Achieving Acoustic Comfort in Medical Health Care Units: Dr. Plaza Capital Medical Health Care Unit: A Case Study

Ahmed M. SELIM *

Department of Architecture, Modern Academy for Engineering and Technology, Cairo, Egypt, ahmed.selim@eng.modern-academy.edu.eg

Doha M. SAEED

Department of Architecture, Faculty of Engineering and Technology, Badr University in Cairo- BUC, Cairo, Egypt, Doha.Mohamed@buc.edu.eg

Nerveen T. SOLIMAN

Department of Architecture, Modern Academy for Engineering and Technology, Cairo, Egypt, nervien.tarik@eng.modern-academy.edu.eg

Heba M. GABER

Department of Architecture, Modern Academy for Engineering and Technology, Cairo, Egypt, heba.m.gaber@eng.modern-academy.edu.eg

* Author to whom correspondence should be addressed

Abstract: - Noise can be emanated from different sources. Road traffic noise (RTN) is one of the noise sources that has an adverse impact on human beings, especially the patients in Medical Health Care Units (MHCUs). Also, it bothers the hospital staff and raises the medical error rates. In the present work, the building envelope (facades) of Dr. Plaza Capital Medical Health Care (PMHCU) at Badr University has been studied. The sound pressure on the facades at different heights was estimated by using MASdBmap as a simulation tool. Based on the results obtained and the acceptance range of sound at hospitals, the sound transmission class (STC) was calculated. Then, three scenarios of curtain walls were examined based on the typical module parameters. The reverberation time (RT_{60}) at the receiving room was calculated for each scenario using Sabine's equations. (D2m,nT,w) results were compared with the required (STC) for each façade. The analysis showed that the third scenario (CS3) using a curtain wall section with double glazing, 4–2 mm glass, and a 30 mm air gap is the optimum solution.

Keywords: - Road traffic noise, Health care units, Curtain wall, MASdBmap.

1. INTRODUCTION

The World Health Organization (WHO) and the Environmental Protection Agency (EPA) recognize noise pollution's bad and harmful effects on health. It can badly affect patients' well-being, and staff productivity, and raise the medical error rates [1]. Understandably, environmental acoustic noise is considered a high risk for today's population's health where it causes auditory and non-auditory health effects [2]. Therefore, high noise levels in Medical Health Care Units (MHCUs) have become a vital challenge for the medical society [3].

In this respect, health facility projects, especially Medical Health Care Units (MHCUs), are in great need of affording the right level of acoustical comfort [4]. (MHCUs) include a variety of different spaces with different requirements and levels of sensitivity to noise levels [5]. Similarly, the medical functionality of (MHCUs) is essential in the healing process in patients' wards. Thus, the acoustical environment in the (MHCUs) needs to be investigated to achieve the best level of patients' acoustical comfort [6].

The noise problem in (MHCUs) is mostly connected to noise generated by many resources, especially Road Traffic Noise (RTN) [7]. In fact, (RTN) is considered a critical threat to human health. Since a global hazard, rapid urbanization and exponential traffic growth have aggravated the problem [8]. Indeed, each country has different descriptors and related limit values for the acoustic requirements of (MHCUs).

The World Health Organization (WHO) recommended that during the night it is advisable to have an indoor equivalent sound pressure level (LA_{eq}) not greater than 35 dB(A) (average over 8h), and a maximum sound pressure level (LA_{max}) not greater than 45 dB(A) for non-continuous noise [9].

From this perspective, this study was intended to discuss the acoustic requirements of (MHCUs) and to introduce acoustic treatments for its facades to reduce the negative impact of (RTN) which is considered the essential reason that affects the acoustical comfort of the patients, and staff. Additionally, the study adopts a case study of Dr. Plaza Capital Medical Health Care (DPMHCU), located at Badr University, and located nearby major traffic conjunction to evaluate the impact of (RTN). Where an acoustic simulation was performed using MASdBmap as a simulation tool. The Road Traffic Noise (RTN) was estimated, and therefore, the pressure noise was recorded. Based on the simulation results, three scenarios of curtain wall system as a façade treatment were proposed to achieve acoustic comfort in the building.

2. LITERATURE REVIEW

Noise pollution is the noise beyond the permissible limits [10]. It has emerged as one of the major environmental hazards to public health. Noise can be emitted from different sources such as: factories, aircraft, railways, and road traffic [11]. (RTN) pollution is considered one of the most disturbing factors within hospital environments. Therefore, there is a growing interest in the design and manufacture of effective noise treatments for the (MHCUs) premises [12]. The World Health Organization (WHO) has specific requirements for achieving acoustic comfort for this type of building.

2.1. Acoustic comfort in (MHCUs)

Noise pollution in hospitals is recognized as a serious health hazard [13]. According to the World Health Organization (WHO), noise disturbance within (MHCUs) wards is directly related to the well-being and psychophysical response of patients, affecting the quality of rest, response, and the healing process [14].

Likewise, noise pollution, especially (RTN) can cause annoyance and interfere with sleep, communication, concentration, cardiovascular health, hypertension, and mental health [15]. Additionally, achieving acoustic comfort is an important influence factor in the stress recovery of patients [16]. In this sense, the required sound insulation depends on the outdoor noise and the maximum accepted indoor noise level in hospitals according to the country's regulations and acoustic code recommendations.

The outdoor noise levels are measured based on the local traffic road noise (RTN), and therefore, the limit values may be varied depending on the location and the site conditions [17]. Likewise, many organizations recommended sound pressure levels, whether surrounding the hospitals or inside the building as shown in (Table 1**)**. Despite this, many previous studies have mentioned that the sound pressure level values in hospitals exceeded the (WHO) recommendation with maximum peaks reaching 116 dB(A) [18].

2.2. Acoustic treatments for the building envelope (facades)

Many studies have highlighted, that the building envelope is regarded as the most fundamental main path for outdoor-indoor noise in buildings [19-20]. In the same context, the physical properties of the facades and windows should be defined based on the building function to achieve the occupants' requirements [21]. Recently, a structured glazed facade (curtain wall) was one of the common building envelope types used in public buildings (commercial, administrative, health care) to attain thermal and acoustic insulation.

Correspondingly, curtain walls are considered the weakest element in the building envelope from the point of sound insulation [22].

Table 1. Acoustic recommendations for hospitals.

Organization	Surrounding the hospital		Inside building	
	7am: 10 pm	10 pm: 7 am	7am: 10 pm	10 pm: 7 am
The World Health Organization (WHO)	-		35	30
United States Environmental Protection Agency (USEPA)	55		45	35
US Environmental Protection Agency (EPA)	55		45	
Health Technical Memorandum (HTM)	-		40	35
The Egyptian code for acoustics	50	40	40	
American Institute of Architects (AIA)	55		30	
International Health Facility Guidelines (IHFG)	55		45	
The LEED credit for Acoustic Performance	-		35	
International Organization for Standardization (ISO)	-		35	

In this regard, the scrutinized literature indicated that many researchers investigated acoustic solutions and recommendations for this type of building envelope. For instance, Caniato M. [23] analyzed the noise insulation for curtain walls by using a combined simulation approach and laboratory tests. The result underlined the significant influence of the mullion components on the final acoustic performance and noise control of the curtain wall. Also, Bliudzius R et al. [24] investigated the sound performance of the triple insulating glass (IGU) with an inner safety laminated glass sheet. Their results indicated that the highest sound insulation was occurred by increasing the gas cavity and the thickness of the external glass layer.

Additionally, Secchi Set al. [25] discussed the sound transmission between rooms with curtain wall facades. The study concluded that the good design of mullions of the curtain wall can reduce the structural and airborne sound transaction by optimizing the spatial distribution of the inner room partitions in correspondence with the concrete pillars and avoiding the connection with the façade mullions.

2.3 CASE STUDY: location description and characteristic

Dr. Plaza Capital Medical Health Care Project (DPMHC) at Badr University. (DPMHC) consists of 5 floors with total net area 63329.4 m2, building area 36051.4 m2, and parking area 27278 m2, as illustrated in (Table 2). For its location, the capital Med site is on the north-east side of the junction between Cairo-Suez Road. Cairo-Suez Road connects the site to the north towards Badr city and the south to the capital and connects the site to the west towards Cairo and the east towards the Red Sea. The project is located about 10 min away from Badr City public bus transport station. The site is located near a major traffic conjunction, (Figure 1) illustrates the site location, (Figure 2) illustrates the building location and the future expansion of the university.

Table 2. Floors functions and area of (DPMHCP)

Number of floors	Function	Net area (m2)
Ground floor plan	Reception, clinics, emergency	3956.8
Level 1 floor plan	Radiology and Medical Analysis	4001.8
Level 2floor plan	Patients' rooms	4001.8
Level 3 floor plan	Patients' rooms	4001.8
Level 4 floor plan	Patients' rooms	4001.8
Level 5 floor plan	Surgery rooms, intensive care unit	4001.8
Roof 1 floor plan	Mechanical equipment	374.8
Total	**24340.6**	

3. METHOD

The main source of noise in hospitals comes from outside [26]. As a result of the sensitivity of (DPMHC) as a medical Centre, the building envelope should be assessed in the early design process, where it plays a key role in improving the acoustic comfort conditions. In this respect, and according to the client's request to design the building envelope as a structured glazed facade (curtain wall) the study was divided into three sections as illustrated in (Figure 3).

Figure 1. Project location for (DPMHCP)

Figure 2. General layout and prospective for (DPMHC) and the future expansion of the university

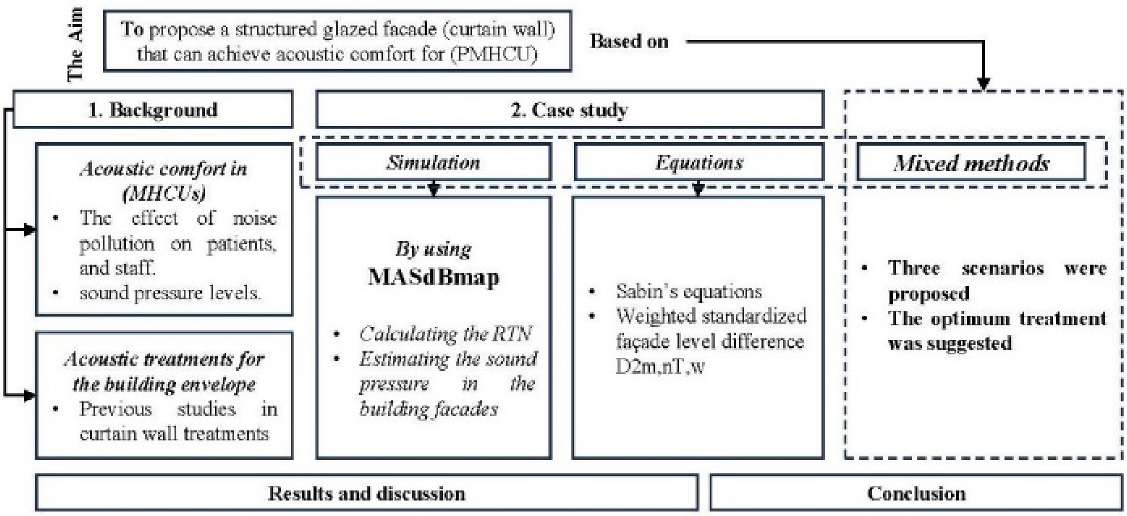


Figure 3. The reserch methodolgy.

a. The first: is based on the previous studies. The study investigated the importance of achieving Acoustic comfort in (MHCUs), and the negative effect of noise especially external noise on the patients and the staff's performance. Also, the specialist organizations' acoustic standards and recommendations for (MHCUs) were mentioned and summarized. Additionally, the acoustic treatments for the building envelope were discussed with a concentration on the curtain walls types.

b. The second: by using MASdBmap Version 0.5 developed by MAS Environmental Ltd [27] as a simulation tool, and based on ISO 9613 calculations, the *site noise mapping* was conducted through *three steps* as follows:

Step 1: Calculating the noise sources by determining the expected worst-case scenario. Where the case study (the simulation scenario) was modeled with related heights, continuous cars (noise sources) were added along all main roads (line 1 to line 6) as shown in (Figure 4), and no any adjacent buildings were considered. It is noteworthy, that the traffic loads of the main roads were compared depending on Google Earth Maps, therefore the highest scenario was chosen, and then the sound power level for traffic noise sources was estimated by MASdBmap as illustrated in (Table 3).

Step 2: Traffic noise source was taken in this simulation 98.5 dB(A) to be a total sound power level and 94.4 dB(A) for audiences. Furthermore, this source was entered as a linear continuous line of cars along all roads 1m above the ground as a multi-noise source as shown in (Table 4).

Step 3: Sound receivers were positioned on different heights at each facade of the building at 1m, 5m, 10m, 15m, 20, and 25m. The simulation was carried out and the noise pressure in the sides of the building facades was recorded by the receivers at the different heights as illustrated in (Figure 5), and the result below in the next section.

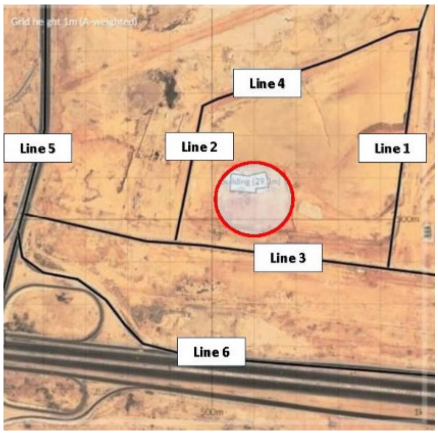


Figure 4. The location of the sound sources (line 1 to line 6)

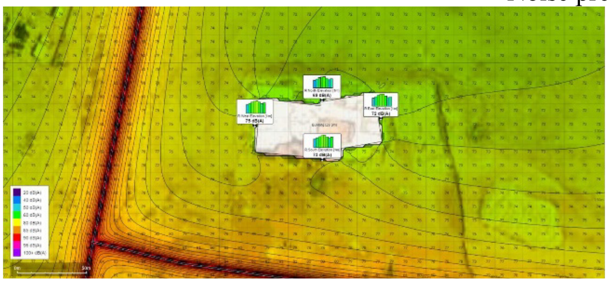
Table 3. Sound power level for traffic noise source

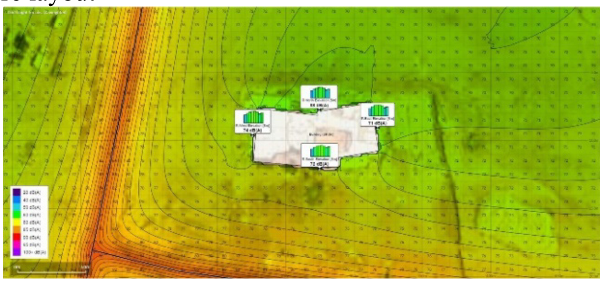
Frequency	63	125	250	500	1K	2K	4K	8K	Hz
Level	92	90	91	90.5	90	84	76	89	dB /m
Total	98.5								
A-weighted level	65.8	73.9	82.4	87.3	90	85.2	77	87.9	dB(A) /m
Total	94.4								

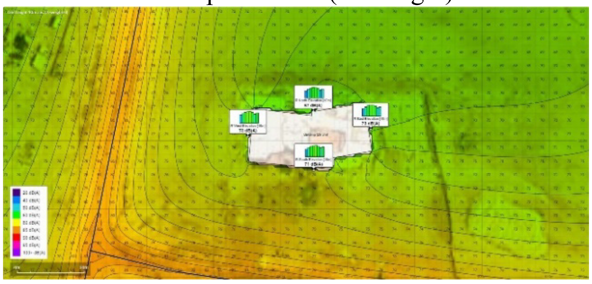
Table 4. Multi- noise sources and its sound power level

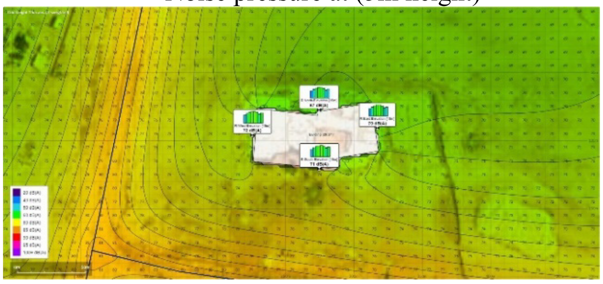
Source Name	Height (m)	Overall Level (dB)	31.5Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Line-1 To 6	1	98.5	92	90	91	90.5	90	84	76	89

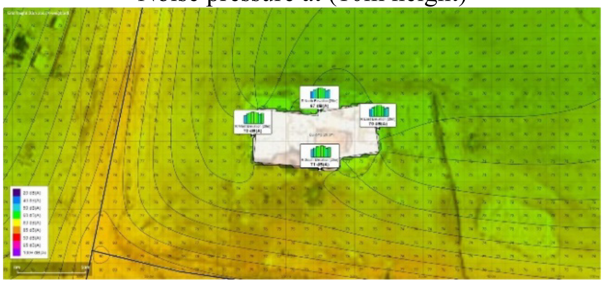
Noise pressure layout


Noise pressure at (1m height)


Noise pressure at (5m height)


Noise pressure at (10m height)


Noise pressure at (15m height)


Noise pressure at (20m height)

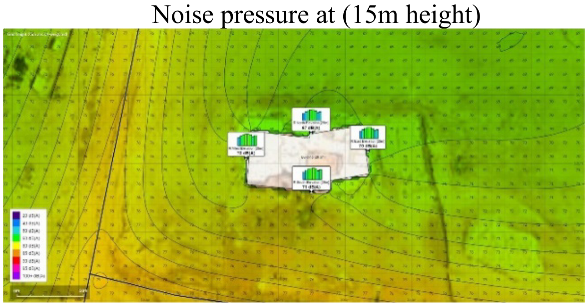

Noise pressure at (25m height)

Figure 5. Noise pressure levels in the sides of the building facades

c. The third: is based on the simulation results for each façade, and the project owner request to provide suitable curtain wall sections for the building facades. Therefore, three scenarios were proposed as;

- Scenario 1(SC1), curtain wall section with Single panel of glass 3mm,
- Scenario 2(SC2), curtain wall section with Single panel of glass 6mm,
- Scenario 3(SC3), curtain wall section with double glazing, 4–2mm glass, and 30 mm air gap.

Regarding, the acceptance range of sound at hospitals 35 dB at night and 40 dB at morning, the Sound Transmission Class (STC) was estimated for each facade as illustrated in (Table 5) and the result below in the next section. Then, the three scenarios were examined through the following:

- A patient room with size (3.5m.(w)* 5m.(l)* 4.5m.(h)) was imposed as indoor function behind the curtain wall section as illustrated in (Figure 6). The finishing materials for the room were described as; (1) vinyl tiles for flooring, (2) mineral wool tiles with 180 mm airspaces at the ceiling, (3) glazed painting (acrylic base) on masonry wall, (4) Acoustic door, steel frame, double seals, absorbent in airspace, Double sheet steel skin (1.50*2.20m), (5) window size 3.50 (w) *3.50 (h), considering curtain facades divided into separated panels as shown in (Figure 6).

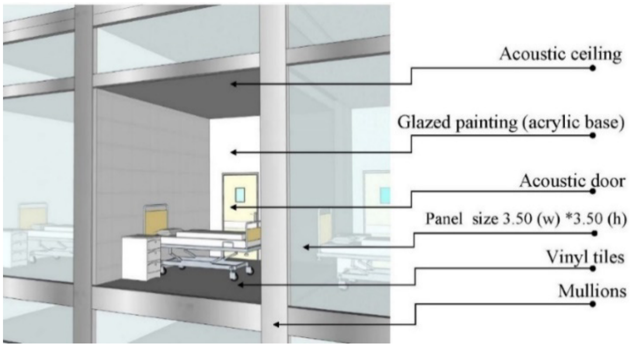


Figure 6. The repeated typical module of the curtain wall in the facades.

- The average surface absorption coefficient (α) for the room was deemed according to its finishing materials as shown in (Figure 6), and (Table 6). The reverberation time (RT_{60}) at the receiving room was calculated for each scenario (SC1, SC2, SC3) through Sabine's [28] equations as illustrated in (Table 7) and the result below, where the acceptance range of RT_{60} at patient's rooms at the hospital should be lower than 0.6s at 500 Hz as:

$$RT_{60} = (0.161 \text{ s/m})\, V/ Se \quad (1)$$

$$Se = \alpha_1 S_1 + \alpha_2 S_2 + \alpha_3 S_3 + \ldots \quad (2)$$

where:

RT_{60} (s): reverberation time, V(m^3): room Volume, Se: effective absorbing area, α: the average surface absorption coefficient, and S (m^2): the surface area.

- Weighted standardized façade level difference D2m,nT,w was computed for each receiver in the façades according to EN ISO 140-5 equation [29]:

$$D_{2m,nT,w} = L_{1,2m} - L_2 + 10 \text{ Log } (T / T0) \quad (3)$$

where:

$L_{1,2m}$ (dB) is the external sound pressure level, L_2 (dB) is the sound pressure level in the receiving room, T (s) is the reverberation time, and T_0 (s) is the reference value of reverberation time of 0.5.

- D2m,nT,w results were compared with the required STC for each façade, and for each scenario as illustrated in (Table 8**)** and the results below.

Table 5. The Sound Transmission Class (STC)

Receiver level	West façade		
	Measurements	Required	STC
1.00	75.00	35.00	**40.00**
5.00	74.00	35.00	**39.00**
10.00	73.00	35.00	**38.00**
15.00	73.00	35.00	**38.00**
20.00	72.00	35.00	**37.00**
25.00	72.00	35.00	**37.00**
	required glass STC ranged between **37** to **40** dB		

Table 6. The average surface absorption coefficient (*α*)

Material	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Mineral wool tiles, 180mm airspace	0.42	0.72	0.83	0.88	0.89	0.80
Single panel of glass, 3 mm	0.30	0.20	0.10	0.07	0.05	0.02
vinyl tile on concrete	0.01	0.01	0.02	0.02	0.02	0.02
Acoustic door	0.35	0.39	0.44	0.49	0.54	0.57
Glaze plaster on masonry wall	0.01	0.01	0.01	0.02	0.02	0.02

Table 7. Reverberation time ($RT_{60\text{- }500\text{ Hz}}$) for scenario (SC1)

Material	(*α*) 500Hz	S	Se	V
Mineral wool tiles, 180mm airspace	0.83	17.50	14.53	61.25 m3
Single panel of glass, 3 mm	0.10	12.25	1.225	
vinyl tile on concrete	0.02	17.50	0.35	
Acoustic door	0.44	3.30	1.45	
Glaze plaster on masonry wall	0.01	43.95	0.439	
Se (Total)			**17.99**	
$RT_{60\text{-}500\text{ Hz}}$			**0.55**	

Table 8. Standardized west façade level difference (D) for scenarios (SC1, SC2, SC3)

Receiver level	East façade			D with different scenarios		
	Measurements	Standard	STC	SC1	SC2	SC3
1.00	72.00	35.00	37.00	37.40	37.58	37.61
5.00	71.00	35.00	36.00	36.40	36.58	36.61
10.00	70.00	35.00	35.00	35.40	35.58	35.61
15.00	70.00	35.00	35.00	35.40	35.58	35.61
20.00	69.00	35.00	34.00	34.40	34.58	34.61
25.00	69.00	35.00	34.00	34.40	34.58	34.61
required glass STC ranged between **34** to **37** dB				**Achieved**		

4. RESULT

The noise pressure measurements in the sides of the building facades were recorded by the receivers at different heights, as illustrated as follows:

- East facade receivers were exposed directly to noise from line 1, semidirect from lines 3 and 4, and indirectly from the last sources. Receivers' results were decreased from the lower floors to the highest one, as shown in (Table 9). The first receiver which was located (1 m) above ground was recorded 72 dB(A). The last receiver which was located (25 m) above ground was recorded 69 dB(A). At middle floors, the results were counted down gradually. At receiver (5 m) was recorded 71 dB(A), then recorded 70 dB(A) at receivers (10 m) and (15 m) to be a constant number. Then, the results decreased again at the last two receivers.
- West facade receivers recorded the same decreased gradually results as illustrated in (Table 10). The highest result was at the lowest floor, and the lowest result was at the upper floor. The receiver (1 m) recorded 75 dB(A), then the lowest one at the receiver (25 m) was 72 dB(A). Then, constant results at receivers (10 m) and (15 m) were recorded 73 dB(A). Also, constant results at receivers (20 m) and (25 m) were recorded 72 dB(A). West elevation receivers were recorded as the highest results at all receivers. It was exposed directly to lines 2, 5, and 3, semi-direct to lines 4, and 6, and indirectly from the last ones.

Table 9. Receivers results at East elevation

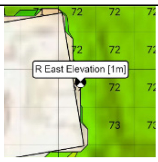
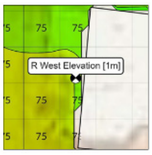
Receiver Name	Height (m abs.)	Overall Level dB(A)	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz
	1	**72**	47	55	63	67	68	61	50	54
	5	**71**	46	54	62	66	67	59	48	52
	10	**70**	45	53	61	65	66	59	48	52
	15	**70**	45	53	61	65	66	59	48	52
	20	**69**	44	52	60	64	65	58	47	51
East Elevation	25	**69**	44	52	60	64	65	58	47	51

Table 10. Receivers results at West elevation

Receiver Name	Height (m abs.)	Overall Level dB(A)	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz
	1	**75**	49	57	66	70	71	65	55	61
	5	**74**	48	56	64	68	70	64	54	60
	10	**73**	47	55	64	68	70	63	53	60
	15	**73**	47	55	64	68	70	63	53	60
	20	**72**	46	54	63	67	69	62	52	59
West Elevation	25	**72**	46	54	63	67	69	62	52	59

- North facade receivers were exposed directly to noise from line 4, semi-direct from line 1 and line 2, and indirect from the latter sources. The receiver recorded the highest level at the first floor and the lowest at the last floor. At the receiver (1m), it was 69 dB(A), and at the last receiver (25 m) was 66 dB(A). It was decreased gradually at receiver (5 m) which was recorded 68 dB(A). Then it was recorded constant numbers at receiver (10 m) and (15 m). It was recorded 67 dB(A). Then, the lowest recorded and constant results were at receiver (20 m), and (25 m) which was 66 dB(A). North elevation receiver had the lowest results out of all receivers as illustrated in (Table 11). Although, all roads have the same sound power level.
- South facade receivers were exposed directly for lines 3 and line 6, semi-direct from line 2, and 1 and indirect from the last ones. It was similar to the last two receivers. Results were decreased gradually from the lowest floors to the upper floors as shown in (Table 12**)**. It was the highest result at the lower one and the lowest results at upper floor. The receiver (1 m) was recorded 73 dB(A) and the receiver (25 m) was recorded 70 dB(A). Receiver 10 m and (15 m) were constant which were recorded 71 dB(A). Then, receiver (20 m) and (25 m) were constant also which were recorded 70 dB(A).

Table 11. Receivers results at North elevation

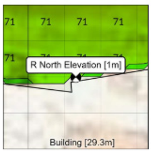
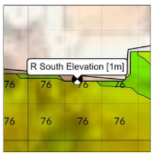
Receiver Name	Height (m abs.)	Overall Level dB(A)	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz
	1	**69**	44	52	60	64	65	59	48	53
	5	**68**	42	50	59	63	64	57	46	51
	10	**67**	42	50	58	62	63	57	46	51
	15	**67**	42	50	58	62	63	57	46	51
	20	**66**	41	49	57	61	62	56	45	50
North Elevation	25	**66**	41	49	57	61	62	56	45	50

Table 12. Receivers results at South elevation

Receiver Name	Height (m abs.)	Overall Level dB(A)	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz
	1	**73**	47	56	64	68	69	63	53	59
	5	**72**	46	54	62	67	68	61	51	58
	10	**71**	46	54	62	66	68	61	51	58
	15	**71**	46	54	62	66	68	61	51	58
	20	**70**	45	53	61	65	67	60	50	57
South Elevation	25	**70**	45	53	61	65	67	60	50	57

Meanwhile, Reverberation time ($RT_{60\text{- }500\ Hz}$) for the three scenarios (SC1, SC2, SC3) were in order 0.55s, 0.57s, 0.58s as shown in (Table 13). All the results were lower than 0.6s at 500 Hz, therefore it was accepted.

Table 13. Reverberation time ($RT_{60\text{- }500\ Hz}$) for scenario (SC1)

	SC1	SC2	SC3
Se (Total)	17.99	17.26	17.13
$RT_{60\text{-}500\ Hz}$	0.55	0.57	0.58

As previously mentioned, the weighted standardized façade level difference D2m,nT,w was computed for all facades, and for the three scenarios (SC1, SC2, SC3). All the results were compared with the required STC for each façade as illustrated in (Table 14)**,** and **(**Figure 7).

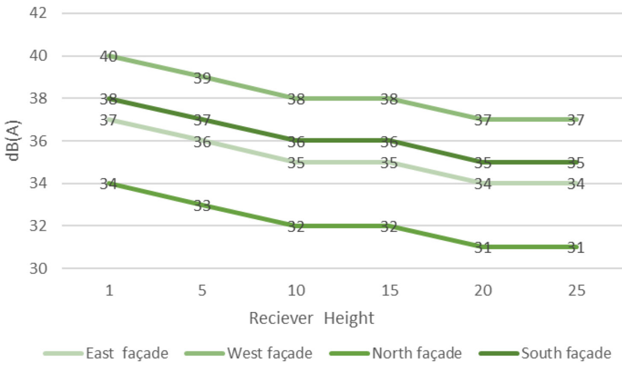


Figure 7. The Sound Transmission Class (STC) for all facades.

Table 14. The Sound Transmission Class (STC) for all facades / all scenarios

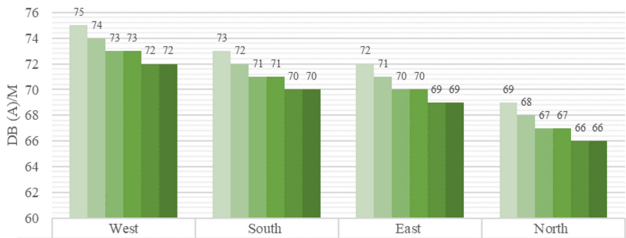
Receiver level	West façade	D/scenarios			North façade	D / scenarios			South façade	D/scenarios		
	STC	SC1	SC2	SC3	STC	SC1	SC2	SC3	STC	SC1	SC2	SC3
1.00	40.00	40.40	40.58	40.61	34.00	34.40	34.58	34.61	38.00	38.40	38.58	38.61
5.00	39.00	39.40	39.58	39.61	33.00	33.40	33.58	33.61	37.00	37.40	37.58	37.61
10.00	38.00	38.40	38.58	38.61	32.00	32.40	32.58	32.61	36.00	36.40	36.58	36.61
15.00	38.00	38.40	38.58	38.61	32.00	32.40	32.58	32.61	36.00	36.40	36.58	36.61
20.00	37.00	37.40	37.58	37.61	31.00	31.40	31.58	31.61	35.00	35.40	35.58	35.61
25.00	37.00	37.40	37.58	37.61	31.00	31.40	31.58	31.61	35.00	35.40	35.58	35.61
STC required		required glass STC ranged between **37** to **40** dB			required glass STC ranged between **31** to **34** dB				required glass STC ranged between **35** to **38** dB			
Achieved/ Not achieved		**Achieved**			**Achieved**				**Achieved**			

Note: East façade analysis was mentioned in the methodology

5. DISCUSSION

According to client's desire, the curtain walls can be used as an architectural treatment for building envelop due to its benefits in sound insulation. This study was conducted to evaluate the optimum cross section for the structured glazed facade (curtain wall) based on the site conditions, by using *simulation* tool and *equations*.

Regarding the simulation results, the highest results for all the facades were at the lowest floors, and the lowest results were at the upper floors as illustrated in (Figure 8). In fact, it was a logical result, where the lower floors were closer to the noise sources than the others. The highest value was recorded at the west façade, it was 75 dB(A), and the lowest one was recorded at the north façade, which was 69 dB(A). Additionally, the receivers' result showed, that it was reduced gradually in relation to the receivers' height on the facades. In this respect, the receivers' results had reduced gradually, Where, more distance between sound sources and receiver location means less sound pressure level was recorded. Therefore, the relationship between receiver location and noise source was an inverse relationship. More specifically, the west façade recorded the highest results, because the sound exposure for it was from a direct sound of lines 2,5, and 3. In contrast, the north façade was exposed directly from line 4 only, therefore, it was recorded as the lowest values. Understandably, although all the noise sources had the same sound power level, the receivers had different results. Indeed, it was different according to the receivers height (location), the distance between the sound source and the receivers, and the number of sources and the angle of sound rays received in the façade.



	West	South	East	North
1	75	73	72	69
5	74	72	71	68
10	73	71	70	67
15	73	71	70	67
20	72	70	69	66
25	72	70	69	66

Figure 8. Comparison between all receivers results at each façade.

Likewise, the evaluation of the three scenarios (SC1, SC2, and, SC3) which assumed in the study, the reverberation time ($RT_{60\text{- }500\text{ Hz}}$) for the three scenarios was different as a result of the change of the glass thickness, the number of the glass layers, and using the air gap. Noteworthy, all the ($RT_{60\text{- }500\text{ Hz}}$) values were accepted, where it was under 0.6s. Furthermore, the sound transmission class (STC) was estimated by the difference between the receivers' values as an external sound source and the accepted indoor sound pressure as 35 dB(A). based on the ($RT_{60\text{- }500\text{ Hz}}$) values, and considering the ($L_{1,2m}$) the simulation results at each receiver, and in each façade, the weighted standardized façade level difference (D) was computed. Consequently, three scenarios (SC1, SC2, and, SC3) were evaluated, where all the scenarios were accepted. Substantially, the (D) results of scenarios SC2 and SC3 for all facades were slightly different. Even so, the SC3 has great potential for improving energy efficiency where it can also provide thermal insulation [30]. Therefore, SC3 was the optimum solution for this case study.

Moreover, it was shown that the use of curtain walls has great benefits in reducing the transmission of airborne noise from the external environment to the indoor spaces and preventing noise pollution from disturbing the occupants [31]. In this vein, glass type, and thickness are not only the parameters responsible for achieving optimal sound insulation. Many design considerations and parameters have significant effects on the curtain wall sound and thermal insulation, for instance:

- Using solar protection systems [32] for the large glass surfaces (glass panels) as a multi-layer film enhance the sound insulation.
- The quality of Poroelastic materials, metal studs, mullion components, and accessories especially the gasket, foam, and silicone sealing play a crucial role in reducing sound transmission [33-34].
- Using inner laminated glass [35] reduces the noise passes.
- In the double glass curtain wall, increasing the thickness of the external glass and gas cavity can raise the values of sound insulation [36].

Notably, many transparent sound-absorbing materials can used instead of glass to reduce noise levels while maintaining visibility through them. They include microperforated panels, acoustic films, acoustic glass, acoustic curtains, and transparent acoustic panels [37]. These materials are commonly used in architectural applications where both acoustic performance and visual transparency are important. By absorbing sound waves while allowing light to pass through, transparent sound-absorbing materials offer a balance between noise control and aesthetics.

6. CONCLUSIONS

The goal of this study was to predict the acoustic performance of a proposed structured glazed facade (curtain wall), that can achieve acoustic comfort for Dr. Plaza Capital Medical Health Care (PMHCU) at Badr University according to the client's request. The study investigated the accepted sound pressure levels in hospitals by the specialized organizations in this context. Additionally, the study discussed the acoustic treatments for the building envelope with a concentration on the structured glazed façade (curtain wall). Furthermore, the finding of the simulation by MASdBmap showed that the highest value of (RTN) was recorded at the west façade, it was 75 dB(A), and the lowest one was recorded at the north façade, it was 69 dB(A). Similarly, the optimal scenario for the curtain wall cross-section was concluded based on the weighted standardized façade level difference (D) calculation for each scenario. The three scenarios (SC1, SC2, and SC3) were accepted according to the calculation. Moreover, the SC3 has great potential for improving energy efficiency where it can also provide thermal insulation. Therefore, SC3 was the optimum solution for this case study. Noteworthy, Future effort is required by the researchers to improve the interior comfort conditions whether acoustic or thermal in the face of consequences of rapid urbanism, therefore the increasing of (RTN), and climate change. The limitation of this study is that it discussed only the effect of outdoor road traffic noise (RTN) on medical health care units, while the effect of indoor noise, both manual and instrumental, which can have a negative impact on achieving the acoustic comforts has not been taken into account.

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