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# SIMULATION OF ACOUSTICALLY DEMANDING SPACE BY USING ODEON SOFTWARE

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## ABSTRACT

In the designing of an acoustic room or other acoustically demanding spaces such as concert hall, community hall and classroom, it is essential to have the sound is distributed equally to all part of the room. Conventionally, the calculation of acoustic room model is done manually by inserting vertices and surfaces one by one from the sound source respect to the model room which is the process is time consuming. This project proposes the way of modelling the room acoustics prediction by using MATLAB to meet the specification of acoustically demanding space. First, the 3D model of the room or halls is being created in SketchUp and the file will analyse using Odeon. In the same time, calculation will be done by using MATLAB. Subsequently, by using Odeon software, the calculation can be proven, thus the sound propagation can be simulated from any part of the room or halls easily than before to modelling the acoustically demanding space. Thus, the room acoustics prediction can be done accurately and the optimum room for audio demanding space can be created.

**Keywords:** acoustic room, odeon, sound propagation.

## INTRODUCTION

Nowadays, human are exposed to many type of sounds from low frequency such as animal infrasound to the high frequency one such as in construction site. Humans are gifted by one pair of ears which will be used until the end of the life. Thus, creating a safe and convenient place for safe hearing range is important either in auditorium, hall or even workplace. Based on the IFC Environmental Guidelines for Occupational Safety and Health Administration (OSHA) had outlined the permissible noise exposure time which is 85dB for heavy industries (Hussin, 2012). Take note that, prolonged exposure to this noise will lead to hearing loss over time. The environmental factors in office such as noise, lighting, temperature, and existence of windows could influence employee attitudes, behaviors, satisfaction and performance. Recent studies conducted by Universiti Malaysia Pahang (UMP) students in automotive industry found out that the calculated value of sound pressure is 88.16 dB which is higher than the standard value that is permissible, 85db (Ismail, *et al.* 2012). Also, creating a convenient room for acoustically demanding space such as concert hall or even the meeting room are required in order to increase the quality of the sound throughout the room. A good concert hall or meeting room are achieved if all the audience or members could hear what the performers or their leaders trying to convey whether they sit in the front seat or at the back. A best surrounding in the lecture hall or classrooms lies between 35db to 40db, meeting room (45dB) and for large auditoriums which can occupy more than 500 seats is 30dB-35dB (Asfandyar, 2013). Take note that acoustic demand space are differently, which is depending on the activity and type of room and the people inside it. Therefore, a good sound will spread all over the room without any problem. In addition, there are so many benefits of creating a good sound environment in such places. A good communication may increase the engagement between the speakers and the listeners as the quiet sound environment provide clearer listening within the room. Management can be ease as the acoustic space may assisting in the way of helping the speakers to identify where a sound is coming from among the speakers if a discussion take place. Furthermore, clear directivity of sound will discourages the listeners to disrupting the place with talks among them. Meeting or performing will become more effective as all the listeners seem to focus more on what the people in front trying to say. The drawback can be described as the custom room design of acoustically demanding space might be expensive. A huge room often have many problems such as standing waves, nodes and large amount of reflection which these require a lot of treatment to be rectified. The large size of walls in larger space means that more acoustic treatment is required. Also, the surface material of a room might come with disadvantages too. Wood is known to be an ideal material for absorbing sound because it can prevents echo and noise by absorbing sound. Wood thus extensively used in concert halls but over time, wood could be shrinkage and swelling as it is a hygroscopic material. Fungi might grow too as the favorable temperature is between 25-30$^{o}$C while the room temperature is lies on 27$^{o}$C.

Therefore, this project is being worked on how to solve the problem of creating good acoustic space based on its major criteria. Currently there are so many techniques on modelling the acoustic demanding space from using the manual calculation to the highly accurate prediction models and it is been developing over the last decades.

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## LITERATURE REVIEW

### Properties of acoustic room

Properties of acoustic room can be easily change by changing the area of the room, number of surfaces, absorption coefficients of the surface material which will affect the reverberation time and decay rate.

### Absorption coefficient

Sound do travel in wave form. The question is, how far material light of a particular wavelength can travel before it is being absorbed. This is measured by using absorption coefficient. Material with high absorption coefficient will absorb as much as the energy that it could thus it is not good for developing acoustic room because the sound will be diminish early before its even reach at the end of the room. Absorption coefficient in acoustics often refers to the materials that are able to absorb the sound in the room. It can be defined as in (1) (ASTM E1050),

$$\alpha = 1 - \frac{I_R}{I_I} \quad (1)$$

α = sound absorption coefficient
$I_R$ = one-sided intensity of the reflected sound
$I_I$ = one-sided intensity of the incident sound

To make things easier, absorption coefficients of the material that are being used in our daily life had been recorded. Some of it can be seen in the Figure-1.

### Reverberation time

Reverberation can be defined as the persistence of found in enclosed space as a result of multiple reflection or scattering of the sound after the source had stopped. Once sound wave hits a surface, some of it are being reflected to another surface while some of it will reflect. Gradually, the sound energy will be reduced over time until the sound is no longer can be heard. Standard reverberation time had been defined as the time taken for the sound pressure level to diminish below 60dB of its original value from the source (Rindel, 2000). Approximate reverberation time can be calculated by using Sabine Formula, as in (2)

$$RT_{60} = \left(0.161\frac{s}{m}\right)\frac{V}{S_e} = \left(0.049\ s/ft\right)\frac{V}{S_e} \quad (2)$$

$V$ = volume of the enclosure
$S_e$ = effective absorbing area = $a_1S_1 + a_2S_2 + a_3S_3 + \ldots$

### Past research

This part is discussing some of those previous studies and research which are based on journals, conferences and book which are related to the studies of hybrid methods in simulation of acoustically demanding space by using Odeon Software. This might help when it comes to give ideas and techniques that are need to be done better and effectively in the future to complete this project successfully. Several interesting research are listed as in Table-1.

| Materials | Coefficients | | | | | |
|---|---|---|---|---|---|---|
| | 125Hz | 250Hz | 500Hz | 1000Hz | 2000Hz | 4000Hz |
| Brick, unglazed | .03 | .03 | .03 | .04 | .05 | .07 |
| Brick, unglazed, painted | .01 | .01 | .02 | .02 | .02 | .03 |
| Carpet, heavy, on concrete | .02 | .06 | .14 | .37 | .60 | .65 |
| Same, on 40oz hairfelt or foam rubber | .08 | .24 | .57 | .69 | .71 | .73 |
| Same, with impermeable latex backing on 40oz hairfelt or foam rubber | .08 | .27 | .39 | .34 | .48 | .63 |
| Concrete Block, light, porous | .36 | .44 | .31 | .29 | .39 | .25 |
| Concrete Block, dense, painted | .10 | .05 | .06 | .07 | .09 | .08 |

**Figure-1.** Absorption coefficient.

**Table-1.** Previous research outcome.

| Author, Year | Institute | Research outcome |
|---|---|---|
| Jens Holger Rindel (2011) | Technical University of Denmark | Studying echo problems in ancient theaters such as Aspendos by using Odeon Software |
| Jelle, V.M, Stephen, O., Aglaia, F., Damian, T.M., (2014) | University of York, United Kingdom | Hybrid acoustic modelling of historic space by using Blender |
| Gino Iannace, Luigi Maffei, Patrizia Trematerra, (2011) | Second University of Naples, Aversa, Italy | Study of acoustic evolution of the large theatre of Pompeii before and after reconstruction by using Odeon |
| Gino Iannace, Patrizia Trematerra, Ahmad Qandil, (2013) | Second University of Naples, Aversa, Italy ; Philadelphia University, Amman, Jordan | Studying about the acoustic correction of classrooms in historical buildings with numerical simulation by using Odeon. |

## METHODOLOGY

### Data collection

Type of material surfaces of the room are taken by using digital single-lens reflex (DSLR) camera. Figure-2 shows the flow chart of the project. Hundreds images of surfaces are captured at different locations in the room to improve the accuracy of the system. Also, the location of the camera to the material surface is be fixed at a certain distance and the settings of the camera is not being changed.

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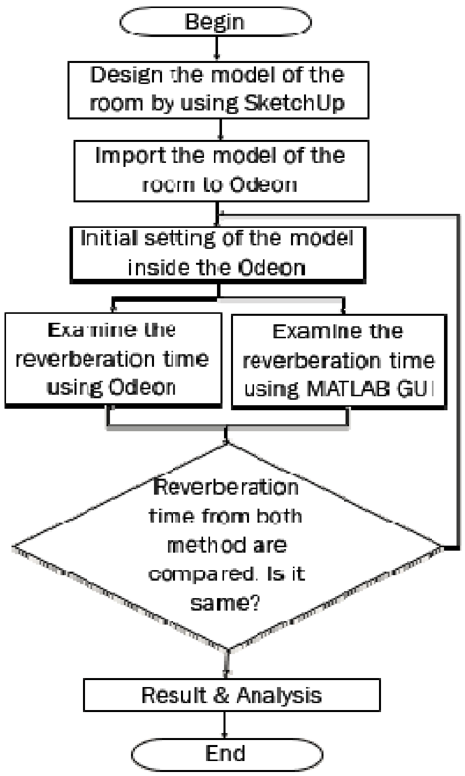


**Figure-2.** Flowchart of the project.

**Reverberation time**

Reverberation time value have be taken into account as this is the main focus of this project. By using Odeon, estimated reverberation time and global estimation can be obtained. The output then will be proven mathematically by using Matlab in which the method will be discussed later in this paper.

**Absorption coefficient**

Absorption coefficient value are being taken respectively to the material that involves in the room. From GLCM, the texture can be identified thus the correct absorption coefficient can be taken thus the data can be analyzed from the image itself. RGB to Grey Image by using MATLAB command and Grey Level Co-Occurrence Matrices (GLCM) are the two methods that have be used in tabulation of data on how often different combinations of pixel brightness vales occur in an image (Mahamad, *et al.* 2014), (Zainudin, *et al.* 2014).

**Odeon software**

Odeon is being used to get the Reverberation Time, $RT_{60}$ of the acoustically demanding space. Also, Odeon is also be used to get the value of the absorption coefficient inside the acoustic room. From the acoustically demanding space that had been modelled earlier, the model can be imported to the Odeon Software by using licensed software provided by the University Tun Hussein Onn Malaysia

**RESULTS AND ANALYSIS OF DATA**

At the end of this research, the method that had been proposed is expected to be able to develop an acoustically demanding space which will deliver a good sound environment thus creating the best and convenient space. Also, the hybrid methods used in Odeon software hopefully will contribute to a great and accurate result compared to other old methods that have been practice since before.

**Sketchup**

Using Sketchup, the model of an acoustic room can be modelled in which will be imported to the Odeon Software to be analyzed. The dimension that had been used is taken from the tutorial room in UTHM library, with adjustment to the nearest decimals in order to perform the calculation easier. Figure-3 shows the model that had been sketch in earlier phase of this project. The dimensions of this model are setup as follows:

Height : 3 meters
Length : 13 meters (Longer Side), 12 meters (Shorter side), 1 meters (Shortest side)
Width : 7 meters (Longer Side), 4.8 meters (Shorter side), 2.2 meters (Shortest side)

The acoustic room that had been modelled is then being imported to the Odeon by using Odeon plugin for Sketchup. Par files is created which then can be used for simulation purpose. Next, all the surface material will be assigned to each of the surface inside the model room which are ceiling, floor and wall. A sound source will be put inside the room alongside with the receiver.

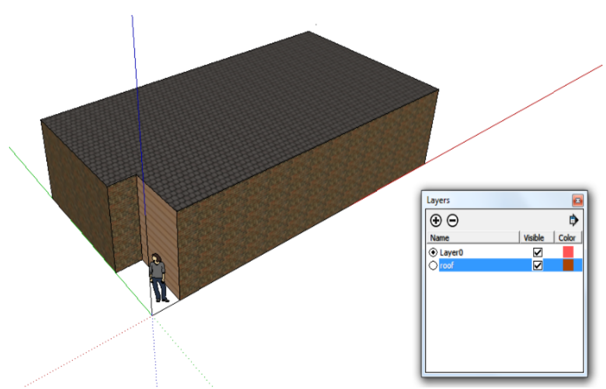

**Figure-3.** Example of acoustic room model (with ceiling).

**Simulation comparison: ODEON and MATLAB**

From input data, quick estimation of reverberation can be analyse using Odeon as shown as in Figure-4. Take note the reverberation time of Sabine theory by using 63Hz of frequency as the time are being compared later in the process of verification.

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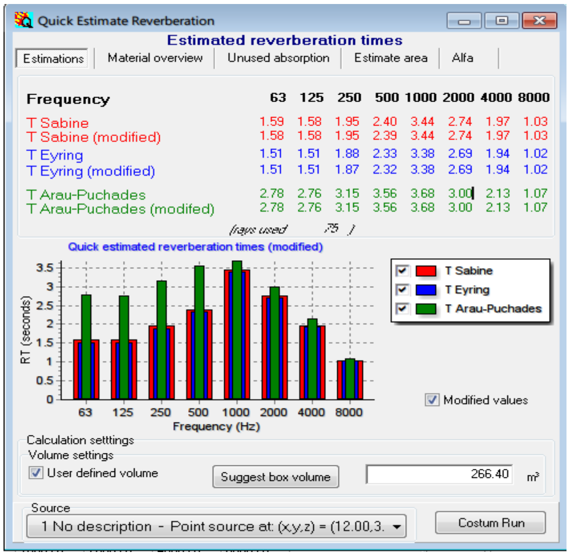


**Figure-4.** Quick estimation of reverberation time inside odeon.

The material surface which had been predefined inside the Odeon alongside with its absorption coefficient can be selected at the initial setup of the room before the simulation of the acoustic room been carried out. From the Figure-4, it is clearly stated that the reverberation time of the acoustic room with respect to the frequency used inside it. Sabine theory is taken into account here as it is the theory that are the main calculation that used in this project.

Table-2 shows the frequency used and its corresponding reverberation time inside the Odeon. This table will be used to ease the comparison later.

GUI that had been programmed then is being used to verify the calculation of the reverberation time by using Sabine theory as in (2).

**Table-2.** Frequency and reverberation time inside the Odeon.

| Frequency (Hz) | Reverberation Time |
|---|---|
| 63 | 1.59 |
| 125 | 1.58 |
| 250 | 1.95 |
| 500 | 2.40 |
| 1000 | 3.44 |
| 2000 | 2.75 |
| 4000 | 1.97 |

From Figure-5, verification then are being done manually by using calculator to compare whether the system is developed successfully or not when are being compared to the one in Odeon. In this calculation, only the frequency of 63Hz are being used for the verification purpose as same calculation is applied across all the frequencies. Based on (2), the dimension of the room is recorded as:

Volume of the room: (12x7x3) + (4.8x1x3) = 266.4 m$^3$.

Table-3 shows the surface area of the model of the room used. Meanwhile, Table-4 shows the calculation to get the total absorbing area inside the room. The value of absorption coefficient is taken out directly from the Odeon Software based on the material list selected inside the room.

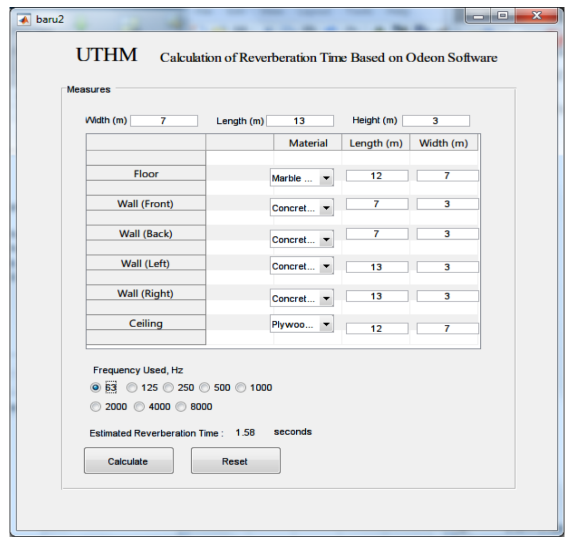


**Figure-5.** GUI display after the calculation had being made.

**Table-3.** Surface area of the room.

| Surface of the room | Area ($m^2$) |
|---|---|
| Floor | (12x7)+(4.8x1) = 88.8 $m^2$ |
| Front side | 7x3 = 21 $m^2$ |
| Back side | (4.8x3)+(2.2x3) = 21 $m^2$ |
| Left side | 13x3 = 39 $m^2$ |
| Right Side | (12x3)+(1x3) = 39 $m^2$ |
| Ceiling | (12x7)+(4.8x1) = 88.8 $m^2$ |

$$RT_{60} = \left(0.16\frac{s}{m}\right)\frac{V}{S_c} = 1.58 \text{ seconds}$$

In addition, inside the Odeon, air absorption are taken into account here. Table-5 shows the air absorption value in m$^2$ Sabine through the Odeon in order to verify the accuracy of the system calculation using the Matlab GUI as the system programmed is not taken the air absorption value into its computation.

Using the value of air absorption from Table-5, Table-6 shows the comparison of the reverberation time inside the simulation of the Odeon and the system programmed inside the Matlab GUI. Steps used are same as in (2).

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**Table-4.** Total absorbing area inside the room.

| Material surface inside the room | Area ($m^2$) | Absorption Coefficient at 63Hz ($\alpha$) | Effective Absorbing Area (Area*$\alpha$ = $S_e$) |
|---|---|---|---|
| Floor – Marble or glazed title (Harris, 1991) | 88.8 | 0.01 | 0.89 |
| Front side - Smooth concrete, painted or glazed (Bobran, 1973) | 21 | 0.01 | 0.21 |
| Back side - Smooth concrete, painted or glazed (Bobran, 1973) | 21 | 0.01 | 0.21 |
| Left side - Smooth concrete, painted or glazed (Bobran, 1973) | 39 | 0.01 | 0.39 |
| Right Side - Smooth concrete, painted or glazed (Bobran, 1973) | 39 | 0.01 | 0.39 |
| Ceiling – Plywood paneling, 1 cm thick (Harris, 1991) | 88.8 | 0.28 | 24.87 |
| Total Absorbing Area (*$m^2$ sabine*) | | | 26.96 = 27 |

**Table-5.** Air Absorption inside the room.

| Frequency (Hz) | Air Absorption (Sabine) |
|---|---|
| 63 | 0.0 |
| 125 | 0.1 |
| 250 | 0.3 |
| 500 | 0.7 |
| 1000 | 1.2 |
| 2000 | 2.6 |
| 4000 | 7.8 |
| 8000 | 27.6 |

**Table-6.** Comparison of reverberation time inside the Odeon and the Matlab GUI.

| Frequency (Hz) | RT60 (s) MATLAB | RT60 (s) ODEON |
|---|---|---|
| 63 | 1.58 | 1.59 |
| 125 | 1.57 | 1.58 |
| 250 | 1.95 | 1.95 |
| 500 | 2.38 | 2.40 |
| 1000 | 3.41 | 3.44 |
| 2000 | 2.71 | 2.75 |
| 4000 | 1.96 | 1.97 |
| 8000 | 1.02 | 1.03 |

By comparing the GUI that was programmed before alongside with the mathematically verification through the calculation with the one simulated in the Odeon, it shows that the value of the reverberation time is same, which is around 1.58-1.59 seconds. There might be a milliseconds different due to decimal point taken during the calculation. Last but not least, this program are easier to be used and the process of determining reverberation time is faster than in Odeon. Thus, the objectives of this project is achieved as the theory is mathematically proven by using Matlab GUI.

As shown on result above, the reverberation time of an acoustically demanding space can be obtained by simulation inside the Odeon. Also, the material surface and its absorption coefficient can be selected at the initial setup of the room before the simulation of the acoustic room been carried out. This project can be divided into 3 phases. Phase 1 is the simulation of the acoustic room inside the Odeon while Phase 2 is on proving the simulation provided by the Odeon by using Matlab calculation and GUI. Phase 3 is comparison of simulation of the result inside the Odeon and simulation of the result of the acoustically demanding space by using Matlab GUI.

## CONCLUSIONS

As a conclusion, an acoustically demanding space had been successfully designed by using SketchUp with respect to the original measurement of height, width and the area of space. Also, the room that had been modelled was developed inside the Odeon Software. Lastly, the parameters of the acoustically demanding space can be proven by using Matlab. Formulation of reverberation time and absorption coefficient are being used in order to prove the accuracy of the result of simulation provided by the Odeon inside the MATLAB program. A graphical-user interface were built in which can be used to calculate the reverberation time of an acoustically demanding space. Thus, the objectives of this project had been achieved.

## ACKNOWLEDGEMENTS

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