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Evaluating the Effects of Building Characteristics of Worship Auditoriums on Speech Intelligibility in Makurdi Metropolis

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Abstract:- To enjoy the comfort of the indoor environment of any enclosed space, it is important to have a reasonable measure of understanding of any spoken word in the room. In line with the above this study assessed the characteristics of worship auditoriums with regards to speech intelligibility in Makurdi metropolis with the view to identifying building characteristics that affect speech intelligibility worship auditoriums. The study was carried out through the employment of walkthrough survey and physical observation; a well structured checklist was employed for the study. Measurements of lengths, widths and heights were carried out, from which the room volume was obtained to have an insight of the space under consideration. The auditoriums of ten worship centres in Makurdi Metropolis were studied. The findings that showed all the auditoriums were rectangular in shape. It was found that there was use of inappropriate application of materials for surface finishes in the auditoriums. In terms of room volume, it was found that G recorded the highest volume with 17064.00m^3 while E recorded the lowest volume of 756.00m^3. The mean volume of the auditoriums was calculated to be 517.64m^3, the Standard Deviation (SD) was 4733.44 and the Coefficient of Variation (CV) was found to be 81.36%. The study recommended that **proper selection and application of surface finish materials be ensured during construction of worship centres. Also, that acoustic treatment is applied in auditoriums where defects are identified, with the aim of effectively enhancing speech intelligibility in worship auditoriums in Makurdi Metropolis.**

Keywords:- *Building Characteristics, Worship Auditoriums, Speech Intelligibility.*

I. INTRODUCTION

Pleasant sounds help create a sense of wellbeing in any environment, it also aids relaxation. Good acoustic conditions generally are fundamental to the quality and enjoyment of homes, workplaces, worship places, educational places, social places and many other buildings that people occupy. From mosques to churches, acoustic comfort is regarded as an important consideration [1] these buildings generally have a complex challenge when it comes to acoustical design. The environment has to accommodate speech and music, which appears to be conflicting at times, hence the need to balance the space to soothe the congregation. The main goal of worship is to provide the required message to all its participants, hence it is necessary for the auditorium to have good acoustics to allow good verbal and musical communication [2]. One of the most important things a building must do amongst others is to provide a place where speech can be clearly understood [3]. For an acoustic environment to be qualified as good or poor, it is essential to understand how the 'instrument' works and how it fails [4]. When sound is clear it is easy to understand and remember the message passed, because the message cannot be easily forgotten.

Speech intelligibility is an important measure of the effectiveness of a communication system in a noisy environment [5]. In every daily life situation, it is imperative to understand what is being said and to be able to react to acoustic signals of different kinds at any point in time. Generally, speech communication can be referred to as the 'understandability' of speech, the connection between the target of the speaker and the reaction of the listener; and the ability to use speech to communicate efficiently in everyday state of affairs [6]. Communication on its part can be defined as a procedure in relation to sharing of ideas, information and messages with other people, in a particular time and place [7]. This includes writing, talking and various other forms of expression of the body such as sign language; all relating to sending/receiving signals, visual

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and electronic media. The place to which communication takes place matters a lot, hence the need for it to be taken care of, in order to minimise any form of distortion within and around such a place to the smallest possible amount. This is done so as not to deform the message passed across to listeners, this is because such deformation could have serious negative effects on people and the society in general [8]. Communication in any given room depends on the acoustics of the room for it to be effectively delivered.

Acoustics is that part of science that deals with planning, designing and construction of buildings to attain proper comfort inside and the area around the building [9]. The acoustical atmosphere in worship auditoriums is articulated in terms of Reverberation Time (RT) value [10]; and most contemporary designers fail to focus on these requirements at the conceptual design stage. Some of the requirements for worship auditoriums include: sound audibility, speech intelligibility and naturalness of the speaker; these requirements connote elements of a good communication [11]. In general, a good acoustic environment helps people to hear better what they want to hear and hear less of what they don't want to hear; which is what every public building design ought to have [12].

The primary use of speech is to communicate between people; unfortunately with regards to communication in a room, many factors impair the transmission of speech and make it less intelligible [13]. According to [14] children's learning abilities are influenced by the acoustic quality of environments where they spend most of the time during their everyday life. This is because at the first stages of education children need classrooms with good speech intelligibility for their activities, which are basically sounds and speech. When the sound in such an environment is distorted, it does not only impair speech intelligibility but also have a detrimental effect on the academic performance of the students, and more stress on the instructors. Similarly, [15] affirmed that Acoustic conditions of classrooms have proven to have significant influence on the performance of students and the working stress of teachers. This is because poor acoustics leads to difficulties in learning and social interaction; as well as greater time loss to unruly activities during lessons. Also, it has been found that occupational speech users, especially teachers and preachers develop voice disorders at higher rates than the general population, this is attributed to poor room acoustics [16]. It has been observed that one of the major problems encountered in auditoriums is 'understandability'. In a large audience, it is not easy for the entire audience to hear clearly and completely in many auditoriums; the sound can be so muddled and the vocal quality so poor that the sound is absurd, gabled and becomes unintelligible [17]. It can be further observed that one of the problems of room acoustics is that musical sounds and speech are extremely variable in their complexity. These are both affected by distortions emanating from material of construction which includes: doors, windows and surfaces causing the space to be unintelligible [18]. Therefore, to tackle the nuisance emanating from deformations in any given space, the application of acoustic treatment in the designed places propagates the desired message to the target audience [19].

Worship auditoriums in Makurdi metropolis have evolved over time with regards to architectural features such as shape and surface finishes; these rooms have become larger in volume as well. The contemporary pews are being replaced with upholstery and plastic chairs. Walls and floor tiles as well as rugs are now very common and the replacement of ceiling materials to more refined finishes; sophisticated Public Address Systems (PAS) are being installed in these spaces as well. There is however a trend of continuous expansion of the PAS in many worship auditoriums to enhance hearing, this is a clear case of unintelligibility, hence the study.

This study assesses the building characteristics of worship auditoriums with regards to speech intelligibility in selected worship auditoriums in Makurdi metropolis, with a view to enhancing the comfort of the indoor environment for proper understanding of the gospel. The objective was to investigate the building characteristics of selected worship auditoriums and compare it with standard acoustic guidelines from which recommendations will be made for improvement.

II. LITERATURE REVIEW

Acoustics is very broad and it is multi-disciplinary [20]; with regards to architecture, acoustics is one of the many branches also referred to as building acoustics. It involves the scientific understanding of how to attain good sound in a building, which typically involves the study of speech intelligibility, music quality, and speech privacy in the built environment. There are many characteristics associated with acoustics, a few of these relate to building and can be attributed to specific measurable properties of the room [21]; some of them include: - Liveliness, intimacy, fullness, clarity, warmth, brilliance, texture, blend and ensemble.

Building acoustics is very complex. It can be said to be the science of controlling noise in buildings, and the control of other characteristics of sound within the spaces themselves [22]. Acoustic services control sound within specific spaces and the noise transmission is greatly minimised [23]; this can be achieved through material selection, design and acoustics techniques. This makes acoustic a very crucial element in the design, construction and operation of buildings.

- *Factors that affect Speech Intelligibility in a Room*

There are many factors that affect acoustical propagation in enclosed spaces, these include the size and shape of the enclosure as well as the materials used in the construction of the building [24]. Other related factors include:- room design, room acoustics, room reflection and absorption rate, background noise, sound system quality, sound reinforcement, audience behaviour, seating arrangement as well as speaker articulation and projection. By addressing these factors through proper acoustic design,

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sound system configuration and audience management, speech intelligibility can be effectively optimised in any given auditorium.

While there are many factors influencing a worship space's performance, the most critical and most obvious to the congregants is Reverberation Time (RT). It is an important and essential tool used to estimate the acoustics of any space [25]. The actual, measurable, reverberation time for a space is dependent largely upon its physical volume, the kind of surfaces it has and the materials used in its construction. This is because if the reverberation time is too long and/or if the speaker does not speak with understanding, a listener will actually hear sound from more than one word simultaneously; the outcome is a muffled sound that is not easily understood [26].

- *Acoustical Defects and Treatment*

There are various defects associated with building acoustics, the following defects as observed by [27] include: formation of echoes, reverberation, reverberation time (RT), sound foci and dead spot. These are basically formed as a result of the building characteristics such as room orientation, shape, size and the construction materials used on the structure; as well as the materials occupying the room.

There are many types of acoustic treatments applied to surfaces to address acoustic problems. The type of treatment depends on the problem in question and the materials available for the treatment as produced by different companies. Some of the types of acoustic treatments provided by [28] include: bass traps, acoustic panels, ceiling clouds, diffuser panels, sound reflectors, acoustic foam, fibreglass insulation, and Helmholtz resonators. These are made up of different materials and designs some of which serve as acoustic materials as well as aesthetic purposes.

- *Speech Intelligibility*

Speech intelligibility can be described as the measure of how good persons understand a spoken message [29]. Speech Intelligibility is affected by the loudness and quality of the speech signal, the type and level of background noise, reverberation (reflections) and the properties of the communication system [30]. There are basically two methods to measuring speech intelligibility, objective and subjective. The objective measurement methods are more scientific, it includes: Speech Transmission index (STI), Room Acoustics Speech Transmission Index (RASTI), Standard Transmission Index Public Address (STIPA) [31]. Thus, for a room to be adjudged acoustically excellent or bad it has to meet the Standard Transmission Index (STI) scale [32] and [33]. These findings are incorporated into a speech intelligibility metre that is able to display the intelligibility result as a single number between 0 (bad intelligibility) and 1.0 (excellent intelligibility).

- *Worship Auditoriums*

An auditorium can be defined as that part of the theatre, concert hall, or any other public building in which the audience sits [34]. It further describes the auditorium as a large building used for public gatherings, typical speeches or stage performances. Similarly, [35] defined auditorium as an enclosure, covered or open where people can assemble for watching a performance displayed on the stage. Some of these performances include; worship, recital, media interaction, dance, opera, concert, drama, conference, meeting and the likes.

There are different types of auditoriums for different purposes and the acoustic finishes applied to the surfaces are carried out with such purposes in mind. Theatres have evolved over time presenting different internal layouts, below are the most common types of auditoriums as compiled by [36]. They include:- proscenium, thrust, arena, theatres in-the-round, black box (studio), platform, hippodromes and open air. These auditoriums may have different shapes and dimensions to fit inside the building structure so as to meet the aesthetics needs, efficiently enable logistics, and improve on acoustic issues. These shapes usually have both advantages and disadvantages especially with respect to projection, sightlines and acoustics [37].

III. METHODS AND DATA ANALYSIS

The population of this study was based on public buildings with specific focus on worship centres. Ten (10) worship centres in Makurdi metropolis with large auditoriums were selected for the study, most of which are headquarters of various church denominations and mosques located in the various segments of the township. Based on these, the 10 worship centres made up the population as well as the sample size of the population. Judgmental sampling was employed in the selection of the samples for this study; the major requirements that form the criteria for selection were that: - (i) the building must be purpose-built structure for worship, (ii) all such structures were enclosed spaces, (iii) the buildings were not undergoing any form of construction/maintenance. For the purpose of this study and anonymity the selected worship centres were substituted with alphabets accordingly and in the way they are arranged above; A, B, C… J.

This research involved field survey and extensive literature review. A checklist was adopted as well as field measurements for data collection. The data collected includes; shape of the worship auditoriums, size of the auditoriums and material finishes on the surfaces (ceilings, walls and floors). The materials used for doors and windows were noted, as well as material used for construction of the seats were recorded here presented in Tables 4.1 – 4.3. Descriptive statistics was used to summarise the mean, minimum, maximum, standard deviations and cumulative values for discussion.

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IV. RESULTS AND DISCUSSION

The results of materials used as surface finishes in the selected auditoriums were presented in Table 1. The result shows that: on ceiling finishes, three of the auditoriums A, I and J were finished in aluminium sheets; four of the auditoriums B, F, G and H were finished in Celotex board while one, C was finished with PVC sheets. The other two D and E were of concrete finish being part of the suspended slab of a storey building.

Table 1 Types of Surface Finishes in the selected Worship Auditoriums

ID	Ceiling Finish	Wall Finish	Floor Finish
A	Aluminium	Oil paint, Wood & Stone pitching	Terrazzo
B	Celotex	Emulsion & Oil paint	Terrazzo
C	PVC	PVC	Tiles
D	Concrete slab	Tiles	Tiles
E	Concrete slab	Texcoat	Tiles
F	Celotex	Oil paint	Tiles
G	Celotex	Emulsion	Terrazzo
H	Celotex	Emulsion	Tiles
I	Aluminium	Emulsion & Oil paint	Terrazzo
J	Aluminium	Texcoat	Terrazzo

Source: Field Survey, (2019)

Also from Table 1, it was observed that, on wall finishes, one of the auditoriums, D was finished with wall tiles while one, C was finished with PVC Ceiling sheets. Five of the auditoriums E, F, G, H and J were painted in texcoat, emulsion or oil paint; while the remaining three A, B and I had multiple finishes in different areas. They have two or more finishes consisting emulsion paint and oil paint, with A having stone pitching on some portions of its wall. The auditorium floor finishes were of either terrazzo or floor tiles thus: five of the auditoriums A, B, G, I and J were finished with terrazzo while the other five C, D, E, F and H were finished with different types of floor tiles.

The appropriate use of surface finishes in a space tackles the menace arising from sound deformation in the space; this enables propagation of desired message to the target. From the findings of this study, three of the auditoriums A, I and J used aluminium sheets for ceiling; this is a very poor acoustic material because it has high resonance hence it aid reverberation in a room, except for aluminium panels specially designed for acoustics. C used PVC which is very light, hence a poor acoustic material; there are however thick PVC panels specifically designed for acoustics. Auditoriums B, F, G and H used Celotex; this is one of the best acoustic materials used in buildings. Celotex is a perfect use for sound absorption, noise reduction and fire protection; it can be used for ceiling, wall and floor finishes. Suspended concrete floors served as the ceiling for two auditoriums, D and E; concrete is a very hard surface and hard surfaces tend to diffuse sound thus distorting it. Concrete finishes can however serve as good soundproofing material when properly treated; such as finishing the concrete surface with Plaster of Paris (POP) or emulsion paint.

Auditorium D used ceramic tiles on the entire internal walls of the auditorium. This type of surface treatment is not advisable with regards to acoustic. This is because ceramic and porcelain tiles are hard and have very slippery surfaces; these tend to reflect any sound that comes in contact with it. With multiple reflections, sound in the auditorium may result to echo thus distorting the entire message; except other acoustic treatment measures are put to place. F used Oil paint on its entire wall, just like wall tiles, oil paints makes the surfaces reflective too; hence a similar effect to that produced by wall tiles; water based paint are better for indoor surfaces. C used light PVC as its wall surface finish material; probably improvised for aesthetics but the type of PVC used here is not a good material for wall finish as it concerns acoustics. Auditoriums C, D, E, F and H used ceramic tiles as its floor finish; tiles are durable materials and good for the floor finishing but ceramic tiles can also cause acoustics defects due to its reflective surface. However, Auditoriums C, D and E covered parts of the floor with rugs, which is a very good absorbing material and one of the best in terms of sound absorption. Auditoriums A, B, G, I and J used terrazzo as its floor finish. Terrazzo is one of the most durable floor finishes and can be easily maintained, hence its maximum patronage; however terrazzo floor finish, though a hard surface is better an acoustic finish than tiles.

It has been established by previous studies that room acoustics is greatly affected by physical characteristics of the space, which construction materials and surfaces furnishes are greatly part of [38]. Also, [39] affirm that sound waves reflect from hard surfaces, soft materials can absorb sound; as sound originates from a vibrating body pushes and pulls on the air particles about it.

The findings show that three of the ten auditoriums B, G and H struck an acoustic balance in its surface finishes, with Celotex ceiling, emulsion painted walls and Terrazzo/Tiled floors. The floor might be hard but other acoustic treatment measures can be put to place in curtailing defects. The other seven had its surfaces finished as either being too hard or surfaces with high level of resonance; these worship centres will need stringent measures in fixing the acoustic defects in the auditoriums.

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Table 2 Shape of the Selected Worship Auditoriums and Room Features

ID	Room Shape	Door Material	Window Material	Seat Type(s)
A	Rectangle	Steel	Glass	Pews
B	Rectangle	Steel	Glass	Pews
C	Rectangle	Steel	Glass	Plastic
D	Rectangle	Steel	Glass	Rug
E	Rectangle	Steel	Steel	Rug
F	Rectangle	Steel	Glass	Cushion
G	Rectangle	Steel	Glass	Cushion & plastic
H	Rectangle	Steel	Glass	Cushion
I	Rectangle	Steel	Glass	Pews
J	Rectangle	Steel	Glass	Plastic

Source: Field Survey, (2019)

Table 2 shows the shape of each of the auditoriums, and some of the construction materials used, as well as the types of seat used in the auditoriums. The table shows that the ten auditoriums are all of rectangular shape. It also shows that, all the major doors used to gain access into the auditoriums were made of steel; and nine of the auditoriums A, B, C, D, F, G, H, I and J used glass windows on aluminium or steel frames, while the other one, E used steel panelled material for its windows. Three of the auditoriums A, B and I used pews for seats, while D and E used rug. F and H used cushion chairs as its seating materials, C and J used plastic chairs as its seating material while G combined the use of cushion chairs and plastic chairs as its seating materials

In relating the result presented in Table 2 to previous studies, it can be observed from the table that all the ten worship auditoriums were found to be rectangular in shape, which shows that rectangular shape is one of the best options in the construction of worship auditoriums. This is in line with the findings of [40] that there is spatial distribution of sound in the rectangular shaped buildings than all other shapes; the study concluded that octagonal shapes usually have concentration in the middle due to cancellation from opposite directions, hence the preference for it than others. Therefore the adoption of rectangular shaped buildings in Makurdi metropolis is said to conform to the recommendations of other scholars across the globe.

All the ten doors were of steel, probably for security reasons but steel resonates a lot, which could result in increase in reverberation as well as background noise. With regards to room features, in a related study, [41] carried out a comparative analysis to ascertain the relationship between room features and speech intelligibility. The findings showed that speech intelligibility was affected by acoustical characteristics of the surface materials in the room. This is because room features either absorb or reflect sound, thus reducing the amount of sound originally propagated into the space. Pews are made of wood, these can reduce the amount of sound in a building because wood absorbs sound. This is the same with cushion chairs which are made of foam and covered with wool or other forms of cloth materials; if the sound in an auditorium is not loud enough, these materials can absorb it all thereby reducing the required reverberation time needed in the building. Rugs are equally in the same category as that of cushions, as the fur used in its production greatly absorbs sound propagated into a space. Of all the seating materials it is the plastic chairs that are less absorptive in nature, but can cause other forms of distortion to sound. This inappropriate use of some of these materials greatly affects speech by distortions emanating from materials of construction which includes doors, windows, walls and floors; thus causing poor intelligibility in room spaces.

Table 3 Sizes of the Selected Worship Auditoriums

ID	Length (m)	Width (m)	Height (m)	Area (m^2)	Volume (m^3)
A	35.00	18.00	9.00	630.00	5670.00
B	38.00	25.00	10.00	950.00	9500.00
C	25.00	20.00	6.50	500.00	3250.00
D	24.00	17.50	3.50	428.75	1500.63
E	18.00	12.00	3.50	216.00	756.00
F	24.00	14.00	9.00	336.00	3024.00
G	30.00	47.40	12.00	1422.00	17064.00
H	36.00	23.60	8.00	849.60	6796.80
I	35.00	20.00	8.80	700.00	6160.00
J	22.50	18.00	11.00	405.00	4455.00
Mean	28.80	21.55	8.13	643.73	5817.64
SD	6.89	9.88	2.87	356.95	4733.44
CV (%)	23.92	45.85	35.30	55.45	81.36
Min	18.00	12.00	3.50	216.00	756.00
Max	38.00	47.40	12.0	1422.00	17064.00

Source: Field Survey, (2019)

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Table 3 shows the sizes of the auditoriums as measured on the field, the lengths, widths, and heights were measured through which the area was calculated to further obtain the volume. The volume for each of the auditoriums is presented thus: G had the highest volume of 17064.00m^3 followed by B with 9500.00m^3, then H with the volume of 6796.80m^3. I measured 6160.00m^3 in volume, with A measuring 5670.00m^3, followed by J with 4455.00m^3. This was followed by C which measured 3250.00m^3 and F with 3024.00m^3; the auditoriums with the least volumes were D which measured 1500.63m^3 and E with a distant volume of 756.00m^3.

Volume is part of the physical properties of the room that affect sound in a room. According to [42] room volume affects sounds thus, the bigger the room, the more sound it can hold, this is because it takes more time for sound to reach absorbing materials than in smaller rooms; this implies that it takes more sound to fill a big room than the small room. Conversely, the sound in a small room will be louder than if played in a bigger room, because the sound will be swallowed in the space, thus bigger rooms have more volumes therefore hold sound much longer. However, two rooms with different shapes might have the same volume but different surface areas, but the room with the larger surface area will have its sound die out faster.

V. CONCLUSION

From the measurement carried out in the selected worship auditoriums in Makurdi Metropolis, the results show that all the ten worship auditoriums were found to be rectangular in shape conforming to the standard in many previous findings. The interior finishes were of: aluminium sheets, PVC sheets, Celotex and concrete slab for ceiling; oil paint, emulsion paint, texcoat paint, PVC sheets and tiles for walls; terrazzo and tiles for floors. Also, all the doors in the selected auditoriums were made of steel; and most of the windows were made of aluminium most being acoustically unsuitable for auditoriums due to their high level of resonance. The seats were of: pews, plastic chairs, cushion chairs, and rugs/mats. The sizes of the auditoriums show that: G recorded the largest volume of 17064.00m^3 while E recorded the lowest volume of 756.00m^3. The mean volume obtained was 5817.64m^3 with the standard deviation of 4733.44 and a coefficient of variation of 81.36%. This was carried out to show relativity in terms of the sizes of the auditoriums, this will give an insight as to how sound will behave in the rooms.

From the results of the study, the following can be concluded; the shapes of the buildings conform to worldwide practices. However, none of the sampled auditoriums satisfied all the acoustic requirements with regards to surface finishes and materials for doors and windows. This is believed to have adverse effect on speech intelligibility in the worship auditoriums in Makurdi metropolis. It is recommended that when applying surface finishes in the worship auditoriums selection and application of building materials should be carried out under strict compliance, with the aim to also control sound in the auditoriums.

REFERENCES

[1]. Kit, P. S., & Din, N. b. (2023). A Comparison of Acoustical Performance Between Traditional and Modern Church. *The International Journal of Integrated Engineering , Vol. 15 No.1 (2023) 321-330*.

[2]. Nazli bin Che Din, L. H. (2016). Relationship between room characteristics and speech intelligibility in contemporary churches in Malaysia. *International Journal of Automotive and Mechanical Engineering (IJAME) , Volume 13* (Issue 2), PP 3451-2461.

[3]. ASC. (2014). *Auditorium Acoustics*. (Acoustic Sciences Corporation) Retrieved April 18, 2017, from Church Acoustics: www.church-acoustics.com.

[4]. Griesinger, D. H. (2013). *What is Clarity and how can it be measured?* (Vol. Vol 19). Montreal - Canada: Acoustical Society of America.

[5]. Bruel, P. V., & Kjaer, V. (2013). *Measuring Speech Intelligibility using DIRAC Type 7841: Application Note.* Naerum, Denmark: DIRAC.

[6]. Pascoe, M. (2017). *Speech Intelligibility - How to Evaluate and Provide Treatment*. Retrieved June 16th, 2017, from Apraxia Kids - Library: Diagnosis & Treatment: www.apraxia-kids.org

[7]. Texas Acoustics. (2017). *What is Acoustics?* Graduate School, Department of Mechanical Engineering. Texas Publishers.

[8]. Knoras, M. (2011). *Intelligibility 101*. Atlanta, USA.: System Sensor.

[9]. ANSI. (2003). *Acoustics*. Retrieved July 15th, 2019, from Acoustical Terminology: https://en.wikipedia.org/wiki/ANSI/ASA_S1.1-2013

[10]. Ismail, M. R. (2013). *A Parametric investigation of the Acoustical Performance of Contemporary Mosques.* United Kingdom: Elsevier, Science Direct.

[11]. Othman, A. R., & Mohamed, M. R. (2012). Influence of Proportion towards Speech Intelligibility Mosque's Praying Hall. *Procedia - Social and Behavioral Sciences , 35*, 321-329.

[12]. King, S., & Timmis, G. (2019). *Acoustic Design and Testing for Health and Wellbeing.* Watford, England: BRE Trust.

[13]. Odya, P., Kotus, J., Kurowski, A., & Kostek, B. (2021). Acoustic Sensing Analytics Applied to Speech in Reverberation Conditions. (C. Kwan, Ed.) *Sensors* , pp. 1-18.

[14]. Minelli, G., Puglisi, G. E., Astolfi, A., Hauth, C., & Warzybok, A. (2023). Objective Assessment of Binaural Benefit from Acoustical Treatment in Real Primary School Classrooms. *International Journal of Environmental Research and Public Health* .

[15]. Cucharero, J., Hänninen, T., & Lokki, T. (2019). Influence of Sound-Absorbing Material Placement on Room Acoustical Parameters. *Acoustics* .

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24MAR500

[16]. Rollins, M. K., Leishman, T. W., Whiting, J. K., Hunter, E. J., & Eggett, D. L. (2019). Effects of added absorption on the vocal exertions of talkers in a reverberant room. *Journal of Acoustical Society of America , 142* (Issue 2), 775–783.

[17]. Jensen, D. (2016). *Improving Sound in Your Auditorium.* Retrieved April 18th, 2017, from Christian School Products: www.christianschoolproducts.com

[18]. Everest, F. A. (2001). *Master Handbook of Acoustics.* United Kingdom: McGraw Hill.

[19]. Riedel, S. (2014). *Acoustic Challenges in Worship Space Design.* Yale Institute of Sacred Music, Music. Wisconsin, USA: Yale Publishers, 409 Prospect street, New Heaven.

[20]. Acoustic Society of America. (2013). *Acoustics Appendix*. Retrieved November 12th, 2019, from PACS Regular Edition: https://cpb.iphy.ac.cn/Regular-Edition.pdf

[21]. Encyclopedia Britannica. (2023). *Acoustics.* Bemingham, United Kingdom: The Britannica Group.

[22]. Designing Building Wiki - The Construction Industry Knowledge base. (2017). *Building Acoustics.* United Kingdom: Designing Buildings Ltd.

[23]. Hallstrom, C. (2020, February 23). *How to design healthier buildings*. Retrieved from Alpin: http:www.alpine.com

[24]. Oniku, S. A., & Bello, T. A. (2011). A Review of Acoustic Consideration in Public and Multifunctional Building Design. *FUTY Journal of the Environment* (ISSN: 1597-8826), 104-109.

[25]. Tamas-Gavrea, D.-R., Munteanu, C., Fernea, R., Babota, F., & Muresan, L. (2018). Study on The Acoustic Rehabilitation of a Church. *11th International Conference Interdisciplinarity in Engineering* (pp. 384-391). Cluj-Napoca România: Elsevier Procedia Manufacturing.

[26]. Ampel, F. (2017). *Intelligibility and Acoustics Part 2: Speech Vs Music*. USA: Rave Pubs Publication.

[27]. Deshpande, S. S., Patil, S. N., & Gupta, A. K. (2010). Acoustics - Essentials Requirement for Public Buildings. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)* , 25-28.

[28]. Integration Illuminated. (2023). *Seven Types of Acoustics Treatments.* 2900 Canby Street, Harrisburg: www.integrationilluminated.org.

[29]. NTI. (2017). *Speech Intelligibility: Measurement with XL2 Analyzer*. Australia: NTI Audio.

[30]. Robinson, G. S., & Casali, J. G. (2003). Speech Communication and Signal Detection in Noise. (E. H. Berger, & J. D. L. H. Royster, Eds.) *The Noise Manual.*

[31]. Wijngaarden, S. V., Verhave, J., & Steeneken, H. (2012). *The Speech Transmission Index after four decades of development.* Netherland: Embedded Acoustics.

[32]. BS EN 60268-16. (2011). *Sound System Equipment.* United Kingdom: British Standard.

[33]. Wijngaarden, S. V., & Verhave, J. (2014). *Speech Intelligibility Measurements in practice: Obtaining accurate and reliable data using STIPA tools.* Molengraaffsingel, Netherlands: Embedded Acoustics White Paper.

[34]. Oxford Languages. (2021). *Oxford Languages and Google.* United Kingdom: Oxford University Press.

[35]. Sharma, V. (2017). *Auditorium Design: Literature Study and Design Consideration.* Slide Share.

[36]. Theatre Trust. (2021). *What are the Types of Theatre Stages and Auditoria*. United Kingdom: Theatre Trust.

[37]. Gjestland, R. (2020). *How to Design a Cinema Auditorium.* Norway: UNIC Publishers.

[38]. Moran, M. (2014). *Designing for Intelligibility vs Audibility*. 273 Branchport Avenue, Longbranch, USA: Cooper Notification Solutions.

[39]. Berg, R. E. (2016, December 29th). *Acoustics.* Retrieved June 16th, 2017, from Encyclopaedia Britannica: http//:www.sciencedaily.com

[40]. Abdou, A. A. (2003). Comparison of the Acoustical Performance of Mosques Geometry Using Computer Model Studies. *Eight International IBPSA Conference,*. Eindhoven, Netherlands.

[41]. Lee, S. (2003). *Comparative Analysis of Speech Intelligibility in Church Acoustics using Computer Modeling.* University of Florida, Architectural Studies, USA.

[42]. Noxon, A. (2001). *Understanding Church Acoustics: A Guide to Better Church Acoustics.* 5th Avenue, Eugene, USA.: Acoustic Science Corporation.