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Reassessing Noise Comfort in High-Rise Housing in Ho Chi Minh City Vietnam: The Role of Urban Morphology and Road Noise Propagation

Hanh **Vu Thi Hong**[2][0009-0005-4327-2721] ***Hai*** **Tran Nhan**[1][0009-0005-9672-7128],

Department of Architecture, University of Architecture Hochiminh City

Abstract: High-rise apartment buildings have rapidly expanded in urban centers to address housing demand, offering environmental and economic benefits. However, residents often face persistent exposure to traffic noise. Despite adherence to regulatory acoustic standards during design and construction, significant discrepancies remain between predicted and actual indoor noise levels.

This study hypothesizes that these discrepancies arise from three main factors: (1) differences between projected and actual traffic noise characteristics; (2) environmental conditions influencing noise propagation; and (3) the acoustic performance of the building envelope. Focusing on the second factor, this paper investigates how two key environmental variables affect façade-level noise attenuation in high-rise residential buildings in Ho Chi Minh City: (i) the surrounding spatial morphology and (ii) the orientation and height of buildings relative to noise sources.

Using SoundPLAN Noise simulation software, the study identifies how urban form and building siting influence noise reduction patterns and the formation of acoustic shadow zones. The findings aim to support more accurate noise prediction models and inform urban planning and architectural strategies that improve acoustic comfort in dense residential environments.

Keywords: *Road noise, high-rise apartment, noise propagation, Acoustic comfort, Hochiminh City, SoundPLAN*

1. Introduction

In Ho Chi Minh City (HCMC), transportation and commuting demands have increased at nearly twice the rate of population growth [1], resulting in dense, diverse traffic flows that contribute significantly to road noise pollution. A 2018 survey involving 150 receivers across 30 arterial roads found that traffic noise levels consistently exceeded both Vietnamese national limits and World Health Organization (WHO) guidelines [2,3,4]. Strikingly, average road noise levels in HCMC have been reported to surpass those in major global cities such as Tokyo, Japan [5].

Globally, road traffic noise is increasingly recognized as a critical environmental stressor, with well-documented adverse effects on human health and well-being. In Vietnam, the Ministry of

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Health attributes approximately 33% of all deaths to cardiovascular diseases—many of which are linked to long-term exposure to high noise levels [6].

In response to rapid urbanization, HCMC has embraced high-rise apartment buildings as a dominant housing typology. Between 2016 and 2020, 157 commercial high-rise projects were completed, delivering over 9 million square meters of residential space—exceeding official targets by 137.4% [7]. Despite being certified in accordance with national building and acoustic standards, many of these developments face persistent challenges related to traffic noise, which remains the primary external environmental disturbance reported by residents [8].

To support urban noise mitigation strategies, traffic noise prediction models have increasingly been adapted to reflect local climatic, spatial, and socioeconomic conditions [9]. Recent advances in simulation technologies and environmental data collection now enable more precise, context-sensitive assessments of noise propagation in complex urban environments [10].

2. Objectives

2.1 Research Questions

Main research question:

How do environmental spatial factors—specifically the morphology of setback areas and the orientation and height of buildings—affect road traffic noise reduction in high-rise residential developments in Ho Chi Minh City?

Three research sub-questions:

- Which environmental and spatial variables are influenced by sound ray incidence and sound shadow in the calculation of road traffic noise reduction?
- What are the relationships between sound reduction levels and the characteristics of sound ray incidence and sound shadow formation?
- How do sound reduction patterns vary in response to changes in key spatial variables such as setback morphology, building orientation, and height?

2.2 Research Hypotheses

- **H1:** Sound reduction is significantly correlated with surrounding urban morphology, particularly the spatial configuration of setback areas and adjacent structures.
- **H2:** Sound reduction is influenced by the orientation and height of buildings, which affect the angle of incidence of sound rays on building facades at receiver points.
- **H3:** Receivers located within sound shadow zones exhibit greater sound reduction due to the decreased density of sound rays reaching these locations.

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Research Question	Hypothesis	Key Variables	Analytical Method
1. Which environmental and spatial variables are influenced by sound ray incidence and sound shadow in the calculation of road traffic noise reduction?	H1: Sound reduction is significantly correlated with surrounding urban morphology. H2: Sound reduction is influenced by building orientation and height.	- Setback distance - Adjacency of other buildings - Building height - Orientation angle	Spatial modeling (GIS) SoundPLAN simulation
2. What are the relationships between sound reduction levels and the characteristics of sound ray incidence and sound shadow formation?	H2: Sound reduction is influenced by the angle of sound ray incidence. H3: Receivers in sound shadow zones show higher noise reduction.	- Angle of incidence - Sound ray path density - Shadow zone presence	Ray-tracing analysis Noise level comparison
3. How do sound reduction patterns vary in response to changes in key spatial variables such as setback morphology, building orientation, and height?	H1–H3 (combined): Variations in urban form and geometry shape spatial patterns of noise attenuation in high-rise environments.	- Noise reduction level (dB) - Receiver height and location - Façade exposure	Scenario-based simulation Comparative pattern mapping

2.3 Research Objectives

This study aims to:

1. **Examine the relationship** between sound ray incidence, sound shadow formation, and traffic noise exposure in high-rise residential buildings in Ho Chi Minh City, using simulation data generated by *SoundPLAN Noise* software.

2. **Analyze the influence** of two key spatial variables on sound reduction:

   ○ **Horizontal dimension (dX):** the characteristics of surrounding urban morphology and building orientation;

   ○ **Vertical dimension (dY):** the height level of the building.

3. **Evaluate how variations in spatial configuration** affect noise exposure patterns, with the goal of identifying effective urban and architectural strategies for mitigating road traffic noise in high-rise environments.

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3. Methods

3.1 Noise Measurement Methods - Justification for Simulation Tool Selection

Vietnam currently lacks a national computational model for environmental noise prediction comparable to international standards such as ISO 9613-2. As a result, researchers and environmental assessment professionals commonly adopt internationally recognized modeling frameworks, particularly **ISO 9613-2**, implemented through simulation software such as SoundPLAN**,** CadnaA. In practice, the outcomes of these simulations are evaluated against national regulatory benchmarks, notably **QCVN 26:2010/BTNMT**, which defines permissible environmental noise limits.

Among the available tools, **SoundPLAN Noise** was selected for this study due to its advanced capabilities in simulating *outdoor environmental noise propagation*, especially in complex and high-density urban contexts like HCMC. The software allows integration of detailed *geospatial and building geometry data*, enabling the creation of highly accurate 3D models that represent real-world urban morphology, including *street layout, building façade design, and terrain variation* [11]**.**

A key strength of SoundPLAN is its implementation of the ISO 9613-2 standard, which accounts for critical variables in sound propagation such as *atmospheric absorption, ground surface effects, and diffraction around structures***.** This makes it particularly effective for modeling road traffic noise in dense urban environments.

In addition, SoundPLAN supports custom receiver placement, allowing users to measure sound levels at various *heights and positions along building envelopes*. This feature is essential for examining how *setback distance, building height, and orientation* influence *noise exposure and reduction patterns*.

The software also generates *high-resolution noise contour maps* and provides detailed acoustic metrics (e.g., *LAeq values*), which facilitate both *spatial interpretation* and *statistical analysis* of traffic noise impacts. These capabilities make SoundPLAN Noise a robust and reliable tool for investigating the relationship between *urban form and acoustic comfort* in high-rise residential environments.

3.2 Study Plan – experimental approach

Step 1: Case Study Selection

High-rise residential buildings in **HCMC** are selected based on their exposure to *significant road traffic noise*, as determined by their proximity to various levels of the *urban road hierarchy*. These cases are representative of differing conditions of *noise propagation and reduction*, allowing for comparative analysis across spatial variables.

The building selection was guided by the following criteria:

- **Variation in surrounding urban morphology**, including differences in **building density**, **setback dimensions**, and **adjacent road types** (e.g., arterial vs. local roads);
- **Diversity in building orientation and height**, which influence the angle and distribution of incident sound rays;
- **Controlled exclusion of façade material properties**, to isolate the influence of **spatial and geometric factors** on noise reduction.

This selection framework ensures that the case studies reflect a range of urban acoustic conditions relevant to HCMC's high-rise residential development patterns, while enabling focused analysis on the role of urban form in traffic noise exposure.

Road Hierarchy and Traffic Characteristics in Vietnam

Urban roads in Vietnam are broadly categorized into three levels, each associated with distinct *traffic volumes***,** *vehicle types***,** *speed limits***,** and *lane configurations*:

- *Federal Roads (Main Urban Axes and Ring Roads):* These include key intercity routes such as the North–South and East–West corridors**,** along with Ring Roads 01, 02, and 03**.**
  - Speed limit**:** 80 km/h
  - Traffic volume**:** 40,000–100,000 vehicles/day
- *District or State Roads (Main Urban Roads):* Major internal roads serving district-level traffic.
  - Speed limit**:** 50 km/h
  - Traffic volume**:** 40,000–100,000 vehicles/day
- *Community or Inter-Regional Roads***:** Smaller-scale roads embedded within local residential areas.
  - Speed limit**:** 50 km/h
  - Traffic volume**:** 30,000–60,000 vehicles/day

These categories reflect the urban transportation structure in Ho Chi Minh City and form the basis for analyzing corresponding levels of **road traffic noise exposure**.

High-Rise Building Classification in Vietnam

According to **Vietnamese Standard TCVN 13592:2022**, high-rise residential buildings are classified based on total height and number of stories:

- **Type A:** 9–16 stories (up to 50 meters)

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- **Type B:** 17–25 stories (up to 75 meters)
- **Type C:** 26–40 stories (up to 100 meters)
- **Type D:** Over 41 stories (*super high-rise; excluded from this study*)

This classification framework is used to examine **vertical variability** in sound exposure and to ensure consistency across selected case studies.

Figure 1 presents the nine selected high-rise residential buildings in Ho Chi Minh City, chosen based on the established framework and criteria, including road hierarchy, surrounding urban morphology, and building envelope characteristics.


A1 - D1 MESION RESIDENCE
A2 - THANH MY LOI RESIDENCE
A3 - SUNSHINE BUILDING
B1 - AN GIA STAR RESIDENCE
B2 - LA ASTORIA RESIDENCE
B3 - TARA RESIDENCE
C1 - LAVIDA PLUS RESIDENCE
C2 - THE GOLDEN STAR APARTMENTS
C3 - Xi GRAND COURT RESIDENCE

Fig. 1. The Satellite map of line case studies (Source: from Goolge map)

To assess the influence of surrounding urban morphology on noise reduction, **Case Study B1*** (8X Plus Residence on Truong Chinh Road—a main urban road) was further analyzed under **two simulated scenarios** representing different levels of surrounding density. By comparing

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these conditions, the simulation highlights how nearby buildings and surface features contribute to **noise shadow effects** and influence façade-level sound reduction.

Similarly, **Case Study C1*** was simulated with varying building heights to examine **vertical noise exposure patterns**, allowing for a better understanding of how elevation affects sound propagation and attenuation in high-rise residential contexts.

Step 2: Sound Simulation Using SoundPLAN Noise
To evaluate how spatial variables influence traffic noise exposure, environmental noise simulations were conducted using **SoundPLAN Noise**, applying the ISO 9613-2 standard for outdoor sound propagation. This step translates geometric and morphological conditions into quantifiable acoustic outcomes.

For each of the nine selected high-rise buildings, the simulation followed three key procedures:

- **Traffic data input:** Realistic site-specific variables—road hierarchy, traffic volume, speed, and vehicle composition—were input to define the noise source profile under typical operating conditions.

- **Receiver point configuration:** Sound receivers were strategically positioned across building façades at multiple vertical levels (dY) and horizontal positions (dX)**,** capturing variation in exposure due to *height***,** *setback*, and *orientation*.

- **LAeq calculation:** The A-weighted equivalent continuous sound level (LAeq) was computed for each receiver, enabling detailed comparison of sound incidence and reduction patterns across spatial dimensions.

This simulation framework provides a controlled environment to isolate the acoustic impact of **urban morphology** and **building geometry**, revealing how spatial configuration shapes traffic noise distribution in dense, high-rise contexts.

Step 3: Projection and Analysis of Sound Reduction Patterns

Following the simulation phase, the modeled acoustic data were analyzed to evaluate **spatial variations in noise exposure** across the façades of each high-rise building. The objective was to identify how **urban form** and **building geometry** shape sound reduction performance.

The analysis involved three key components:

- **Quantitative assessment** of sound reduction as a function of **building orientation** and **surrounding morphology**, with particular attention to **setback dimensions**, adjacent structures, and street alignment;

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- **Comparative analysis** of exposure across **vertical (dY)** and **horizontal (dX)** axes to detect patterns of **sound shadowing** and **direct sound ray incidence**, revealing how façade position and height influence acoustic performance;
- **Spatial visualization** through **noise contour maps** and **sectional noise profiles**, enabling the interpretation of LAeq distributions and the identification of zones with critical exposure or effective attenuation.

This analytical process clarifies the relationship between **spatial configuration** and **traffic noise attenuation**, offering a foundation for **geometry-based design strategies** aimed at enhancing acoustic comfort in high-rise residential settings.

3.3 SoundPLAN Noise Exposure Simulation

All selected cases were simulated using **SoundPLAN Noise** software, employing the **German RLS-19 (Richtlinien für den Lärmschutz an Straßen)** methodology for road traffic noise prediction. While the computational model followed this standardized approach, the simulation parameters were customized using detailed **site-specific inputs**, including road classifications, traffic volumes, vehicle composition, building heights, and geometric forms (see **Figure 2**).

A **Digital Ground Model (DGM)** was constructed using base data from **OpenStreetMap**, then refined with current local topography and built environment conditions to ensure alignment with the actual urban morphology of **Ho Chi Minh City (HCMC)**.

The simulation integrated localized variables such as Traffic speed and density per road type, Vehicle class distribution (light vs. heavy), Accurate building footprint, height, and orientation

The simulation produced two key outputs, including (1) **Façade Noise Maps:** Showing the spatial distribution of sound pressure levels (LAeq) across different building orientations and elevations, (2) **Cross-Section Noise Maps:** Depicting vertical noise gradients along the building envelope, useful for identifying shadow zones and critical exposure areas at varying heights.

These outputs provided the basis for analyzing how **urban form and building geometry** influence noise attenuation, supporting spatial diagnostics of acoustic comfort in dense high-rise environments.

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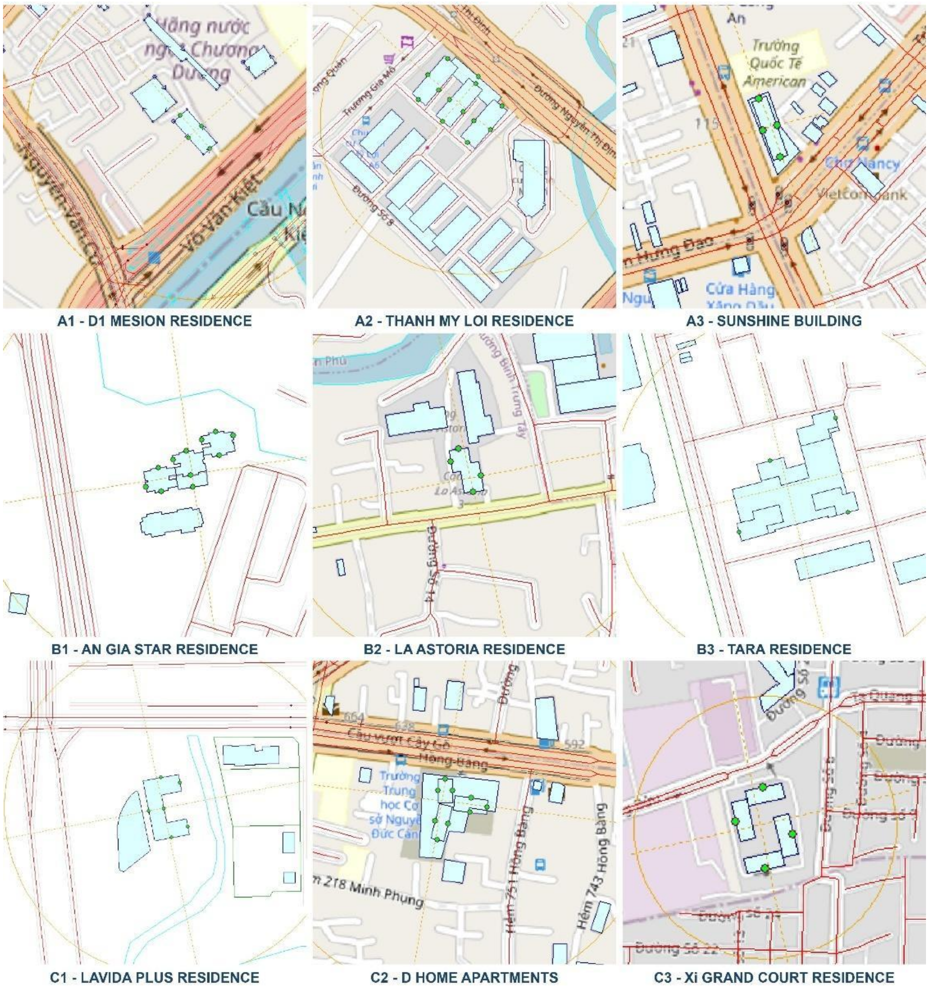
A1 - D1 MESION RESIDENCE
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C3 - Xi GRAND COURT RESIDENCE

Fig. 2. Nine case studies with actual input parameters by SoundPLAN Noise program

4. Results

4.1 Influence of Surrounding Morphology on Noise Exposure

While **setback distance** clearly show impects and already accounted for in traffic noise calculation models (which is the further the better), simulation results indicate that **surrounding morphological features**—including nearby low-rise buildings, vegetation, and varied surface materials—contribute additional **localized sound shadow effects**. These elements act as **partial acoustic barriers**, reducing direct sound ray incidence through **diffraction, reflection, and absorption**.

This effect is most evident at the **lower floors**, where adjacent structures interrupt the line of sight to road-level noise sources, resulting in additional attenuation of up to **3–6 dB(A)** in case B1* - X8 Plus residence (see Figure 3).. At higher elevations, this influence diminishes as façades become more directly exposed to traffic noise.

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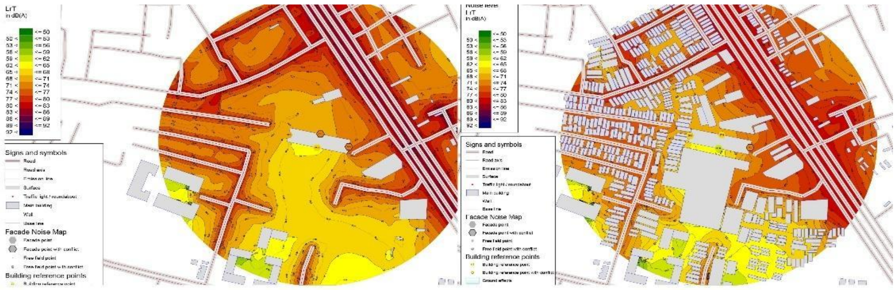
These findings highlight the role of **urban texture and built density** in shaping micro-scale noise environments. Even beyond modeled setbacks, spatial configurations in **dense or mixed-height urban contexts** can offer **passive acoustic benefits**.


FACADE NOISE MESH
B1* - 8x PLUS RESIDENCE LESS EXISTING BUILDINGS

FACADE NOISE MESH
B1* - 8x PLUS RESIDENCE EXISTING BUILDINGS

Fig. 3. The possitive impact of surrounding morphologies upon noise most recieving building facades of X Plus residence high-rise apartment (B1* case study) (exclusive on the left and inclusive at the right picture)

When surrounding features are mostly excluded, the simulation of the nine case studies isolates the relative impacts of **road type**, **setback distance**, and **building orientation** on façade-level noise exposure (see Figure 4**).** Results show that **stand-alone buildings** tend to experience higher noise levels, while building complexes—with multiple blocks arranged in proximity—provide **mutual shielding**, effectively reducing the noise received at each building envelope.

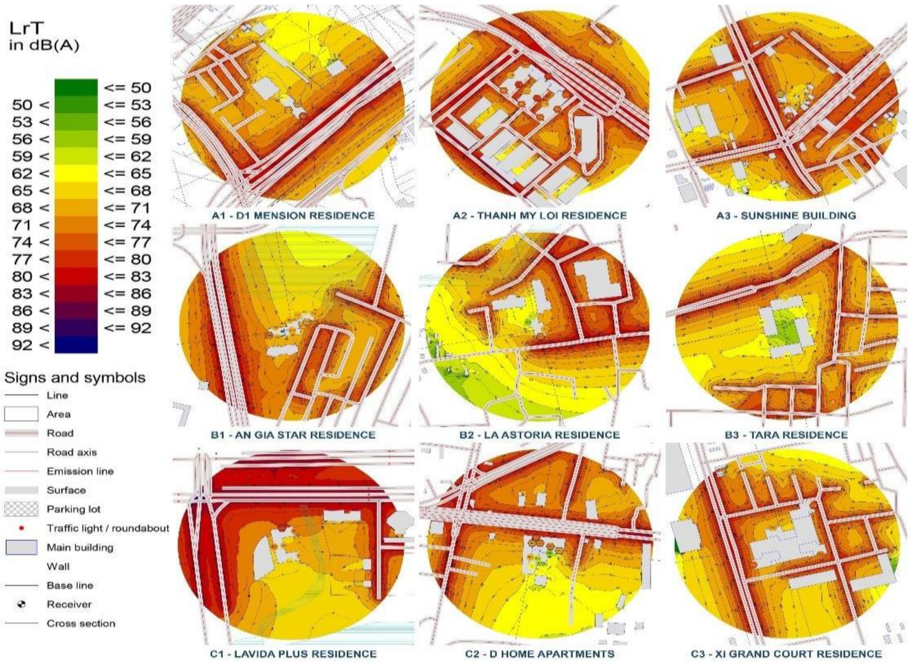


Fig. 4. *Road noise level reduction on the building facade of nine case studies*

4.2 Building Orientation and Its Effect on Noise Reduction

Simulation results show that building orientation significantly affects traffic noise exposure. Façades facing major roads consistently register higher sound levels, while those oriented away benefit from reduced direct sound ray incidence and sound shadowing (see Figure 4, Table 1).

At C2 – D-Home Residence, the contrast between opposing façades exceeds 20 dB(A), clearly illustrating how the angle of incidence and the presence of shadow zones directly influence façade-level sound attenuation (Table 2). These results confirm that orientation and vertical alignment are not neutral factors—they actively shape the spatial distribution of traffic noise across high-rise façades.

These findings highlight that 'the omission of directional geometry can lead to incomplete or inaccurate assessments'. Façade orientation—across both horizontal and vertical planes—emerges as a key variable in understanding and simulating real-world noise exposure, help develope better-informed frameworks for evaluating acoustic comfort in high-density urban environments such as Ho Chi Minh City.

Table 1. Sound level on the building facade building of nine **case studies**

N.o	**Case Study**	**The angle of deviation relative incident ray**	**Sound Level (dB-A)**							
			FRONT (F)		RIGHT (R)		LEFT (L)		BACK (B)	
			D	N	D	N	D	N	D	N
1	A1-D1 Mension	0	73.49	66.57	67.53	60.53	67.08	60.12	62.51	55.58
2	A2-Thanh My Loi	0	68.16	61.54	70.77	63.62	76.61	69.10	75.66	68.07
3	A3-Sunshine	27.7	74.12	66.79	68.75	61.37	74.15	66.84	70.68	63.33
4	B1-AN Gia Star	0	69.21	62.60	64.78	57.50	65.63	59.03	65.39	57.79
5	B2-La Astoria	6.4	72.10	64.79	69.02	61.61	58.38	50.84	61.92	54.35
6	B3-Tara	0	71.52	64.21	70.06	62.47	66.93	59.47	73.95	66.36

7	C1*-Lavida	12.4	69.09	62.48	61.24	54.46	61.53	54.92	55.76	48.66
8	C2-D-Home	3	70.67	63.53	63.48	56.56	50.14	42.89	56.83	49.63
9	C3-Xi Grand	9.6	67.25	59.93	64.60	57.03	63.04	55.71	62.39	54.79

Table 2. Sound level deduction between building facades - dBA

N.o	**Case Study**	**The angle of deviation relative incident ray**	**Sound Level Deduction dB-A**											
			Front right		Front left		Font back		Right left		Right back		Left back	
			D	N	D	N	D	N	D	N	D	N	D	N
1	A1-D1 Mension	0	**5.96**	**6.04**	**6.41**	**6.45**	**10.98**	**10.99**	0.45	0.41	5.02	4.95	4.57	4.95
2	A2-Thanh My Loi	0	-2.61	-2.08	-8.45	-7.56	-7.50	-6.53	-5.84	-5.48	-4.89	-4.45	0.95	-4.45
3	A3-Sunshine	27.7	5.37	5.42	-0.03	-0.05	3.44	3.46	-5.4	-5.47	-1.93	-1.96	3.47	-1.96
4	B1-AN Gia Star	0	**4.43**	**5.10**	**3.58**	**3.57**	**3.82**	**4.81**	-0.85	-1.53	-0.61	-0.29	0.24	-0.29
5	B2-La Astoria	6.4	**3.08**	**3.18**	**13.72**	**13.95**	**10.18**	**10.44**	10.64	10.77	7.10	7.26	-3.54	7.26
6	B3-Tara	0	**1.46**	**1.74**	**4.59**	**4.74**	-2.43	-2.15	3.13	3	-3.89	-3.89	-7.02	-3.89
7	C1*-	12.4	7.3	8.0	7.5	7.5	13.	13.	-	-	5.48	5.8	5.77	5.80

	Lavida		6	2	6	6	34	82	0.29	0.46		0		
8	C2-D-Home	3	**7.19**	**6.97**	**20.53**	**20.64**	**13.84**	**13.90**	13.34	13.67	6.65	6.93	-6.69	6.93
9	C3-Xi Grand	9.6	2.65	2.9	4.21	4.22	4.86	5.14	1.56	1.32	2.21	2.24	0.65	2.24

4.3 Vertical Sound Reduction

In the absence of surrounding urban elements—such as streetscapes, vegetation, or adjacent buildings—sound levels on high-rise façades generally follow a predictable vertical gradient**,** decreasing steadily from lower to upper floors. However, this pattern can be significantly altered by nearby urban morphology or architectural configurations, which introduce **sound reflections, diffractions, or shadowing**, thereby disrupting the expected reduction trend.. (see **Fig. 4**).

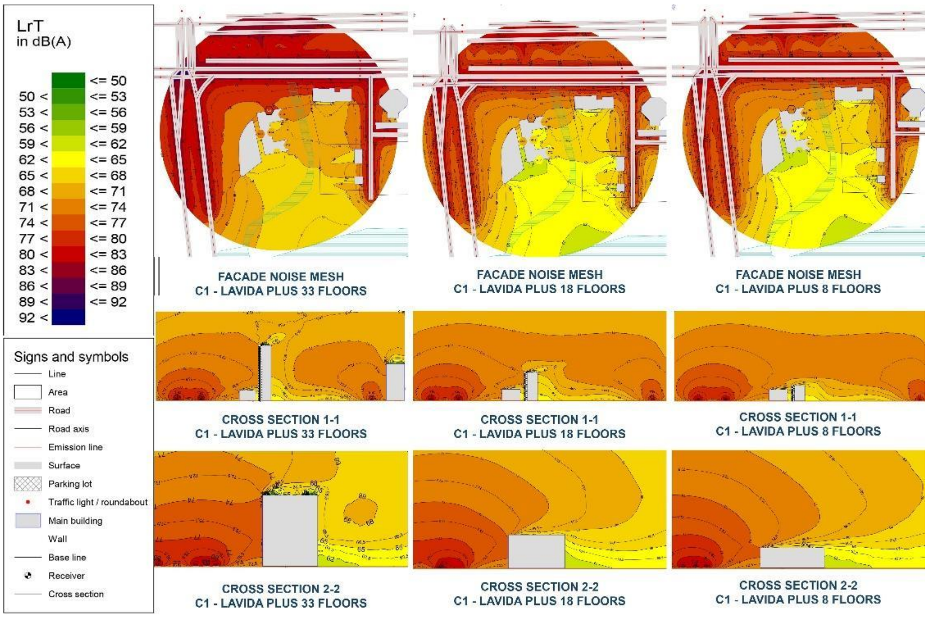


Fig. 4. Case study C1* facade noise map and cross section map in three different high level of building

5 Discussion

The simulation outcomes and case study analyses directly respond to the research question: How do urban morphological variables and building configurations influence variation in sound reduction across high-rise façades exposed to traffic noise?

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The results strongly support the study's hypotheses on two fronts. First, regarding urban morphology (dX – horizontal dimension), the findings confirm that setback distance alone does not account for façade-level sound attenuation. The presence of surrounding buildings, vegetation, and surface complexity—often excluded from standard noise prediction models—contributes to micro-scale sound shadow effects, particularly at lower floors. This supports the hypothesis that urban form meaningfully shapes traffic noise exposure beyond simple linear distance metrics.

Second, in terms of building geometry (dY – vertical dimension), variations in noise levels along building height reveal that orientation and vertical positioning significantly influence sound reduction. Façades facing away from roadways consistently exhibited lower noise levels, with reductions exceeding 20 dB(A) in some cases. These results validate the hypothesis that the angle of sound ray incidence and the vertical arrangement of façades are critical factors in traffic noise exposure.

Together, the study demonstrates that sound ray behavior and shadow zone formation—shaped by both urban context and building form—are key mediators of traffic noise impact. These findings not only confirm the original hypotheses but also emphasize the importance of integrating spatial-acoustic analysis into early-stage urban and architectural design to better predict and mitigate environmental noise in dense, high-rise residential environments.

6. Conclusion

This study confirms that both horizontal and vertical spatial configurations play a critical role in mitigating road traffic noise in high-rise residential environments. Site-specific simulations using SoundPLAN Noise show that building orientation, urban morphology, and façade height significantly affect noise attenuation—often beyond what standard prediction models assume.

Key findings reveal that façade orientation alone can cause up to 20 dB(A) variation in noise levels, while dense or mixed-height surroundings provide effective sound shadowing, especially below 15 meters. Vertical exposure is shaped not only by building height but also by the surrounding spatial context.

These results highlight the importance of integrating acoustic performance into early-stage planning. In rapidly growing cities like Ho Chi Minh City, urban planners and designers can improve livability by aligning building orientation with traffic flow, introducing buffer zones, and encouraging staggered or clustered forms to enhance noise shielding.

Future research should link acoustic simulation with land-use data and 3D urban morphology models to inform noise-sensitive, health-focused urban development strategies across Vietnam's evolving cities.

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