Journal of Architectural Sciences and Applications
JASA 2024, 9 (2), 756-773
Research article
e-ISSN: 2548-0170
https://dergipark.org.tr/en/pub/mbud

Environmental Noise Assessment of Residential Buildings with Ground Floor Commercial Function Specific to the Canyon Effect

Derin Hilal BİLMEZ [1]*, Cüneyt DİRİ [2]

ORCID 1: 0000-0002-3318-1982
ORCID 2: 0000-0003-4217-6381
[1] *Mimar Sinan Fine Arts University, Institute of Postgraduate Education, Building Physics and Material, 34427, Istanbul, Türkiye*
[2] *Mimar Sinan Fine Arts University, Faculty of Architecture, 34427, Istanbul, Türkiye*
**** e-mail**: derinhilalb@gmail.com*

Abstract

Environmental noise is one of the primary important factors that negatively affect human health and quality of life. The canyon effect occurs in the regions between the long structure groups. Canyon effect can cause different conditions in terms of noise, heat, lighting or ventilation. This difference: It depends on the building-road relationship, traffic density, climatic conditions, building dimensions and geometry. Within the scope of this study: The road-structure height relationship of environmental noise specific to street canyons and the trade-housing relationship within the building were examined. Highway was preferred as the sound source. 12 separate operational models were created, and a total of 168 measurement results were obtained from 4 indoor and 10 outdoor measurement points in each model. The results showed the level of the canyon effect specific to different variables.

Keywords: *Canyon effect, environmental noise, trade, housing, operational model.*

Kanyon Etkisi Özelinde Zemin Katı Ticari Fonksiyonlu Konut Binalarının Çevresel Gürültü Değerlendirmesi

Özet

Çevresel gürültü, insan sağlığını ve yaşam kalitesini olumsuz etkileyen önemli faktörlerin başında gelmektedir. Kanyon etkisi, uzun yapı grupları arasında kalan bölgelerde ortaya çıkar. Kanyon etkisi gürültü, ısı, aydınlatma veya havalandırma açısından farklı koşullara neden olabilir. Bu farklılık: Yapı-yol ilişkisine, trafik yoğunluğuna, iklim koşullarına, bina boyutlarına ve geometrisine bağlıdır. Bu çalışma kapsamında: Cadde (sokak) kanyonlarına özgü çevresel gürültünün yol-yapı yüksekliği ilişkisi ve yapı içindeki ticaret-konut ilişkisi incelenmiştir. Ses kaynağı olarak karayolu tercih edilmiştir. 12 ayrı operasyonel model oluşturulmuş ve her bir modelde 4 iç mekan ve 10 dış mekan ölçüm noktasından toplam 168 ölçüm sonucu elde edilmiştir. Sonuçlar farklı değişkenlere özgü kanyon etkisinin seviyesini göstermiştir.

Anahtar Kelimeler: *Kanyon etkisi, çevresel gürültü, ticaret, konut, operasyonel model.*

Citation: Bilmez, D. H. X. & Diri, C. (2024). Environmental noise assessment of residential buildings with ground floor commercial function specific to the canyon effect. *Journal of Architectural Sciences and Applications*, 9 (2), 756-773.
DOI: https://doi.org/10.30785/mbud.1471935

Received: *April 22, 2024 –* ***Accepted:*** *October 4, 2024*

1. Introduction

After the industrial revolution, the population in cities increased due to job opportunities (Carlo et al., 2024; Li et al., 2017; Li et al., 2020; Pouya, 2022). City centers have developed and changed rapidly over time (Toy & Esringü, 2021; Yılmaz Bakır, 2020). Due to the increasing urban population, irregular planning and urbanization, the number of vehicles and vehicle roads have shown various developments (Carlo et al., 2024; Li et al., 2020; Thaker & Gokhale, 2016; Yükrük Akdağ, 2003). The increase in the number of vehicles has caused a certain traffic density and the roads to be shaped accordingly (Thaker & Gokhale, 2016; Yükrük Akdağ, 2003). Roads (transportation network) have become one of the main elements of the city. At the International Congress of Modern Architecture (CIAM) held in 1933, the city was divided into 4 functional regions: Housing, recreation, work and transportation (Gold, 1998; Mumford, 1992; Yılmaz Bakır, 2020).

Cities are areas with compact settlements(Kim et al., 2022). In compact settlements, unwanted settlements may occur between vehicle roads and buildings (Arpacıoğlu, 2006, 2012; Sayın, 2022; Šprah, Potočnik & Košir, 2024; Toy & Esringü, 2021; Yuan, Edward & Norford, 2014). Some of these settlements may lead to the formation of microclimate regions (Nasrollahi, Namazi & Taleghani, 2021). Street canyons are the area surrounded by high-rise buildings on both sides of the road (Şimşek & Özçevik Bilen, 2021). Examples of microclimate regions can be given. It has a shape like an open top tunnel (Toy & Esringü, 2021). There are areas exposed to the canyon effect in our country and many cities around the world (Shen et al., 2017; Toy & Esringü, 2021; Ünal Çilek, 2022).

Canyon effect in terms of noise: It is the transmission of sound at a much higher sound level to much longer distances than normal by reflecting many times between high-rise buildings aligned in parallel (Can, Fortin & Picaut 2015; Yılmaz et al., 2023). The canyon effect is the decrease in environmental quality in the region where the noise, emission, and heat from the vehicles cannot be removed due to high buildings (Fatehi & Nilsson, 2022; Gu et al., 2011; Schiff, Hornikx & Forssén, 2010). It consists of more reflected sound than direct sound from the source (Can et al., 2015; Kang, 2000). Standard sound insulation and noise control calculations may be insufficient when designing in areas where the canyon effect is observed (Can et al., 2015; Schiff et al., 2010; Yılmaz et al., 2023). Therefore, at the beginning of the design phase, the land, building-road relationship should be analyzed.

1.1. The Canyon Effect

Canyon: "They are geographical shapes consisting of steep slopes formed by the erosion and cleavage of water permeable rocks under weather conditions or river effect." (Wikipedia, 2024; Zorer & Öztürk, 2021). Due to the similarity between the geometric shapes of the canyons and the locations of the buildings, the settlements where the road is located between the buildings are called "street canyon" in architecture and urbanism (Ünal Çilek, 2022). The concept of "canyon effect" takes its name from here. Canyon effect: "Microclimatic changes in street canyons" (Yılmaz et al., 2023). Sound (Can et al., 2015; et al., 2024; Yılmaz et al., 2023), heat (Battista et al., 2021; Buccolieri et al., 2015), lighting (Šprah et al., 2024), air quality (Du et al., 2023; Li et al., 2020) is effective in multiple comfort parameters. It may cause the formation of heat islands or noisy areas, deteriorate air quality and cause serious effects on human health (Babisch, 2008, 2014; Babisch et al., 2005; Carlo et al., 2024; Farrell et al., 2015; Lugten et al., 2024; Nosek et al., 2022; Schiff et al., 2010; WHO, 2018). It may cause an increase in environmental pollutants (Li et al., 2017; McMullan & Angelino, 2022).

The reason why street canyons are special areas is that they create different conditions according to their surroundings due to the airflow between the buildings (Di Bernardino et al., 2018). In street canyons, turbulence is lower than in open terrain, while air swirls form at the corners and the air becomes more stagnant. These vortices in the canyons cause wind and sub wind levels to differ in terms of air pollution, heat and sound (Farrell et al., 2015). As the height of the building increases, a deeper canyon is formed (Murena & Mele, 2016), and the difference between the lower and upper elevations of the physical environment components increases. For example, many studies have shown that road-level air pollution (for the same vehicle road and traffic density) is higher in an area under the influence of deep canyon than in an open area (Farrell et al., 2015; Murena & Favale, 2007; Vardoulakis, Gonzalez-Flesca & Fisher, 2002). Another result that supports this is: On roads where traffic flow is free, the air pollution concentration at the road level of the canyon (at the lower level of the building) is much lower than at the upper level (Di Bernardino et al., 2018; Kim et al., 2022; Thaker & Gokhale, 2016).

Many design elements have an impact on the canyon effect. It is affected by elements such as wind direction, building geometry, roof plane, road width, building height (Balogun et al., 2010; Buccolieri et al., 2015; Carpentieri et al., 2012; Eliasson et al., 2006; Karra, Malki-Epshtein & Neophytou, 2017; Kim et al., 2022, 2023; Kluková et al., 2021; Lugten et al., 2024). Situations such as the slope, flat or roundness of the roof design, the degree of slope, and the partial design affect the air vortex on the street (Alwi et al., 2023; Kluková et al., 2021). There are various types of roofs in today's cities. Especially in areas with snow and rainfall, the majority of buildings have sloping roofs (Badas et al., 2017). In the studies conducted for such settlements, it is very important to enter the roof details into the simulation in terms of the realism of the results.

Observation (measurement) or simulation can be performed for physical environmental control in street canyons. Observation ensures that instantaneous and unobservable data are also taken into account. Therefore, it is a more suitable method especially for pollution research (Farrell et al., 2015; Guillaume, Gauvreau & L'Hermite 2015; Yagi et al., 2017). Simulation, on the other hand, allows the evaluation of various geometric and meteorological conditions, and since it can be repeated, it is a suitable method for the design phase (Can et al., 2015; Farrell et al., 2015; Guillaume et al., 2015; Kanda, 2006; Schiff et al., 2010). In the simulation, a "numerical model" or "operational model" (Vardoulakis et al., 2003) can be used. Numerical models work with "computational fluid dynamics". However, it is a high-cost calculation method (Guillaume et al., 2015). Therefore, it cannot be used for every canyon. Operational models are an alternative to numerical models. It can also be created and used by non-experts. Although the sources of information are limited, they provide a lot of data on the subject (Kang, 2005; Lee & Jeon, 2011; Lee & Kang, 2015; Murena & Mele, 2016; Yilmaz et al., 2023). Operational models are generally created in such a way that the buildings are accepted as boxes and calculated by mass equation. Since the boxes are considered homogeneous and stable, it is easier to calculate the average values of the pollutants in the street (Murena et al., 2011).

2. Material and Method

The aim of the study is to investigate the relationship between trade and housing functions and building and vehicle road heights in building groups exposed to the canyon effect. Within the scope of the study, uniform operational canyon models were created and environmental noise calculations were made specific to the measurement points.

SoundPLAN software was used for environmental noise calculation. The scenarios planned to be evaluated within the scope of the study are drawn in AutoCAD 2018. Noise data is entered into the model in SoundPLAN. The results were compared with each other for different scenarios. The images of the study were drawn by hand in the Designer-2 application.

3. Findings and Discussion

Within the scope of the study, ground floor residential buildings with commercial functions were evaluated specific to the canyon effect. For this, a building type and a road section were designed, first the combination of commercial and residential functions of this building, then the combination of height between the road and the building was changed. As seen in Figure 1, the types of street canyons used in this study are common in today's cities. Especially in densely populated areas, even deeper canyons are encountered.

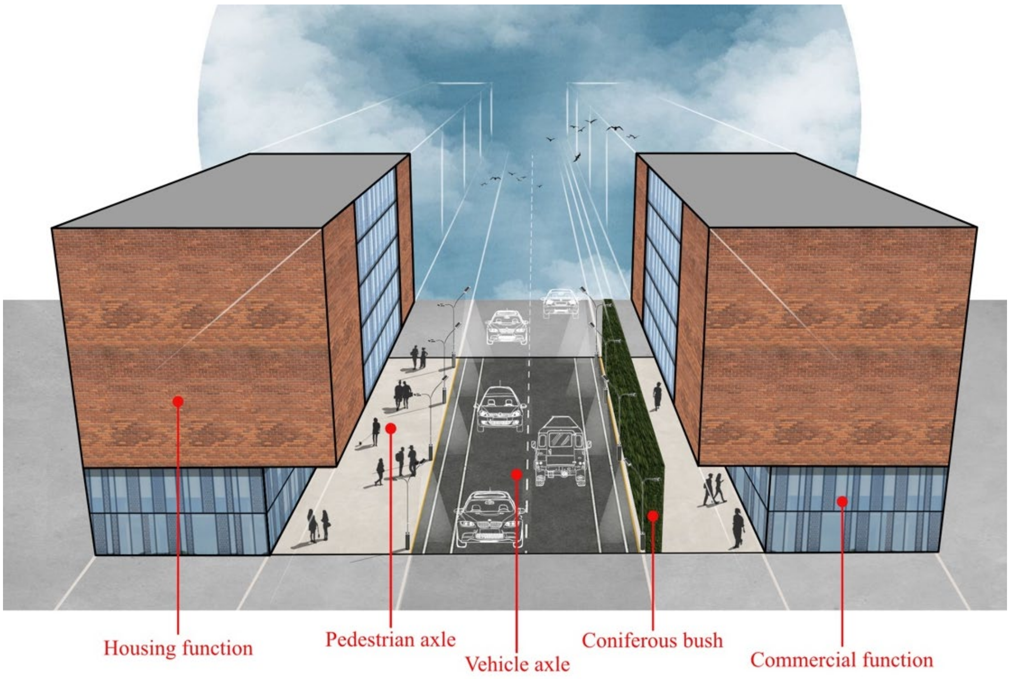


Figure 1. Three-Dimensional Rendering of the Model 7

The road facade of the designed building is 20 meters wide without a flat balcony. The facade consists of glass and brick. Facade size (cm) and material use are shown in Figure 2. Only brick and glass material was used in the residential unit and only glass material was used in the trade.

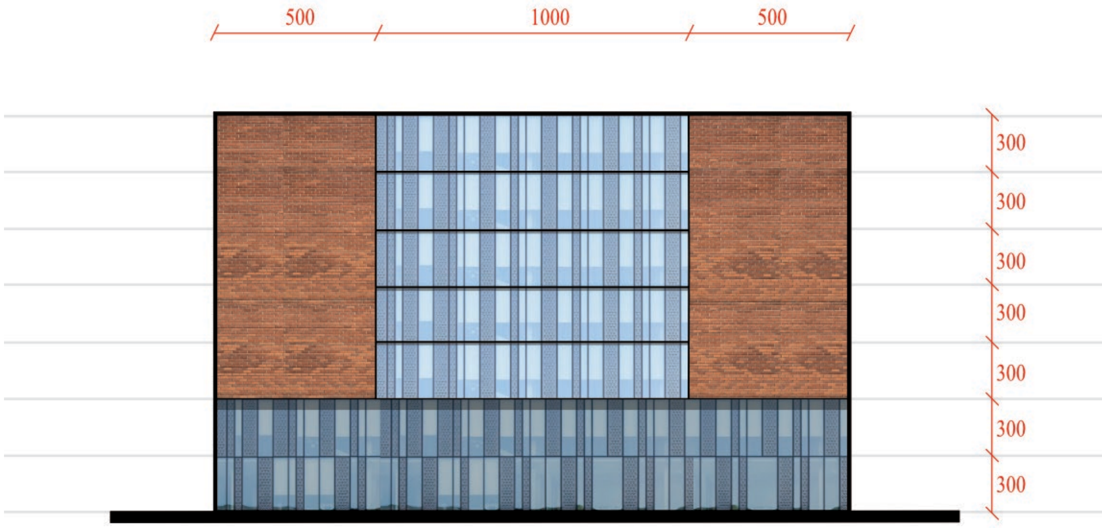


Figure 2. Road Front of the Building (Model 7)

Figure 1 The example of a building model with two commercial five-storey houses is shown in Table 2. The combinations of the building in Figure 2 in 12 scenarios are given in Table 1. The sound absorption values of the materials used in building and road design are given. It is "Rw: 24" for glass material.

Table 1. Sound absorption (α) values of materials used in design

	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz
Glass (Large Panel) *	0,18	0,06	0,04	0,03	0,02
Brick (Machined Brick Mesh) **	0,01	0,02	0,02	0,03	0,04
Asphalt (9,5 mm size aggregate, 4,3 cm thickness) ***	0,01	0,01	0,05	0,8	0,15
Stone (Marble) **	0,01	0,01	0,01	0,02	0,02
Needle Leaf Shrub ****	0,02	0,04	0,03	0,04	0,1

* (Egan 2007), * * (Colorlib & Jekyll 2021), * * * (Knabben et al. 2016), * * * * (M. Li et al. 2020)

3.1. Scenario Design

In the literature, heterogeneous, semi-idealized models have generally been used in studies on the canyon effect (Allegrini, 2018; Coceal et al., 2006; Du et al., 2023; Goulart et al., 2019; Lo & Ngan, 2015; Michioka, Takimoto & Sato, 2014; Nosek et al., 2018; Shen et al., 2017). Uniform street canyons usually consist only of high-rise buildings. However, mixed street canyons are formed in various urban areas with canyon effect today. There is variability in factors such as traffic density, building height, road width (Gu et al., 2011). The models used in the study were aimed to be similar to today's street canyons. Figure 2 shows a three-dimensional rendering of a model.

Scenario design stages are as follows:

• For the examination of the commercial-housing combination: The floor layout of the building is planned as "Ground floor + 6 floor", seven floors in total. The facade was retracted 2,5 meters from the road on the commercial floors of the building. In the scenario editing, three different combinations are included: one layer commercial, two layers commercial and three layers commercial.

• In order to examine the canyon effect, the road section (vehicle and pedestrian) was kept constant, and different elevation heights specific to the road and building were evaluated. Road: The pedestrian axle on both sides (a pedestrian axle 2,5 meters) is planned with a total width of 12 meters in the middle, open to bi-directional traffic and unable to park (double lane, 7 meters). The vehicle path data is taken from the SoundPLAN library. "Road day histogram library + OGT + 24%" was selected and variable and bidirectional traffic was determined. "Main Road" was selected as the road type, and for light vehicles, day speed was entered as 60 km/h (variable), 50 km/h (variable) in the evening, and 40 km/h (constant) at night. For heavy vehicles, 50 km/h (variable) was entered during the day, 40 km/h (variable) in the evening, 30 km/h (constant) at night. Within the scope of these entered and selected values, SoundPLAN calculated the following values for the road: Lday 76,45 dB (A), Levenning 70,62 dB(A), Lnight 66,90 dB(A). This path calculation was used for all models. Asphalt was preferred as vehicle road material and stone (marble) was preferred as pedestrian road (pavement) material. Four different combinations are included: the road is lower than the ground level of the building, the ground floor of the building is at the same height as the first floor and the second floor.

A total of 12 different scenarios were created by crossing commercial-housing combinations with road-building combinations. In the models, the building and road are formed in a length of 20 meters, and the measurement points are at the midpoint of the model (at 10 meters). A total of 14 measurement points were determined in each scenario model, 4 in the building (2 in commerce, 2 in housing) and 10 outside the building. The measurement points are co-located on the right and left sides of the model. In each model, it was decided to place identical buildings on both sides of the road.

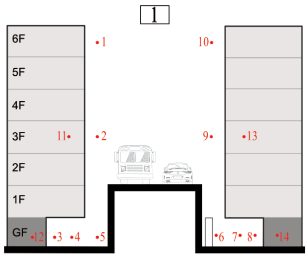
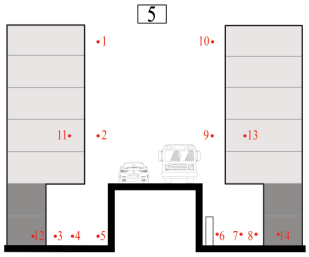
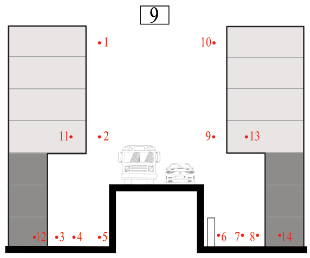
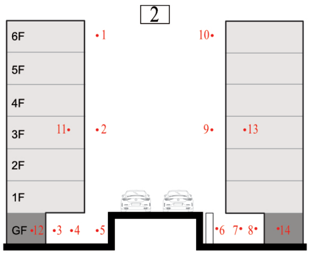
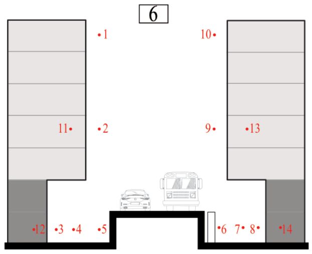
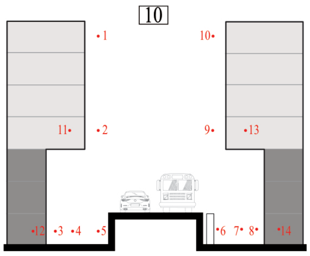
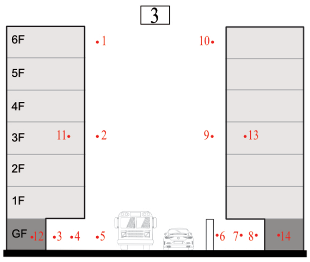
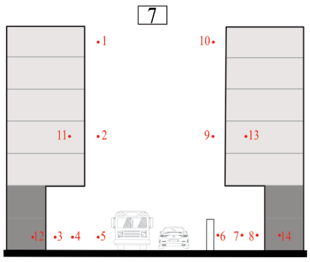
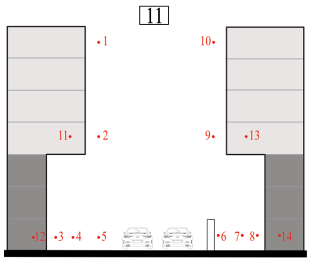
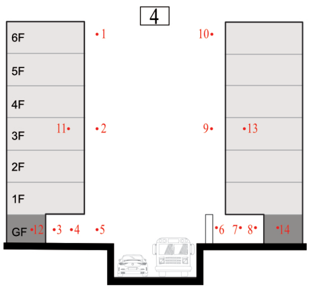
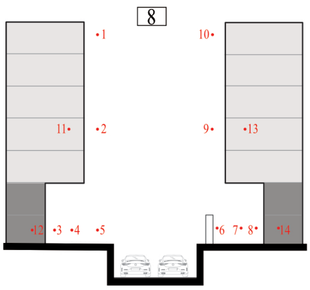
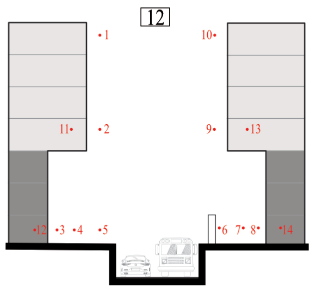
In each model, a coniferous bush with a height of 3 meters and a width of 90 cm is placed parallel to the road (continuing throughout the entire model) on the pedestrian axis on the right side of the road. This bush is planned to act as a natural noise barrier. In addition, bushes have the feature of supporting ventilation and social life under the influence of canyon and preventing the formation of wind corridors (Can et al., 2015; Carlo et al., 2024; Fellini et al., 2022; Van Renterghem & Botteldooren, 2008, 2010). The bush is placed at the pavement elevation and is positioned independently of the road elevation. The shrub height is chosen in accordance with the height of the garden protection wall used in any sheltered site.

It was preferred to leave the cantilever distance in the buildings (between the commercial and residential floors) 2,5 meters and to prefer the materials whose sound absorption values are given in Table 1 to ensure that the models comply with the values allowed by the structural and regulations. In models 1, 2, 4, 5, 6, 8, 9, 10 and 12, when the road elevation is changed, the road edges are assumed to be the same as the road material.

For the meteorological data (wind, temperature and humidity) of the study, Cmet(daytime): 2, Cmet(evening): 1 and Cmet(night): 0,5 values were entered.

Table 2 cross-sections and measurement points of 12 scenarios (14 in each scenario) are shown in. Spaces coloured dark gray represent commerce, and light greys represent housing. In the table, each row shows the same elevation height between the road and the building, and each column shows the same commercial housing combination. The models are designed in three dimensions, shown in their cross-sections in Table 2.

Table 2. Scenarios (Red: Measurement point)

Road-Building Combination	Commercial-Housing Combination		
	"Ground Floor" Commercial	"Ground+1" Commercial	"Ground+1+2" Commercial
The Road is at the Second Floor Elevation of the Building			
The Road is at the First Floor Elevation of the Building			
The Road is at the Ground Floor Elevation of the Building			
At the Underground Elevation of the Road Building			

The locations of the measurement points were selected at similar horizontal and vertical coordinates for convenience in calculation and comparison. Measurement points 1, 2, 9 and 10 are located 1 meter away from the building facade. Measurement points 3 and 8 are located 0,5 meters away from the building facade. The X-axis coordinates of measurement points 1,2 and 5 are the same. The X-axis coordinates of measurement points 6, 9 and 10 are the same. The Y-axis coordinates of measurement points 3, 4, 5, 6, 7, 8, 12 and 14 are the same. Measurement points 11 and 13 refer to residential indoor noise, while measurement points 12 and 14 refer to commercial indoor noise. The locations of the measurement points are given in Figure 3. Figure 3 shows the measurement points on Model 3.

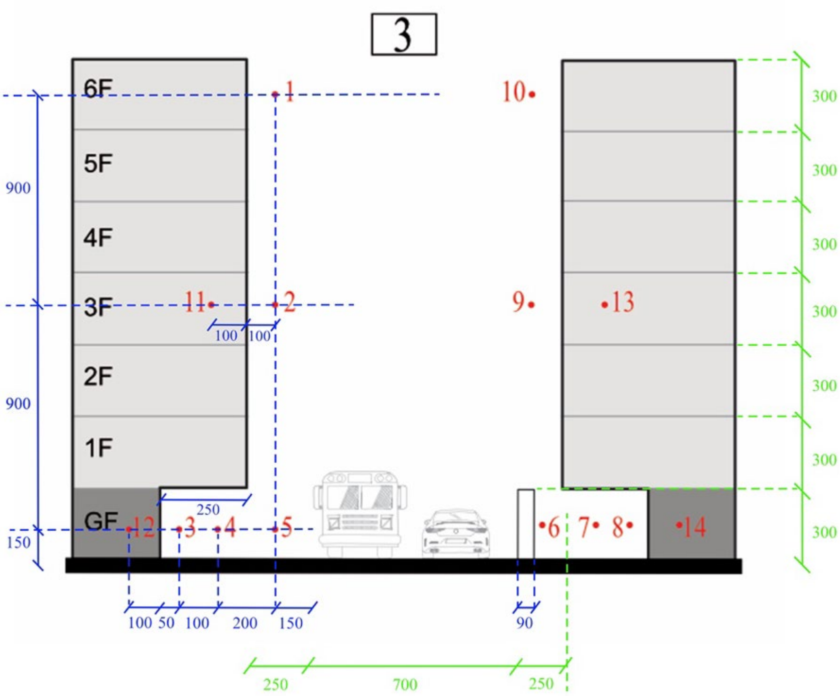


Figure 3. Location of Measurement Points (Model 3)

In the continuation of the study, the measurement points were named according to the name of each scenario. For example, the measurement points of the first scenario are named as 1.1, 1.2, 1.3, 1.4, etc.

4. Conclusion and Suggestions

For the 12 models calculated within the scope of the study, 168 different result data were obtained, 48 of which were indoors (24 in commerce, 24 in housing) and 120 outdoors. Simulation results are given in Table 3. Daily average value (Lden) was used to compare the measurement results. The painted columns in the same color show the measurement point name and the result value.

Table 3 the measurement results given in are examined with the following graphs. Table 5 in, it is shown that the sound reaches long distances without decreasing due to the canyon effect. For this, the 1st, 2nd and 5th measurement points (aligned in the vertical plane) were used from each model. The 5th point is at the pavement level and is the closest to the road, while the 1st point is at the upper level of the building and is the farthest from the road.

- The noise level difference between the 1st and 2nd points is between a minimum of 0,5% (0.3 dB(A), model 12) - a maximum of 2,7% (1,6 dB(A), model 10).
- The noise level difference between the 1st and 5th points is between a minimum of 0,7% (0.4 dB(A), model 2) and a maximum of 8,2% (4,8 dB(A), model 8).
- The noise level difference between the 2nd and 5th points is between a minimum of 0,3% (0,2 dB(A), model 8) - a maximum of 1,5% (0,9 dB(A), models 3, 6 and 10).

Table 3. SoundPLAN simulation results (Lden results dB(A))

Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
measurement point	*result*	*measurement point*	*result*	*measurement point*	*result*	*measurement point*	*result*	*measurement point*	*result*	*measurement point*	*result*
1.1	56,2	***2.1***	56,3	***3.1***	54,7	***4.1***	53,6	***5.1***	56,9	***6.1***	57,2
1.2	57,4	***2.2***	57,3	***3.2***	55,7	***4.2***	54,1	***5.2***	58,6	***6.2***	58,9
1.3	24,3	***2.3***	24,3	***3.3***	23,4	***4.3***	23,3	***5.3***	24,3	***6.3***	24,4
1.4	28,3	***2.4***	28,3	***3.4***	27,0	***4.4***	28,8	***5.4***	28,5	***6.4***	28,2
1.5	56,9	***2.5***	56,7	***3.5***	56,6	***4.5***	54,5	***5.5***	57,8	***6.5***	58,0
1.6	50,4	***2.6***	50,4	***3.6***	48,8	***4.6***	48,5	***5.6***	50,5	***6.6***	50,5
1.7	45,5	***2.7***	45,8	***3.7***	39,9	***4.7***	40,3	***5.7***	46,4	***6.7***	45,6
1.8	22,3	***2.8***	22,4	***3.8***	18,4	***4.8***	18,3	***5.8***	22,5	***6.8***	22,5
1.9	55,4	***2.9***	56,4	***3.9***	56,7	***4.9***	56,0	***5.9***	55,3	***6.9***	55,5
1.10	54,3	***2.10***	54,5	***3.10***	55,2	***4.10***	55,3	***5.10***	54,5	***6.10***	54,5
1.11	29,9	***2.11***	29,3	***3.11***	28,2	***4.11***	26,6	***5.11***	31,1	***6.11***	31,4
1.12	7,3	***2.12***	7,3	***3.12***	6,3	***4.12***	6,3	***5.12***	7,3	***6.12***	7,4
1.13	27,9	***2.13***	28,9	***3.13***	29,2	***4.13***	28,5	***5.13***	27,8	***6.13***	28
1.14	4,9	***2.14***	5	***3.14***	1	***4.14***	1,1	***5.14***	5,1	***6.14***	5,1

Model 7		Model 8		Model 9		Model 10		Model 11		Model 12	
measurement point	*result*	*measurement point*	*result*	*measurement point*	*result*	*measurement point*	*result*	*measurement point*	*result*	*measurement point*	*result*
7.1	53,3	***8.1***	53,2	***9.1***	56,7	***10.1***	57,0	***11.1***	54,1	***12.1***	53,2
7.2	54,0	***8.2***	54,3	***9.2***	58,1	***10.2***	58,6	***11.2***	54,7	***12.2***	53,5
7.3	23,4	***8.3***	23,3	***9.3***	24,4	***10.3***	24,3	***11.3***	23,3	***12.3***	23,4
7.4	26,9	***8.4***	26,4	***9.4***	28,0	***10.4***	28,5	***11.4***	26,9	***12.4***	27,0
7.5	54,2	***8.5***	58,0	***9.5***	57,4	***10.5***	57,7	***11.5***	55,2	***12.5***	53,9
7.6	49,0	***8.6***	48,8	***9.6***	50,4	***10.6***	50,5	***11.6***	48,8	***12.6***	48,7
7.7	40,3	***8.7***	40,0	***9.7***	45,2	***10.7***	45,2	***11.7***	40,0	***12.7***	22,5
7.8	18,4	***8.8***	18,4	***9.8***	22,4	***10.8***	22,3	***11.8***	18,4	***12.8***	18,4
7.9	57,3	***8.9***	56,8	***9.9***	55,8	***10.9***	55,8	***11.9***	56,6	***12.9***	55,9
7.10	56,0	***8.10***	56,0	***9.10***	54,6	***10.10***	54,6	***11.10***	55,6	***12.10***	55,6
7.11	26,5	***8.11***	26,8	***9.11***	30,6	***10.11***	31,1	***11.11***	27,2	***12.11***	26
7.12	6,4	***8.12***	6,3	***9.12***	7,4	***10.12***	7,3	***11.12***	6,3	***12.12***	6,4
7.13	29,8	***8.13***	29,3	***9.13***	28,3	***10.13***	28,3	***11.13***	29,1	***12.13***	28,4
7.14	1	***8.14***	1	***9.14***	5	***10.14***	4,9	***11.14***	1	***12.14***	1

Continuous traffic flowing highways are line sources. When environmental factors are neglected (such as wind, temperature, weather), the sound level at the line source is calculated with the formula:

"*L2 = L1 – 10log(r2/r1)*" dB

(L: sound level, r: distance) (Yüğrük Akdağ, 2024). Since the sound line source (road) height changes in the models, it is necessary to calculate with different r values. Table 4 in which model, which r values are entered is written. (While calculating the r value, the geometric midpoint of the vehicle road at 1,5 meters above the ground is accepted as the center of the sound source.)

Table 4. R (distance) values in models for line source sound level reduction formula (m)

	Models 1, 5, 9			**Models 2, 6, 10**			**Models 3, 7, 11**			**Models 4, 8, 12**		
	r_1	r_2	$r_2 = r_1$	r_1	r_2	$r_2 = r_1$	r_1	r_2	$r_2 = r_1$	r_1	r_2	$r_2 = r_1$
Point 1 (r_2) and Point 2 (r_1)	**6**	**13,7**	2,2	**8,3**	**16,6**	2	**10,9**	**19,5**	1,7	**13,7**	**22,4**	1,6
Point 1 (r_2) and 5 (r_1)	**7,5**	**13,7**	1,8	**5,4**	**16,6**	3	**1**	**19,5**	19,5	**5,4**	**22,4**	4,1
Point 2 (r_2) and 5 (r_1)	**6**	**7,5**	1,2	**8,3**	**5,4**	0,6	**10,9**	**1**	0,1	**13,7**	**5,4**	0,3

The sound level in the line source was calculated with the data in Table 4. The results are given in Table 5.

Table 5. SoundPLAN simulation and theoretical account levels differences of the 1st, 2nd and 5th measurement points in the models in Table 2 (dB(A))

	Point 1 (r_2) and Point 2 (r_1)		**Point 1 (r_2) and 5 (r_1)**		**Point 2 (r_2) and 5 (r_1)**	
	SoundPLAN	Account	SoundPLAN	Account	SoundPLAN	Account
Model 1	1,2	3,4	0,7	2,5	0,5	0,8
Model 2	1	3	0,4	4,7	0,6	-2,2
Model 3	1	2,3	1,9	12	0,9	-10
Model 4	0,5	2	0,9	6	0,4	-5
Model 5	1,7	3,4	0,9	2,5	0,8	0,8
Model 6	1,7	3	0,8	4,7	0,9	-2,2
Model 7	0,7	2,3	0,9	12	0,2	-10
Model 8	1,1	2	4,8	6	3,7	-5
Model 9	1,4	3,4	0,7	2,5	0,7	0,8
Model 10	1,6	3	0,7	4,7	0,9	-2,2
Model 11	0,6	2,3	1,1	12	0,5	-10
Model 12	0,3	2	0,7	6	0,4	-5

According to the data we obtained,

- Table 5 In, the differences between the simulation values and the calculation values are high (the sound does not decrease in direct proportion to the distance)
- The 5th point, which is the closest measurement point to Table 3 the vehicle road, should be minimum 53,9 dB(A), maximum 57,8 dB(A) (difference 3,9 dB(A)), the road noise calculated by SoundPLAN should be lower than the difference value (9,55 dB(A) in the range of minimum 66,9 dB (A), maximum 76,45 dB(A)
- Table 6 Although the second measurement point is moderately close to the road, it can reach higher values than the measurement point closest to the road (5th point).

It is caused by the fact that the sound reflects many times between the mutually parallel surfaces, that is, the canyon effect. Based on this information, the measurement results Table 3in show that these models are suitable for examining a group of buildings exposed to the canyon effect.

According to Table 2 and Table 3 indoor noises, sidewalk noises and building outdoor noises were examined. Color legend is used in the tables. Pink-Purple: Indoor noise level, Blue: Residential outdoor noise level, Yellow-Orange: Sidewalk elevation (commercial) outdoor noise level.

Table 6. Building outdoor noise level dB(A), (Dark gray: 1st, Medium Gray: 2nd, Light gray: 3rd measurement point)

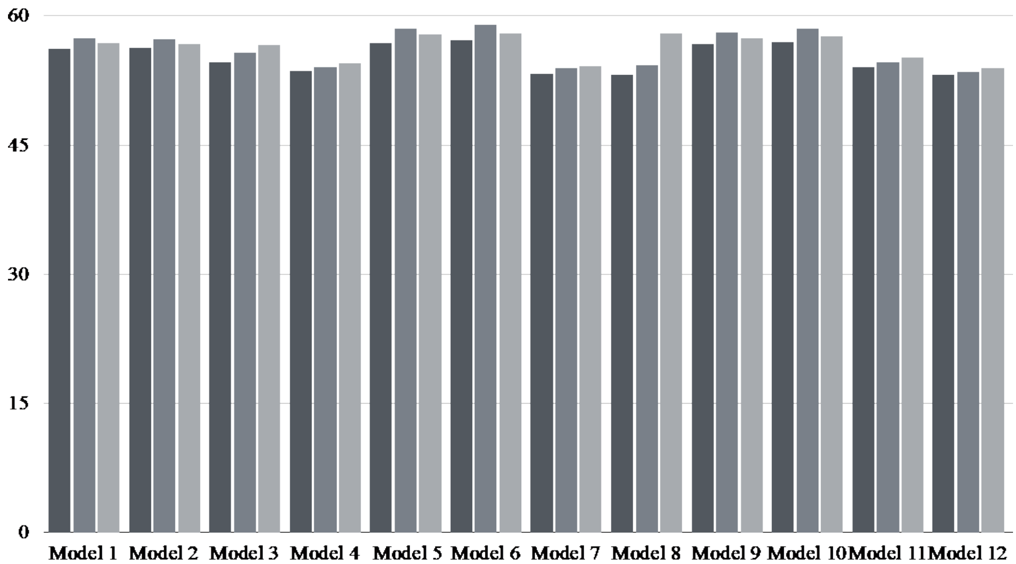


Table 7 and Table 8 the indoor noises of the building were examined in Table 7. It was observed that the commercial indoor noise was lower on the sidewalk side where the natural noise barrier (coniferous bush) was used. The most obvious difference between barrier and non-barrier (right and left) was observed in model 3, model 4, model 7, model 8, model 11 and model 12. The noise level difference between commercial interiors is between 82, 5% (model 4) and 87,3% (Model 7). The difference in these models is more pronounced because the road elevation is lower than or flush with the bush. The difference is clearly read in Table 7. As the road elevation increases from low to high, the noise level in the commercial interior also increases. In other models, no similar effect was observed as the road was positioned at a higher elevation than the bush. The models with the least difference are 1, 5 and 9. In these models, the road is at the same height as the upper level of the bush or 3 meters higher than the road bush. However, a decrease was observed in almost every model due to the presence of the bush.

Table 7. Commercial indoor noise level dB(A), (pink: 12th and purple:14th measurement points)

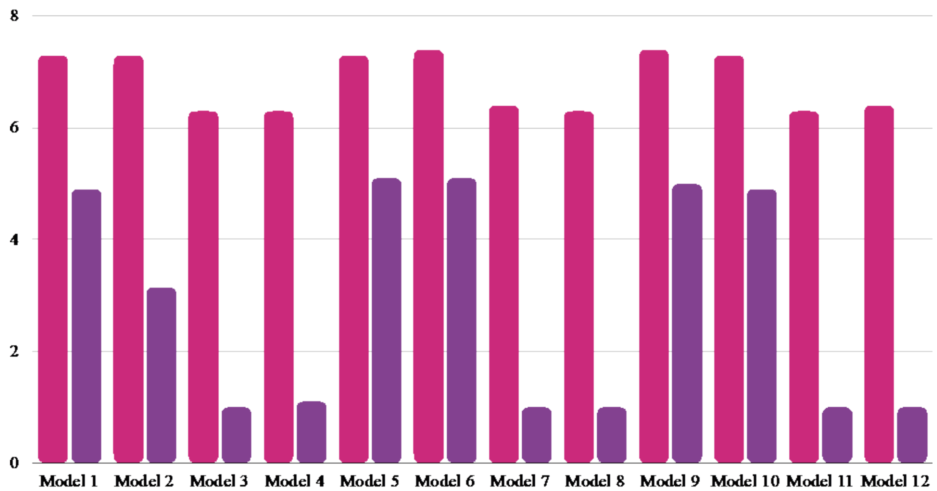


Table 8 The noise difference between the residential interiors in was taken from the 11th and 13th measurement points on the 4th floor. These two measurement points are positioned exactly symmetrically to each other, since the buildings are completely identical to each other, the measurement difference between them is due to the effect of the bush at the pavement level on the sound reflection. The difference is 10,1%, that is, 3,3 dB(A), at most in model 5. However, in some of the models, the sound level was lower in the houses on the opposite side of the bush in some of the building on the bush side. This is due to the fact that the play affects the mutual parallel inter-surface reflections of the sound wave.

Table 1. Residential indoor noise level dB(A), (Pink: 11th and purple:13th measurement points)

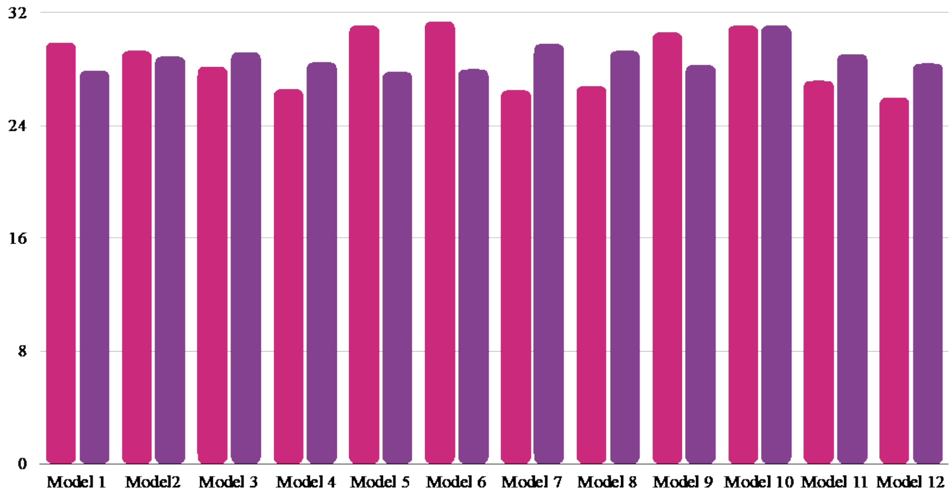


Table 9 The outdoor noise level of the house at the level of the 3rd floor was evaluated in. Measurement points 2 and 9 were used. Both are located one meter away from the facade. The biggest difference between the measurement points is in model 6. 3,4 dB(A) is 5,7%.

Table 2. Residential outdoor noise level at floor level dB(A), (Light Blue: 2nd and dark blue:9th measurement points)

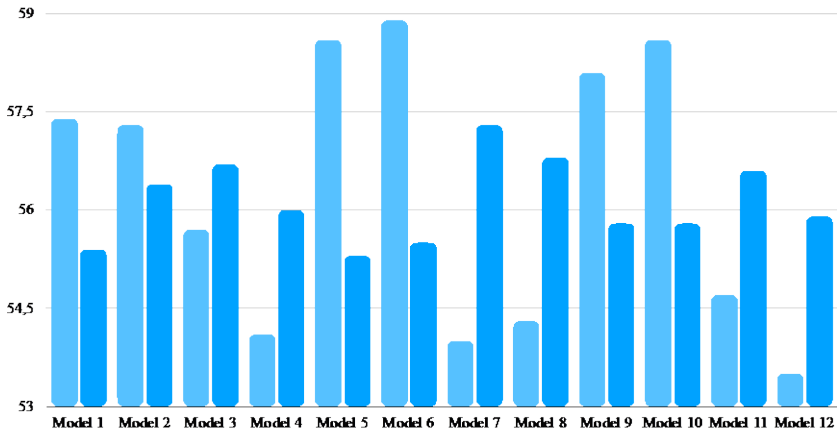


Table 10 The outdoor noise level on the top floor of the building (6th floor, residence) was compared in. The 1st and 10th measurement points were used. The measurement points are located 1 meter away from the facade of the building where they are located. The largest difference is 5% in model 8, with a value of 2,8 dB(A).

Table 3. Residential outdoor noise level at floor level dB(A), (Light Blue: 1st and dark blue:10th measurement points)

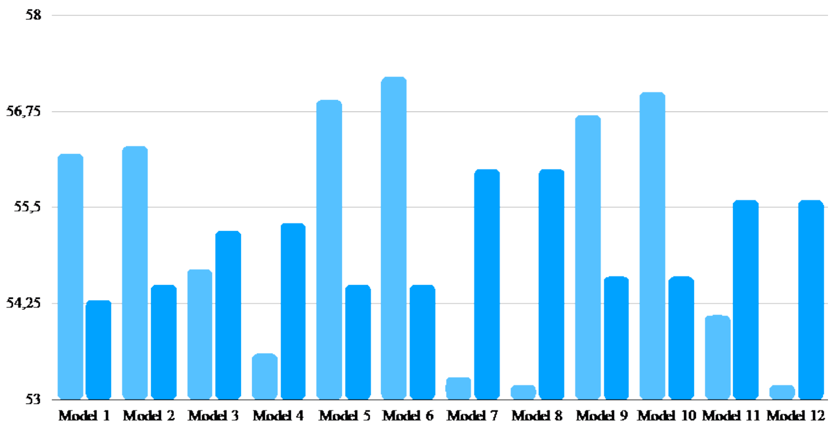
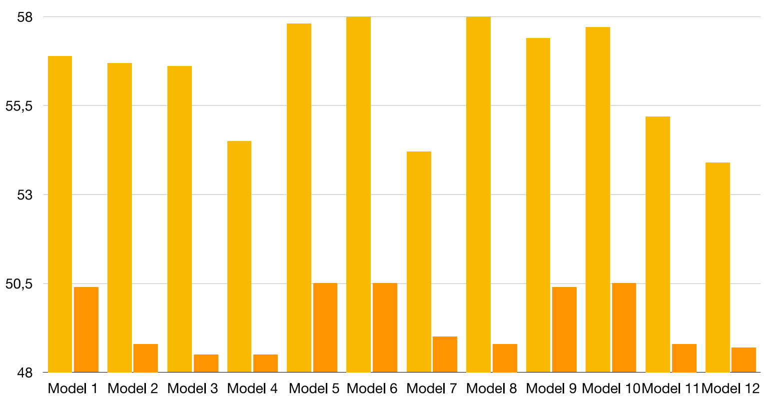


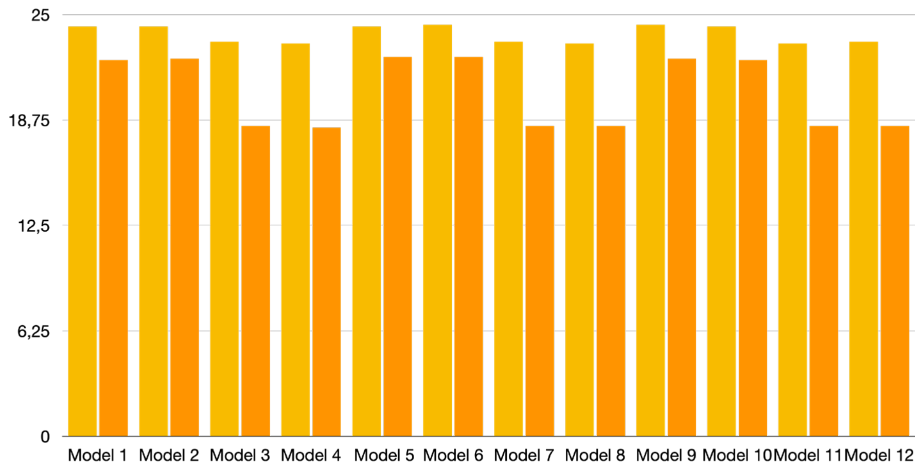
Table 11 In, the outdoor noise level of the pavement elevation was taken from the 5th and 6th measurement points. These points are closest to the vehicle road. While the 6th point is located just behind the bush, there is no obstacle between the 5th point and the road. The difference between them is at most 9,2 dB(A), 15,8% in model 8.

Table 4. Sidewalk outdoor noise level dB(A), (Yellow: 5th and orange: 6th measurement point)



In Table 12, the outdoor noise level of the pavement elevation was taken from the 3rd and 8th measurement points closest to the building (commercial). These measurement points were created in order to evaluate the sounds reflected from the building facade. These points are located 1 meter away from the facade. The maximum difference between them was found to be equal in models 3, 4, 7, 11 and 12, and 5 dB(A) was 21,4%.

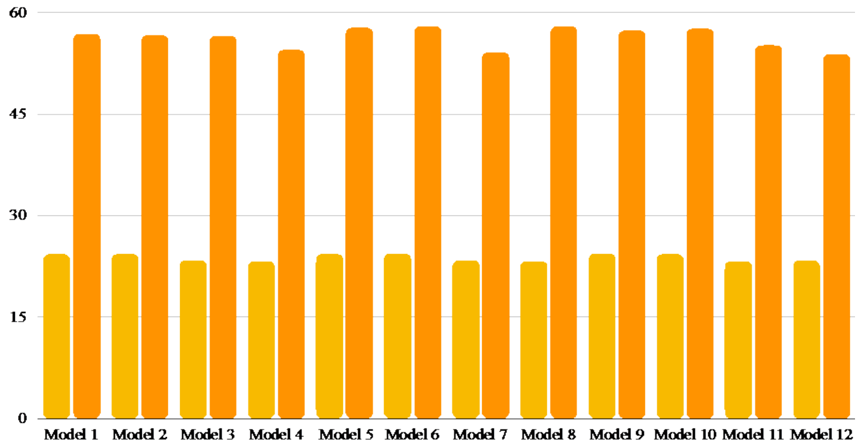
Table 5. Sidewalk outdoor noise level dB(A), (Yellow: 3rd and orange: 8th measurement point)



Unlike other graphs, Table 13 is prepared to compare the measurement points on the same side of the building, not the measurement points in Table 14 reciprocal buildings. The selected measurement points were on the same side of the building and were used to examine the level change of the sound due to the echo. The selected points are the closest points to the road and the closest points to the building at the pavement elevation.

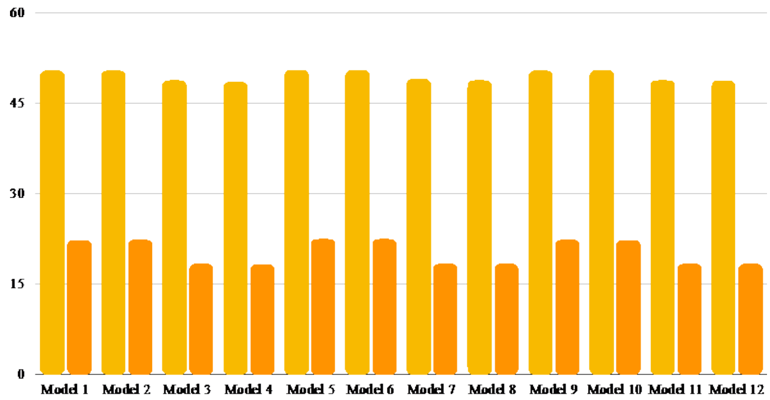
Table 13 In the models, a comparison was made in the building on the left (without bushes). The 3rd point is closest to the building and the 5th point is closest to the vehicle road. The difference between them is at least 30.5 dB(A), 56,5% in model 12. The maximum difference is 33,6 dB(A), 57,9% in model 6.

Table 6. Sidewalk outdoor noise level dB(A), (Yellow: 3rd and orange: 5th measurement point)



In Table 14, a comparison was made in the building on the right (with a bush) in the models. The 6th point is closest to the vehicle road and the 8th point is closest to the building. Point 6 is on the side of the bush close to the building. The difference between them is at least 30,5 dB(A), 56,5% in model 12. The maximum difference is 34,7 dB(A), 59,8% in model 8.

Table 7. Sidewalk outdoor noise level dB(A), (Yellow: 6th and orange: 8th measurement point)



Conclusion

The canyon effect does not work according to the principle that the sound decreases as it moves away from the source. The results of the study summarize this situation:

- Table 6 and Table 7 in the sound levels in models 1, 2, 5, 6, 9, and 10 are higher than the sound levels in other models. This situation is directly proportional to the increase in the sound level as the road height increases. On the other hand, the reason for the relatively lower noise levels in models 4, 8 and 12 can be attributed to the fact that the edges of the vehicle road are closed up to the pavement level.
- Reflections caused by the canyon effect caused the results in Table 9 and Table 10 to be different from Table 6, Table 7 and Table 8. The results in Table 9 and Table 10 show both the effect of the canyon effect on sound reflections and how the environmental noise level creates a change, and that the bush creates an impact not only for the building group in front of it, but also for the entire canyon region.
- Table 12 showed the effect of the bush on the noise level at the road level. The bush served as a natural noise barrier as intended.
- Table 6 and Table 13 consider the 3rd, 4th, 5th measurement results in all models according to the values in and, the effect of reflections from the building protrusions was not observed sufficiently.

Accordingly: Physical environmental conditions should be examined well when designing in a built environment under the influence of a canyon. If necessary, various measures should be taken at the pavement level. It should be noted that road height is a dominant factor.

The latest updated regulations in our country do not allow building overhangs. However, there are buildings with slab overhangs (vertical discontinuities) in the existing building stock. The results of this study provide information about the environmental noise that will be generated and affected by roads or structures that will be built near such structures. It also shows how noise at ground floor height affects the upper floors of buildings. It has caused high levels of noise in both commercial and residential functions. In conclusion: This study revealed with quantitative data that there was a change in the environmental noise level for all areas where there was a canyon effect. It was observed and calculated that the noise decreased less than it should in all combinations at the road building height. It explained one of the factors that architects, urban district designers and engineers should pay attention to in terms of environmental noise. Therefore, the current situation and future scenarios should be considered and well-planned when planning the settlement. If necessary, support from experts should be sought.

Acknowledgements and Information Note

We would like to thank for their support and contributions dear members of TÜBİTAK Marmara Research Center, Environment, Cleaner Production, Climate Change and Sustainability, Air Quality and Environmental Noise Technologies Research Group, Senior Principal Investigator Dr. Deniz SARI and scholarship holder Rümeysa ÖNEN.

Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the article. There is no conflict of interest.

References

Allegrini, J. (2018). A wind tunnel study on three-dimensional buoyant flows in street canyons with different roof shapes and building lengths. Building and Environment 143:71–88. doi: 10.1016/j.buildenv.2018.06.056.

Alwi, A., Mohd F. M., Naoki I., and Razak, A. A. (2023). Effect of protruding eave on the turbulence buildings over two-dimensional Semi-Open Street Canyon. Building and Environment 228:109921. doi: 10.1016/j.buildenv.2022.109921.

Arpacıoğlu, Ü. (2006). Geçmişten Günümüze Kerpiç Malzeme Üretim Teknikleri ve Güncel Kullanım Olanakları. Pp. 15–17 in Ulusal Yapı Malzemesi Kongresi.

Arpacıoğlu, Ü. (2012). Mekânsal kalite ve konfor ıçin önemli bir faktör: Günışığı. Mimarlık 368.

Babisch, W. (2008). Road traffic noise and cardiovascular risk. Noise and Health 10(38):27. doi: 10.4103/1463-1741.39005.

Babisch, W. (2014). Updated Exposure-response relationship between road traffic noise and coronary heart diseases: A meta-analysis. Noise and Health 16(68):1. doi: 10.4103/1463-1741.127847.

Babisch, W., Bernd, B., Marianne, S., Norbert, K. & Ising, H. (2005). Traffic noise and risk of myocardial ınfarction. Epidemiology 16(1):33–40. doi: 10.1097/01.ede.0000147104.84424.24.

Badas, M. G., Simone, F., Michela, G. & Querzoli, G. (2017). On the effect of gable roof on natural ventilation in two-dimensional urban canyons." Journal of Wind Engineering and Industrial Aerodynamics 162:24–34. doi: 10.1016/j.jweia.2017.01.006.

Balogun, A. A., Tomlin, A. S., Wood, C. R., Barlow, J. F., Belcher, S. E., Smalley, R. J., Lingard, J. J. N., Arnold, S. J., Dobre, A., Robins, A. G., Martin, D. & Shallcross, D. E. (2010). In-street wind direction variability in the vicinity of a busy ıntersection in Central London." Boundary-Layer Meteorology 136(3):489–513. doi: 10.1007/s10546-010-9515-y.

Battista, G., Vollaro, E. L., Ocłoń, P. & Vallati, A., (2021). "Effect of mutual radiative exchange between the surfaces of a street canyon on the building thermal energy demand." Energy 226:120346. doi: 10.1016/j.energy.2021.120346.

Buccolieri, R., Salizzoni, P., Soulhac, L., Garbero, V. & Di Sabatino, S. (2015). The breathability of compact cities. Urban Climate 13:73–93. doi: 10.1016/j.uclim.2015.06.002.

Can, A., Fortin, N. & Picaut. J. (2015). Accounting for the effect of diffuse reflections and fittings within street canyons, on the sound propagation predicted by ray tracing codes. Applied Acoustics 96:83–93. doi: 10.1016/j.apacoust.2015.03.013.

Carlo, O. S., Fellini, S., Palusci, O., Marro, M., Salizzoni, P. & Buccolieri, R. (2024). Influence of obstacles on urban canyon ventilation and air pollutant concentration: An experimental assessment. Building and Environment 250:111143. doi: 10.1016/j.buildenv.2023.111143.

Carpentieri, M., Salizzoni, P., Robins, A. & Soulhac, L. (2012). Evaluation of a neighbourhood scale, street network dispersion model through comparison with wind tunnel data. Environmental Modelling & Software 37:110–24. doi: 10.1016/j.envsoft.2012.03.009.

Coceal, O., Thomas, T. G., Castro, I. P. & Belcher, S. E. (2006). Mean flow and turbulence statistics over groups of urban-like cubical obstacles.” Boundary-Layer Meteorology 121(3):491–519. doi: 10.1007/s10546-006-9076-2.

Colorlib, & Jekyll. (2021). Sound Absorption Coefficients. Retrieved February 6, 2024 (http://heyizhou.net/notes/absorption-coefficients).

Di Bernardino, A., Monti, P., Leuzzi, G. & Querzoli, G. (2018). Pollutant fluxes in two-dimensional street canyons. Urban Climate 24:80–93. doi: 10.1016/j.uclim.2018.02.002.

Du, H., Savory, E. &Perret, L. (2023). Effect of morphology and an upstream tall building on the mean turbulence statistics of a street canyon flow. Building and Environment 241:110428. doi: 10.1016/j.buildenv.2023.110428.

Egan, M. D. (2007). Architectural Acoustics. New York.

Eliasson, I., Offerle, B., Grimmond, C. S. B. & Lindqvist, S. (2006). Wind Fields and Turbulence Statistics in an Urban Street Canyon. Atmospheric Environment 40(1):1–16. doi: 10.1016/j.atmosenv.2005.03.031.

Farrell, W. J., Cavellin, L. D., Weichenthal, S., Goldberg, M. & Hatzopoulou, M. (2015). Capturing the urban canyon effect on particle number concentrations across a large road network using spatial analysis tools. Building and Environment 92:328–34. doi: 10.1016/j.buildenv.2015.05.004.

Fatehi, H. & Nilsson, E. J. K. (2022). Effect of buoyancy on dispersion of reactive pollutants in urban canyons. Atmospheric Pollution Research 13(8):101502. doi: 10.1016/j.apr.2022.101502.

Fellini, S., Marro, M., Del Ponte, A. V., Barulli, M., Soulhac, L., Ridolfi, L. & Salizzoni, P. (2022). High resolution wind-tunnel ınvestigation about the effect of street trees on pollutant concentration and street canyon ventilation. Building and Environment 226:109763. doi: 10.1016/j.buildenv.2022.109763.

Gold, J. R. (1998). Creating the charter of Athens: CIAM and the functional city, 1933-43. Town Planning Review 69(3):225. doi: 10.3828/tpr.69.3.2357285302gl032l.

Goulart, E. V., Reis, N. C., Lavor, Ian. V. F., Castro, P., Santos, J. M. & Xie., Z. T. (2019). Local and non-local effects of building arrangements on pollutant fluxes within the urban canopy. Building and Environment 147:23–34. doi: 10.1016/j.buildenv.2018.09.023.

Gu, Z., Zhang, Y. Cheng, Y. & Lee, S. (2011). Effect of uneven building layout on air flow and pollutant dispersion in non-uniform street canyons. Building and Environment 46(12):2657–65. doi: 10.1016/j.buildenv.2011.06.028.

Guillaume, G., Gauvreau, B. & P. L’Hermite. (2015). Numerical study of the ımpact of vegetation coverings on sound levels and time decays in a canyon street model. Science of The Total Environment 502:22–30. doi: 10.1016/j.scitotenv.2014.08.111.

Kanda, M. (2006). Large-Eddy Simulations on the effects of surface geometry of building arrays on turbulent organized buildings. Boundary-Layer Meteorology 118(1):151–68. doi: 10.1007/s10546-005-5294-2.

Kang, J. (2000). Sound propagation in street canyons: comparison between Diffusely and Geometrically Reflecting Boundaries. The Journal of the Acoustical Society of America 107(3):1394–1404. doi: 10.1121/1.428580.

Kang, J. (2005). Numerical modeling of the sound fields in urban squares. The Journal of the Acoustical Society of America 117(6):3695–3706. doi: 10.1121/1.1904483.

Karra, S., Malki-Epshtein, L. & Neophytou, M. K. A. (2017). Air flow and pollution in a real, heterogeneous urban street canyon: A field and laboratory study. Atmospheric Environment 165:370–84. doi: 10.1016/j.atmosenv.2017.06.035.

Kim, J., Baik, J., Han, B., Lee, J., Jin, H., Park, K., Yang, H. & Park, S. (2022). Tall-building effects on pedestrian-level flow and pollutant dispersion: large-eddy simulations. Atmospheric Pollution Research 13(8):101500. doi: 10.1016/j.apr.2022.101500.

Kim, J., Baik, J., Park, S. & Han, B. S. (2023). Impacts of building-height variability on turbulent coherent buildings and pollutant dispersion: Large-Eddy simulations. Atmospheric Pollution Research 14(5):101736. doi: 10.1016/j.apr.2023.101736.

Kluková, Z., Nosek, Š., Fuka, V., Jaňour, Z., Chaloupecká, H. & Ďoubalová, J. (2021). The combining effect of the roof shape, roof-height non-uniformity and source position on the pollutant transport between a street canyon and 3D urban array. Journal of Wind Engineering and Industrial Aerodynamics 208:104468. doi: 10.1016/j.jweia.2020.104468.

Knabben, R. M., Trichês, G., Gerges, S. N. Y. & Vergara, E. F. (2016). Evaluation of sound absorption capacity of asphalt mixtures." Applied Acoustics 114:266–74. doi: http://dx.doi.org/10.1016/j.apacoust.2016.08.008.

Lee, P. J., & Jeon, J. Y. (2011). Evaluation of speech transmission in open public spaces affected by combined noises. The Journal of the Acoustical Society of America 130(1):219–27. doi: 10.1121/1.3598455.

Lee, P. J., & Kang, J. (2015). Effect of height-to-width ratio on the sound propagation in urban streets. Acta Acustica United with Acustica 101(1):73–87. doi: 10.3813/AAA.918806.

Li, Z., Xu, J., Ming, T., Peng, C., Huang, J. & Gong, T. (2017). Numerical simulation on the effect of vehicle movement on pollutant dispersion in urban street. Procedia Engineering 205:2303–10. doi: 10.1016/j.proeng.2017.10.104.

Li, M., Renterghem, T. V., Kang, J., Verheyen, K. & Botteldooren, D. (2020). Sound absorption by tree bark. Applied Acoustics 165. doi: https://doi.org/10.1016/j.apacoust.2020.107328.

Li, Z., Shi, T., Wu, Y., Zhang, H., Juan, Y., Ming, T. & Zhou, N. (2020). Effect of traffic tidal flow on pollutant dispersion in various street canyons and corresponding mitigation strategies. Energy and Built Environment 1(3):242–53. doi: 10.1016/j.enbenv.2020.02.002.

Lo, K. W., & Ngan, K. (2015). Characterising the pollutant ventilation characteristics of street canyons using the tracer age and age spectrum. Atmospheric Environment 122:611–21. doi: 10.1016/j.atmosenv.2015.10.023.

Lugten, M., Wuite, G., Peng, Z. & Tenpierik, M. (2024). Assessing the ınfluence of street canyon shape on aircraft noise: results from measurements in courtyards near Amsterdam Schiphol Airport." Building and Environment 255:111400. doi: 10.1016/j.buildenv.2024.111400.

Marini, S., Buonanno, G., Stabile, L. & Avino, P. (2015). A benchmark for numerical scheme validation of airborne particle exposure in street canyons. Environmental Science and Pollution Research 22(3):2051–63. doi: 10.1007/s11356-014-3491-6.

McMullan, W. A. &Angelino, M. (2022). The effect of tree planting on traffic pollutant dispersion in an urban street canyon using large eddy simulation with a recycling and rescaling ınflow generation method. Journal of Wind Engineering and Industrial Aerodynamics 221:104877. doi: 10.1016/j.jweia.2021.104877.

Michioka, T., Takimoto, H. and Sato, A. (2014). "Large-Eddy Simulation of Pollutant Removal from a Three-Dimensional Street Canyon." Boundary-Layer Meteorology 150(2):259–75. doi: 10.1007/s10546-013-9870-6.

Mumford, E. (1992). CIAM urbanism after the Athens charter. Planning Perspectives 7(4):391–417. doi: 10.1080/02665439208725757.

Murena, F., Di Benedetto, A., D'Onofrio, M. & Vitiello, G. (2011). Mass transfer velocity and momentum vertical exchange in simulated deep street canyons. Boundary-Layer Meteorology 140(1):125–42. doi: 10.1007/s10546-011-9602-8.

Murena, F. & Mele, B. (2016). Effect of balconies on air quality in deep street canyons." Atmospheric Pollution Research 7(6):1004–12. doi: 10.1016/j.apr.2016.06.005.

Murena, F. & Favale, G. (2007). Continuous monitoring of carbon monoxide in a deep street canyon." Atmospheric Environment 41(12):2620–29. doi: 10.1016/j.atmosenv.2006.11.017.

Nasrollahi, N., Namazi, Y. & Taleghani, M. (2021). The effect of urban shading and canyon geometry on outdoor thermal comfort in hot climates: A case study of Ahvaz, Iran." Sustainable Cities and Society 65:102638. doi: 10.1016/j.scs.2020.102638.

Nosek, Š., Fuka, V., Kukačka, L., Kluková, Z. & Jaňour, Z. (2018). Street-canyon pollution with respect to urban-array complexity: The role of lateral and mean pollution fluxes." Building and Environment 138:221–34. doi: 10.1016/j.buildenv.2018.04.036.

Nosek, Š., Kluková, Z., Jakubcová, M. & Jaňour, Z. (2022). the effect of courtyard buildings on the ventilation of street canyons: A wind-tunnel study." Journal of Wind Engineering and Industrial Aerodynamics 220:104885. doi: 10.1016/j.jweia.2021.104885.

Pouya, S. (2022). İdeal ses peyzajın planlaması ve tasarımı." Mimarlık Bilimleri ve Uygulamaları Dergisi (MBUD) 7(2):919–34. doi: 10.30785/mbud.1166229.

Sayın, T. (2022). A research on facade configuration through transparency in architectural design. Mimarlık Bilimleri ve Uygulamaları Dergisi (MBUD) 119–31. doi: 10.30785/mbud.1030583.

Schiff, M., Maarten H. & Forssén, J. (2010). Excess attenuation for sound propagation over an urban canyon. Applied Acoustics 71(6):510–17. doi: 10.1016/j.apacoust.2010.01.005.

Shen, J., Gao, Z. , Ding, W. & Ying Yu. (2017). An ınvestigation on the effect of street morphology to ambient air quality using six real-world cases. Atmospheric Environment 164:85–101. doi: 10.1016/j.atmosenv.2017.05.047.

Šprah, N., Potočnik, J. & Košir, M. (2024). The ınfluence of façade colour, glazing area and geometric configuration of urban canyon on the spectral characteristics of daylight. Building and Environment 251:111214. doi: 10.1016/j.buildenv.2024.111214.

Şimşek, O. & Özçevik Bilen, A. (2021). Yapı cephe özellikleri ve yol genişliğinin çevresel gürültü düzeyine etkisinin kentsel yol kesitleri üzerinden incelenmesi. Journal of the Faculty of Engineering and Architecture of Gazi University 37:3. doi: 10.17341/gazimmfd.919498

Thaker, P. & Gokhale, S. (2016). The ımpact of traffic-flow patterns on air quality in urban street canyons. Environmental Pollution 208:161–69. doi: 10.1016/j.envpol.2015.09.004.

Toy, S. & Esringü, A. (2021). Erzurum'da kent kanyonlarının gelişimi ve peyzaj mimarlığı açısından alınabilecek tedbirler. ATA Planlama ve Tasarım Dergisi. doi: 10.54864/ataplanlamavetasarim.1038118.

Ünal Çilek, M. (2022). The ınfluence of urban canyon geometry on land surface temperature: Kurtuluş Neighborhood." Turkish Journal of Remote Sensing and GIS. doi: 10.48123/rsgis.1095619.

Van Renterghem, T. & Botteldooren, D. (2008). Numerical evaluation of sound propagating over green roofs. Journal of Sound and Vibration 317(3–5):781–99. doi: 10.1016/j.jsv.2008.03.025.

Van Renterghem, T. & Botteldooren, D. (2010). The ımportance of roof shape for road traffic noise shielding in the urban environment. Journal of Sound and Vibration 329(9):1422–34. doi: 10.1016/j.jsv.2009.11.011.

Vardoulakis, S., Gonzalez-Flesca, N. & Fisher, B. E. A. (2002). Assessment of traffic-related air pollution in two street canyons in Paris: Implications for exposure studies. Atmospheric Environment 36(6):1025–39. doi: 10.1016/S1352-2310(01)00288-6.

Vardoulakis, S., Bernard, Fisher, E. A., Koulis, P. & Gonzalez-Flesca, G. (2003). Modelling air quality in street canyons: A review. Atmospheric Environment 37(2):155–82. doi: 10.1016/S1352-2310(02)00857-9.

WHO, C. (2018). Ambient (Outdoor) Air Pollution. p. 15–25 in air quality guidelines% 22 estimate, related deaths by around.

Wikipedia. (2024). Canyon.

Yagi, A., Atsushi, I., Manabu, K., Chusei, F, & Fujiyoshi, Y. (2017). Nature of streaky buildings observed with a doppler lidar. Boundary-Layer Meteorology 163(1):19–40. doi: 10.1007/s10546-016-0213-2.

Yılmaz, N. G., Pyoung-Jik L., Muhammad I. & Jeong, J. (2023). Role of sounds in perception of enclosure in urban street canyons. Sustainable Cities and Society 90:104394. doi: 10.1016/j.scs.2023.104394.

Yılmaz Bakır, N. (2020). Replacing 'mixed use' with 'all mixed up' concepts; a critical review of Turkey Metropolitan City Centers. Land Use Policy 97:104905. doi: 10.1016/j.landusepol.2020.104905.

Yuan, C., Edward, N., & Norford, L. K. (2014). Improving air quality in high-density cities by understanding the relationship between air pollutant dispersion and urban morphologies. Building and Environment 71:245–58. doi: 10.1016/j.buildenv.2013.10.008.

Yüğrük Akdağ, N. (2003). Kent planlamada gürültü haritalarının önemi: Barbaros Bulvarı çevresi örneği. Mimarlık Dergisi.

Yüğrük Akdağ, N. (2024). Gürültü Denetimi 2 - Gürültünün Açık Havada Yayılmasında Önem Taşıyan Etkenler. İstanbul.

Zorer, H., and Öztürk, Y. (2021). "Masiro Kanyonu'nun (Pervari) Flüvyo-Karstik Gelişimi ve Yakın Çevresinin Jeomorfik Özellikleri." Journal of Geography 0(42). doi: 10.26650/JGEOG2021-825470.