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Using design strategies to achieve acoustic comfort in Hospital's buildings

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abstract

Acoustic comfort has been a vital aspect of the built environment, through which sustainability standards may be achieved, especially in healthcare facilities, especially hospitals. The higher noise levels, above their normal rates, may lead to several health harms, which affect both patients and healthcare providers and thus create obstacles to making the building sustainable. The research discussed the concept of sustainability in general, then touched on the study of sustainability in hospital buildings, and its environmental, social, and economic aspects. It then focused on acoustic comfort and its importance in creating a sustainable environment in hospital buildings. Acoustic comfort and permissible noise rates in hospital buildings have been identified according to regional and international standards, and the sources of internal and external noise have been identified too. The effect of higher noise rates on patients and healthcare providers has also been addressed. This paper aims to study and acknowledge the methods we may use to reduce the noise levels in hospital buildings, to reach permissible noise rates according to international standards. A case-study technique was used to identify, analyze, and measure the external noise of Ain Shams Maternity Hospital building, and then a simulation tool was employed to study and evaluate solution alternatives and treatments, making use of the acoustic properties of building materials and other design solutions to reduce the noise rates in the case-study building, and recommendations have been made do reduce noise rates to reach a sustainable healthcare building.

Introduction

Acoustical comfort is an important determinant that can be employed in achieving a sustainable built environment in hospitals, considering thathigher noise levels above the permissible levels cause health harm to both patients and healthcare providers, thisharm varies according to the strength of the noise, as following:(1)

1. The level of 40 – 50 dB leads to adverse effects and reactions represented by anxiety, stress, psychological discomfort, disorder, and lack of healthy harmony.
2. The level of 60 - 80 dB hurts the nervous system and leads to severe headaches, lack of ability to work, and disturbing dreams
3. The level of 80 – 110 dB leads to a decrease in the intensity of hearing and causes disorders in the nervous and cardiac systems.
4. The level above 120 dB causes pain to the auditory system and leads to the inability to distinguish sounds and their direction.

Studies have shown that noise is a major cause of prolonging the healing time, delaying wound healing, increasing drug consumption rates, and therefore additional consumption of medication and therapeutic equipment, which leads to an increase in waste and garbage, which contradicts the sustainability goals of hospitals.

The noise level at Ain Shams Maternity Hospital in the Abbasiyah area in Cairo has exceeded the permissible international rates for hospital buildings with values ranging from 65dB to 85dB.This negatively affects the health of patients and hospital staff,whichnecessitates pursuing means and treatments that contribute to reducing noise values in the hospital building.

The research assumes that using design solutions and treatments could reduce noise levels both inside and outside the hospital building to provide acoustical comfort and tranquility to both patients and hospital staff.This research paper aims to evaluate different design solutions and interventions to reduce external noise levels within the accommodation area of Ain Shams Maternity Hospital, to achieve sustainability regarding acoustic comfort.

Material and methods

The research adopts a descriptive-analyticalstrategy, and employs a case-study technique, by studying and analyzing the situation of a hospital building in a crowded noisy area; specifically, inside the accommodation department at Ain Shams Hospital for Women and Obstetrics (case study), through monitoring the values of external and internal noise in the building, and evaluate possible design strategies which could be used to reduce noise levels in it, to implement sustainability concepts. Where the action plan to protect or reduce noise requires a field study and follow-up of these procedures, one of the most important stages in these studies is to identify the current situation of the noise problem in the city and its relationship with the functional elements in the hospital, utilizing the great development in measurement devices and acoustic simulation software that facilitate the work of the necessary studies.

To determine the importance of acoustic comfort in achieving sustainability in hospital buildings, the research reviews some important concepts about sustainability in general and sustainability of hospital buildings in specific.

Sustainability in healthcare buildings (green hospitals):

Sustainabilitywas defined by the World CommissiononEnvironment and Development (WCED) as: *"satisfying the basic needs of the present generations and meeting their aspirations for a better life without harming or compromising the right of future generations to meet their living needs."*(Al Saleh 2004), The elements of sustainability are structured in three basic categories: environmental, economic and social sustainability.

According to the standards and areas of sustainability in healthcare buildings, social sustainability represented 27% of the overall measurement, environmental sustainability represented 59%, and economic sustainability represented 14%, as shown in Figure 1. (11)

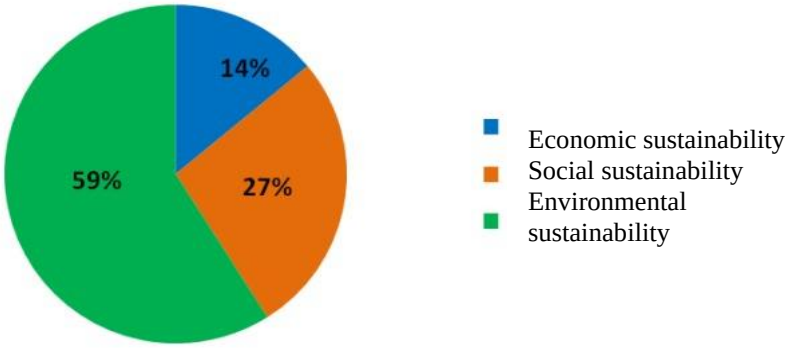


Figure (1) The percentages of sustainability elements in healthcare buildings.
(Source Reference 11)

Environmental sustainability was divided into five main components; waste management, sanitation, reducing carbon emissions, reducing toxic elements, and rationalizing water consumption. Social sustainability was divided intothree basic components; human, comfort, and distribution. The last element is economic sustainability, its main components are medical, administrative, and technological performance. Acoustic comfort is a part of the social sustainability under the subcategory "comfort" in healthcare buildings, itrepresents 8% of thepoints of "Social Sustainability, as figured in Table (1).

table No. (1) the basic criteria of sustainability elements in healthcare buildings.

Element of sustainability	Essential elements	The Standards
Environmental Sustainability 59%	Waste managemen t	Construction waste
		Medical waste
		Waste Recycling
	Wastewater	Hazardous Waste Disposal Separation
		Chemical treatments of hazardous waste
		Energy Saving
		Green Architecture Techniques

	Gas emission reduction	Use of alternative and renewable energy
		Sustainable transport
		Use of sustainable materials
	Toxic chemicals	Use of environmentally friendly chemicals
		Disposal of toxic substances
	Water consumption	Water Recycling
		Quality of fittings
		Environmentally friendly health devices
Social sustainability 27%	humanizations	Safety & Security
		Social aspects
		satisfaction
		Health Promotion
	Comfort	Natural lighting
		Thermal comfort
		Air Quality
		Acoustic
	Distribution	Tracks
		Elasticity of blanks
		Hospitalization blocks
		Doctors' Rooms
Economic sustainability 14%	Clinical performance	Infection Control Measures
		Reducing the side effects of medications
	Managerial performance	Team Qualifications and Experience
		Judo ergonomics
		Digitization of management information
	Technological performance	Use of biomedical technology
		Use of information technology

Egyptian Hospital Sustainability Standards:

The Green Hospital Rating System (GHRS) was issued in Egypt by the Green Buildings Council in 2019, andit will be completed in the second edition with a guideline for the design of hospitals(7). It has not been the first Egyptian rating system asit was preceded in 2010 by The Green Pyramid Rating System GPRS. (6)

Table (2) shows the weights set to the criteria of the GHRS, which consists of seven criteria, including six basic ones with a total of 156 points, and a seventh item was added, which is innovation, to add points to the building to be evaluated.

Table. (2) The criteria of the GHRS and its weights.

NO	Standard	Points	Relative weight
1	Sustainable location and accessibility	17	11%
2	Energy efficiency	35	23%
3	Water use efficiency	25	16%
4	Materials and resources	27	17%
5	Quality of the indoor environment and creating a healthy, healing environment	30	19%
6	The field of management and operation	22	14%
7	Creativity in design	Extra Points	

Permissible Noise levels and standards in hospitals:

The maximum noise level in hospitals was set by the World Health Organization (WHO), and the USA standards for 2013 (U.S.C), and the British Health technical guide(HTM) that noise levels in hospitals should not exceed the rate of 45 decibels for the morning time, 40 dB for the evening time and 35 dB for the night time.(10)

Noise levels are likely to increase as a result of increased traffic, as it is the main source of noise in the city, it ranges from 68 dB to 80 dB according to the WHO.

The Egyptian environmental law also set noise standards according to the type of activities, which determined the noise levels inside

hospitals at rates ranging between 40-35-30 dB and over a period of 24 hours. The standards and noise levels inside hospitals have been determined for guidance by “the Egyptian Design Standards Manual for hospitals and health facilities. Part 2”, which was issued in 2012 according to the type of each internal space as shown in Table.(6)

Table (6): The equivalent noise levels in hospital spaces according to the Egyptian code

Space type	equivalent noise intensity level (dB)
private room	30-40
Operations room	35-45
patients’ room	35-40
Laboratory, corridors	40-50
Rest stops and waiting areas	40-50
Bathrooms	45-55

The Egyptian Housing and Building National Research Center (HBRC), has clarified the mandatory conditions and basic requirements for the indoor environment’s quality of the for acoustic comfort according to their importance. The following table No. (7) shows the classification of these conditions and clarifies these conditions.

Table (7): Mandatory conditions and basic requirements for the quality of the indoor environment for acoustic comfort - (Source: Reference 6)

No	Clause	Points
Acoustic comfort		
1	Environmental noise assessment	Mandatory condition
2	Background noise	1
3	Sound insulation	1
4	Acoustic absorption	1

Sources of noise in hospitals

Internal noise sources in hospitals vary due to the diversity of diagnostic and therapeutic devices and users. Figure 2 shows the sources of internal and external noise in hospitals.

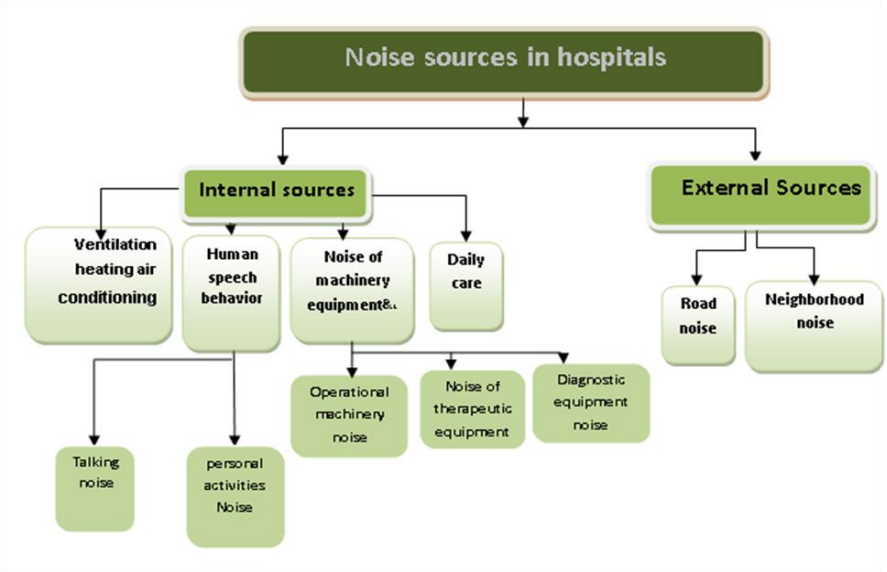


Figure (2) shows the sources of external and internal noise in hospitals
(Researcher source)

Noise measurement and analysis devices:

With the great technologicaldevelopment, there are currently several devices and applications for measuring the noise level, including the sound level meter device as shown in Figure(3).

Figure (3): sound level meter device for measuring noise level

Special programs were also used to analyze the noise levels taken in the case study, such as the sound plan program(as in Figure 4), which is a paid program. Several architectural and design solutions were also tested to help in reducing the noise level inside the studied building.

Figure (4): SoundPlan 7.4 program for analyzing noise levels

Monitoring and evaluatingthe noise levels at Ain Shams Maternity Hospital:

Ain Shams Maternity Hospital located in Abbasiya area in Cairo is an educational Hospital of Ain Shams Faculty of Medicine. The dimensions of its main block are about 50*90 m, it has 6 floors and a bed capacity of 373 beds. The average number of visitors to the reception is 30 thousand patients a year, while the average number of admissions is 23 thousand. Figure No (5) shows the hospital site.

Noise values on the facades of the building were measuredby the noise measuring device and SoundPlan 7.4 software was used to simulate and measure noise levels at every floor level on the façade, they showed high readings of 83.3 dB, 82 dB, 80.7 dB, 79.6 dB, 78.7 dB, and 77.2 dB on the ground, first, second, third, fourth and fifth floors respectively.They are much higherthan Egyptian standards.Figure No. (6) shows the noise values at the hospital's site—and Figure (7) associates the readings to thehospital's floors, as Table No. (7) and

figure No. (8) shows the values of internal and external noise on the different accommodation floors of the hospital.

Figure (5): The site of Ain Shams Maternity Hospital

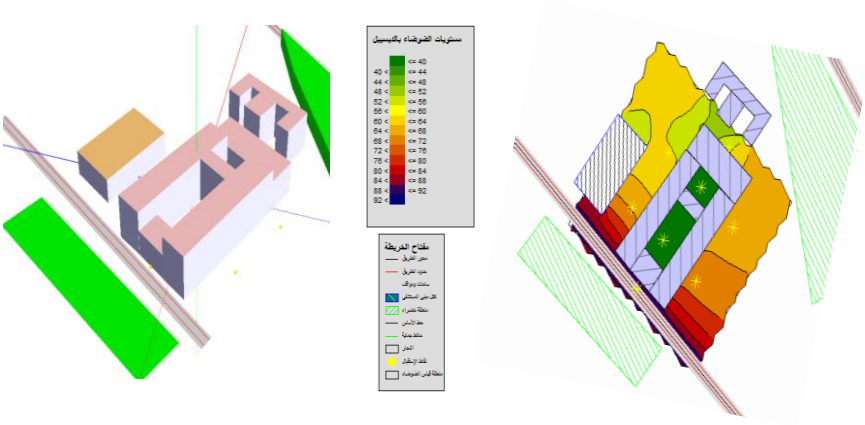


Figure (6): The site with the measured noise values

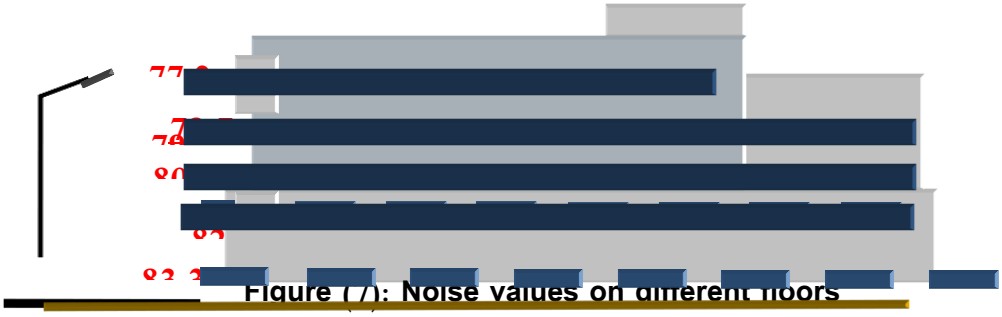


Figure (7): Noise values on different floors

Table (7): Comparison of the internal and external noise values of the hospital's floors

	reality of situation	Orientation	Distance	Afforestation	Barrier	mass
ground floor	83.3	83.3	71.8	82.8	73.9	71.5
first floor	82	82	72.3	81.8	80.7	71.7
second floor	80.7	80.7	72.9	80.7	79.7	71.9
Third Floor	79.6	79.6	73.4	79.7	78.8	72.1
Fourth floor	78.7	78.7	72.5	78.8	78.1	72.2
Fifth Floor	77.2	77.9	71.9	78.1	77.5	72.9

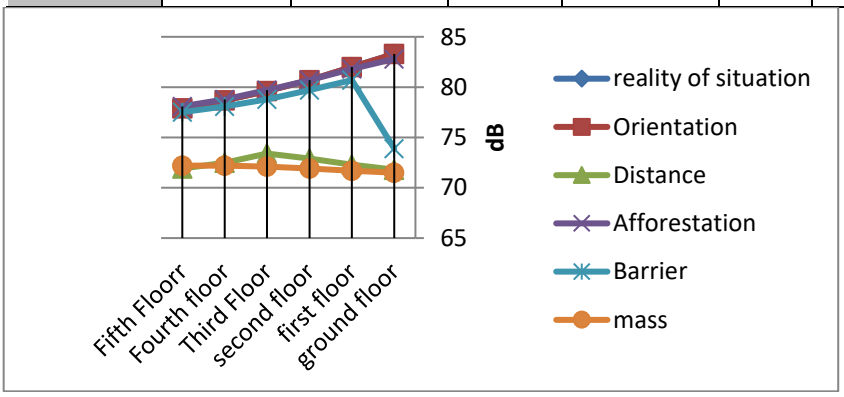


Figure (8): Comparison of the internal and external noise values of the hospital's floors

Using architectural and planning strategies to reduce noise levels

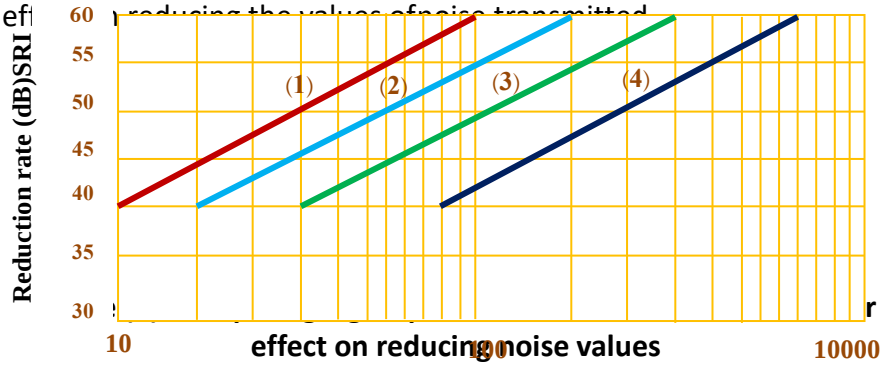
Using several planning and design strategies would reduce noise levels in hospital buildings, including manipulating the building's shape and orientation, and using fences with good acoustic properties. Using trees and green areas is also an effective strategy to reduce noise levels, as they absorb sound and disperse sound waves.()

Employing the acoustic properties of building elements and finishes in reducing noise values:

The sound insulation of the patient's accommodation rooms can be used to overcome the noise as the other planning methods have proven limited impacts on reducing the noise values or are difficult to use in our case study.The external walls and windows can be treated and the acoustic properties of materials that can reduce the noise inside the patient rooms can be used.

walls:

External walls are important elements of curbing external noise, to prevent noise transmission to the inner spaces. Thewalls'soundproofing efficiency depends on the acoustic properties of its materials, the wall'smass is determined by the mass of a unit area of the wall,and it depends on itsmaterial and thickness, this increases with increasing the density of the material and as the wall thickness increases. Figure (9) compares a set of different wall masses and their ef



effect on reducing noise values

Windows:

The windows are considered one of the building elements through which noise is transmitted to the inner spaces, as they usually have poor sound insulation compared to other parts of the building.The Window has an average sound transmission loss of about 50 decibels, which is roughly the same as the average transmission loss of a 20 cm thick concrete wall.

Recently, new technologies have appeared that have increased the performance of noise-proofing windows with the possibility of entering the fresh air naturally. For example, a type of Window based on the idea of Helmholtz resonant, where voids were developed to

prevent noise, and these windows have achieved a noise reduction of up to 35 dB with the possibility of air passing almost naturally (), through changing the air path with the use of absorbents to increase the effect. There are many different designs for this type of window.These windows may not be suitable for Egyptian cities on a large scale due to high costs, high temperatures, and the need for most of these types of windows for continuous ventilation. ()Another technique is the use of double glazing to reduce the transmission of sound with the passage of air and lighting naturally, as shown in Figure (10).

Figure (11) shows the different configurations of double-glazed windows and air vacuum and the amount of sound reduction resulting from them, and Figure (12) shows the relationship of the openings to the sound source and how to process them to reduce noise.

Figure (10): The use of double glazing and theamount of reduction in noise level C Source: Reference (10)

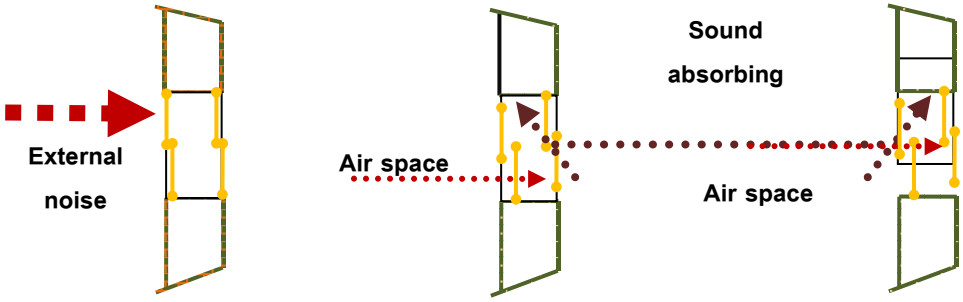


Figure (11): The formation of the double-glazed window, the air vacuum, and the resulting sound reduction( )

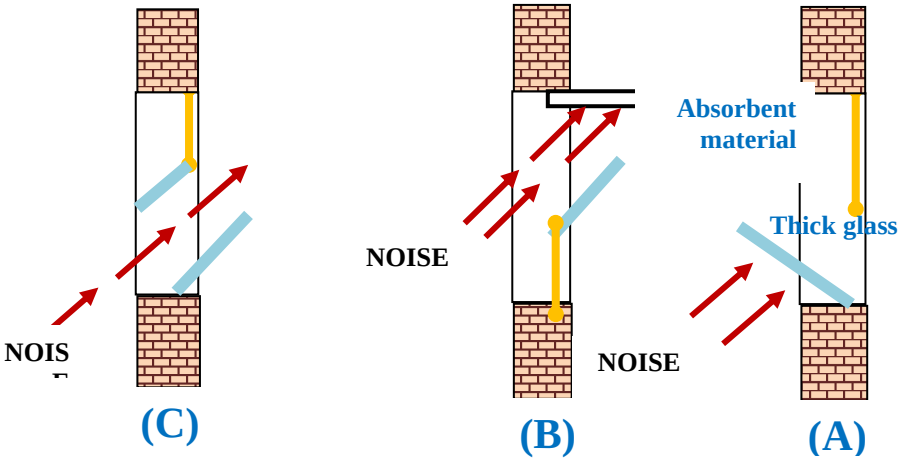


Figure (12): The relationship of openings to the sound source and how to treat them to reduce noise( )

Doors

Acoustic door thresholds are door blockers designed to prevent Noise from entering from the bottom of the door as in Figure (13), they can be used with the doors of patient accommodation rooms as a cheap solution.

Figure (13) Sound insulation in the door threshold (Source: Reference 13

Vitiate sound insulation:

It is high-quality, lightweight decorative elements or sheets, used as sound insulation in places where loud and annoying sounds are emitted, such as engine rooms, cooling and water heating machine rooms, and also used in places where noise and disturbance are not allowed to enter, such as operating rooms, intensive care, and patients'accommodation rooms

Soundproofing coating some anti-sound PAINT:

It is used to isolate and reduce the intensity of sound, as through experiments and analysis it was found that it absorbs sound and attenuates it by about 10-25dB per 1 mm thickness and attenuates about 48.5 dB per 2 mm for 100 hertz. These standards are certified by accredited Turkish CAC laboratories (16).

Flooring: Rubber plates and rolls:

They are made of natural, synthetic rubber, or petroleum materials and are characterized by their plasticity and high sound absorption capacity and are considered one of the distinctive sound absorption materials. (15)

Figure (14) Reducing noise coming from inside) Source: Reference 14

Figure (15) Rubber coils (Source: Reference (15)

Results

1- The noise levels are considered high, especially on the highways near the abbaseyah area and the educational hospital.

3- It is possible to resort to protecting the building through architectural design and sound insulation architecturally when the protection measures are not fully implemented.

4- Noise levels rise at peak times and Morning Times on working days above the permissible limits in most components of the hospital buildings

5- Noise levels increase in parking areas, which spread randomly in the areas surrounding the hospital

6- The facades of buildings are affected by the noise outside due to the failure to achieve sustainability standards in such a way that patients in the hospital have sleep disorders
7- multiple sources of noise pollution in the hospital, most notably the sounds of cars, congestion, and the lack of sustainability standards in the hospital

recommendations

1- Attention should be paid to the element of noise and achieving sustainability through sound insulation in the future general plan of the hospital and taking into account the impact of adding or modifying any uses on noise levels.
2- Restriction of urban extensions towards highways and highways, which are considered one of the most important sources of noise
3- Working on the implementation of protection measures and reducing noise levels in the areas surrounding the hospital by determining the uses and all other available means of sustainability standards that achieve sound insulation.
5- Afforestation of streets because it has a big role in absorbing a large part of the noise level and achieving the required sustainability standards
6- spreading environmental values and awareness through the world's means in order to warn of the dangers of noise pollution and the dangers it causes.
7- Proper urban planning so that hospitals are far from noise sources.
8- Attention to acoustic studies at the design stage and directing the building
9- Attention to achieving sustainability in hospitals, as there is a complete absence of such studies.

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