ARC3413: BUILDING SCIENCE 2

PROJECT 1: LIGHTING AND ACOUSTIC PERFORMANCE EVALUATION AND DESIGN

KL TZU-CHI JING-SI HALL: THE BOOK CAFÉ

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Abstract

The lighting and acoustic qualities of a building play a very significant role in the user experience of a piece of architecture. The amount of both daylight and artificial light can affect the amount of energy required to sustain the building, as well as creating a desirable ambience within the space. On the other hand, the acoustic qualities impacts and pinpoints what the user hears in the space. Both these qualities contribute greatly to the poetics and the usability of the space.

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1.0 Introduction

As part of the syllabus of ARC3413: Building Science 2 in Taylor's University, students were to study the lighting and acoustic qualities of a chosen space in a building that fits the Green Building Index (GBI) criteria.

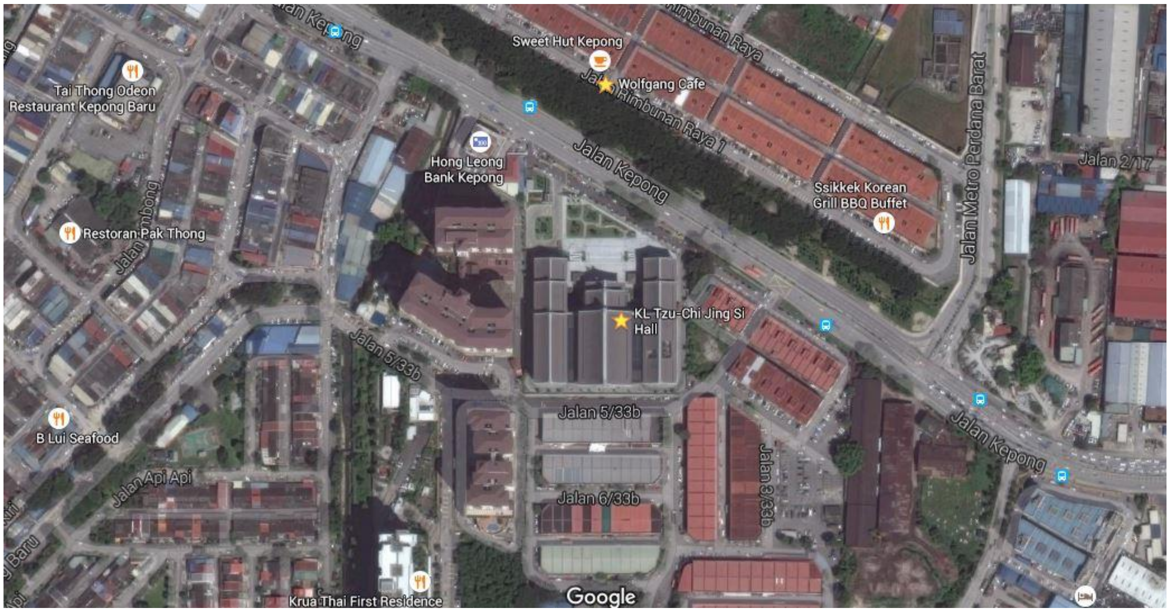
1.1 Aim and Objective

The aim of this project is to understand the daylighting & lighting and acoustic characteristics & acoustic requirement in a suggested space, to determine the characteristics and function of day-lighting & artificial lighting and sound & acoustic within the intended space and to critically report and analyze the space.

From this project, students will be able to produce a complete documentation on analysis of space in relation to lighting requirement e.g. natural and artificial lighting. (Pictures, sketches and drawing) and analysis of factors which effects the lighting design of a space. Students will also learn to explore and apply understanding of building physic eg. Lighting towards building / construction technology and building materials on existing building projects, and to evaluate and explore the improvisation by using current material and technology in relevance to present construction industry. They will develop a basic understanding and analysis of lighting layout and arrangements by using certain methods or calculations eg. Lumen method and PSALI, and understand of the analysis of acoustic design layout and arrangements by using certain methods or calculations e.g. reverberation time and sound transmission coefficient.

1.2 Site Study

The site that this group has chosen is the KL Tzi-Chi Jing-Si Hall, located in Kepong, Selangor, Malaysia.



Picture 1.2: Site Plan

1.2.1 Introduction of KL Tzu-Chi Jing-Si Hall

The Tzu-Chi Foundation Malaysia originated from Taiwan, and closely follows the teachings of Dharma Master Cheng Yen. Born in 1937 in Qingshui, Master Cheng Yen has had an international influence, despite never having travelled out of Taiwan. The KL sector was introduced in 1995, and expanded very quickly, and moved into its current premises in 2004.

Located in Kepong, Kuala Lumpur, the KL Tzu-Chi Jing-Si Hall is an understated magnificent piece of architecture. In 2015, the building is still undergoing the finishing touches of its construction. Designed to fit perfectly into its site, the KL Tzu-Chi Jing-Si Hall is very eco-friendly. From design strategies including large louvres for windows and high ceilings to cool the interior, to skylights and a solid integration between indoor and outdoor for natural lighting, the structure consumes little energy.

The openness of the structure leaves it vulnerable to the city sounds of cars and people passing by outside, but holds greater benefits with great natural lighting and natural cooling.

1.2.2 Selection Criteria

The group of students chose to focus on the Jing-Si Book Cafe, due to accessibility. Activities are constantly occurring throughout the building, and so to avoid interference with their work, the students chose a space that would disturb less people.

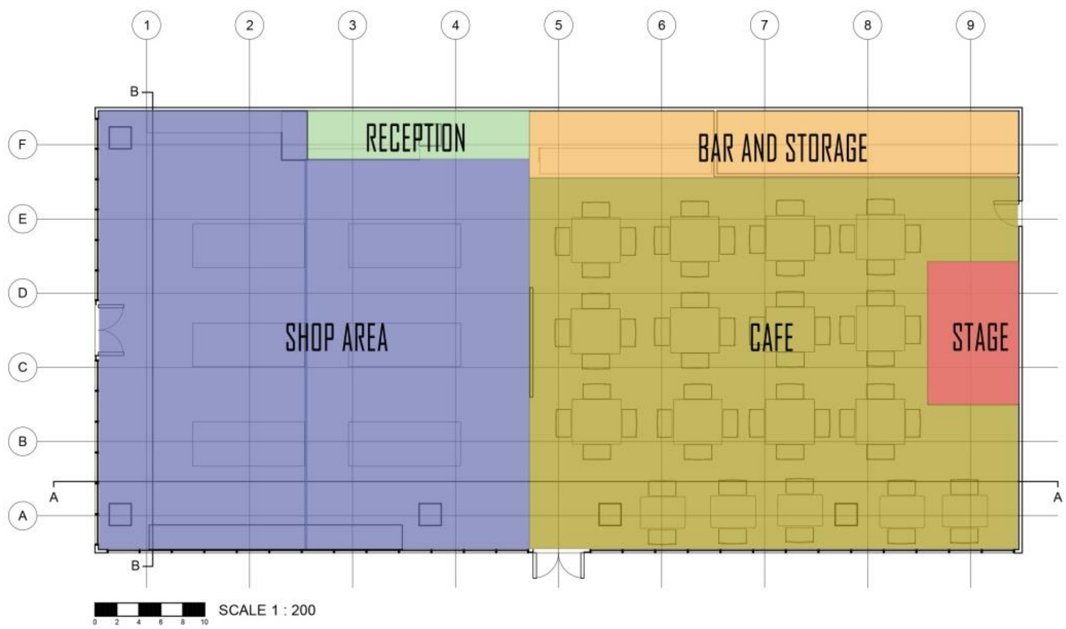
The cafe opens two of its four walls up for natural daylighting, with wall sized windows to allow not only natural lighting, but also great views for the visitors in the cafe.

Along with the sound of people chatting and having tea, the cafe also has music playing over the speakers for its visitors.

1.2.3 Architectural Drawings

The drawings of the cafe are not official, and have been drawn by a student who has visited the cafe and measured it by hand. Note that it is subject to human error.

1.2.4 Zoning



Zone 1: Shop Area

Zone 2: Reception

Zone 3: Bar and Storage

Zone 4: Café Seating Area

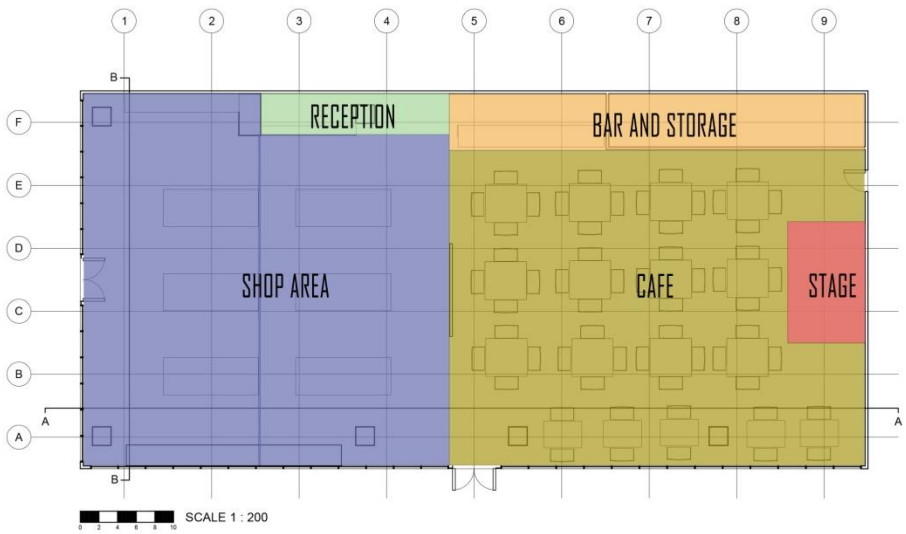
Zone 5: Stage

2.0 Methodology

2.1 Lighting Data Collection Method

The floor plan of the book cafe is drawn with grids to produce with a maximum of 50 intersecting points. A group member then stands at each intersecting point with the LUX meter and another group member will record the data from the LUX meter.

The LUX meter is placed at both 150 meters and 100 meters above the ground at the corresponding intersecting points on the cafe.



2.1.1 Lighting Data Collection Equipment

1. LUX Meter: LX-101

Picture 2.1.1: LUX Meter

2. Camera

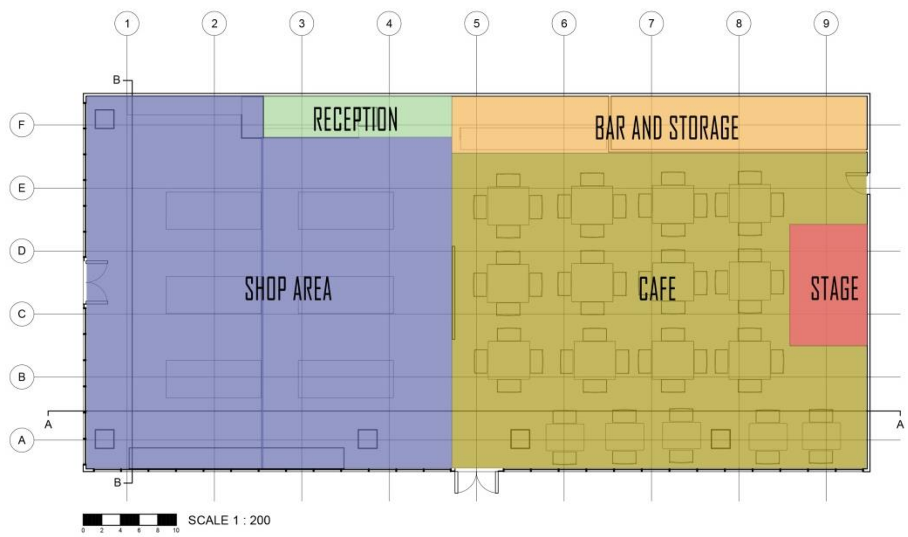
The camera is used to capture the sources of noise.

3. Measuring tape

The measuring tape is used to measure the height of which the lux meter should be placed when measuring. The height required is 1.5 meters. The measuring tape was also used to measure the area of our boundaries.

2.2 Acoustics Data Collection Method

Firstly we identified the grid line of 2m x 2m within the site's floor plan for data collecting position. We obtain data with sound level meter (dB), by placing the device at the designated position with the height of 1.5m. We waited until stable surrounding, and record the data reading on light meter. We then identified data whether is it logical or not by observing site condition and noise source position. After that, we tabulated the data collected. Lastly, we calculate and process the data and determine the acoustic quality according to Chartered Institution of Building Services Engineers (CIBSE) standard.



2.2.1 Acoustics Data Collection Equipment

1. Sound Level Meter

Picture 2.1.2: Digital Sound Level Meter

Standard Reference	IEC 804 and IEC 651
Measurement Range	60-120 dBA; 30-90 dBA
Lp Measurement	Fast
Linearity	$\pm$1.5 dB
Overload	from 93 dB and 123 dB Peak
Battery	9V 6LR61/PP3 type
CE Marking	13727

2. Camera

The camera is used to capture the sources of noise.

3. Measuring tape

The measuring tape is used to measure the height of which the lux meter should be placed when measuring. The height required is 1.5 meters. The measuring tape was also used to measure the area of our boundaries.

2.3 Limitations

As the cafe is a public space, and recording was taken during its opening hours (during peak and non-peak hours for acoustics, and day and night for lighting) it was not possible to measure out the space exactly. Plans were not provided by the KL Tzu-Chi Jing-Si Hall, and were only roughly sketched out roughly measured by the group members. Therefore the accuracy of the architectural drawings is not high.

For similar reasons, the grid drawn, and the grid which dictates where data collection is taken is also inaccurate and is subjected to human error.

On both the LUX meter and the sound level meter, readings may have fluctuated for both acoustics and lighting. Therefore, group members had to use their own judgement as to what the approximate mean was for each data collection. Data is hence also subjected to human error.

3.0 Precedent Studies

3.1 Lighting Precedent Studies

3.1.1 OJALA Cafe

Picture 3.2.1: Front view of OJALÁ Café (Source: http://www.archdaily.com/621388/ojala-andres-jaque)

Built in 2014, the OJALÁ Café is a café is located in Malsana, Madrid. The architect in charge of designing the café is Andrés Jaque, with the assistance of the Jorge Lopez Conde design team. It has a well-planned lighting system that illuminates natural and artificial lighting throughout the building.

Picture 3.2.2: Location of OJALÁ Café (Source: http://www.archdaily.com/621388/ojala-andres-jaque)

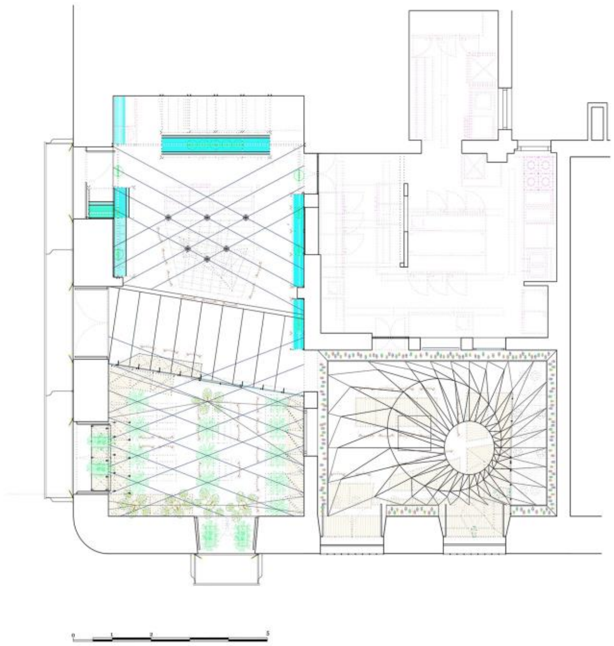


Diagram 3.2.1: Ground Floor Plan (N.T.S) (Source: http://www.archdaily.com/621388/ojala-andres-jaque)

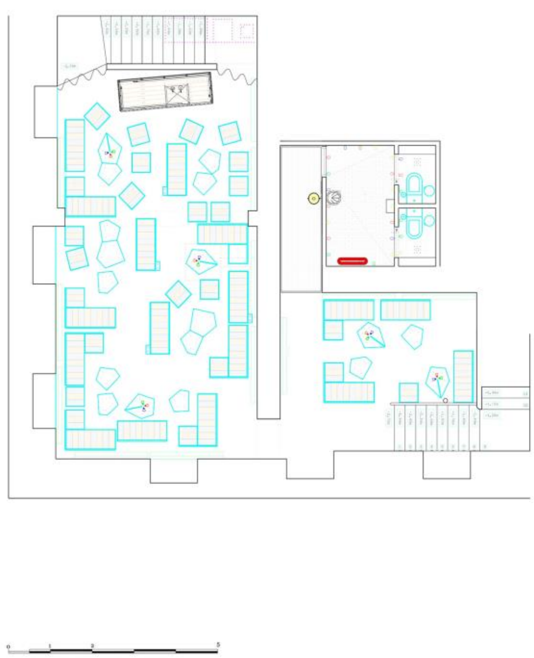


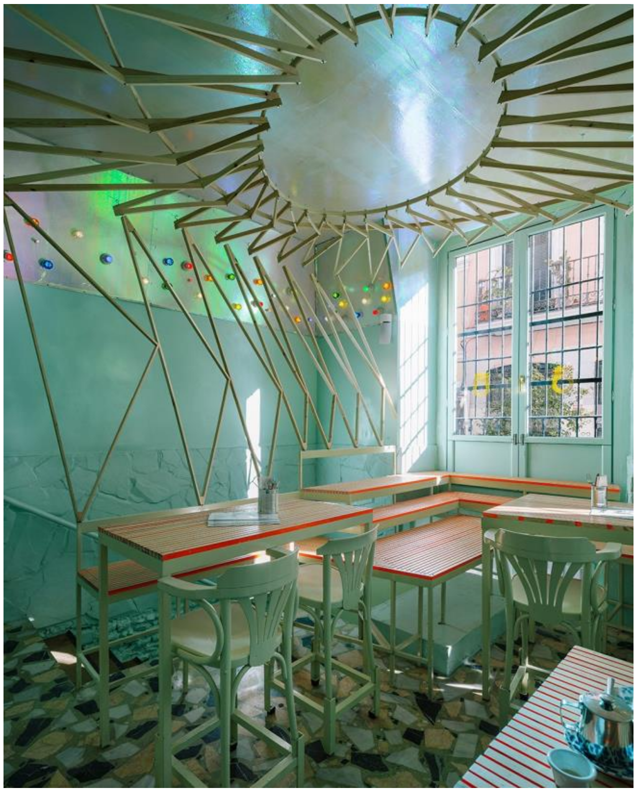
Diagram 3.2.2: First Floor Plan (N.T.S) (Source: http://www.archdaily.com/621388/ojala-andres-jaque)

3.1.2 Design Strategies

The concept of the café from the architect's point of view was that it is an architectural response to the social diversity and community of the locals living in Malasana. A community or a diversity that manifests itself in everyday life as an accumulation of various ways to talk, meet, eat and drink. The design of the café has an indoor and outdoor relation whereby it creates a continuous space where everyone can be establish and be involved to stay aware of each other's action.

In order to maintain such relationship across spatial boundaries, the café has installed number of glass doors, which can be seen in picture 3.3. In addition, picture 3.4 shows that a geometric like glass wall is placed connecting the transition spaces between the eating area and the entrance. Where the geometric glass wall reflects the abundant natural light coming in and creating a luminous natural lighting effect. Therefore, customers can enjoy coffee in café space, while looking outdoor and indoor through glass doors and the geometric glass wall.

Besides, as shown in diagram 3.5, different lighting fixtures are used in different spaces of the café. As seen in picture 3.2.3, coloured halogen bulbs and incandescent bulbs are used within the whole café to create different spatial experiences in each space.



Picture 3.3: Glass doors that connect inside-outside space (Source: http://www.archdaily.com/621388/ojala-andres-jaque)

Picture 3.4: Geometric like glass wall (Source: http://www.archdaily.com/621388/ojala-andres-jaque)

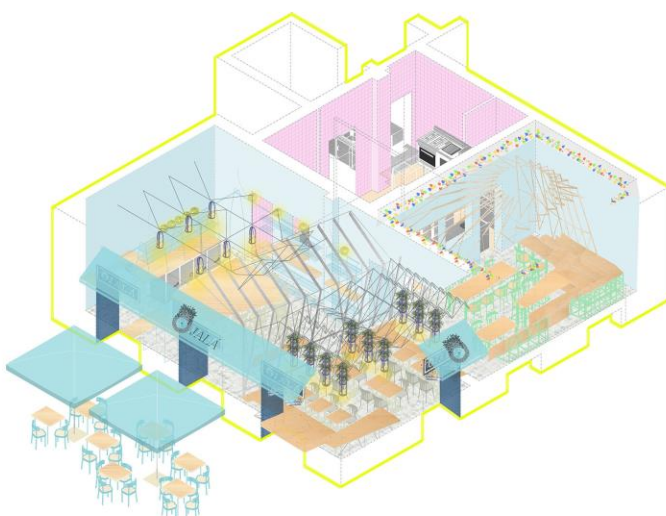


Diagram 3.5: Different lighting fixtures (Source: http://www.archdaily.com/621388/ojala-andres-jaque)

Picture 3.2.3: Geometric like glass wall (Source: http://www.archdaily.com/621388/ojala-andres-jaque)

3.1.3 Existing Lighting Source

Types of Lighting in OJALA Cafe	Wattage (W)	Luminance Efficiency (Lux)	Colour Temperature (K)	Colour Rendering Index (Ra)
 Coloured Halogen Bulbs	28		various	80

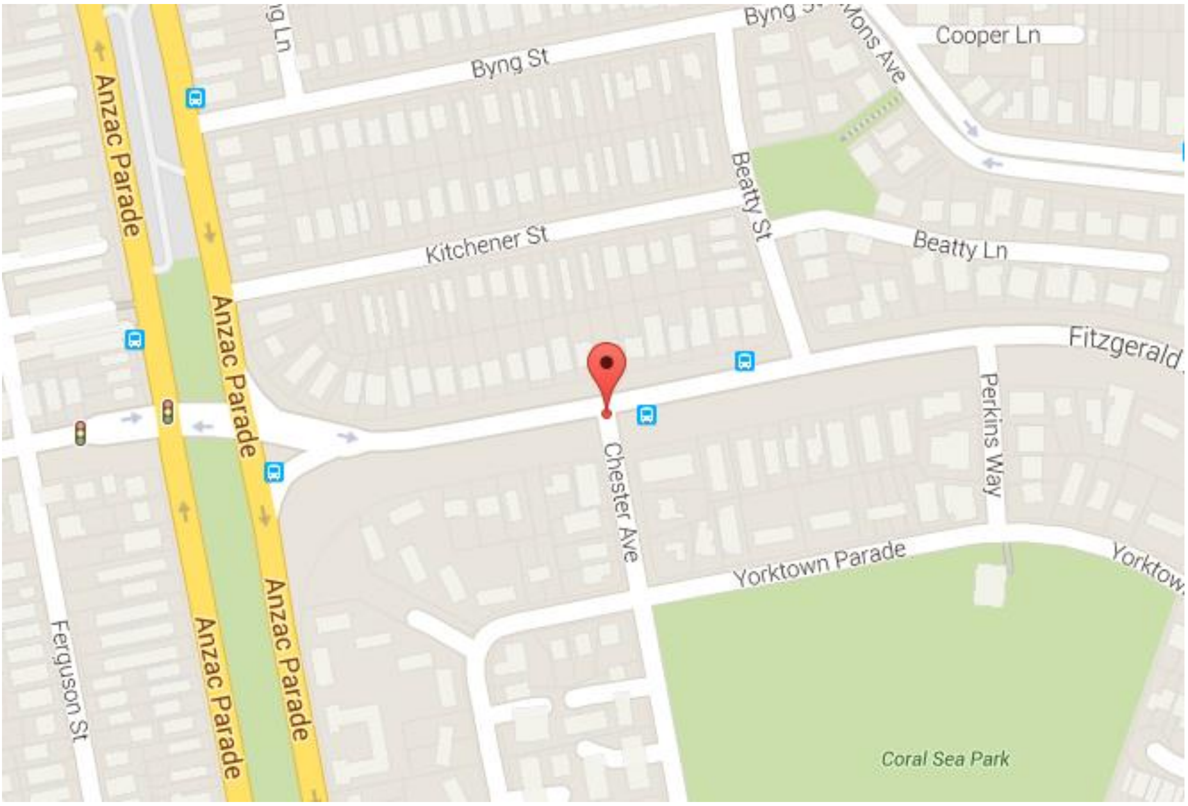
 Incandescent bulbs	40	14 lm/W	2700	82
 LED tube	29.7		3500	82

3.2 Acoustic Precedent Studies

3.2.1 Cave Restaurant by Koichi Takada

Picture 3.2.1.1: The Interior View of Cave Restaurant (Source: http://architectureau.com/articles/ocean-room-and-cave/)

The Cave Restaurant was design by Koichi Takada Architects with the acoustics built in. It is located in Sydney, Australia. Originally, the design theme came from a fact that the architects wanted a restaurant which considered an acoustic as the main focused element. Timber ribs are the main materials used in this restaurant.



Picture 3.2.1.2: The Location of Cave Restaurant (Source: http://www.archdaily.com/56011/cave-restaurant-koichi-takada-architects)

3.2.2 External and Internal Noises

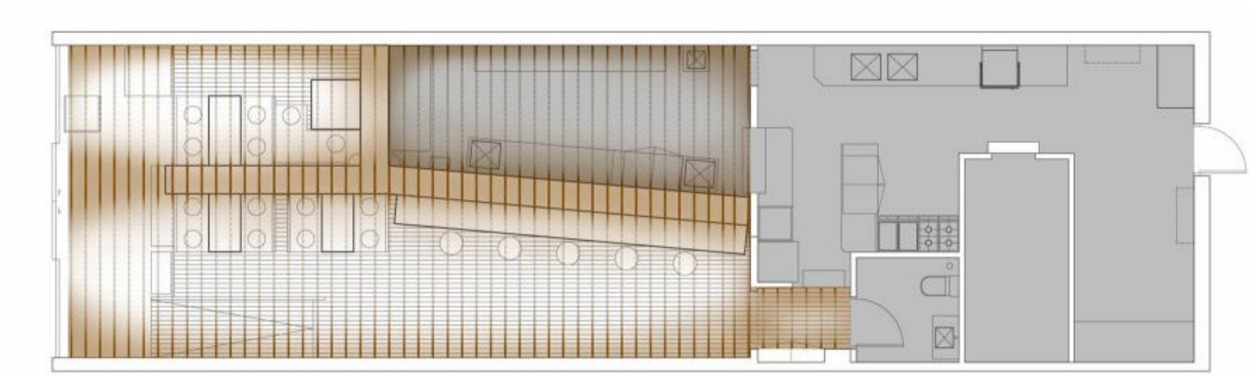
In this case, the timbers were arranged at regular intervals down the length of the space, absorbing sound and promoting a good dining noises as well as acting to divide individual seating into their own acoustical zones.

Once the guests entered this restaurant, they were completely screened off from the noise of the city outside. The timber ribs also mask an existing ventilation duct that runs diagonally across the ceiling. As a result, the restaurant has a unique and appealing layout with a highly intriguing interior. A lovely atmosphere is created from the combination of the timbers' curves.

Picture 3.2.2: The Exterior of the Cave Restaurant

(Source: http://maps.google.com/)

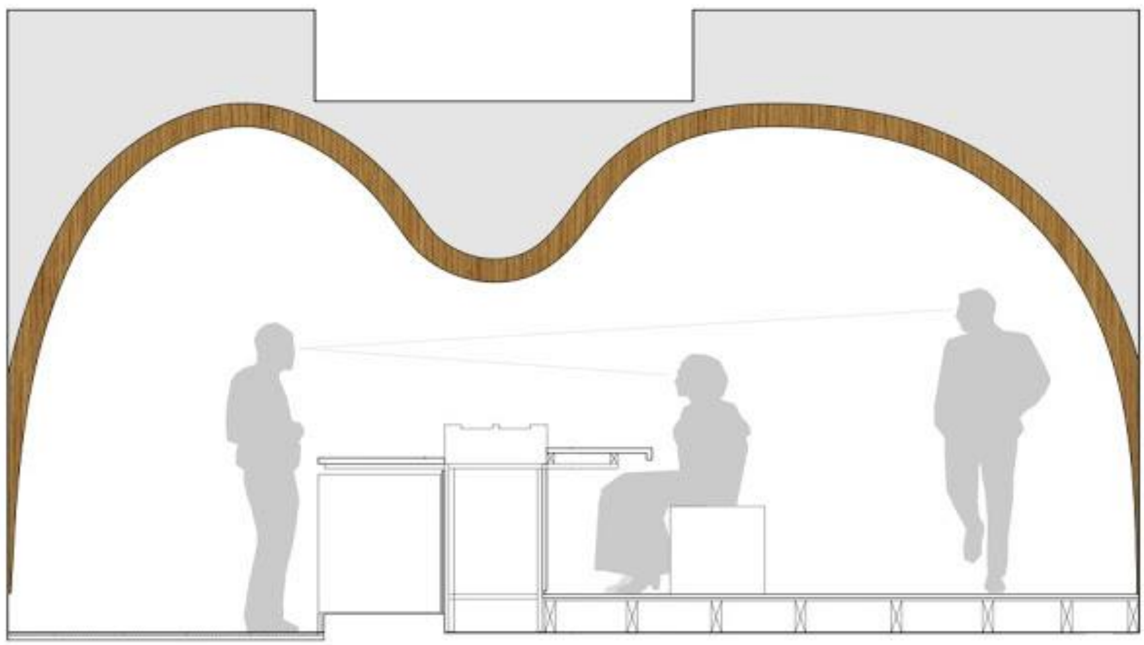
3.2.3 Design Strategies



Picture 3.2.3.1: Acoustic Timber Ceiling Plan of Cave Restaurant (Source: http://housevariety.blogspot.my)

The architects experimented with noise levels in relation to the comfort of dining and the ambiance a cave like environment can be created. Hence, the usage of timbers generates a sound studio atmosphere and a pleasant 'noise' of dining conversation and offered a more comfortable experience as well as a visually interesting and complex surrounding. Several acoustic curvatures were at the basis of this restaurant design, each was constructed with the help of special 3D modeling computer programs and using Computer Numerical Control (CNC) technology.

Picture 3.2.3.2: Sectional View of the Curvature in Cave Restaurant (Source:

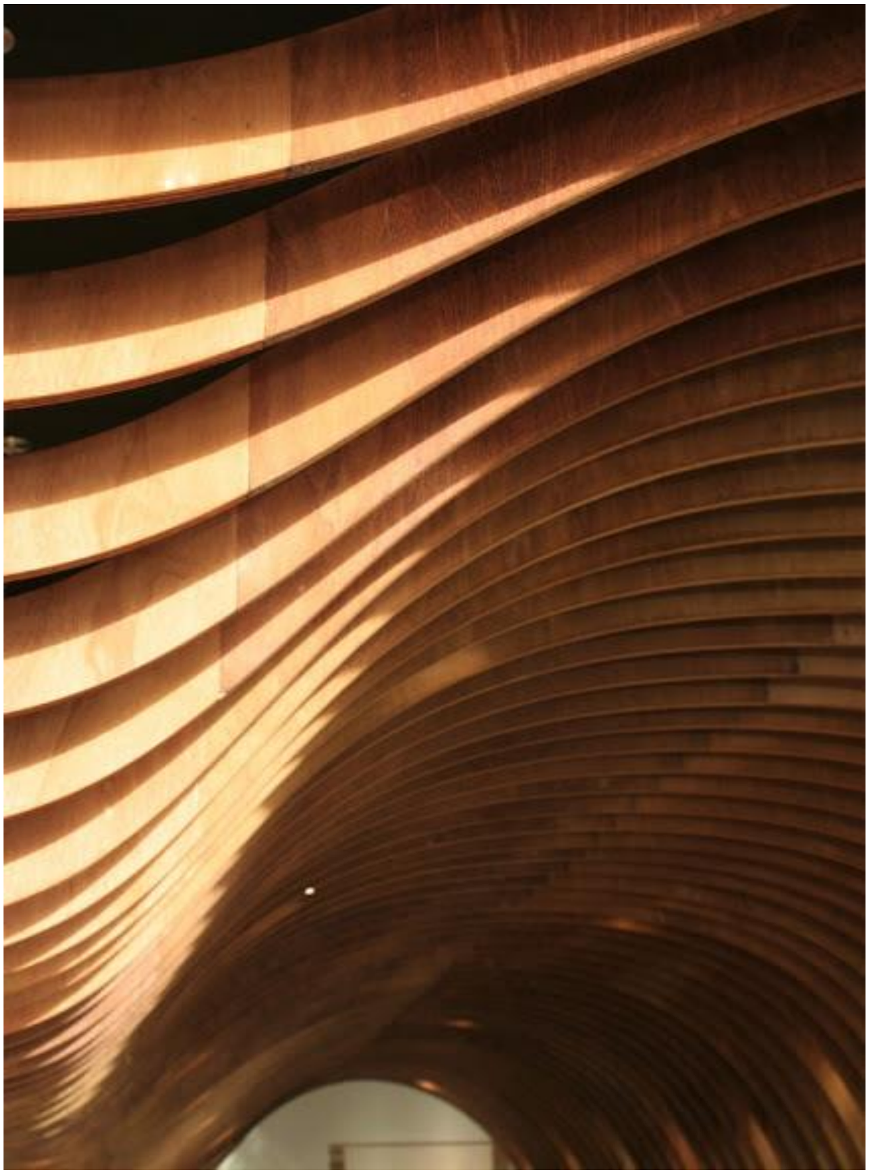


http://housevariety.blogspot.my)

It is to be said that the design of this restaurant works such as when the breeze from the ocean sweeps into the restaurant, the individual dowels become animated as they undulate and clatter in the wind. The sculpture was also intended as a dialogue with the iconic Opera House just across the water.

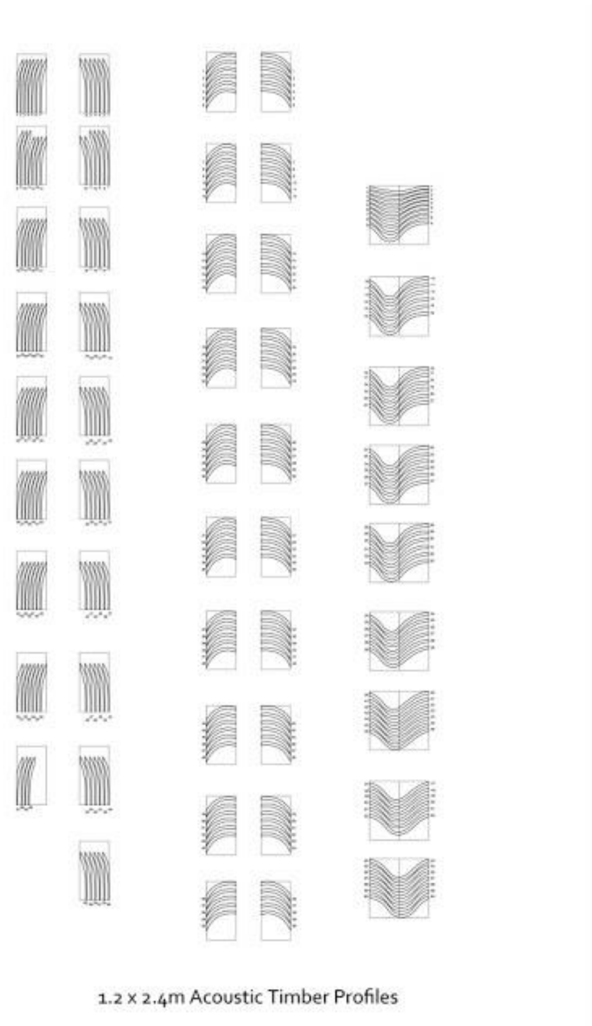
Takada has imbued the Ocean Room interior with luxurious and edgy feel of an inner-city hot spot but with a considered response to the harbour beyond. He has also emulated and enhanced the fine food dining experience through the use of delicate and muted materials. Every design decision revolves around how it would feel to be in the space.

It's an idea that Takada has pushed to the limit in another of his latest projects, a Sushi Train franchise restaurant in Maroubra which he has dubbed "The Cave." "It was my umpteenth restaurant interior for the client," he explains. "I felt that, based on the brief and our history, it was time to push the boundaries. My first instinct was to address the issue of acoustics - most popular establishments are really noisy. It is important to me that my design results in a comfortable and pleasant place to eat."



Picture 3.2.3.3: The Interior's Timbers Arrangement of Cave Restaurant (Source: http://housevariety.blogspot.my)

Through an intensive process of experimentation with various materials and their acoustic properties, Takada generated the idea of a cave-like shape, composed of laminated plywood pieces, forming the walls and ceiling of the space. Each curved shape, a number of biscuit-jointed segments, was then cut using sophisticated three-dimensional programming tools before being manually fitted together on site. The result is astonishing - a muted decibel level, even when the restaurant is at capacity. It’s a similar experience to standing in the Ocean Room where the sound-absorbent qualities of the timber keeps the background buzz to a minimum.



Picture 3.2.3.4: The Arrangements of the Timbers of Cave Restaurant (Source: http://housevariety.blogspot.my)

Aside from an inherent complexity, Takada’s designs are often labour intensive to construct. The Ocean Room required two tonnes of steel and a painstaking labelling and installation process. “We couldn’t do it without the support of our wider team,” explains Takada. “It’s a collaborative experience. As designers we need to translate our three-dimensional concepts into legible construction drawings so that they become realistic constructs. This is critical in ensuring successful projects."

Takada is also passionate about the design process, evident in both schemes. "We often work in section as a way to explore the possibility and viability of our designs," he says. "We document the journey of every job. By doing this, we are constantly aware of our goal - the experience of the end user. It is critical to design for others and not for yourself. What would be the point of that?"

4.0 Literature Review

4.1 Lighting Literature Review

4.1.1 The Color Spectrum

The color spectrum is defined by Merriam-Webster dictionary, as “a continuum of color formed when a beam of white light is dispersed (as by passage through a prism) so that its component wavelengths are arranged in order”.

Colors are the way or brain, by use of our eyes, interprets electromagnetic radiation of a wavelength within the visible spectrum. Visible light must usually lie somewhere in between 400 and 700 nanometers.

Every color is conveyed through a different wavelength, and so a spectrum organizes colors in accordance to the wavelength, and produces a rainbow of colors. Each color varies in lightness and darkness, hue, and saturation, and so on. It is estimated that the naked human eye is able to distinguish about 10 million color variations.

This progression from left to right is by the wavelength; from long wavelength to short wavelength, and from low frequency to high frequency light. The wavelengths are commonly expressed in nanometers (1 nm = 10-9 m). The visible spectrum is roughly from 700 nm (red end) to 400 nm (violet end). The letter I in the sequence above is for indigo - no longer commonly used as a color name. It is included above strictly for the reason of making the sequence easier to say as a mnemonic, like a person's name: Roy G. Biv - a tradition in the discussion of color.

How we perceive light comes through these colors on the spectrum.

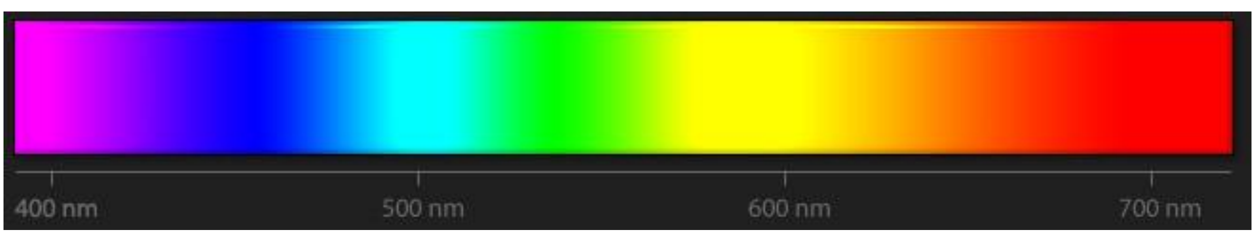


Figure 4.1.1: A color spectrum
(Johansson)

4.1.2 Brightness and Luminance

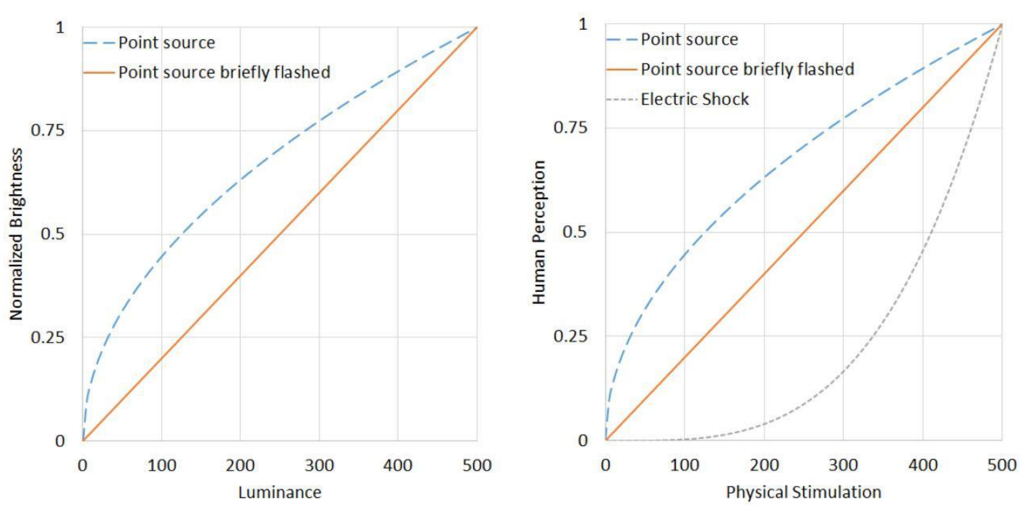
Merriam-Webster’s dictionary defines brightness as the attribute of light-source colors by which emitted light is ordered continuously from light to dark in correlation with its intensity. It refers to our subjective perception of how bright an object is. Therefore, what may seem very bright to you may be less bright to me. We can use subjective words such as dim and very bright to describe our perceptions of brightness.

On the other hand, luminance is the measure of light an object gives off or reflects from its surface. Luminance is measured in different units such as candela (cd/m2), footlambert (ftL), mililam-bert (mL), and Nit (nt).

Luminance is a term used to characterize light emission from flat, diffuse surfaces. The luminance indicates how much luminous power will be detected by an instrument looking at a lighted surface from a particular angle of view. Luminance can only be used to quantitatively describe the output of a measurement system. Luminance is not an indicator of how bright the surface will appear.

The graphs below show the relationship between Brightness and Luminance based on the mathematical relationship outlined by Stevens' Power Law.

The graph on the left shows that while increasing luminance steadily the perceived brightness increases slowly above the lower ranges of visual perception. The graph also shows that increasing luminance in a flashing or moving light increases perceived brightness equally. As a point of reference, electric current shock perception is added to the graph on the right. Minor shocks like static discharge create minimal human response. The response then increases very rapidly as the electric current shock increases. (Lumvatech)



4.1.3 Daylight Factor

The concept of Daylight Factor (DF) was first introduced and developed in the United Kingdom in the early 20th century. It is a ratio that represents the amount of illumination available indoors relative to the illumination present outdoors at the same time under overcast skies. Daylight Factor is typically calculated by dividing the horizontal work plane illumination indoors by the horizontal illumination on the roof of the building being tested and then multiplying by 100. For example, if there were 20,000 lux available outdoors and 400 lux available at any given point indoors, then the DF for that point would be calculated as follows DF = 400/20,000 *100 or DF=2.

The Daylight Factor is to be used under overcast sky conditions only. Daylight factor is the most common metric used when studying physical models to test daylighting designs in 'overcast sky simulators'. It is reasonably easy to calculate in real buildings or physical models with illumination meters. It is possible to calculate DF with digital models but care should be taken to understand the 'sky model' that is referenced and interpret the data accordingly.

Daylight Factor outputs are helpful in making quick comparisons of relative daylight penetration under overcast sky conditions and is arguably less useful in climates with a great deal of sun. However, most climates across the United States have substantial periods of overcast skies and DF is a useful metric to inform design decisions for these periods.

Early versions of the USGBC, LEED rating system originally required a DF 2 for at least 75% of the critical visual task zones to achieve indoor environment credit 8.1. British Standard Institution, BS 8206-2 requires DF 2 or 5 depending on electric lighting requirements to support human well-being.

Daylight Factor can be reported with static or dynamic measures, however it is most commonly considered statically (at a single point in time) as shown above. In fact, the stability of DF regardless of the time of day and year (assuming an overcast sky) is one of the benefits of the metric. (Patternguide.advancedbuildings.net)

4.1.4 Natural Daylighting and Artificial Electric Lighting

In the short span of 20 years, electric lighting has transformed the workplace by meeting most or all of the occupants' lighting requirements. Recently, energy and environmental concerns have made daylighting a rediscovered aspect of building lighting design. The physics of daylighting has not changed since its original use, but the building design to use it has. Daylighting is often integrated into a building as an architectural statement and for energy savings. However, benefits from daylighting extend beyond architecture and energy. The psychological and physiological aspects of natural light should also be considered. The comforting space and connection to the environment provided to building occupants provide benefits as significant as the energy savings to building owners and managers. Daylighting has been associated with higher productivity, lower absenteeism, fewer errors or defects in products, positive attitudes, reduced fatigue, and reduced eyestrain. (U.S. Department of Energy)

The use of daylighting decreases utility costs and improves the well-being of building occupants. The effects of natural light on building occupants should be an important consideration for building design because studies have shown the strong influence light has on people in many different environments. Daylighting can provide satisfaction for both building occupants and owners. (U.S. Department of Energy)

Artificial light sources are other sources of light which developed to compensate for or assist the natural light. It will have different frequencies and wavelengths that determine the light color. Artificial light sources can include incandescent bulbs, fluorescent tubes and light-emitting diodes (LEDs). The five most common light sources include incandescent lamp, compact fluorescent lamp, fluorescent tube, discharge lamps, light Emitting Diode (LED).

A luminaire is a device that distributes filters or transforms the light emitted from one or more lamps. The luminaire includes all the parts necessary for fixing and protecting the lamps, except the lamps themselves. In some cases, luminaires also include the necessary circuit auxiliaries, together with the means for connecting them to the electric supply. The basic physical principles used in optical luminaire are reflection, absorption, transmission and refraction. (Electrical-knowhow.com)

4.1.5 Lumen Method

The quantity of light reaching a certain surface is typically the main consideration in designing a lighting system for a space. This quantity of light is dictated by the illuminance measured in lux, and as this level varies across the working plane, an average figure is used. (Arca53.dsl.pipex.com)

The lumen method is based on fundamental lighting calculations. The lumen method formula is easiest to appreciate in the following form.

$$E = \frac{n \times N \times F \times UF \times LLF}{A}$$

where E = average illuminance over the horizontal working plane

n = number of lamps in each luminaire

N = number of luminaire

F = lighting design lumens per lamp, i.e. initial bare lamp luminous flux

UF = utilization factor for the horizontal working plane

LLF = light loss factor

A = area of the horizontal working plane

Light loss factor (LLF) is the ratio of the illuminance produced by the lighting installation at the some specified time to the illuminance produced by the same installation when new. It allows for effects such as decrease in light output caused by the fall in lamp luminous flux with hours of use, the deposition of dirt on luminaire, and reflectance of room surfaces over time.

Utilization factor (UF) is the proportion of the luminous flux emitted by the lamps which reaches the working plane. It is a measure of the effectiveness of the lighting scheme. Factors that affect the value of UF include light output ratio of luminaire, flux distribution of luminaire, room proportions, room reflectance and spacing/mounting height ratio. (Personal.cityu.edu.hk)

4.1.6 Lighting in Architecture

Light is truly the most important factor in the appreciation and understanding of Architecture. The relationship between light and architecture is grounded in the principles of physics; it is about energy and matter but in this particular case it also implies an emotional effect on people. The quality of lighting in a space defines its character and creates impressions. The human eye perceives its form through the incidence and reflection of light and in that way acquires information about the ambiance in a given place. Visual impressions are interpreted in our brains and put in context to create emotions that move us to take particular actions.

Light defines the architectural space; it contributes to its perception and understanding while adding value to its function and bringing an emotional component for its users. Of course, light as a form of energy used in architecture requires electricity. This means that the use of light has an impact in the environment and therefore it is also essential to plan and design the lighting in the most energy efficient way in order to preserve our planet. (International Year of Light Blog)

Architectural lighting design focuses on three fundamental aspects of the illumination of buildings or spaces. The first is the aesthetic appeal of a building, an aspect particularly important in the illumination of retail environments. (Iald.org)

Comprehensive lighting design requires consideration of the amount of functional light provided, the energy consumed, as well as the aesthetic impact supplied by the lighting system. Some buildings, like surgical centers and sports facilities, are primarily concerned with providing the appropriate amount of light for the associated task. Some buildings, like warehouses and office buildings, are primarily concerned with saving money through the energy efficiency of the lighting system. Other buildings, like casinos and theatres, are primarily concerned with enhancing the appearance and emotional impact of architecture through lighting systems. Therefore, it is important that the sciences of light production and luminaire photometric are balanced with the artistic application of light as a medium in our built environment. These electrical lighting systems should also consider the impacts of, and ideally be integrated with, daylighting systems. Factors involved in lighting design are essentially the same as those discussed above in energy conservation analysis. (Iald.org)

4.2 Acoustics Literature Review

4.2.1 The Human Ear

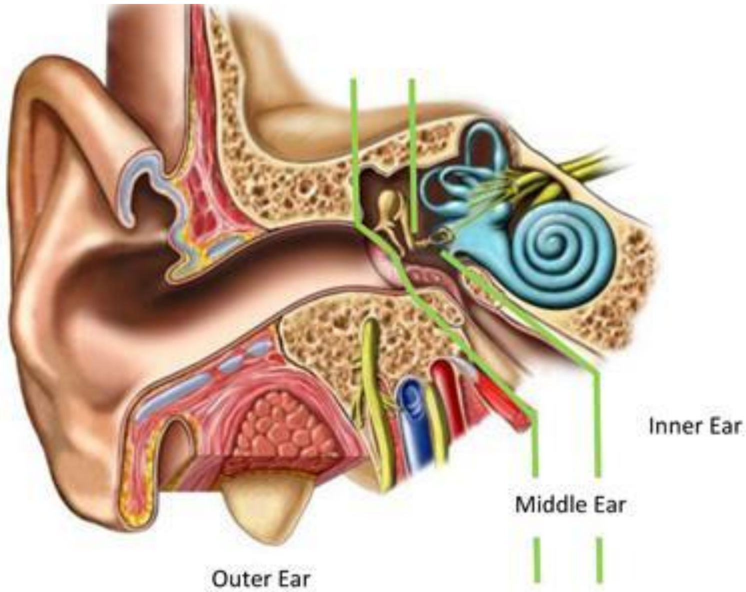


Diagram: Illustration of a human ear’s structure (Source: http://www.hearinglink.org/how-the-ear-works)

The ear is the organ of the human body that detects sound. The sound wave enters the ear through the ear canal and vibrates the eardrum. The vibration causes the ossicles to move. It then impacts the fluid in the cochlea which in turn triggers the hearing nerve. Lastly, the hearing nerve transmits the information to the brain and it will be registered as sound.

4.2.2 Sound Pressure Level

The Sound Pressure (SPL) is the average sound level at a space which is due to a sound wave. It can be easily measured by a microphone. SPL is also a logarithmic measure of the effective sound pressure of a sound relative to a reference value, which is calculated in decibels (dB).

The Sound Pressure Level:

$SPL_p = 10 \log(p^2 / p_o^2)$

where

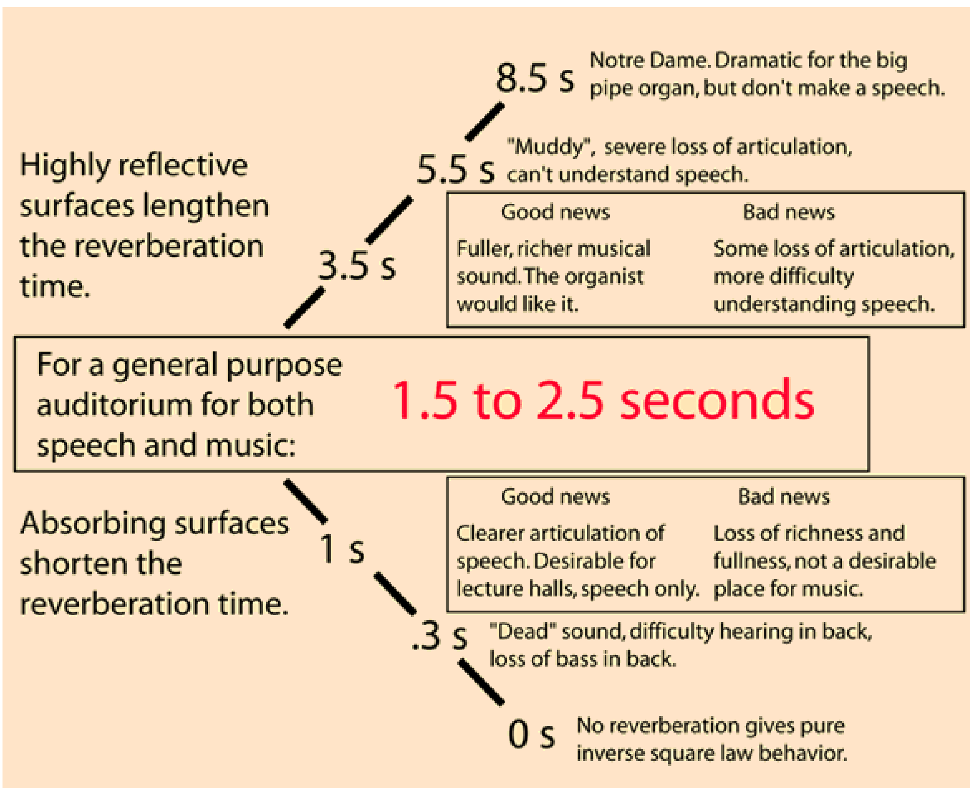
L_p = *sound pressure level (dB)*

p = *Root mean squared pressure* (n/m^2)

p_o = *reference pressure* $(2 \times 10^{-5} N/m)$

4.2.3 Reverberation Time

Reverberation time is one of the important parameters in room acoustics. It measured how long the acoustic energy emitted from sound sources inside a room will linger. Reverberation time is also a measure for the amount of absorption present inside a regular room with an equal distribution of sound absorption. The optimal reverberation time determined by the use of the enclosure. For example, in order to build a large concert hall, the longer reverberation times are often preferred, since this supports the music. Halls for speech should have a shorter time, since otherwise lingering sound will blend with subsequent spoken words, making it difficult to understand what is said. Factory halls should also have short reverberation time. In this situation the goal is to prevent the accumulation of sound energy. This will help reduce the overall sound pressure level and the noise exposure for all workers in the hall. (Bksv.com)



Picture 4.2.3: Desirable Reverberation Time (Source: http://hyperphysics.phy-astr.gsu.edu/)

4.2.4 Behavior of Sound

When sound wave encounters the end of the medium or any obstacles, it will undergo certain behaviors: reflection, refraction and diffusion.

Reflection is when a longitudinal sound wave strikes a flat surface, sound is reflected in a coherent manner provided that the dimension of the reflective surface is large compared to the wavelength of the sound. As a result, the overall nature of the reflection varies according to the texture and structure of the surface. For example, porous materials will absorb some energy, and rough materials (where rough is relative to the wavelength) tend to reflect in many directions, meaning to scatter the energy, rather than to reflect it coherently. This leads into the field of architectural acoustics, because the nature of these reflections is critical to the auditory feel of a space.

Refraction of waves involves a change in the direction of waves as they pass from one medium to another. Refraction, or bending of the path of the waves, is accompanied by a change in speed and wavelength of the waves. So if the media (or its properties) are changed, the speed of the wave is changed. Thus, waves passing from one medium to another will undergo refraction. Refraction of sound waves is most evident in situations in which the sound wave passes through a medium with gradually varying properties.

Diffraction involves a change in direction of waves as they pass through an opening or around a barrier in their path. Sound waves have the ability to travel around corners, around obstacles and through openings. The amount of diffraction (the sharpness of the bending) increases with increasing wavelength and decreases with decreasing wavelength. In fact, when the wavelength of the wave is smaller than the obstacle or opening, no noticeable diffraction occurs. Diffraction of sound waves is commonly observed, we notice sound diffracting around corners or through door openings, allowing us to hear others who are speaking to us from adjacent rooms. Low-pitched (long wavelength) sounds always carry further than high-pitched (short wavelength) sounds.

4.2.5 Sound Reduction Index

Sound Reduction Index, R is the measured quantity which characterizes the sound insulating properties of a material or building element in a stated frequency band - laboratory measurement.

Sound Reduction Index, R:

$R = L1 - L2 + 10 \lg S/A$ (dB)

where:

L1: average Sound Pressure Level in the source room

L2: average sound pressure level in the receiving room

S: area of the test specimen (m^2)

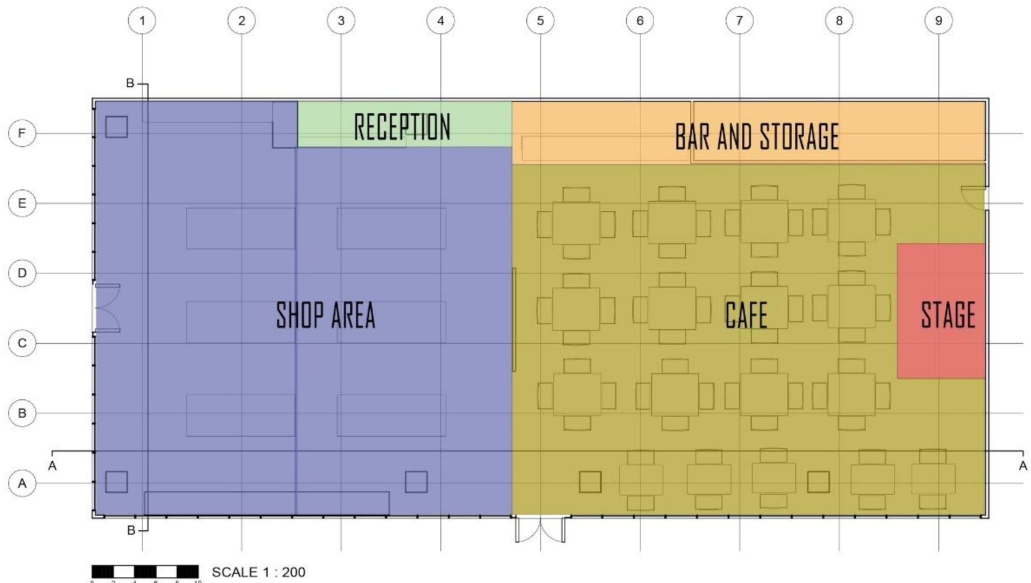
4.2.6 Acoustic in Architecture

Acoustics in architecture is a study on how to design buildings and other spaces that have good sound quality with safe levels. Examples of designs include café's restaurants and event halls. It is necessary to obtain appropriate sound quality for the spaces in the building as inadequate control of sound levels may lead to elevated sound levels within the space which can be annoying and reduce speech intelligibility. The acoustics mood created in the spaces can be affected by the buffer from the building interior design to ultimately achieve good sound quality.

5.0 Lighting Study at KL Tzu-Chi Jing Si Hall

5.1 Tabulation of Data Recordings

5.1.1 Daytime Data



Time: 12pm – 1pm Height: 1.0 meter Unit: Lux

Grid	A	B	C	D	E	F
1	2280	368	650	440	260	180
2	3000	330	312	312	112	50
3	350	157	290	510	110	380
4	400	470	480	383	210	360
5	140	320	310	417	78	54
6	240	390	420	176	167	154
7	130	190	150	140	175	88
8	230	165	130	193	150	64
9	37	42	18	20	12	25

Lux Reading at 1m

Height: 1.5 meter Unit: Lux

Grid	A	B	C	D	E	F
1	503	460	650	389	220	266
2	730	379	457	385	150	59
3	520	165	320	565	92	335
4	1700	350	444	550	195	311
5	204	220	300	560	45	57
6	170	440	550	140	166	88
7	92	170	145	54	167	89
8	120	106	67	1665	124	43
9	37	30	17	17	14	22

Lux Reading at 1.5m

5.1.2 Night-time Data

Time: 8pm – 9pm   Height: 1.0 meter   Unit: Lux

Grid	A	B	C	D	E	F
1	969	80	83	50	28	153
2	149	220	170	210	150	62
3	29	75	179	394	183	63
4	123	89	343	380	108	71
5	29	54	607	387	415	41
6	179	51	98	92	108	62
7	100	212	193	140	129	85
8	209	167	186	138	158	82
9	113	10	16	18	14	23

Lux Reading at 1m

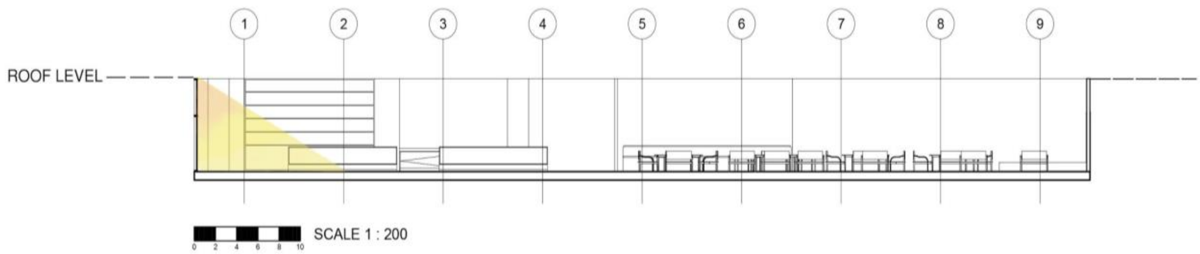
Height: 1.5 meter   Unit: Lux

Grid	A	B	C	D	E	F
1	125	68	60	24	28	370
2	108	120	142	135	76	56
3	25	91	189	338	100	92
4	126	98	387	318	76	40
5	21	48	540	637	584	32
6	304	31	86	64	117	65
7	130	137	199	160	120	115
8	278	161	186	137	165	91
9	40	9	13	17	11	17

Lux Reading at 1.5m

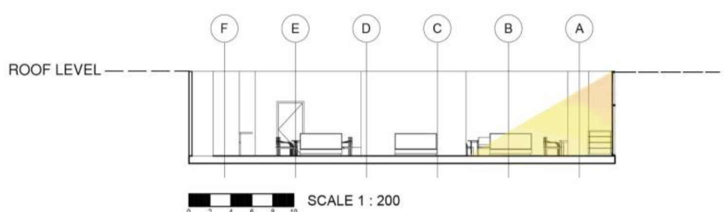
5.2 Day Lighting

5.2.1 Placement of Windows



Direct Sunlight and daylighting at 12pm in the cafe through Section AA'

From above diagram, the daylight enters from the north side of the cafe which is the main entrance to the shopping area. It brightens up the spaces during the day and keeps out extra heat into the cafe, the entrance is built with a covered terrace to enable heat control.



Direct Sunlight and daylighting at 12pm in the cafe through Section BB'

From above diagram, the daylight enters from the west side of the cafe which is the main entrance to the cafe area. It brightens up the spaces during the day and adjustable shades helps prevent extra daylight into the area.

5.2.2 Qualitative Observation of Daylighting in the Space

The qualitative observation of daylighting in JingSi Cafe was to provide sufficient daylighting in the cafe to cut down on the use of artificial lighting. Because the building is built facing the north, the cafe is situated on the east side of the building. Where its windows are opened on the western and northern elevations, the facade allows exposure of direct sunlight to enter the cafe and illuminate the spaces inside.

Daytime hour		Night-time hour	
Highest	: A2 (3000 Lux)	Highest	: A1 (969 Lux)
Lowest	: D9 (12 Lux)	Lowest	: B9 (9 Lux)
Average	: 308.6 Lux	Average	: 149.9 Lux

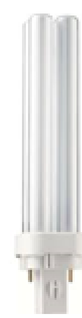
Furthermore, adjustable shades can be found on the west elevation of the cafe where the secondary entrance is; these louvres provide shadings for customers who are sitting too close to the windows.

Wide windows which spans from the roof to the floor located at the north entrance of the cafe and also provides large amount of daylight into the shopping area.

5.3 Artificial Lighting

5.3.1 Types and Specification of Lighting

Product Brand	Philips Led Spot	
Lamp Luminous Flux	420 lumen	
Rated Color Temperature	2700 K (Warm White)	
Color Rendering Index	80	
Beam Angle	36	
Power	4.3 w	
Placement	Spotlight	

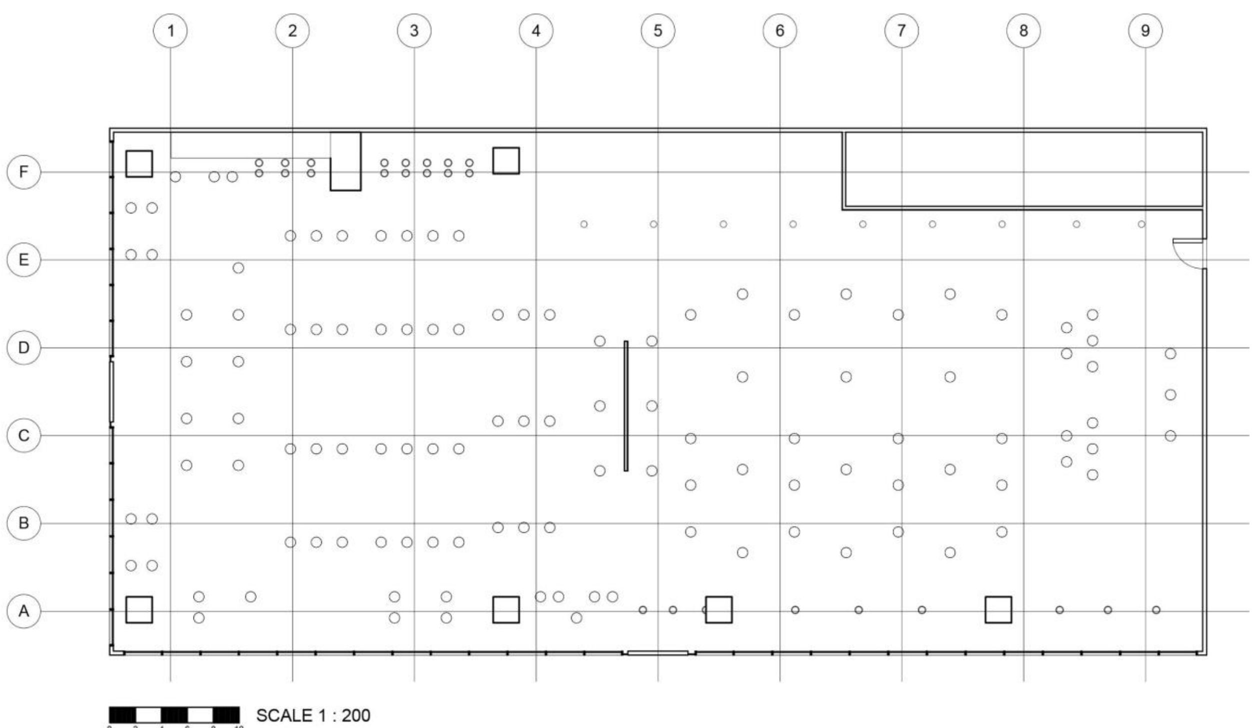
Product Brand	Philips MASTER PL-C 2 Pin	
Lamp Luminous Flux	100 lumen	
Rated Color Temperature	2700 K (Warm White)	
Color Rendering Index	82	
Power	13 W	

Placement	Ceiling	

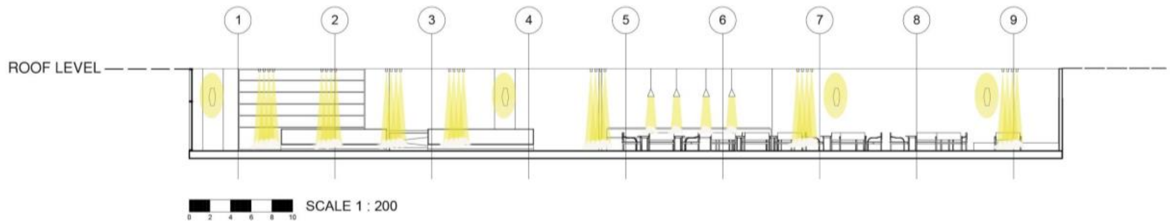
Product Brand	Philips Tornado	
Lamp Luminous Flux	1550 lumen	
Rated Color Temperature	2700 K (Warm White)	
Color Rendering Index	81	
Power	24 W	
Placement	wall	

Product Brand	Philips Tornado	
Lamp Luminous Flux	1550 lumen	
Rated Color Temperature	2700 K (Warm White)	
Color Rendering Index	81	

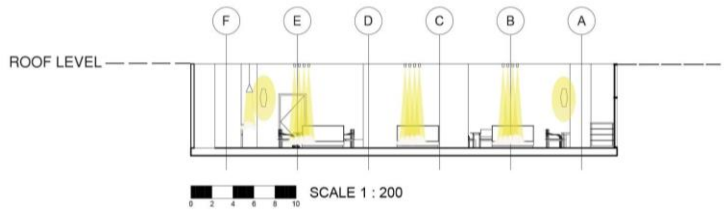
Power	24 W	
Placement	wall	



Reflected Ceiling Plan showing the lighting fixtures in JingSi Cafe.



Artificial lighting in the cafe through Section AA'.



Artificial lighting in the cafe through Section BB'.

5.3.2 Artificial Lighting Analysis

Artificial lightings in JingSi Cafe is designed to brighten up the interior spaces day and night, it also provides appealing visual comfort for the users. Some wall washing lights are used around the reception and bar area to show the significance of the space.

In the shopping area, spotlights are directed on the merchandise on display to highlight and attract the attention of customers. These spotlights are also used to brighten up the artwork and sculptures, some for display and some are for sale.

Oriental lamps attached to the wall are used to brighten up the path around the cafe and also illuminate the corner of the cafe where an alternative entrance is located. It creates a feeling of calm and sensible around the cafe, which also reflects the materiality of the wall.

5.4 Lux Contour Diagram

5.4.1 Daytime Lux Diagram

19 SEPTEMBER 2015

12PM

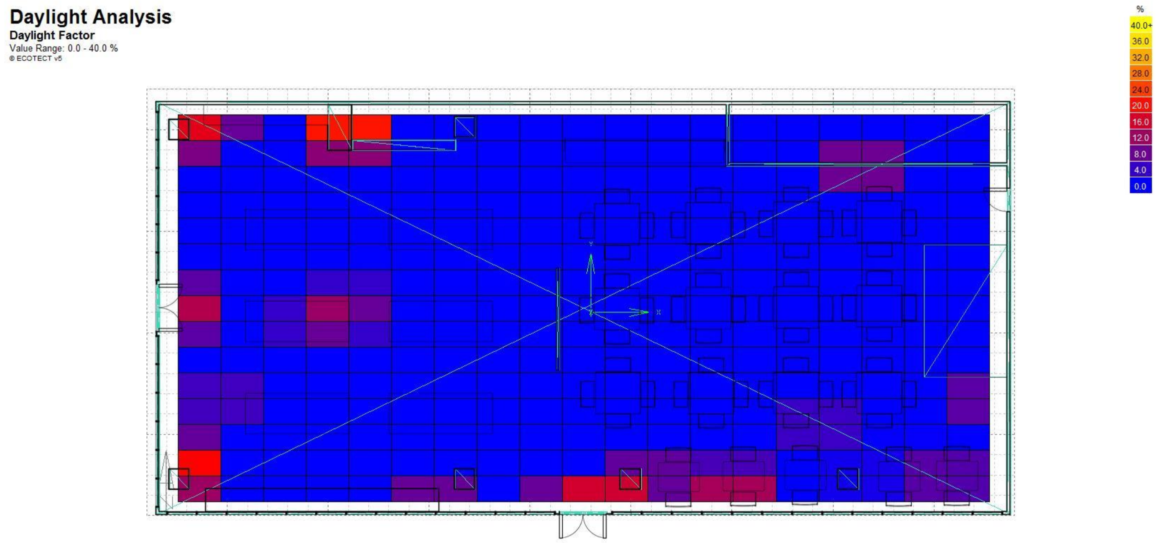


Diagram 5.4: Floor Plan

It can be seen in Diagram 5.4 that the floor plan receives very little daylight lighting at most of 20%. This is due to the tinted windows and the installation of fixed louvers on the exterior of the cafe. It also can be said that due to the installation of fixed louvres which effectively shades the cafe causes the cafe to receive very little daylight.

5.4.2 Artificial Lighting Lux Diagram

24 SEPTEMBER 2015

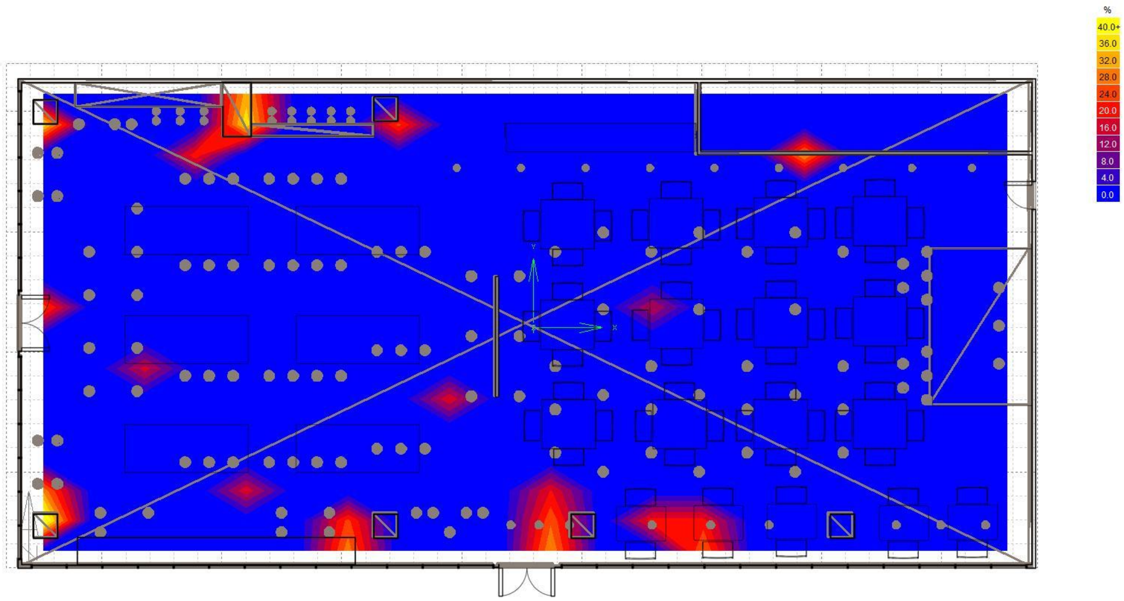
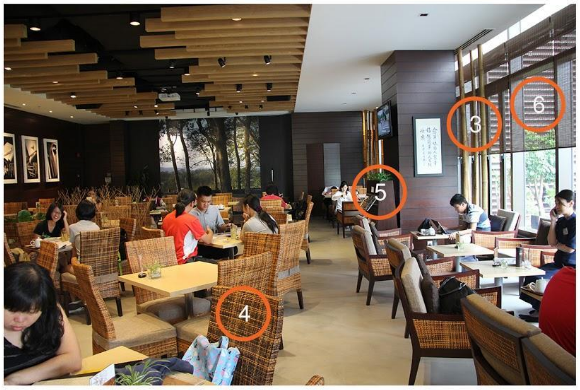


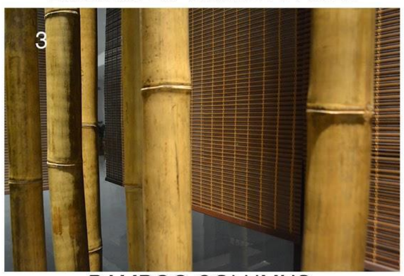
Diagram 5.4: Floor Plan

In diagram 5.4, it can be seen that the cafe has ample amount of artificial lighting throughout the cafe. Moving towards the glass windows, the lux reading slowly decreases. It also can be seen that, the artificial lighting is highest at the reception due to the concentrated amount and arrangement of artificial lighting.

5.5 Light Reflectance of Materials



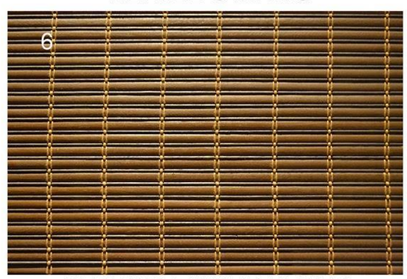
LAMINATED TIMBER PANEL



BAMBOO COLUMNS

WEAVED STRAWS

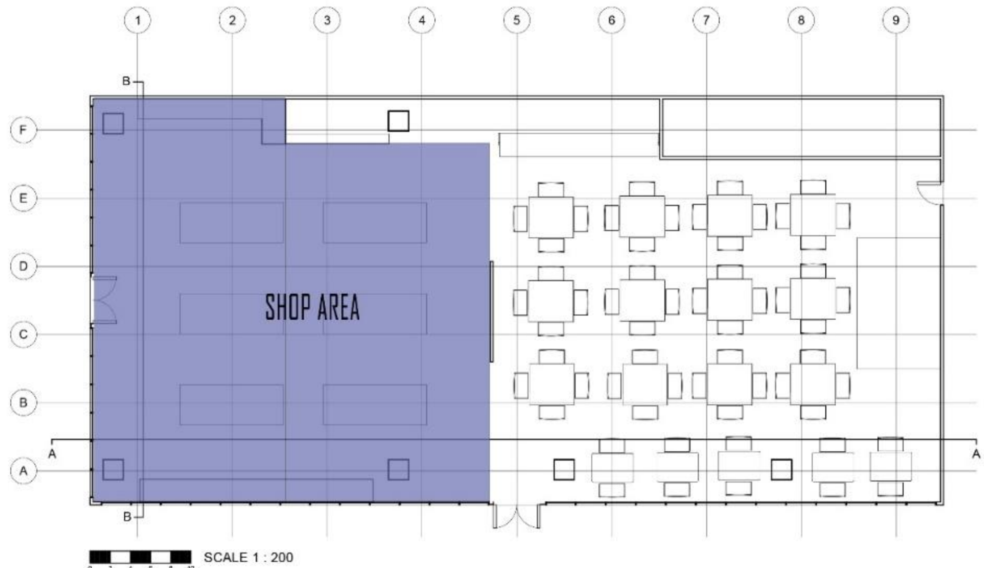
ARTIFICIAL VEGETATIONS



SHADING TIMBER BLINDS

5.6 Analysis and Calculations

5.6.1 Zone 1: Shop Area

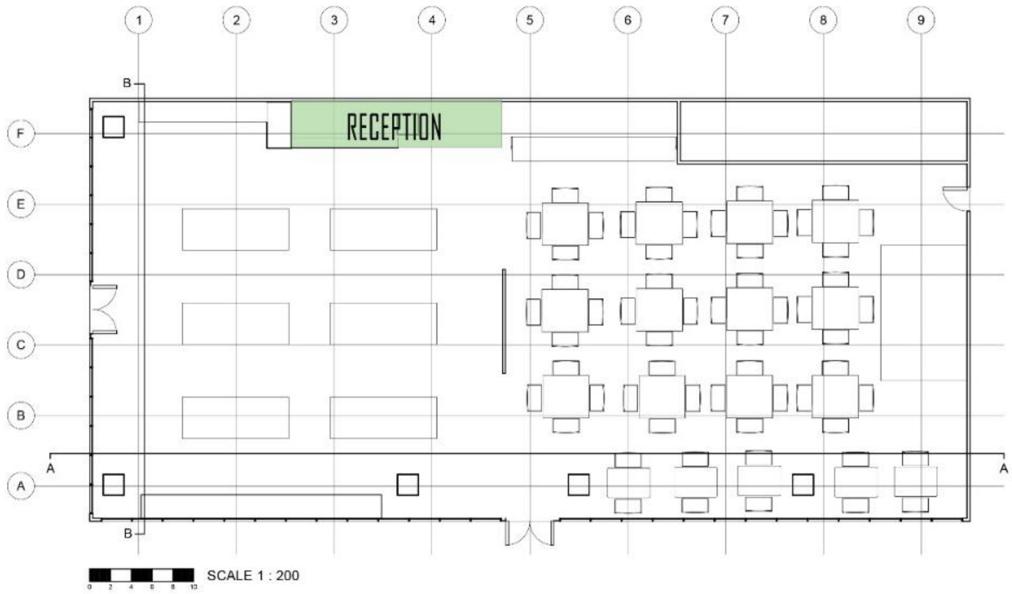


Dimension of Room	20×19.64		
Total Floor Area / A (m^2)	$392.84m^2$		
Type of lighting fixture	Spotlight	Ceiling	Wall
Number of lighting fixture /N	70	12	2

Lumen of lighting fixture / F (lux)	420	100	1550
Work level (m)	0.8		
Mounting Height /H (hm)	2.8	2.8	2.2
Assumption of reflectance value	Ceiling= 0.3	Wall= 0.5	Floor= 0.7
Room Index			
/RI (K) $k = \left[\frac{L \times M}{(L+M)h_m}\right]$	$k = \left[\frac{20 \times 19.64}{(20+19.64)(2.8)}\right]$ $= 3.53$	$k = \left[\frac{20 \times 19.64}{(20+19.64)(2.8)}\right]$ $= 3.53$	$k = \left[\frac{20 \times 19.64}{(20+19.64)(2.2)}\right]$ $= 4.5$
Utilization Factor/UF	0.60	0.58	0.55
Standard Luminance (lux)	200		
luminance Level (lux) $E = \left[\frac{N(F \times UF \times MF)}{A}\right]$	$E = \left[\frac{70(420 \times 0.6 \times 0.8)}{392.84}\right]$ =35.9	$E = \left[\frac{12(100 \times 0.58 \times 0.8)}{392.84}\right]$ =1.42	$E = \left[\frac{2(1550 \times 0.55 \times 0.8)}{392.84}\right]$ =3.47
	Total luminance Level $= 35.9 + 1.42 + 3.47$		
	=40.79		

According to the MS1525, the standard luminance level for a shop area is 200 lux. Despite having a large number of lighting fixtures, Zone 1: Shop area does not meet the recommended luminance level.

5.6.2 Zone 2: Reception

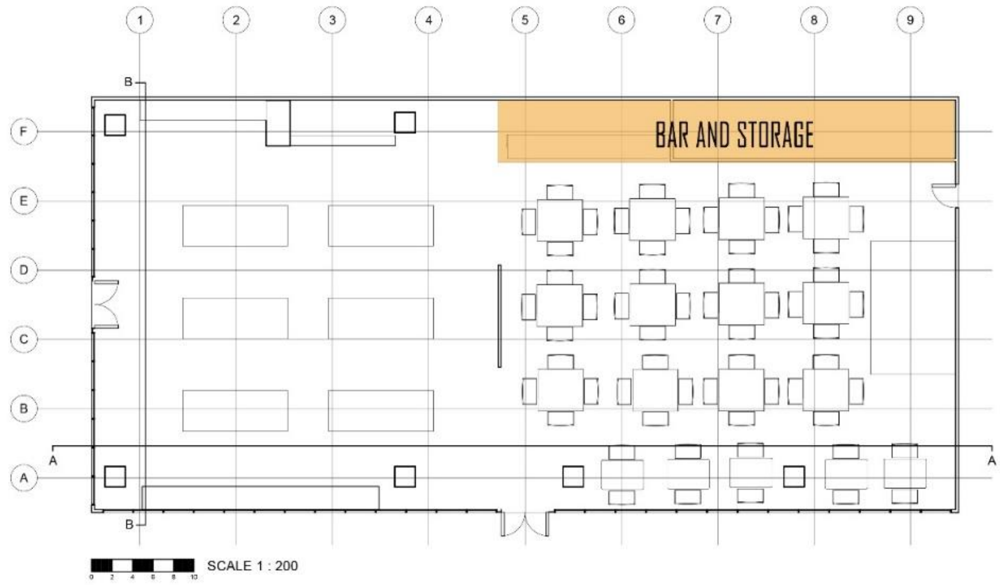


Dimension of Room	5.119×2.257
Total Floor Area / A (m^2)	11.55 m^2
Type of lighting fixture	Ceiling
Number of lighting fixture /N	6
Lumen of lighting fixture / F (lux)	100
Work level (m)	0.8

Mounting Height /H (hm)	2.6
Assumption of reflectance value	Ceiling= 0.3 Wall= 0.5 Floor= 0.7
Room Index /RI (K) $k = \left[\frac{L \times M}{(L+M)h_m}\right]$	$k = \left[\frac{5.119 \times 2.257}{(5.119 + 2.257)(2.6)}\right]$ $= 0.38$
Utilization Factor/UF	0.80
Standard Luminance (lux)	300
luminance Level (lux) $E = \left[\frac{N(F \times UF \times MF)}{A}\right]$	$E = \left[\frac{6(100 \times 0.8 \times 0.8)}{11.55}\right]$ =33.2 Total Illuminance Level $= 33.2$

According to the MS1525, the standard luminance level for a general reception desk area is 300 lux. Zone 2: Reception does not meet the recommended luminance level. This is due to the low lumen level of the lighting fixtures.

5.6.3 Zone 3: Bar and Storage

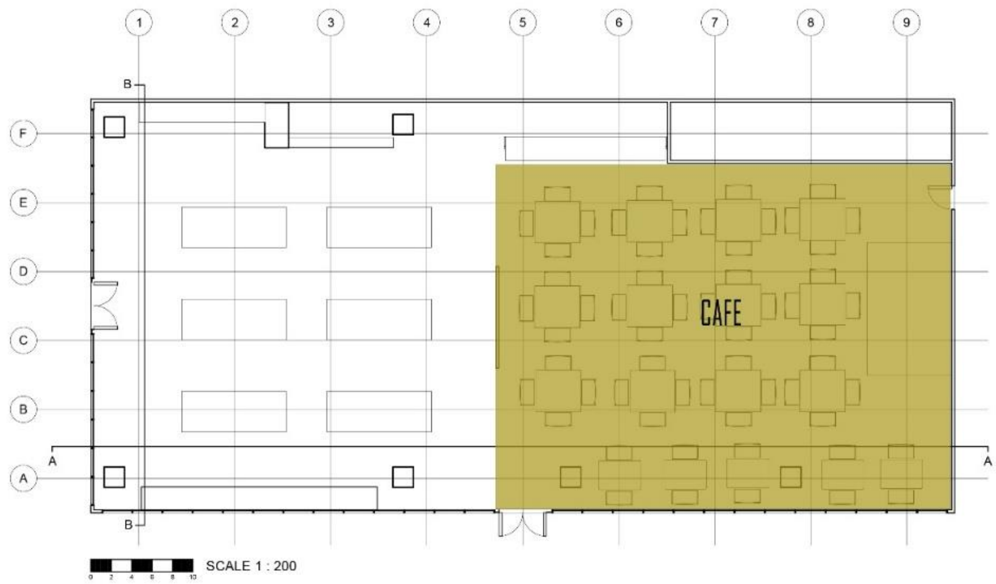


Dimension of Room	21.923×2.852
Total Floor Area / A (m^2)	62.53 m^2
Type of lighting fixture	Ceiling
Number of lighting fixture /N	12
Lumen of lighting fixture / F (lux)	100
Work level (m)	0.8

Mounting Height /H (hm)	2.6		
Assumption of reflectance value	Ceiling= 0.3	Wall= 0.5	Floor= 0.7
Room Index /RI (K) $k = \left[\frac{L \times M}{(L+M)h_m}\right]$	$k = \left[\frac{21.923 \times 2.852}{(21.923 + 2.852)(2.6}\right.$ $= 0.97$		
Utilization Factor/UF	0.80		
Standard Luminance (lux)	500		
luminance Level (lux) $E = \left[\frac{N(F \times UF \times MF)}{A}\right]$	$E = \left[\frac{12(100 \times 0.8 \times 0.8)}{62.53}\right]$ $= 12.28$ Total Illuminance Level $= 12.28$		

According to the MS1525, the standard luminance level for a bar and storage room collectively is 500 lux. Zone 3: Bar and Storage does not meet the recommended luminance level. This is due to the low lumen level of the lighting fixtures.

5.6.4 Zone 4: Café Seating Area

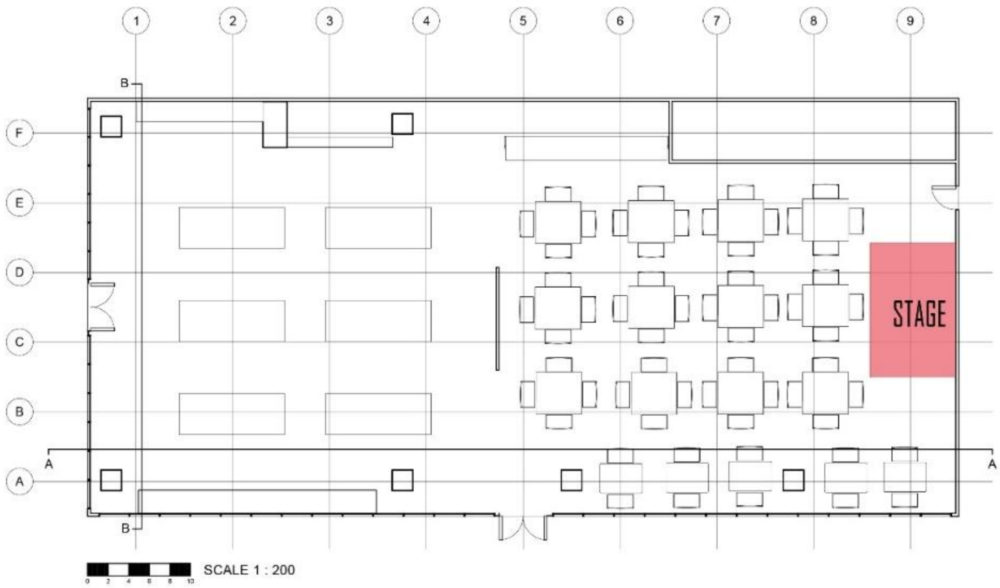


Dimension of Room	22.507×17.308		
Total Floor Area / A (m^2)	$389.55m^2$		
Type of lighting fixture	Spotlight	Ceiling	Wall
Number of lighting fixture /N	35	8	3
Lumen of lighting fixture / F (lux)	420	100	1550
Work level (m)	0.8		

Mounting Height /H (hm)	2.8	2.8	2.2
Assumption of reflectance value	Ceiling= 0.3	Wall= 0.5	Floor= 0.7
Room Index /RI (K) $k = \left[\frac{L \times M}{(L+M)h_m}\right]$	$k = \left[\frac{22.507 \times 17.308}{(22.507 + 19.64)(2.8}\right.$ $= 3.3$	$k = \left[\frac{22.507 \times 17.308}{(22.507 + 19.64)(2.8}\right.$ $= 3.3$	$k = \left[\frac{22.507 \times 17.308}{(22.507 + 19.64)(2.2)}\right]$ $= 4.2$
Utilization Factor/UF	0.60	0.58	0.55
Standard Luminance (lux)	300		
luminance Level (lux) $E = \left[\frac{N(F \times UF \times MF)}{A}\right.$	$E = \left[\frac{35(420 \times 0.6 \times 0.8)}{389.55}\right]$ =18.11	$E = \left[\frac{8(100 \times 0.58 \times 0.8)}{389.55}\right]$ =0.9	$E = \left[\frac{3(1550 \times 0.55 \times 0.8)}{389.55}\right]$ =5.25
	Total Illuminance Level $= 18.11 + 0.9 + 5.25$ =24.26		

According to the MS1525, the standard luminance level for areas used for dining purposes is 300 lux. Despite having a large number of lighting fixtures, Zone 4: Café Seating Area does not meet the recommended luminance level.

5.6.5 Zone 5: Stage



Dimension of Room	6.51×4.135
Total Floor Area / A (m^2)	$25.43m^2$
Type of lighting fixture	Spotlight
Number of lighting fixture /N	9
Lumen of lighting fixture / F (lux)	420
Work level (m)	0.8

Mounting Height /H (hm)	2.8		
Assumption of reflectance value	Ceiling= 0.3	Wall= 0.5	Floor= 0.7
Room Index /RI (K) $k = \left[\frac{L \times M}{(L+M)h_m}\right]$	$k = \left[\frac{6.51 \times 4.135}{(6.51 + 4.135)(2.8)}\right]$ $= 0.8$		
Utilization Factor/UF	0.70		
Standard Luminance (lux)	Special Lighting		
luminance Level (lux) $E = \left[\frac{N(F \times UF \times MF)}{A}\right.$	$E = \left[\frac{9(420 \times 0.7 \times 0.8)}{25.43}\right]$ $= 83.2$ Total Illuminance Level = 83.2		

According to the MS1525, the luminance level for a platform or stage should correspond to the type of activity. Zone 5: Stage is sufficiently lit considering its placement adjacent to an area with a higher luminance level.

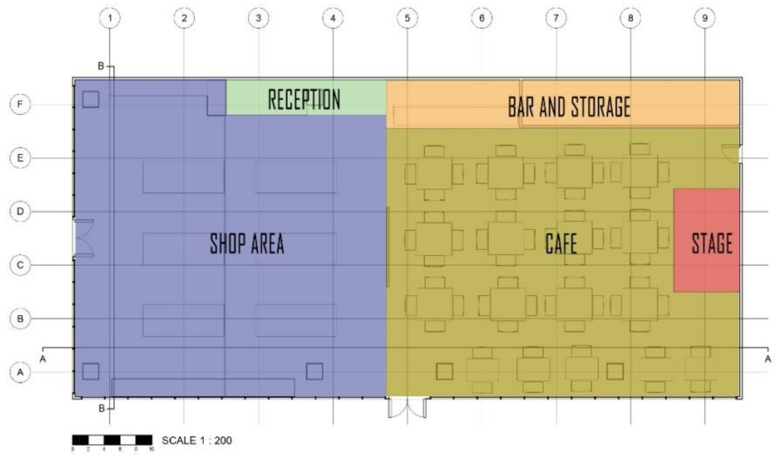
5.7 Design Strategies and Evaluation

The core design strategies of the cafe is to provide customers with a place to chill and take a break, it is not as bright as an office but provides sufficient lighting for a public place. The usage of wide open windows and doors allows natural light to penetrate through in the morning and afternoon hours, these lights are then reflected in the night. Some wall flushing light creates an aesthetic look for the cafe.

The materials used in the cafe are more natural and catches the reflection of the lights well enough to brighten the whole place. The distribution of space also serves as a purpose for ease of circulation in the cafe. Lighting is an important part of a hygienic atmosphere, the bar and reception area are especially bright to keep its cleanliness all day.

6.0 Acoustic Study at KL Tzu-Chi Jing Si Hall

6.1 Tabulation of Data Recordings



6.1.1 Peak Hour Data

	A	B	C	D	E	F
1	55	57	58	57	56	55
2	55	57	61	57	57	60
3	59	60	59	56	58	58
4	55	58	56	55	55	56
5	57	58	62	64	62	60
6	58	59	60	58	58	58
7	56	60	58	58	58	57
8	54	54	54	57	57	56
9	56	56	59	55	56	55

Table: Sound level on peak hour: 12.00 p.m. - 1.00 p.m.

6.1.2 Non-peak Hour Data

	A	B	C	D	E	F
1	53	54	53	52	53	52
2	54	54	56	54	55	54
3	58	56	58	56	56	55
4	57	57	57	57	60	63
5	56	56	57	56	58	64
6	53	54	55	55	57	57
7	55	57	54	54	53	54
8	53	51	52	55	58	58
9	58	57	57	55	54	57

Table: Sound level on non-peak hour: 8.00 p.m. - 9.00 p.m.

6.1.3 Observation & Discussion

Observation

Peak hour		Non-peak hour	
Highest	: D5 (64 dB)	Highest	: F5 (64 dB)
Lowest	: A8, B8, C8 (54 dB)	Lowest	: B8 (51 dB)
Average	: 57.4 dB	Average	: 55.6 dB

Discussion

1. During peak hour, the highest sound level is D5, which is 64 dB. It is relatively higher on the area along 5, from C5 to F5, which is the route for waiters or waitresses to travel from the bar to café. This is due to the high numbers of users visiting the café during peak hour causing the area along this route to be higher than the other.
2. Some points in the shop area are also showing higher sound level compare to others: B3 at 60 and C2 at 61 and the area surrounding these 2 points. This is due to the high numbers of people visiting the shop area during peak hour.
3. The lowest sound level during peak hour is A8, B8 and C8 which is 54 dB. This is most probably due to that particular area is not occupied by users yet.
4. During non- peak hour, the highest sound level is F5, which is 64dB. Right beside F5, F4 is also sowing a high reading: 63 dB. These 2 points are high because they are at or near to the bar where the waiters or waitress are washing and cleaning up to prepare to close the café.
5. The rest of the points are showing relatively lower sound level compare to during peak hour, which the lowest at 51 dB, 3 dB different to the lowest sound level during peak hour. This is caused by fewer amounts of users during non-peak hour.
6. The difference between the average sound level during peak hour and average sound level during non-peak hour is only 1.8 dB. This is most probably due to the constant noise produced by the electrical appliances especially speakers.

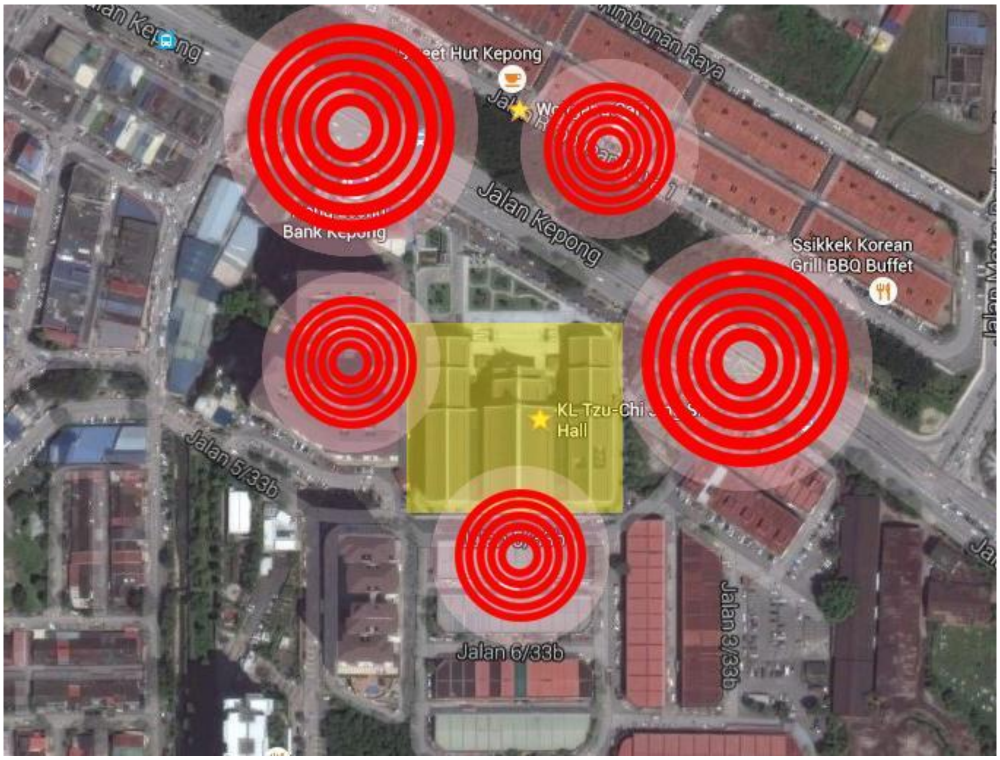
6.2 External Noise Sources

Outdoor Noise Source

KL Tzu-Chi Jing Si Hall is located along Jalan Kepong. However our chosen site, the Books and Café which is located in front of an open space and is located next to an open space, thus the external noise is not a critical issues to the site.

Main Road

During the peak hours 8-10am, 12-2pm and 6-8pm there is a lot of noise generated from the traffic. These are usually through horns of their car and the sound of the engines. Luckily the large empty courtyard acts as a buffer zone. The courtyard with the local flora helps absorb the sound from the traffic and disperse it to the surroundings or negate it completely.



Picture 6.2.1: External Noise Sources

Construction Noise

The construction noise at the site is very soft as there is very little construction happening at the site. The construction is mainly taking place at the main building, top floor which is relatively far from the restaurant. Therefore, the construction noise produced at the main building does not have much effect on the café as shown in the following diagram. As the columns are very thick and big, roughly weighing 1 ton each, the noise is absorbed by it and transferred to the surroundings of the site .Although it is very feint at our site but I can be heard at the areas surrounding it. The buildings designs deter the spreading of noise through its large open spaces. Sound travels slower in the air as compared to solids. The design of the building also incorporates buffer zones, areas that an area lying between two areas providing some space to prevent noise from spreading

Figure 6.2.2: A picture of how the construction was conducted at the site.

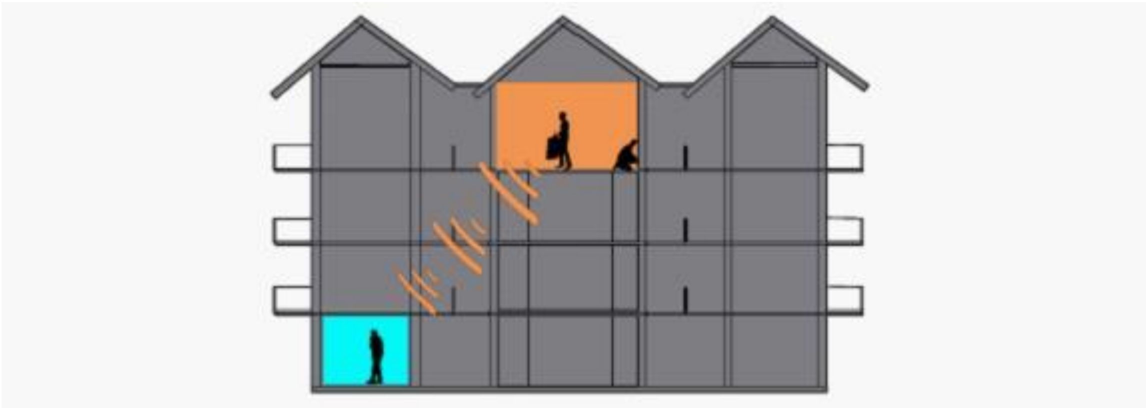


Figure 6.2.3: The construction noise does very little to affect the cafe

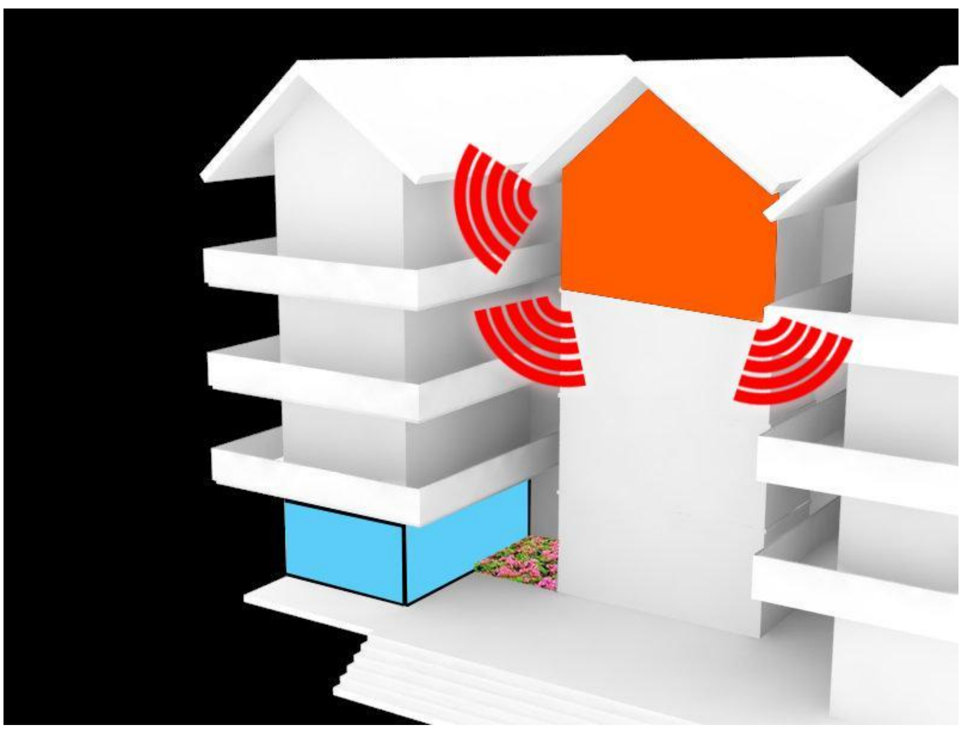


Figure 6.2.4: The construction noise does very little to affect the caf é

External Human Sound

There are many people that pass by the Café during the day as they proceed to the entrance at the main hall. It is especially crowded at the peak hours, especially at the afternoon, weekend and public holidays. The operation hours for the book café is 5.30 am till 9.30pm, non-peak hours are from 10 am to 11.30 am, 3 pm to 5 pm and 8 pm till 9.30 pm .The sound produced is mainly from their talking especially those in larger groups. There is also sound from their children who run around shouting and playing. The design of the courtyard helps to minimize this problem. The steps and stairs are located far away from the café causing the people entering the site to walk further away from the café.

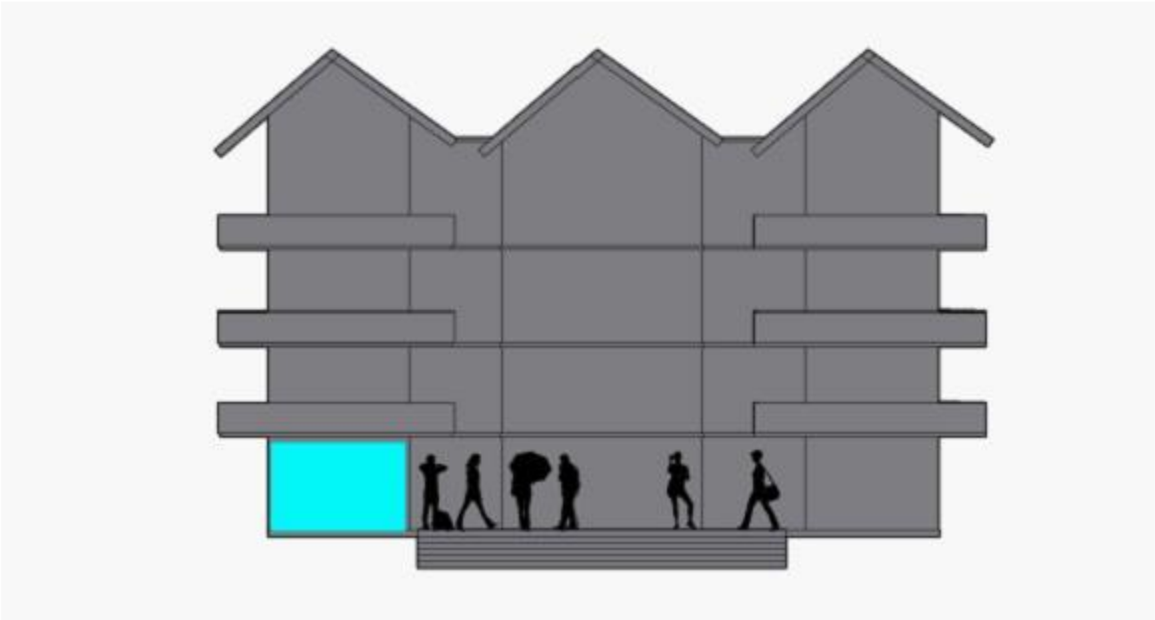


Figure 6.2.5: Shows how the people on the inside effect the sound levels at the cafe

Garden

There is a small garden located next to the café, which is used mainly as a relaxation area. The garden is also used during any outdoor events as a place for people to rest and relax. It is especially crowded during the non-peak hours, especially during the morning and evening. During these times, it is very noisy due to the people talking and laughing especially for the younger children running about and playing. There is also some sound from birds that use the trees nearby as protection and shelter. The original function of the garden is meant to be a buffer zone, but as it being used it creates a problem of its own. Luckily the façade of the building helps absorb some of the sound and transfer it from the garden to other lesser used spaces.

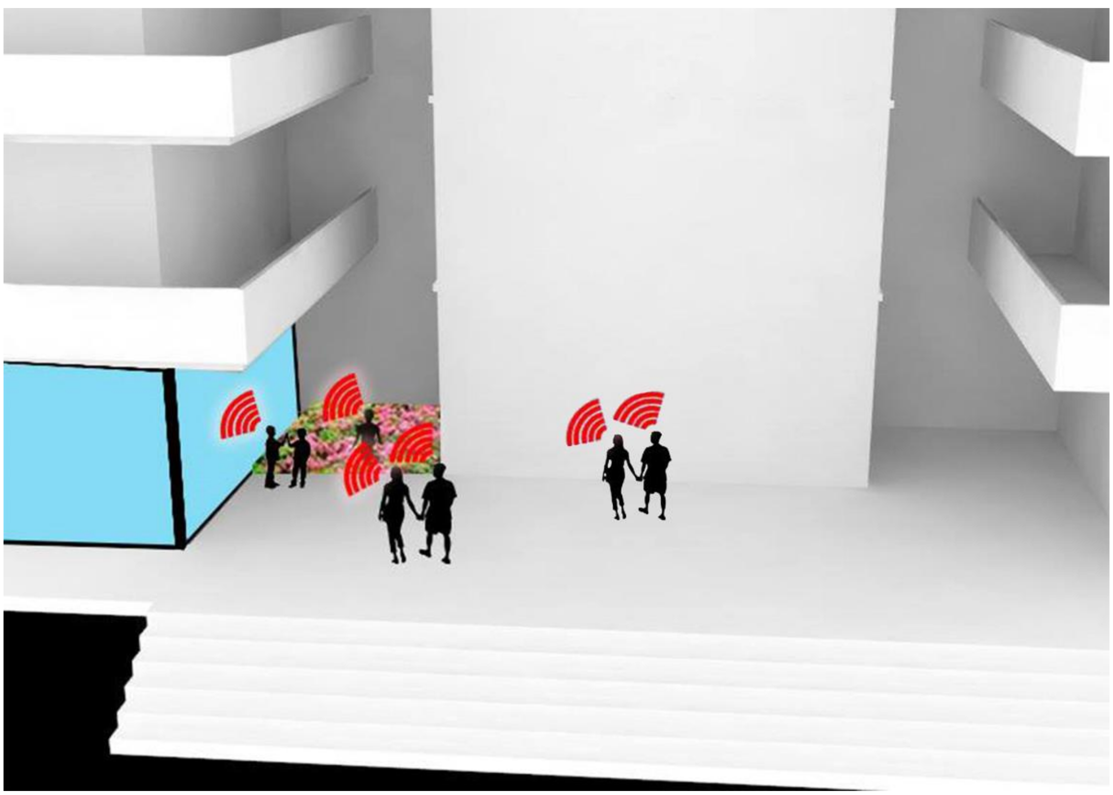


Figure 6.2.7: Shows how people relaxing and talking at the garden affect the cafe

6.3 Internal Noise Sources

The main noise in Jing-Si Books & Café comes from the speakers and televisions. The speakers and televisions produce music and sound constantly to entertain customers, making it the largest noise source. The air conditioners here also constantly produce noticeable faint noise. Other than that, occasional noises coming from the bar area during the waiter or waitress preparing drinks and washing could be heard.

6.3.1 Speakers

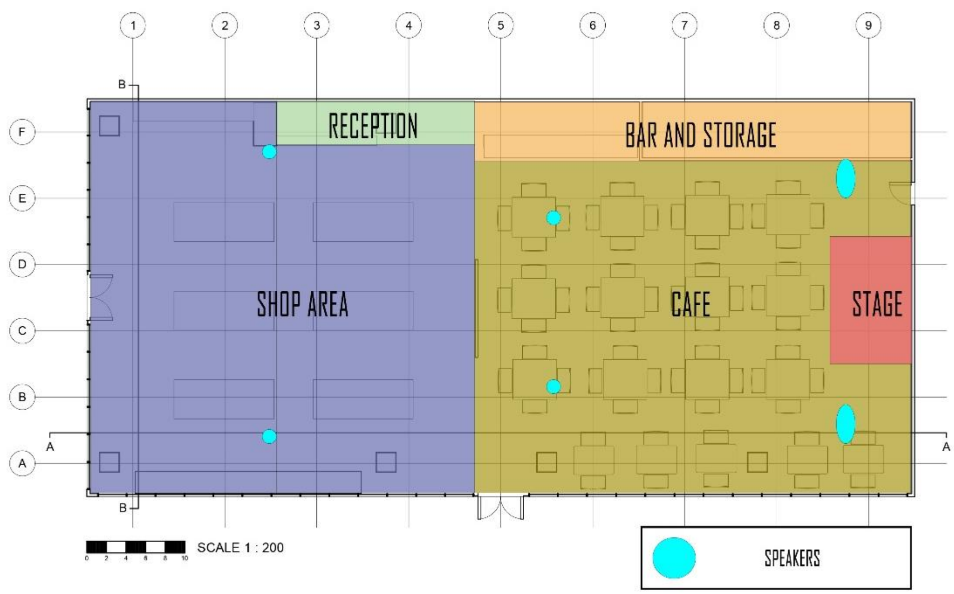


Figure 6.3.1: Positions of speakers in Jing-Si Books & Café.

Total of 6 speakers can be found in Jing-Si Books & Café. 4 of them are surface mount speakers and another 2 are loudspeakers. The sound travels from the speakers through air and structure throughout Jing-Si Books & Café. The volume of the sound produced from the speakers during the peak hour is higher compare to non-peak hour. This is to ensure that the music and sound can still be heard over the noise produced by various human activities. However, at the same time it disturbed the communication of users.

Figures 6.3.2: Two different sizes of speakers found in Jing-Si Books & Café

OBJECT	SPECIFICATION	
JBL Control 23 Surface Mount Speakers 	Frequency Range	100Hz to 21kHz (-10 dB)
	Power Capacity	50 W Continuous Program Power; 25 W Continuous Pink Noise
	Transformer Taps	5 W @ 70V, 10 W @ 100V (IEC pink noise, 100 hrs.)
JBL PRX-415M 15" Two-Way Stage Monitor & Loudspeaker System	Frequency Range	55 Hz – 19 kHz
	Frequency Response	75 Hz – 16 kHz
	Coverage Pattern	90 °x 50 °nominal
	System Sensitivity	98 dB SPL (1w@1m)
	Power Rating, Pink	300 W / 600 W / 1200 W (Continuous/Program/Peak)

	Noise	
	Rated Maximum SPL	129 dB SPL peak
	Nominal Impedance	8 ohms
	Dimension	25.6" x 16.9" x 18"
	Net Weight	46 lbs.

6.3.2 Television

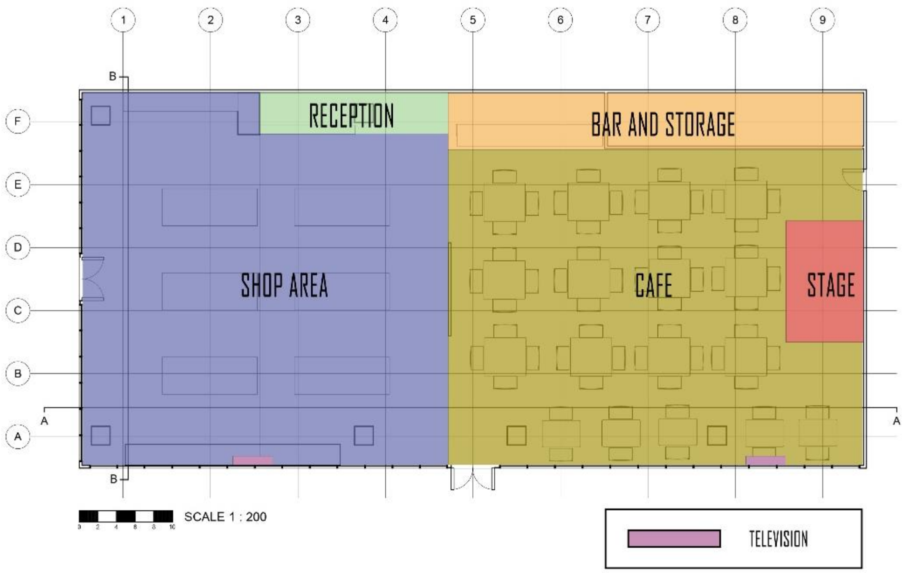


Figure 6.3.3: Positions of televisions in Jing-Si Books & Café

Two televisions can be found in Jing-Si Books & Café. Both are mounted on columns. One is located at the shop area whereas the other one is located at the café. The televisions are used to showcase the origin, teaching and mission of Tzu Chi Foundation. The sound travel through air and structure and spread to the whole Jing-Si Books & Café.

Figure 6.3.4: One of the televisions mounted on a column in Jing-Si Books & Café

OBJECT	SPECIFICATION	
Philips 4200 Series LED TV (Wall Mounted) 	Display	LED HD TV
	Panel Resolution	1366 x 768p
	Mains Power	AC 110 - 240 V 50/60Hz
	Sound Output Power (RMS)	16W
	Standby Power Consumption	< 0.5 W
	Ambient Temperature	5 ℃ to 40 ℃

6.3.3 Air Conditioners

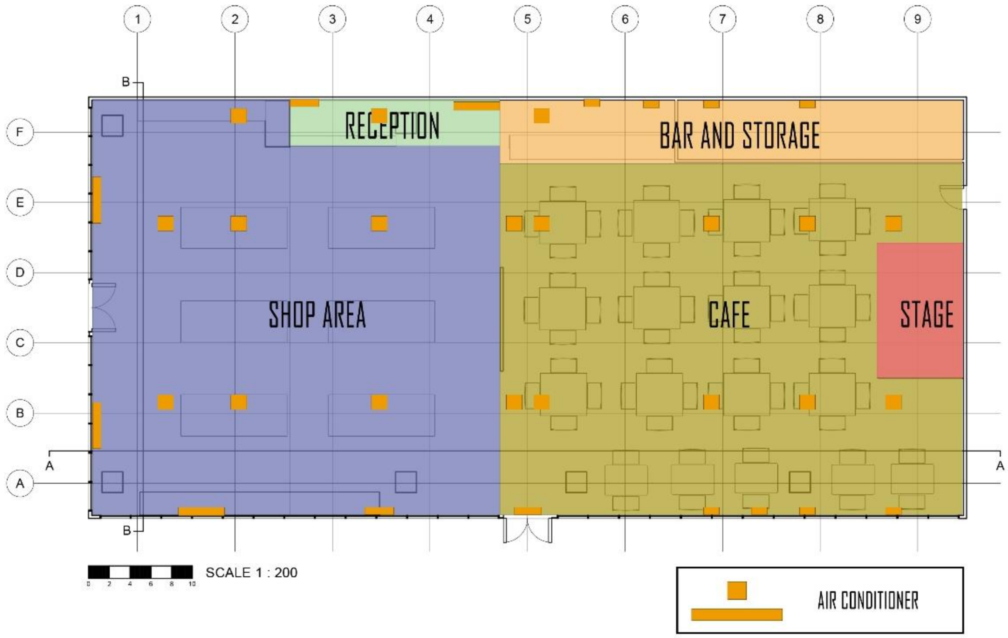


Figure 6.3.5: Positions of ducted air conditioners outlets in Jing-Si Books & Café

The air conditioners in Jing-Si Books & Café are using ducting system. They constantly produce a faint noise that is most of the time cover over by sound from speakers & televisions. The noise travels through air and structure and spread throughout Jing-Si Books & Café

Figures 6.3.6: Two different kinds of outlets for the ducted air conditioner found in Jing-Si Books & Café

OBJECT	SPECIFICATION	
Ducted Air Conditioner 	Capacity	7.81 kW (Max)
	Power Input	2.12 kW
	Running Current	9.5A
	Sound Pressure	29 dBA (Max)

6.3.4 Human Activities

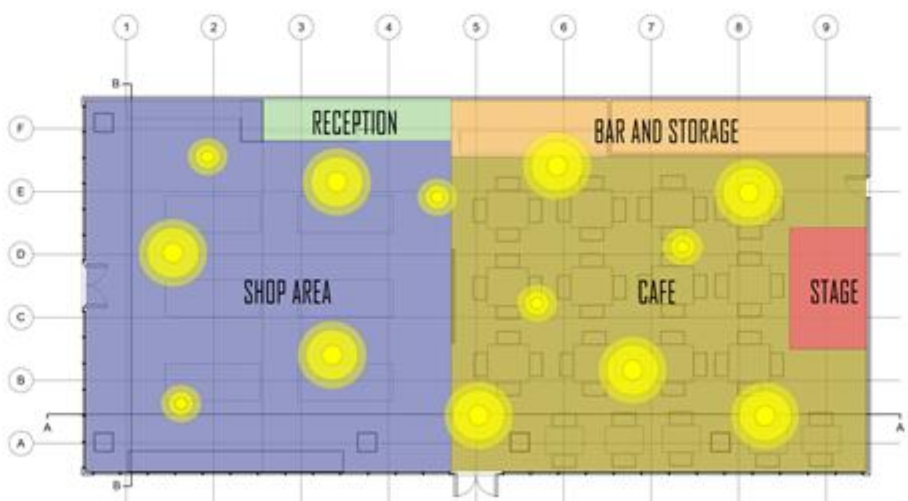
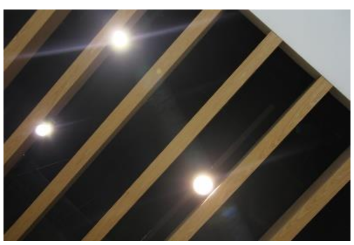


Figure 6.3.7: Human noise source in Jing-Si Books & Café

Most of the noise comes from shop area where people shop and chat or listening to the description of books and other items on sale by shop attendant. Noise is also produce in the café when users are chatting. Other than that, there is also noise produce at the bar by the occasional interaction among waiters or waitresses for example taking orders.

6.4 Materials

Type	Material	Absorption Coefficient			Location
		125 Hz	500 Hz	2000 Hz	
Ceiling	Plaster 	0.01	0.02	0.04	Shop Area, Reception, Bar, Café
	Timber 	0.15	0.10	0.10	Shop Area, Café, Stage
	Concrete	0.01	0.02	0.02	Shop Area, Café, Stage

					
Wall	Timber Furnished Wall 	0.18	0.42	0.83	Whole Area
Floor	Concrete 	0.01	0.04	0.08	Whole Area

Door	Glass 	0.03	0.69	0.96	Main Entrance, Side Entrance

Window	Glass 	0.3	0.10	0.07	Main Entrance, Along Shop Area, Along Café
Furniture	Timber Blinds	0.15	0.10	0.10	On the Windows along Shop Area and Café

					
	Timber Shelves 	0.15	0.24	0.50	Shop Area
	Tables: Timber Top with Metal Stand 	0.15	0.24	0.50	Café

	Chairs: Timber Structure with Fabric Cushion 	0.15	0.24	0.50	Café

6.5 Calculations and Analysis

6.5.1 Reverberation Time (RT)

Zone 1: Shop Area

Space Volume = ($18m^2$ x 3.5m) + ($360m^2$ x 3.5m)

= $63m^3$ + $1260m^3$

= $1323m^3$

Material absorption coefficient in 500 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (500 Hz)	Area, S (m2)	S x α
Ceiling	Plaster	0.02	290.00	5.80
Ceiling	Timber	0.10	290.00	29.00
Ceiling	Concrete	0.02	48.75	0.98
Wall	Timber	0.42	168.00	70.56
Floor	Concrete	0.04	378.00	15.12
Door	Glass	0.69	8.75	6.04
Window	Glass	0.10	14.00	1.40
Blind	Timber	0.10	31.50	3.15
Shelves	Timber	0.24 per unit	8 unit	1.92
Human	-	0.21 per person	6 person	2.76
Total Absorption, A				**136.72**

RT = (0.16 x V)/A

= (0.16 x 1323) / 136.72

= 1.55s

The reverberation time for Zone 1: Shop Area in 500 Hz of absorption coefficient is 1.55s.

Material absorption coefficient in 2000 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (2000 Hz)	Area, S (m2)	S x α
Ceiling	Plaster	0.04	290.00	11.60
Ceiling	Timber	0.10	290.00	29.00
Ceiling	Concrete	0.02	48.75	0.98
Wall	Timber	0.83	168.00	139.44
Floor	Concrete	0.08	378.00	30.24
Door	Glass	0.96	8.75	8.40
Window	Glass	0.07	14.00	0.98
Blind	Timber	0.10	31.50	3.15
Shelves	Timber	0.50 per unit	8 unit	4.00
Human	-	0.51 per person	6 person	3.06
Total Absorption, A				**230.85**

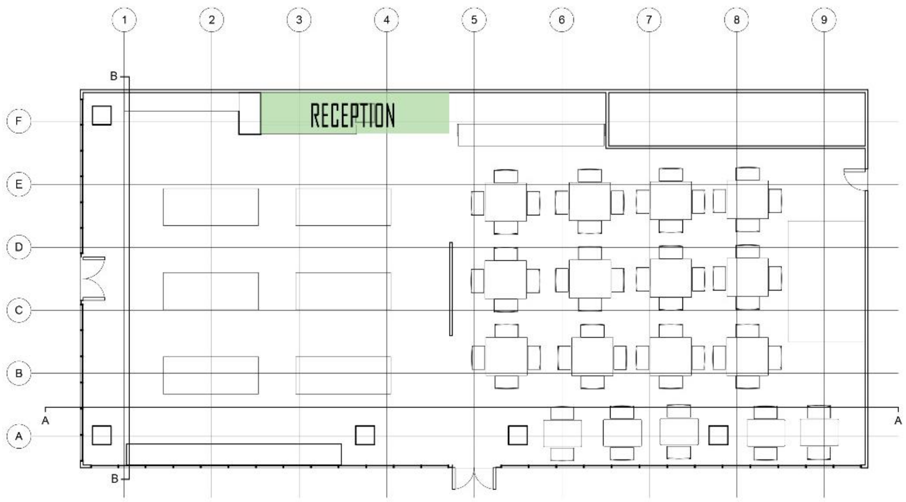
RT = (0.16 x V)/A

= (0.16 x 1323) / 230.85

= 0.92s

The reverberation time for Zone 1: Shop Area in 2000 Hz of absorption coefficient is 0.92s.

Zone 2: Reception



Space Volume = 20m ²x 3.5m

= 70m ³

Material absorption coefficient in 500 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (500 Hz)	Area, S (m2)	S x α
Ceiling	Plaster	0.02	70.00	1.40
Wall	Timber	0.42	35.00	14.7
Floor	Concrete	0.04	70.00	2.8
Human	-	0.46 per person	1 person	0.46
Total Absorption, A				**19.36**

RT = (0.16 x V)/A

= (0.16 x 70) / 19.36

= 0.58s

The reverberation time for Zone 2: Reception in 500 Hz of absorption coefficient is 0.58s.

Material absorption coefficient in 500 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (2000 Hz)	Area, S (m2)	S x α
Ceiling	Plaster	0.04	70.00	2.80
Wall	Timber	0.83	35.00	29.05
Floor	Concrete	0.08	70.00	5.6
Human	-	0.51 per person	1 person	0.51
Total Absorption, A				**37.96**

RT = (0.16 x V)/A

= (0.16 x 70) / 37.96

= 0.30s

The reverberation time for Zone 2: Reception in 2000 Hz of absorption coefficient is 0.30s.

Zone 3: Bar and Storage

Space Volume = 66m ^{2}x 3.5m

= 231m ^{3}

Material absorption coefficient in 500 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (500 Hz)	Area, S (m2)	S x α
Ceiling	Plaster	0.02	231.00	4.62
Wall	Timber	0.42	89.25	37.49
Floor	Concrete	0.04	231.00	9.24
Human	-	0.46 per person	1 person	0.46
Total Absorption, A				**51.81**

RT = (0.16 x V)/A

= (0.16 x 231) / 51.81

= 0.71s

The reverberation time for Zone 3: Bar & Storage in 500 Hz of absorption coefficient is 0.71s.

Material absorption coefficient in 2000 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (2000 Hz)	Area, S (m2)	S x α
Ceiling	Plaster	0.04	231.00	9.24
Wall	Timber	0.83	89.25	74.0775
Floor	Concrete	0.08	231.00	18.48
Human	-	0.51 per person	1 person	0.51
Total Absorption, A				**102.31**

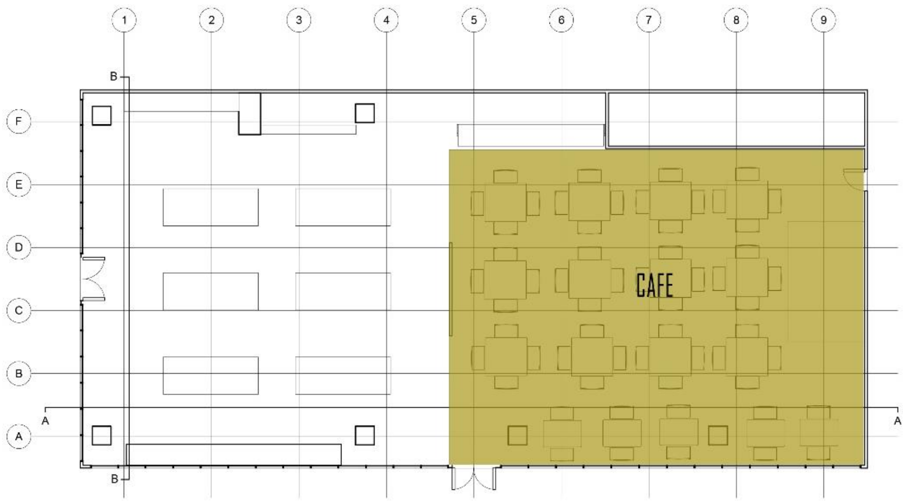
RT = (0.16 x V)/A

= (0.16 x 231) / 102.31

= 0.36s

The reverberation time for Zone 2: Reception in 2000 Hz of absorption coefficient is 0.36s.

Zone 4: Café Seating Area



Space Volume = (143m ^{2} x 3.5m) + (117m ^{2} x 3.5m) + (88m ^{2} x 3.5m)

= 500.5m ^{3} + 409.5m ^{3} + 308m ^{3}

= 1218m ^{3}

Material absorption coefficient in 500 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (500 Hz)	Area, S (m2)	S x α
Ceiling	Plaster	0.02	198.00	3.96
Ceiling	Timber	0.10	198.00	19.80
Ceiling	Concrete	0.02	55.00	1.10
Wall	Timber	0.42	117.25	49.25

Floor	Concrete	0.04	1218.00	48.72
Door	Glass	0.69	8.75	6.04
Window	Glass	0.10	42.00	4.20
Blind	Timber	0.10	42.00	4.20
Tables	Timber	0.24 per unit	17 unit	4.08
Chairs	Timber	0.24 per unit	58 unit	13.92
Human	-	0.46 per person	20 person	9.2
Total Absorption, A				**164.46**

RT = (0.16 x V)/A

= (0.16 x 1218) / 164.46

= 1.18s

The reverberation time for Zone 4: Café Seating Area in 500 Hz of absorption coefficient is 1.18s.

Material absorption coefficient in 2000 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (2000 Hz)	Area, S (m2)	S x α
Ceiling	Plaster	0.04	198.00	7.92
Ceiling	Timber	0.10	198.00	19.80
Ceiling	Concrete	0.02	55	1.10
Wall	Timber	0.83	117.25	97.32
Floor	Concrete	0.08	1218.00	97.44
Door	Glass	0.96	8.75	8.40
Window	Glass	0.07	42.00	2.94
Blind	Timber	0.10	42.00	4.2
Tables	Timber	0.50 per unit	17 unit	8.50
Chairs	Timber	0.50 per unit	58 unit	29.00
Human	-	0.51 per person	20 person	10.2
Total Absorption, A				**286.82**

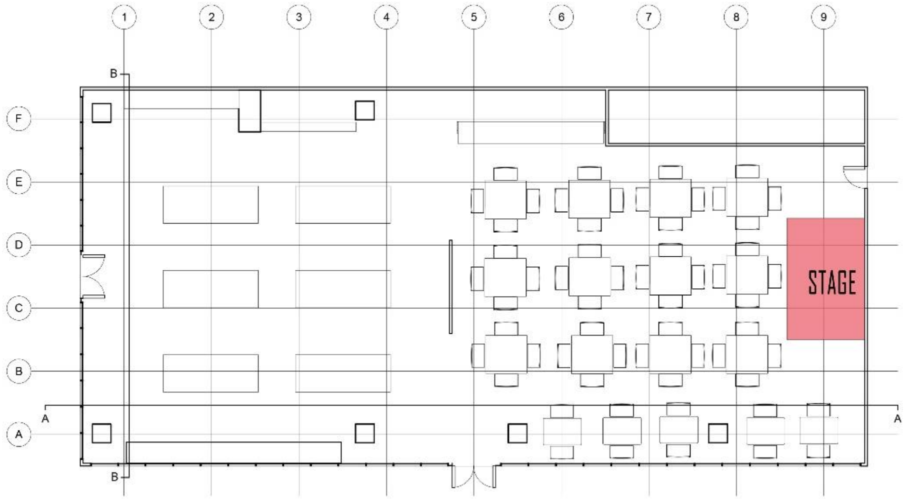
RT = (0.16 x V)/A

= (0.16 x 1218) / 286.82

= 0.68s

The reverberation time for Zone 4: Café Seating Area in 2000 Hz of absorption coefficient is 0.68s.

Zone 5: Stage



Space Volume = 26m ²x 3.5m

= 91m ³

Material absorption coefficient in 500 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (500 Hz)	Area, S (m2)	S x α
Ceiling	Timber	0.10	26.00	2.60
Ceiling	Concrete	0.02	16.00	0.32
Wall	Timber	0.42	22.75	9.56
Floor	Concrete	0.04	91.00	3.64
Total Absorption, A				**16.12**

RT = (0.16 x V)/A

= (0.16 x 91) / 16.12

= 0.90s

The reverberation time for Zone 5: Stage in 500 Hz of absorption coefficient is 0.90s.

Material absorption coefficient in 2000 Hz at peak hour.

Building Elements	Materials	Absorption Coefficient, α (2000 Hz)	Area, S (m2)	S x α
Ceiling	Timber	0.10	26.00	2.60
Ceiling	Concrete	0.02	16.00	0.32
Wall	Timber	0.83	22.75	18.88
Floor	Concrete	0.08	91.00	7.28
Total Absorption, A				**29.08**

RT = (0.16 x V)/A

= (0.16 x 91) / 29.08

= 0.50s

The reverberation time for Zone 5: Stage in 2000 Hz of absorption coefficient is 0.50s.

6.5.2 Sound Pressure Level (SPL)

Zone 1: Shop Area

	A	B	C	D	E	F
1	55	57	58	57	56	55
2	55	57	61	57	57	60
3	59	60	59	56	58	
4	55	58	56	55	55	
5						
6						
7						
8						
9						

Peak Hour:

Highest Reading: 61 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

$61 \quad = 10 \log_{10} (l / 1 \times 10^{-12})$

$l \quad = (10\text{^}6.1)(1 \times 10^{-12})$

$= 1.26 \times 10^{-06}$

Lowest Reading: 55 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

$55 = 10 \log_{10} (l / l \times 10^{-12})$

$l = (10\text{^}5.5)(l \times 10^{-12})$

$= 3.16 \times 10^{-07}$

Total Intensities, I $= (1.26 \times 10^{-06}) + (3.16 \times 10^{-07})$

$= 1.58 \times 10^{-06}$

Using the formula, Combined SPL $= 10 \log_{10} (p^2 / p_o^2)$, where $p_o = l \times 10^{-12}$

Combined SPL $= 10 \log_{10} [(1.58 \times 10^{-06}) / (l \times 10^{-12})]$

$= 62$ dB

	A	B	C	D	E	F
1	53	54	53	52	53	52
2	54	54	56	54	55	54
3	58	56	58	56	56	
4	57	57	57	57	60	
5						
6						
7						
8						
9						

Non-Peak Hours:

Highest Reading: 60 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

$60 \quad = 10 \log_{10} (l / 1 \times 10^{-12})$

$l \quad = (10\text{^}6)(1 \times 10^{-12})$

$= 1 \times 10^{-06}$

Lowest Reading: 52 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

$52 \quad = 10 \log_{10} (l / 1 \text{ x } 10^{-12})$

$l \quad = (10\text{^}5.2)(1 \text{ x } 10^{-12})$

$= 1.58 \text{ x } 10^{-07}$

Total Intensities, I $= (1 \text{ x } 10^{-06}) + (1.58 \text{ x } 10^{-07})$

$= 1.16 \text{ x } 10^{-06}$

Using the formula, Combined SPL = $10 \log_{10} (p^2 / p_o^2)$, where $p_o = 1 \text{ x } 10^{-12}$

Combined SPL $= 10 \log_{10} [(1.16 \text{ x } 10^{-06}) / (1 \text{ x } 10^{-12})]$

= 60.6 dB

Zone 2: Reception

	A	B	C	D	E	F
1						
2						
3						58
4						56
5						
6						
7						
8						
9						

Peak Hour:

Highest Reading: 58 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

$58 \quad = 10 \log_{10} (l / 1 \times 10^{-12})$

$l \quad = (10\text{^}5.8)(1 \times 10^{-12})$

$= 6.3 \times 10^{-07}$

Lowest Reading: 56 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

56 $= 10 \log_{10} (l / \mathrm{l} \times 10^{-12})$

$l = (10^{5.6})(\mathrm{l} \times 10^{-12})$

$= 3.98 \times 10^{-07}$

Total Intensities, I $= (6.3 \times 10^{-07}) + (3.98 \times 10^{-07})$

$= 1.03 \times 10^{-06}$

Using the formula, Combined SPL $= 10 \log_{10} (p^2 / p_o^2)$, where $p_o = \mathrm{l} \times 10^{-12}$

Combined SPL $= 10 \log_{10} [(1.03 \times 10^{-06}) / (\mathrm{l} \times 10^{-12})]$

$= 60.1$ dB

	A	B	C	D	E	F
1						
2						
3						55
4						63
5						
6						
7						
8						
9						

Non-Peak Hour:

Highest Reading: 63 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

$63 = 10 \log_{10} (l / \mathrm{l} \times 10^{-12})$

$l = (10\text{^}6.3)(\mathrm{l} \times 10^{-12})$

$= 2 \times 10^{-06}$

Lowest Reading: 55 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

$55 \quad = 10 \log_{10} (l / 1 \text{ x } 10^{-12})$

$l \quad = (10\text{^}5.5)(1 \text{ x } 10^{-12})$

$= 3.16 \text{ x } 10^{-07}$

Total Intensities, I $= (2 \text{ x } 10^{-06}) + (3.16 \text{ x } 10^{-07})$

$= 2.32 \text{ x } 10^{-06}$

Using the formula, Combined SPL = $10 \log_{10} (p^2 / p_o^2)$, where $p_o = 1 \text{ x } 10^{-12}$

Combined SPL $= 10 \log_{10} [(2.32 \text{ x } 10^{-06}) / (1 \text{ x } 10^{-12})]$

= 63.7 dB

Zone 3: Bar and Storage

	A	B	C	D	E	F
1						
2						
3						
4						
5						60
6						58
7						57
8						56
9						55

Peak Hour:

Highest Reading: 60 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

$60 \quad = 10 \log_{10} (l / 1 \times 10^{-12})$

$l \quad = (10^6)(1 \times 10^{-12})$

$= 1 \times 10^{-06}$

Lowest Reading: 55 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

$55 \quad = 10 \log_{10} (l / 1 \times 10^{-12})$

$l \quad = (10\text{^}5.5)(1 \times 10^{-12})$

$= 3.16 \times 10^{-07}$

Total Intensities, I $= (1 \times 10^{-06}) + (3.16 \times 10^{-07})$

$= 1.32 \times 10^{-06}$

Using the formula, Combined SPL = $10 \log_{10} (p^2 / p_o^2)$, where $p_o = 1 \times 10^{-12}$

Combined SPL $= 10 \log_{10} [(1.32 \times 10^{-06}) / (1 \times 10^{-12})]$

$= 61.2$ dB

	A	B	C	D	E	F
1						
2						
3						
4						
5						64
6						57
7						54
8						58
9						57

Non-Peak Hour:

Highest Reading: 64 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

$64 \quad = 10 \log_{10} (l / 1 \times 10^{-12})$

$l \quad = (10\text{^}6.4)(1 \times 10^{-12})$

$= 2.51 \times 10^{-06}$

Lowest Reading: 54 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

$54 \quad = 10 \log_{10} (l / 1 \times 10^{-12})$

$l \quad = (10^{5.4})(1 \times 10^{-12})$

$= 2.51 \times 10^{-07}$

Total Intensities, I $= (2.51 \times 10^{-06}) + (2.51 \times 10^{-07})$

$= 2.76 \times 10^{-06}$

Using the formula, Combined SPL = $10 \log_{10} (p^2 / p_o^2)$, where $p_o = 1 \times 10^{-12}$

Combined SPL $= 10 \log_{10} [(2.76 \times 10^{-06}) / (1 \times 10^{-12})]$

$= 64.4$ dB

Zone 4: Café Seating Area

	A	B	C	D	E	F
1						
2						
3						
4						
5	57	58	62	64	62	
6	58	59	60	58	58	
7	56	60	58	58	58	
8	54	54	54	57	57	
9	56	56			56	

Peak Hour:

Highest Reading: 64 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

$64 = 10 \log_{10} (l / 1 \times 10^{-12})$

$l = (10^{6.4})(1 \times 10^{-12})$

$= 2.51 \times 10^{-06}$

Lowest Reading: 54 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

54 $= 10 \log_{10} (l / l \times 10^{-12})$

$l = (10\hat{}5.4)(l \times 10^{-12})$

$= 2.51 \times 10^{-07}$

Total Intensities, I $= (2.51 \times 10^{-06}) + (2.51 \times 10^{-07})$

$= 2.76 \times 10^{-06}$

Using the formula, Combined SPL = $10 \log_{10} (p^2 / p_o^2)$, where $p_o = l \times 10^{-12}$

Combined SPL $= 10 \log_{10} [(2.76 \times 10^{-06}) / (l \times 10^{-12})]$

$= 64.4$ dB

	A	B	C	D	E	F
1						
2						
3						
4						
5	56	56	57	56	58	
6	53	54	55	55	57	
7	55	57	54	54	53	
8	53	51	52	55	58	
9	58	57			54	

Non-Peak Hour:

Highest Reading: 58 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

58 $= 10 \log_{10} (l / 1 \times 10^{-12})$

l $= (10\text{^}5.8)(1 \times 10^{-12})$

$= 6.3 \times 10^{-07}$

Lowest Reading: 51 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

51 $= 10 \log_{10} (l / 1 \times 10^{-12})$

$l = (10\text{^}5.1)(1 \times 10^{-12})$

$= 1.26 \times 10^{-07}$

Total Intensities, I $= (6.3 \times 10^{-07}) + (1.26 \times 10^{-07})$

$= 7.56 \times 10^{-07}$

Using the formula, Combined SPL $= 10 \log_{10} (p^2 / p_o^2)$, where $p_o = 1 \times 10^{-12}$

Combined SPL $= 10 \log_{10} [(7.56 \times 10^{-07}) / (1 \times 10^{-12})]$

$= 58.8$ dB

Zone 5: Stage

	A	B	C	D	E	F
1						
2						
3						
4						
5						
6						
7						
8						
9			59	55		

Peak Hour:

Highest Reading: 59 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

$59 \quad = 10 \log_{10} (l / 1 \text{ x } 10^{-12})$

$l \quad = (10\text{^}5.9)(1 \text{ x } 10^{-12})$

$= 7.94 \text{ x } 10^{-07}$

Lowest Reading: 55 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

$55 \qquad = 10 \log_{10} (I / 1 \times 10^{-12})$

$I \qquad = (10\text{^}5.5)(1 \times 10^{-12})$

$= 3.16 \times 10^{-07}$

Total Intensities, I $\qquad = (7.94 \times 10^{-07}) + (3.16 \times 10^{-07})$

$= 1.11 \times 10^{-06}$

Using the formula, Combined SPL = $10 \log_{10} (p^2 / p_o^2)$, where $p_o = 1 \times 10^{-12}$

Combined SPL $\qquad = 10 \log_{10} [(1.11 \times 10^{-06}) / (1 \times 10^{-12})]$

$= 60.5$ dB

	A	B	C	D	E	F
1						
2						
3						
4						
5						
6						
7						
8						
9			57	55		

Non-Peak Hour:

Highest Reading: 57 dB

Using the formula, $L = 10 \log_{10} (l / l_o)$,

$57 \quad = 10 \log_{10} (l / 1 \text{ x } 10^{-12})$

$l \quad = (10\text{^}5.7)(1 \text{ x } 10^{-12})$

$= 5.01 \text{ x } 10^{-07}$

Lowest Reading: 55 dB

Use the formula, $L = 10 \log_{10} (l / l_o)$,

$55 \quad = 10 \log_{10} (l / 1 \times 10^{-12})$

$l \quad = (10\text{^}5.5)(1 \times 10^{-12})$

$= 3.16 \times 10^{-07}$

Total Intensities, I $= (5.01 \times 10^{-07}) + (3.16 \times 10^{-07})$

$= 8.17 \times 10^{-07}$

Using the formula, Combined SPL = $10 \log_{10} (p^2 / p_o^2)$, where $p_o = 1 \times 10^{-12}$

Combined SPL $= 10 \log_{10} [(8.17 \times 10^{-07}) / (1 \times 10^{-12})]$

$= 59.1$ dB

6.5.3 Sound Reduction Index (SRI)

Zone 1: Shop Area

Building Elements	Materials	Sound Reduction Index, SRI	Transmission Coefficient, T	Area, S /m^2
Wall	Timber	22	6.31×10^{-03}	162.00
Door	Glass	26	2.51×10^{-03}	8.75
Window	Glass	26	2.51×10^{-03}	14.00

Wall (Timber)

Using SRI $= 10 \log_{10} 1/T$

$22 = 10 \log_{10} 1/T$

$T = 1 / (10\text{^}2.2)$

$= 6.31 \times 10^{-03}$

Door (Glass)

Using SRI $= 10 \log_{10} 1/T$

$26 = 10 \log_{10} 1/T$

$T = 1 / (10\text{^}2.6)$

$= 2.51 \times 10^{-03}$

Window (Glass)

Using SRI $= 10 \log_{10} 1/T$

$26 = 10 \log_{10} 1/T$

$T = 1 / (10^{2.6})$

$= 2.51 \times 10^{-03}$

$T_{av} = [(6.31 \times 10^{-03}) + (2.51 \times 10^{-03}) + (2.51 \times 10^{-03})] / 184.75$

$= 6.13 \times 10^{-05}$

Overall SRI $= 10 \log_{10} 1/T$

$= 10 \log_{10} 1 / (6.13 \times 10^{-05})$

$= 42.1$ dB

Zone 2: Reception

Building Elements	Materials	Sound Reduction Index, SRI	Transmission Coefficient, T	Area, S /m^2
Wall	Timber	22	6.31×10^{-03}	35.00

Wall (Timber)

Using SRI $= 10 \log_{10} 1/T$

22 $= 10 \log_{10} 1/T$

T $= 1 / (10^{2.2})$

$= 6.31 \times 10^{-03}$

T_{av} $= (6.31 \times 10^{-03}) / 35$

$= 1.80 \times 10^{-04}$

Overall SRI $= 10 \log_{10} 1/T$

$= 10 \log_{10} 1 / (1.80 \times 10^{-04})$

$= 37.4$ dB

Zone 3: Bar & Storage

Building Elements	Materials	Sound Reduction Index, SRI	Transmission Coefficient, T	Area, S /m^2
Wall	Timber	22	6.31×10^{-03}	89.25

Wall (Timber)

Using SRI = $10 \log_{10} 1/T$

22 = $10 \log_{10} 1/T$

T = 1 / (10^2.2)

= 6.31×10^{-03}

T_{av} = $(6.31 \times 10^{-03}) / 89.25$

= 7.07×10^{-05}

Overall SRI = $10 \log_{10} 1/T$

= $10 \log_{10} 1 / (7.07 \times 10^{-05})$

= 41.5 dB

Zone 4: Café Seating Area

Building Elements	Materials	Sound Reduction Index, SRI	Transmission Coefficient, T	Area, S /m^2
Wall	Timber	22	6.31×10^{-03}	117.25
Door	Glass	26	2.51×10^{-03}	8.75
Window	Glass	26	2.51×10^{-03}	42.00

Wall (Timber)

Using SRI $= 10 \log_{10} 1/T$

$22 = 10 \log_{10} 1/T$

$T = 1 / (10^{\wedge}2.2)$

$= 6.31 \times 10^{-03}$

Door (Glass)

Using SRI $= 10 \log_{10} 1/T$

$26 = 10 \log_{10} 1/T$

$T = 1 / (10^{\wedge}2.6)$

$= 2.51 \times 10^{-03}$

Window (Glass)

Using SRI $= 10 \log_{10} 1/T$

$26 = 10 \log_{10} 1/T$

$T = 1 / (10^{2.6})$

$= 2.51 \times 10^{-03}$

$T_{av} = [(6.31 \times 10^{-03}) + (2.51 \times 10^{-03}) + (2.51 \times 10^{-03})] / 168$

$= 6.74 \times 10^{-05}$

Overall SRI $= 10 \log_{10} 1/T$

$= 10 \log_{10} 1 / (6.74 \times 10^{-05})$

$= 41.7$ dB

Zone 5: Stage

Building Elements	Materials	Sound Reduction Index, SRI	Transmission Coefficient, T	Area, S /m^2
Wall	Timber	22	6.31×10^{-03}	22.75

Wall (Timber)

Using SRI $= 10 \log_{10} 1/T$

22 $= 10 \log_{10} 1/T$

T $= 1 / (10\^2.2)$

$= 6.31 \times 10^{-03}$

T_{av} $= (6.31 \times 10^{-03}) / 22.75$

$= 2.77 \times 10^{-04}$

Overall SRI $= 10 \log_{10} 1/T$

$= 10 \log_{10} 1 / (2.77 \times 10^{-04})$

$= 35.6$ dB

6.5.4 Design Strategies and Evaluation

Zone 1: Shop Area

Reverberation time, RT

At 500 Hz of absorption coefficient: 1.55s

At 2000 Hz of absorption coefficient: 0.92s

Combined Sound Pressure Level

At Peak hour: 62 dB

At Non-peak hour: 60.6 dB

Overall Sound Reduction Index: 42.1 dB

According to the standard of reverberation time, the standard comfort reverberation time is between 0.8s to 1.3s. The reverberation time in Zone 1 at 500 Hz of absorption coefficient is slightly longer than the standard comfort reverberation time. However, it does not exceed by a lot where the excess echo produced are most of the time cover by the constant noise from air conditioners and speakers. On the other hand, the reverberation time at 2000 Hz of absorption coefficient falls right between the standard comfort reverberation times. Timber furnished wall, with its high absorption coefficient and large area, contributes the most in providing the comfort reverberation time.

In Zone 1, the combined sound pressure level at peak hour is slightly higher than non-peak hour by 1.4 dB, which is considered indiscernible. This is mainly due to the constant sound from the speakers and televisions and the constant noise from the air conditioners throughout the day. This sound and noise travel both airborne and structure-borne to fill the whole zone. The only slight difference is because there are less people visiting the place during non-peak hour compare to peak hour. Normally, visitors who shop in this zone will have occasional conversation and conversation. Attendant can also be seen explaining each of the items to the visitors. However, all this noise will only travel throughout the first half of Jing-Si Books & Café as there is a timber partition between Zone 1 and Zone 4 to reduce the noise from travelling to Zone 4, which is the Café seating area.

The overall sound reduction index of Zone 1 is 42.1 dB, which is considered high where it effectively reduced the external noise from transmitting through the partition wall into Zone 1. The choice of using timber furnished wall is one of the main reason where the timber furnished wall is a good insulator to absorb and reduce the noise.

Zone 2: Reception

Reverberation time, RT

At 500 Hz of absorption coefficient: 0.58s

At 2000 Hz of absorption coefficient: 0.30s

Combined Sound Pressure Level

At Peak hour: 60.1 dB

At Non-peak hour: 63.7 dB

Overall Sound Reduction Index: 37.4 dB

According to the standard of reverberation time, the standard comfort reverberation time is between 0.8s to 1.3s.The reverberation time in Zone 2 at 500 Hz of absorption coefficient is slightly shorter than the standard comfort reverberation time. However it is not too low so that we have to speak up in order for someone to hear what we have to say. On the other hand the reverberation time at 2000 Hz of absorption coefficient is lower than that of the standard comfort reverberation time. The timber finished walls and timber façade absorb too much sound hence causing the value to drop too low. Hence the reverberation time in zone 2 is slightly shorter than the optimal time.

In Zone 2, the combined sound pressure level at peak hour is slightly lower than during the non-peak hour by 2.6 dB, which is considered indiscernible. This is mainly due to the materials present at the area which are mostly timber that help absorb the sound from the surrounding people and constant sound from the speakers, televisions and air conditioners throughout the day. This so that there is no echo present so that customers can clearly converse with the cashiers when conducting their transaction. The only slight difference is because there are less people visiting the place during non-peak hour compare to peak hour. As compared to other the surrounding Zone 1, less people visit it as not every customer buys things at the café. Most of them only browse through the display objects and occasionally buy things. However, customers have to speak when conversing with the cashier when purchasing items, thus this causes an overall higher sound pressure level when compared to Zone 1.

The overall sound reduction index of Zone 2 is 37.4dB, which is considered high as it the external noise from transmitting to other areas using its timber column and timber façade. The choice of it having an overall small total surface area also helps make it have an overall better sound reduction index and help the wall facades absorb the sound.

Zone 3: Bar & Storage

Reverberation time, RT

At 500 Hz of absorption coefficient: 0.71s

At 2000 Hz of absorption coefficient: 0.36s

Combined Sound Pressure Level

At Peak hour: 61.2 dB

At Non-peak hour: 64.4 dB

Overall Sound Reduction Index: 41.5 dB

According to the standard of reverberation time, the standard comfort reverberation time is between 0.8s to 1.3s.The reverberation time at Zone 3 at 500 Hz of absorption coefficient is slightly lower than the standard comfort reverberation time. However, it is not too low where people have to speak up to be heard. On the other hand, the reverberation time at 2000 Hz of absorption coefficient is lower than the standard comfort reverberation time. The timber furnished walls and timber façade has a high absorption coefficient and causes the comfort reverberation time to be low. Hence, the reverberation time in Zone 3 is slightly shorter than the optimal time.

In Zone 3, the combined sound pressure level at peak hour is slightly lower than during the non-peak hour by 3.2 dB, which is considered just indiscernible. This is mainly due to the materials present at the area, which are mostly timbers that help absorb the sound from the surrounding people and constant sound from the speakers, televisions and air conditioners throughout the day. This so that there is no echo present so that customers can clearly converse with the baristas when placing their orders. The only slight difference is because very few people go to the actual bar to order their drinks, as normally the waiters take the customers' orders at the seating area at the café The more visible sounds are that of the blender crushing ices, or the tap at the sink, which is used to wash the cups and plates. Also occasionally there is the sound of kettle whistling as the water is being boiled. Although the payment for the drinks are usually collected at the seating area, however some customers do come to the bar are to pay for their drinks as well as to browse the menu. Sometimes customers speak to the waiters or waitresses, which causes an overall higher sound pressure level. Also the presence of the air-conditioning vent near the area causes for higher sound pressure level.

The overall sound reduction index of Zone 2 is 41.5dB, which is considered high as it reduces the overall external noise from transmitting to other areas through the timber facades, which are good sound absorber's. Also there is a smaller area compared to other areas, which help reduce the echo and help the absorption of sound by the timber, as timber is a good insulator of sound.

Zone 4: Café Seating Area

Reverberation time, RT

At 500 Hz of absorption coefficient: 1.18s

At 2000 Hz of absorption coefficient: 0.68s

Combined Sound Pressure Level

At Peak hour: 64.4 dB

At Non-peak hour: 58.8 dB

Overall Sound Reduction Index: 41.7 dB

According to the standard of reverberation time, the standard comfort reverberation time is between 0.8s to 1.3s. The reverberation time in Zone 1 at 500 Hz of absorption coefficient is within the standard comfort reverberation time range. The timber based furniture and timber furnished wall with high absorption coefficient helps a lot to provide this comfort reverberation time. On the other hand, the reverberation time at 2000 Hz of absorption coefficient is less than the standard comfort reverberation time. This proves that the timber furnished wall and timber based furniture are too much which resulted in this opposite effect.

In Zone 4, the combined sound pressure level at peak hour is noticeably higher than non-peak hour by 5.6 dB, which is just discernible. This is mainly due to the constant sound from the speakers and televisions and the constant noise from the air conditioners throughout the day. This sound and noise travel both airborne and structure-borne to fill the whole zone. However, there is a noticeably decrease in the sound produced by the speakers and television at non-peak hour.

This is mostly because the sound has to be loud enough to be heard during busy peak hour. So during non-peak hour, the café seating area will be more peaceful. There is also a noticeably difference in amount of visitors and users in this zone during non-peak hour compare to peak hour. The users tend to have loud conversation with each other most of the time during peak hour whereas the users tend to keep to themselves at non-peak hour. Students can be found during non-peak hour doing homework quietly in this zone.

The overall sound reduction index of Zone 4 is 41.7 dB, which is considered high where it effectively reduced the external noise from transmitting through the partition wall into Zone 4. The choice of using timber furnished wall is again the main reason here where the large area of timber furnished wall can act as insulator to absorb and reduce the noise.

Zone 5: Stage

Reverberation time, RT

At 500 Hz of absorption coefficient: 0.90s

At 2000 Hz of absorption coefficient: 0.50s

Combined Sound Pressure Level

At Peak hour: 60.5 dB

At Non-peak hour: 59.1 dB

Overall Sound Reduction Index: 35.6 dB

According to the standard of reverberation time, the standard comfort reverberation time is between 0.8s to 1.3s. The reverberation time in Zone 5 at 500 Hz of absorption coefficient is within the standard comfort reverberation time range. The timber furnished wall with high absorption coefficient successfully provides this comfort reverberation time. On the other hand, the reverberation time at 2000 Hz of absorption coefficient is less than the standard comfort reverberation time. For such a small area, the large area of timber furnished wall might be too much which interrupt the transmission of sound effectively from the stage to Zone 4.

In Zone 5, the combined sound pressure level at peak hour is slightly higher than non-peak hour by 1.4 dB, which is indiscernible. This is mainly due to the constant sound from the speakers and televisions and the constant noise from the air conditioners throughout the day. Also during the time the data is being recorded, there is no function or event happening in this zone, which is the stage. As a result, the difference is not big between peak hour and non-peak hour.

The overall sound reduction index of Zone 5 is 35.6 dB, which is very high for such a small area. It effectively reduced the external noise from transmitting through the partition wall into Zone 5, which is important for the stage, and the performance happens here. Once again, the choice of using timber furnished wall is the main reason here where the large area of timber furnished wall effectively act as insulator to absorb and reduce the noise.

7.0 Conclusion

7.1 Lighting

From the overall analysis, some characteristic of the JingSi Café is that it has a low lighting design and rely more on daylighting to illuminate its spaces. The lux level during the day-time is average 300 lux which is just nice for a café, but at night-time the lux level is reduced to average 150 lux because of the absence of daylighting. A few architectural lighting can be spotted in the space, the lantern lighting fixture on the wall in the insides of the café uses the design of Cornice lighting to brighten up the spaces and also cast an aesthetic shape onto the laminated timber finishes of the wall. Other than that, the use of Track lighting around the café is abundant and somehow distracting. It can be seen in the tabulation of data table, because it is used for brightening the merchandise on display.

7.2 Acoustic

The reverberation time of Jing-Si Books & Café range from 0.30s to 1.55s. By comparing to the standard comfort reverberation time by Chartered Institution of Building Services Engineers (CIBSE), which ranges from 0.8s to 1.3s, the reverberation time of the place is inadequate especially for being too low at certain area where the sound cannot be transfer efficiently. According to the study and calculations conducted, the highest combined sound pressure level at peak level can be found in Zone 1 and Zone 4 where most of the human activities take place. Shoppers shopping in Zone 1 and café users at Zone 4 tend to make noise from occasional interaction and conversation. The highest combined sound pressure at non-peak level can be found in Zone 2 and Zone 3 where the waiters or waitresses use the less busy time to clean up and at night, prepare to close the place. The overall sound reduction index is also good where it effectively prevents unwanted noise, be it external or internal, to penetrates to each of the zones.

Acoustical strategies are incorporated when designing Jing-Si Books & Café in order to counter these unwanted noises. One of the acoustical design strategies of Jing-Si Books & Café is by dividing front half area (shop area) and the back half area (café area) with a timber partition in the middle. It effectively reduces and prevents the noise from travelling from shop area to the café area and vice versa. The usage of timber based building materials that has high absorption coefficient, such as timber furnished wall, timber cladding on ceiling, timber furniture and timber blinds also contributes in the noise control of the place. However, according to the study and calculations conducted, the acoustical strategies are proved to be too much at several occasions. Due to the low reverberation time at certain area especially Zone 5 (Stage), the sound is unable to transmit effectively to other zones.

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