound level for someone consistently exposed for a full day will lead to hearing impairment. Hence, there is a need to understand the noise annoyance level of the residents due to the traffic noise.

Table 4a. Comparison of recorded and equivalent sound pressure level for 10 min

Location	$L_{eq,10min}$ in dB(A)	
	Measured	Predicted
Overhead Bridge	81.7	85.0
NP Staff Apartment Block 90	68.0	70.5
NP Staff Apartment Block 94	70.6	73.0

Table 4b. Comparison of recorded and equivalent sound pressure level for 1 hour (extrapolation)

Location	$L_{eq,1h}$ in dB(A)	
	Measured	Predicted
Overhead Bridge	63.9	77.2
NP Staff Apartment Block 90	50.0	62.7
NP Staff Apartment Block 94	52.8	65.2

C. STRUCTURAL EQUATION MODEL

The statistical software, SPS-Amos was used to create the structural equation model. The data collected from the questionnaires were analyzed in SPSS before using the SPS-Amos. A composite model is established after removing four indicators (Attitude4, PD-Day, ND5, and Concern) due to its low loading or cross-loading among variables. It can be observed that a covariate exists among the mediators. Although some variables are not significant, the indirect effect that mediates through attitude is quite strong. The final Structural Equation Model on annoyance induced by traffic noise with the respective path coefficients is shown in Figure 7. The results from the model fit summary generated from AMOS output are evaluated using [30]. The comparison between the calculated models fit well with the following indices criterion as shown in Table 5.

- Normed Fit Index (NFI)- is the proportion in the improvement of the overall fit of the hypothesized model compared to the independence or null model, theoretically ranges from 0 (poor fit) to 1 (perfect fit);
- Relative Fit Index (RFI)- compare a chi-square for the model tested to one from an independence model, theoretically ranges from 0 (poor fit) to 1 (perfect fit);
- Incremental fit index (IFI)- is a group of indices that do not use the chi-square in its raw form but compare the chi-square value to a baseline model, theoretically ranges from 0 (poor fit) to 1 (perfect fit);
- Tucker Lewis index (TLI) -like NFI but adjusts for model complexity, theoretically range from 0 (poor fit) to 1 (perfect fit);
- Comparative fit index (CFI) - compares the fit of a target model to the fit of an independent model, theoretically ranges from 0 (poor fit) to 1 (perfect fit);
- Root Mean Square Error Approximation (RMSEA) - calculates the size of the standardized residual correlations, theoretically ranges from 0 (perfect fit) to 1 (poor fit).

With the design satisfied the recommended indices criterion, it can be concluded that the Structural Equation Model can account for the relationship between variables used in the model. However, it should be highlighted that the primary indices are RMSEA and CFI. These indices are less sensitive to sample size as shown in the study [31].

Table 5. Comparison between calculated vs accepted criterion model fitness indices.

	Normed Fit Index (NFI)	Relative Fit Index (RFI)	Incremental fit index (IFI)	Tucker Lewis index (TLI)	Comparative fit index (CFI)	Root Mean Square Error (RMSE)
Recommended Criterion	>0.90	>0.90	>0.90	>0.95	>0.90	<0.06
Calculated Criterion	0.956	0.896	0.998	0.995	0.998	0.017

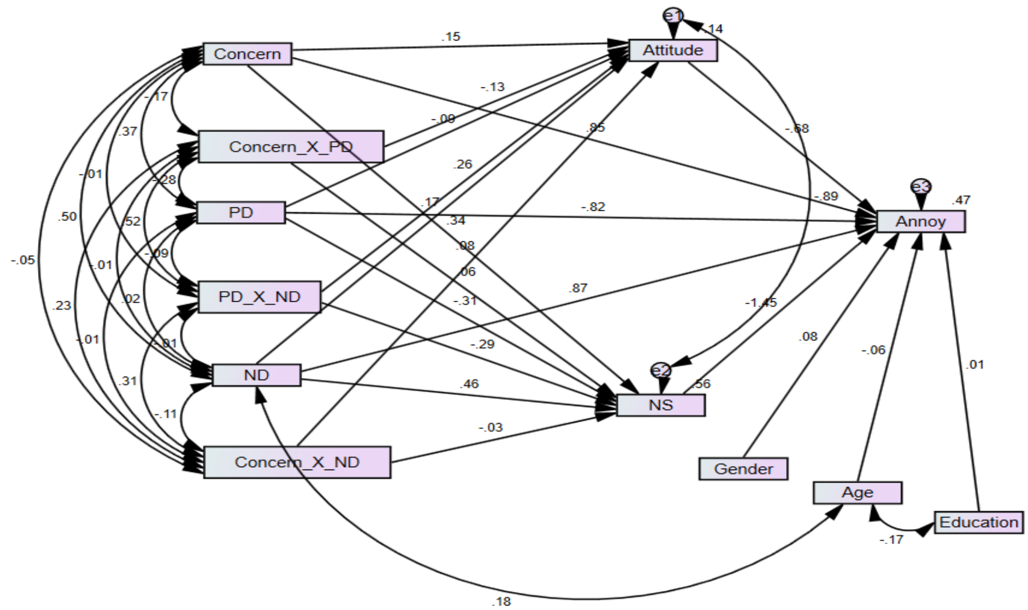

Figure 7. Structural Equation Model for annoyance induced by traffic noise

All measurements and interpretations of the effects used are obtained from a review from [32]. Table 6 provides a summary of the direct, indirect and total effects of the variables loading on the noise annoyance.

By comparing the total effect of the latent variables, the Concern, Perceived Disturbance with Noise Disturbance are the strongest influential to annoyance. An increase in any of these variables will result in higher noise annoyance. The Concern and Noise Disturbance can induce annoyance directly while Attitude, Perceived Disturbance, Noise Sensitivity and Age work in the opposite direction.

It shows that Positive Attitude towards traffic noise does not significantly affect noise annoyance. But negative attitudes significantly increase noise annoyance. The negative Perceived Disturbance and Noise Sensitivity increase noise annoyance. As for the Age group, outside the age group from 24 to 40 years old affects noise annoyance. It may be true as a younger or older-aged group can be quite insensitive to noise. However, how such inhibitory effect works will require further investigation of aging and behavioral science.

The effect of Gender and Education are not evident in noise annoyance as the magnitudes are small. The indirect effect of Noise Sensitivity can be dominated by endogenous variables (such as Concern, Perceived Disturbance, and Noise Disturbance). The attitude can be shaped by a mixture of the interaction terms and endogenous variables of relatively smaller magnitude.

The results of Structural Equation Model also suggest that in addition to Concern and Noise disturbance, which alone accounts for more than half of the variation in noise annoyance. It also shows that in a multi-source acoustic environment, the actual noise exposure level is not very important in defining annoyance. However, the Noise Disturbance on their daily activities and how they feel or Concern over the noise are more important.

The total net effect of road traffic noise-causing Concern, Concern with Perceived Disturbance, Perceived Disturbance with Noise Disturbance, Noise Disturbance, Gender and Education on overall noise annoyance is positive. It suggests that when the noise source due to the traffic vehicles is present, it can induce noise annoyance directly while others (such as Perceived Disturbance, Concern with Noise Disturbance, Attitude, Noise Sensitivity, and Age) work in the opposite direction. Hence, there exists a relationship between the traffic noise visualized as a noise map to the noise annoyance caused by the traffic noise from the Structural Equation Model

Note that the regression equations are not established in this study as it depends on the geographic location and the time of the study. The results of this study are for the selected landscape. Annoyance response to transportation noise is a very complex phenomenon [33-34]. This paper provides some insights and procedure to study on the impact of noise annoyance from highway traffic using noise map and structural equation model in the landscape.

Table 6. Significant direct, the indirect and total effect of all variables affecting noise annoyance caused by traffic.

Variables	Direct Effect	Indirect Effect	Total Effect
Concern	0.853	-0.592	0.261
Concern + Perceived Disturbance	-	0.007	0.007
Perceived Disturbance	-0.823	0.512	-0.311
Perceived Disturbance + Noise Disturbance	-	0.238	0.238
Noise Disturbance	0.873	-0.773	0.1
Concern + Noise Disturbance	-	-0.007	-0.007
Attitude	-0.68	-	-0.68
Noise Sensitivity	-1.45	-	-1.45
Gender	0.08	-	0.08
Age	-0.6	-	-0.6
Education	0.01	-	0.01

4. CONCLUSION

The paper presented a study on the effect of traffic noise (measured by SQobold by HEAD Acoustics) on residential buildings situated near to one of the highways in Singapore. The Structural Equation Model obtained from the online questionnaire responses revealed that the most influential endogenous variables and interaction terms affecting the noise annoyance were due to the exposed traffic noise level is the Concern and Noise Disturbance. The negativity on Perceived Disturbance and Noise Sensitivity could affect the noise annoyance level in this study.

Despite some variations at the exit of the expressway near the left outer lanes, the results from the traffic noise map have provided some insight to the primary cause of sound pressure level due to the heavy trucks with more than three axles. It generated a higher sound pressure level causing the equivalent sound pressure level to increase in particular time of the day. From the results, the residents living near to the traffic, in particular near to the overhead bridge were exposed to the sound pressure level that exceeds the recommended limit of 67 dB(A) over an hour. In summary, the results obtained from this study can provide insights for authorities to regularize the maximum traffic sound pressure level over a certain period around the residential area situated near to the highway.

Future works may consider using nonlinear Structural Equation Model with a larger sample size over more survey sites. The time for noise measurement will be extended to 1 hour. The methodology will be streamlined to minimize manual inputs. The traffic and noise annoyance level data will be shared in the cloud for better use of information for future planning and collaboration.

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