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Assessing the Efficiency of a Residential Building Façade in Reducing Traffic Noise from an Adjacent Distributor Road in Kallyanpur, Dhaka

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Abstract

The capital of Bangladesh: Dhaka has recently been marked as the noisiest city worldwide by the UN Environment Program (UNEP). Government-mandated noise limits are often breached throughout this city. This problem prevails in distributor roads running through mixed-use areas like Kallyanpur. To worsen the situation, these roads are flanked by residential buildings. Together, this arrangement exposes a substantial population to a high level of noise pollution even inside their apartments making them susceptible to numerous mental and health hazards. This paper aimed to calculate the efficiency of the façade for two specific spaces on each level of a four-storey residential building in reducing traffic noise from an adjacent distributor road in Kallyanpur. This work has also investigated the prevailing noise levels inside the habitable spaces of each apartment. The analysis based on the findings shows the presence of noise levels impermissible for both the bedrooms and the living spaces to some extent on all floors. The intended goal of this study is to increase awareness among the occupants about noise levels they are being exposed to and to inspire architects to incorporate design considerations regarding noise reduction while designing new residential buildings prone to noise pollution from traffic.

Keywords: *Noise level; Residential Building; habitable space; Façade's Efficiency; Noise reduction*

1 Introduction

Noise can be defined as unwanted, undesirable, or harmful sound that may have numerous adverse effects on human beings. (Fahy & Thompson, 2015). Development of transportation systems in cities can cause noise pollution which is one of the basic forms of pollution. High noise levels can be generated in cities due to the movement of traffic and honking from traffic congestion. (Kalisa et al., 2022). Exposure to unallowable noise levels may cause hearing impairment, annoyance, sleep disturbance, decreased school performance, and stress-related cardiovascular disorders. (Passchier-Vermeer1 & Passchier2, 2000). Studies have shown that traffic noise is associated with hypertension and contributes to cardiovascular disease (CVD). Nighttime noise can increase the calcification of thoracic aorta by 3.9%. A meta-analysis has found that every 10 dBA increase in traffic noise is responsible for a 6% increase in the risk of coronary heart disease where 50 dBA has been regarded as starting level. 5 dBA Increase in traffic noise is associated with a significant increase in prevalent hypertension. (Münzel et al., 2018). Considering the consequences of noise pollution, information regarding the present noise level in Dhaka city from the report titled 'Frontiers 2022: Noise, Blazes and Mismatches' published on UNEP's website is very alarming. According to that report, Dhaka has an average noise level of 119 dB which is the highest amongst the 61 major cities of the world. While the result encompasses data of all types of zones, it indicates a likelihood of noise levels in mixed-use areas of Dhaka city exceeding permissible limits. According to the "Noise Pollution (control) Act 2006," the maximum allowable noise level should be 45 dBA during the night and 55 dBA during the day in mixed-use areas of Bangladesh. When this is the desirable condition for this type of area, the road traffic noise levels should be limited to a maximum of 70 dBA if the dwellings have sealed windows, and 60 dBA if the windows are meant to be kept open, as stipulated by Bangladesh National Building Code (BNBC), published on February 11, 2021. On the other hand, BNBC has established allowable upper limits for indoor background noise levels in habitable spaces, that include bedrooms and living areas within dwellings. These limits are set at 38 dBA to 48 dBA for living areas and 33 dBA to 48 dBA for bedrooms. As the bedrooms and living areas within the apartments are away from the road both horizontally and vertically, and are separated by a façade, a reduction in noise levels compared to the noise generated on the road can be experienced in habitable spaces due to the properties of sound. The intensity of sound follows the inverse square law, which means it decreases with the distance. Material thickness, density, and porosity also affect the intensity of sound. (Amares et al., 2017). The incident sound energy can be diffracted or reflected based on the ratio of the dimension of the impedance to wavelength. When a sound wave meets any barrier, some of the sound energy is dissipated as heat due to the flow resistance of the material that the barrier consisted of. Again, the coincidence effect of sound which depends on the angle of the incidence causes a more efficient transfer of sound through the wall. (Ginn, 1978). Sine the façade of any residential building has the capacity to reduce noise to some extent, this aspect prompted this paper to investigate the available studies and explore the scope regarding this issue in the context of Dhaka city.

1.2 Relevant Studies and Scope

Noise has been a common concern in a large number of studies and research throughout the world, including Bangladesh. In one research, Wu et al., 2019 measured the traffic noise inside three high-rise residential buildings along Keyun road in an urban area of China and conducted a questionnaire survey regarding the impact of the noise. They concluded that noise levels inside the buildings far exceed the national standard and decrease with an increase in height. The survey results also show that the occupants of those buildings express annoyance regarding traffic noise, and 40% of the participants consider that the traffic noise has negative effect on the physical and psychological comfort of human. However, in Bangladesh, one study conducted by Parvin, 2021 reveals the noise levels in different areas of Dhanmondi, an important mixed-use area of Dhaka city. The result shows the noise levels exceeding the permissible limit. Chowdhury et al. 2010 conducted a survey to measure noise levels at roadsides as well as at a distance of about 50 m away from the road sides at ten major locations in Dhaka city. Most of those locations are situated in mixed-use areas and they concluded that the noise pollution in those locations greatly exceeds the allowable limit. Another study by Husain et al., 2015 found the average and maximum noise level in Kallyanpur area to be 75.12 dB and 89.60 dB respectively during working days, while 61.42 dBA and 87.20 dBA during non-working days. But No study has been found regarding the present traffic noise level at any distributor road in this mixed-use area. As, mixed use development combines retail, office, residential, hotel, recreational or other functions, residential buildings are very common to be seen on both sides of any distributor road in mixed-use area like Kallyanpur. (Wardner, 2014).To the best of my knowledge, no study is also available that has assessed either the prevailing traffic noise levels inside the residential buildings adjacent to any distributor road in Dhaka, or the efficiency of the façade in mitigating that noise.

1.3 Problem Statement and Objectives

The unavailability of data regarding the present noise level at any distributor road in any mixed-use area of Dhaka has led this study to investigate the noise level at a distributor road in Kallyanpur. This road was found to have noise levels more than the permissible level. Given that the high noise levels on the road can be experienced inside the adjacent residential buildings and considering the annoyance expressed by the occupants in those buildings regarding the excessive traffic noise, the focus of this paper is to determine how efficient the façade of a particular residential building beside that surveyed road is in reducing traffic noise. Due to the lack of studies regarding the noise levels inside any residential building next to any distributor road in Dhaka, the intention of this paper is also to determine the noise levels in the bedrooms and living spaces of the mentioned building to be compared with the BNBC-mandated limit to check if the noise levels fall within the allowable range. Again, how people evaluate noise and respond to it is very subjective. Usually, high-frequency, intermittent, and non-localized noise evokes annoyance more than low-frequency, steady and localized noise. (Everest, 2001). Noise that is not continuous and fluctuates such as ringing telephone is defined as intermittent noise. (Kam et al., 1994). This study has also tried to identify the type of prevailing noise and determine how frequently the dwellers get exposed to that type of noise.

2 Methodology:

A reconnaissance survey was conducted to find out a distributor road in the Kallyanpur area that is suitable for the study. “South Pikepara main road” connecting arterial roads “Darus Salam Road” and “Kamal Soroni” was selected considering its attributes as a distributor road busy with inbound arterial traffics, as shown in Figure 1. Photographs along both sides of the road have been taken to illustrate (figure 1 & Figure 2) how this road is serving a mixed-use area. Almost every building along this road has been found to rent the ground floor for commercial purposes. A four-storey apartment building (Figure 2) next to this road has been selected based on the availability of permission to survey all its apartments. The roadside façade of the building is equipped with casement windows, as shown in Figure 2. The facades of other sides of this building have sliding as well as casement windows. Although this kind of windows have the option to be kept open for natural ventilation, for the purpose of this study, it has been assumed that they will be kept shut on all floors. In this way, the number of variables has been reduced for making a comparative analysis among the apartments on different floors. A 2.5 m tertiary road on the east side of the building serves a small gated housing society. Practically, noises generated on that tertiary road due to occasional traffic flow are very insignificant.

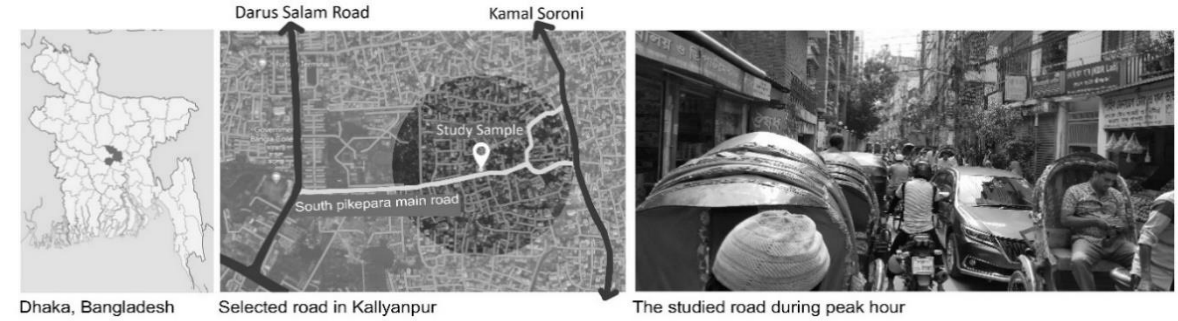

Figure 1: Site location, studied road, traffic condition and commercial activities alongside the road

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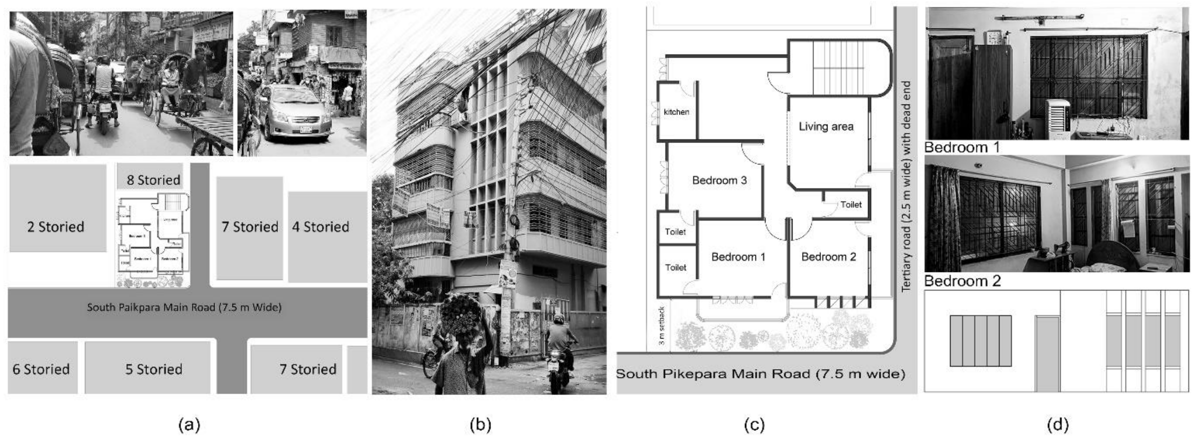

Figure 2: (a) Site surroundings, (b) studied building, (c) typical floor plan and (d) partial elevation of roadside façade

However, to collect data for the study, two time periods in weekdays have been fixed: 12:00 PM-1:00 PM as off-peak hour and 5:00 PM-6:00 PM as peak hour. Noise levels have been measured on road and the types of vehicles associated with the noises were identified. Then, the noise levels in bedrooms and living spaces of all the apartments have been measured to determine the reduction of noise due to the façade of the building. While collecting the data, all the windows and doors were kept closed, and fans, air coolers, or air conditioners, if present, were switched off to avoid the noises generated inside the apartments. Noise levels have been measured using a sound level meter (Model- AS824) set at A-weighting scale and switched to the fast recording mode. At each spot, 30 readings have been taken with 4 seconds intervals over a span of two minutes. All these data have been analyzed to get the average, maximum and minimum noise levels of each spot during both time periods. The collected data has been compared with the Bangladesh National Building Code (BNBC), published on February 11, 2021, to understand whether the average noise levels are within permissible range. Noise spikes more than the upper limit (48 dBA) of the allowable range have also been counted for every bedroom and living space during both time periods. Based on the data and the analysis, the reason for those spikes and the type of prevailing noise have been determined. Finally, using the data of noise levels recorded on the road (A) and bedrooms (B) next to the distributor road, efficiency of the roadside façade in noise reduction have been calculated for those bedrooms. The efficiencies of the façades of those mentioned bedrooms in all the apartments on different floors have been compared subsequently to demonstrate how efficiency changes with height and time. The following formula has been applied to calculate the efficiency:

$E=((A-B)100)/A$ …………… (i)

A= Average noise level on the road

B= Average noise level in the bedroom next to the road

E= Efficiency in terms of percentage

To sum up, all the results regarding average, maximum, and minimum noise levels, along with instances of noise spikes, for the bedrooms and living spaces across all floors, as well as the efficiencies of the façades in mitigating noise in "Bedroom1" and "Bedroom 2" have been summarized in a table.

3 Result and Discussion:

The survey shows that the average noise level on the road during off-peak hours is 77 dBA and 82 dBA during peak hours, while it is very common incident to experience noise level up to 99 dBA. All of these values are even higher than the permissible level of 70 dBA, as stipulated by the BNBC, published on February 11, 2021, for residential buildings situated next to that road with sealed windows. Instead of sealed windows, casement windows have been found on the roadside façade of the studied building. Due to the gaps between the window units and the use of non-insulating glass as window panels, a substantial percentage of noise travels through the windows. To understand the resulting noise condition inside the building, the average noise levels of different spaces of all the floors have been shown in two graphs (Figure 3 & Figure 4) for different periods. During off-peak hours it ranges from 45.2 dBA to 52.6 dBA on the first floor, 44 dBA to 49 dBA on the second floor, and 42.9 dBA to 47.2 dBA on the third floor. Increased traffic flow during peak hours causes an increased average noise level on each floor which ranges from 50.8 dBA to 56.6 dBA, 50.2 dBA to 53.7 dBA, and 45.8 dBA to 50.2 dBA on the first, second, and third floors respectively. Results show that, on each floor, the average noise levels of the two bedrooms ("Bedroom 1" and "Bedroom 2") are higher than those of the other spaces due to their proximity to the road. For "Bedroom 1" the average noise levels are 51.5 dBA, 48.2 dBA and 46.4 dBA on the first, second, and third floors respectively during off-peak hours. These levels increase to 55.6 dBA, 53.7 dBA, and 49.8 dBA during peak hours. Similarly, for "Bedroom 2" they are 52.6 dBA, 49 dBA and 47.2 dBA on the first floor, second floor, and third floors respectively during off peak hours, while during peak hours they rise to 56.5 dBA, 54.4 dBA, and 50.2 dBA. Observations indicate that, as "Bedroom 2" has windows on two sides while "Bedroom 1" has only on one side, "Bedroom 2" is exposed to an average noise which is more than that of "Bedroom 1". It is also clear that, with the increase in height, the average noise level decreases for almost every space.

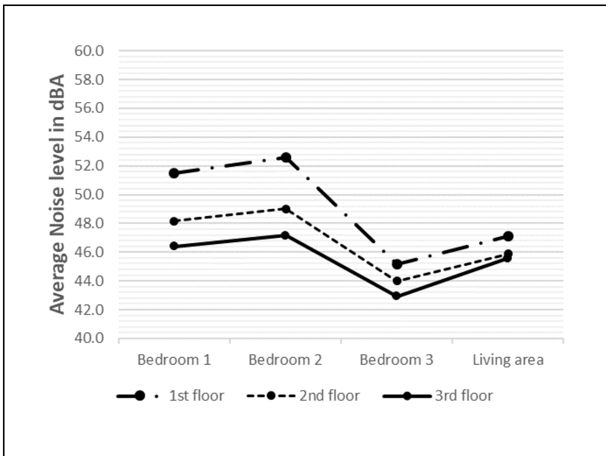

Figure 3: Average noise level conditions during off-peak hours (12:00 pm - 1:00 pm)

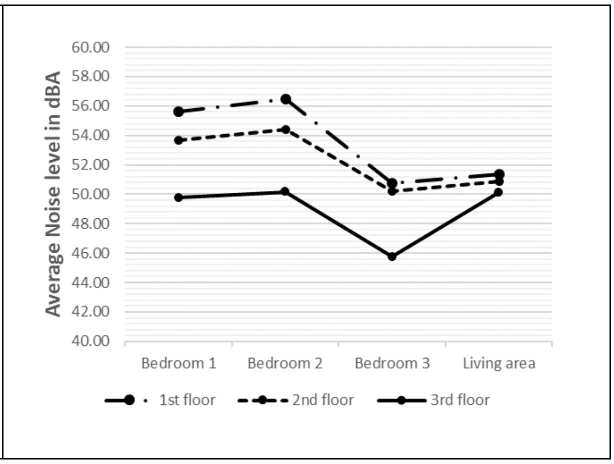

Figure 4: Average noise level conditions during peak hours (5:00 pm - 6:00 pm)

Figure 5: Noise levels analysis for all spots during both time periods

Though the average noise levels in certain spaces, especially on the third floor are within permissible limits, collected data of noise levels, as presented in two separate graphs (Figure 5) for two time periods, indicate that all the spaces across all the floors experience noise spikes. These spikes surpass the upper permissible noise level of

48 dBA designated for bedrooms and living areas, according to BNBC published on February 11, 2021.Those phenomena have been counted 7 to 17 times during the off-peak hours and 9 to 24 times during the peak hours, taking into account both time periods. Bedrooms adjacent to the road experience noise levels reaching up to 78 dBA, while living areas up to 71 dBA, considering both the time periods. From the observations, rickshaw bells, horns from bikes and cars, vibrations from motorized rickshaws, and heavy motorized vehicles like trucks have been identified as the sources of those spikes of noise. Due to the intersections between the local roads and the distributor road at several points, traffics need to sound their horns to avoid collisions resulting noises up to those levels. On the other hand, as the noise levels drop to 35 dBA when there is no traffic on the road, noises generated by the honking can be defined as intermittent noise, which is more annoying than steady noise.

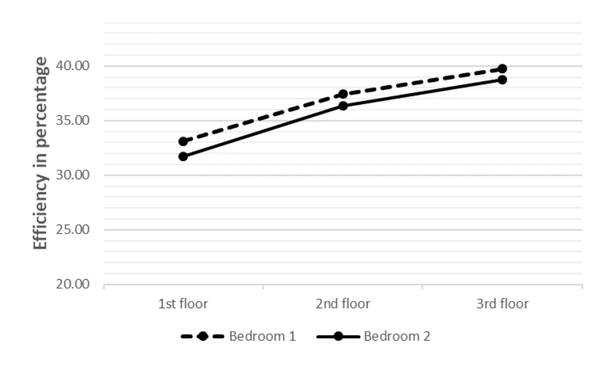

Figure 6: Efficiency of façades of bedrooms in noise reduction during off-peak hours (12:00 pm - 1:00 pm)

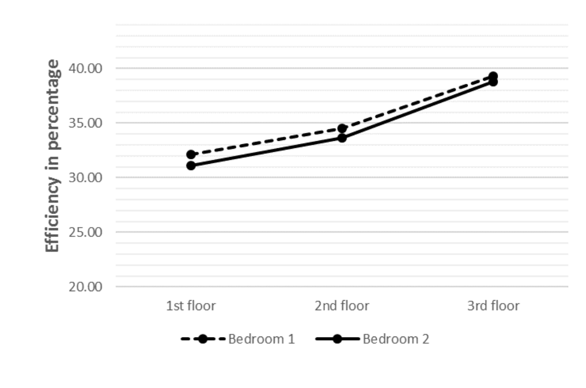

Figure 7: Efficiency of façades of bedrooms in noise reduction during peak hours (5:00 pm - 6:00 pm)

Using the data and equation (i), efficiencies of the façades of "Bedroom 1" and "Bedroom 2" in noise reduction have been calculated for all floors and both periods and presented in separate graphs (Figure 6 & Figure 7). The efficiency of the façade of "Bedroom 1" has been calculated as 33.12% on first floor, 37.45% on second floor and 39.74% on third floor during off-peak hours. During peak hours, these values are 32.15%, 34.55% and 39.31% on the first, second, and third floors, respectively. For "Bedroom 2" efficiencies are 31.73%, 36.36% and 38.74% on the first, second, and third floors, respectively during off peak hours. On the other hand, during peak hours it is 31.10% on first floor, 33.66% on second floor and 38.82% on third floor. The result shows that the façade of "bedroom 2" is less effective at attenuating traffic noise compared to that of "Bedroom 1". This difference can be attributed to the greater number of windows as opposed to "bedroom 1". This also indicates that the efficiency of façade for a particular bedroom increases with the increase in height but decreases slightly during peak hours compared to the efficiency during the off-peak hours. Finally, all the findings have been summarized in Table 1.

Table 1: Summary of the findings

Floors	Spot names	Average Noise Level (dBA)		Maximum Noise Level (dBA)		Minimum Noise Level (dBA)		Noise spike count (More than 48 dBA)		Efficiency of facade (%)	
		Off-peak hours	Peak hours	Off-peak hours	Peak hours	Off-peak hours	Peak hours	Off-peak hours	Peak hours	Off-peak hours	Peak hours
1st floor	Bedroom 1	51.5	55.6	75	76	39	39	17	24	33.12	32.15
	Bedroom 2	52.6	56.5	76	78	39	40	17	22	31.73	31.10
	Bedroom 3	45.2	50.8	65	67	37	37	8	16	N/A	N/A
	Living area	47.1	51.4	69	68	36	35	11	16	N/A	N/A
2nd floor	Bedroom 1	48.2	53.7	76	74	36	41	13	19	37.45	34.55
	Bedroom 2	49.0	54.4	75	76	38	40	14	19	36.36	33.66
	Bedroom 3	44.0	50.2	68	70	35	35	7	12	N/A	N/A
	Living area	45.9	50.9	67	71	36	36	9	16	N/A	N/A
3rd floor	Bedroom 1	46.4	49.8	70	73	35	38	11	11	39.74	39.31
	Bedroom 2	47.2	50.2	73	75	35	38	10	13	38.74	38.82
	Bedroom 3	42.9	45.8	67	67	36	39	7	9	N/A	N/A
	Living area	45.6	50.1	68	69	35	38	10	15	N/A	N/A

4 Conclusion:

This paper aimed to evaluate the effectiveness of roadside façade of a residential building in reducing traffic noise generated by a distributor road running alongside that building. To achieve this, mapping of prevailing noise levels in habitable spaces on different floors has been prepared. It is evident from the result that the façade is not capable enough to reduce the average traffic noise, particularly intermittent noises produced by different motorized and heavy vehicles. Hence, the interior spaces within this specific building are subjected to a noise level that can potentially led to health issues for the occupants. Despite the fact that the building under study is built with a setback of 3 meters from the distributor road, it has been observed that many apartment buildings along this road do not follow the minimum setback rule of BNBC. This situation may position the bedrooms closer to the traffic noise, thereby exacerbating the situation. Again, the façade's efficiency has been assessed in terms of average noise levels. The outcomes would differ for the intermittent noise spikes caused by honking. Furthermore, all the data have been taken with all the windows closed. Otherwise, the prevailing noise levels inside the apartments would be even higher than the found result. Similar to the studied building, the bedrooms in residential buildings are usually positioned next to the road to ensure proper light and ventilation, accommodating windows on the façades next to the noise sources. The alternative layout of apartments can help to place the bedrooms in a way to mitigate the received noise from traffic while also ensuring the utilization of windows for natural ventilation and a source of natural light. Moreover, findings regarding the efficiency of façade in noise reduction may inspire architects to take different approaches for different floors when designing elevations of a single building, rather than making them identical. This approach might entail reducing window-to-wall ratio on lower levels and a gradual increase in the ratio on upper floors. Nonetheless, the average noise level and number of noise spikes more than permissible levels may change with time and day, it has been established that there is a notable presence of elevated levels of intermittent noise. This paper is a small but honest effort to provide a glimpse of the noise pollution occupants are getting exposed to constantly without being aware. This may encourage others to investigate further to produce a detailed noise level map of the spaces designated for living along the other distributor roads. Intended awareness regarding noise pollution may lead to a viable solution to provide a proper sonic environment in the habitable spaces of residential buildings.

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