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SCHOOL OF ARCHITECTURE, BUILDING AND DESIGN
Bachelor of Science (Honours) (Architecture)

BUILDING SCIENCE 2 [ARC 3413]

PROJECT 1:

Lighting & Acoustic Performance Evaluation and Design

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Furthermore, we would also like to acknowledge with much appreciation the crucial role of the staff of Ploy Restaurant, who facilitates us to measure all required readings of light and acoustic level throughout the restaurant in order to complete the task.

Last but not least, we want to take this opportunity to express a deepest sense of gratitude to manager of Ploy Restaurant, Mr. Prakash, for his cordial support, valuable information and guidance, which helped us in completing this task.

Abstract

For this case study students are to study lighting and acoustic performance in a particular space. Each group were to conduct site visit to their respective case study building. The Ploy restaurant in Damansara is chosen as case study for our group. Prior to site visit, precedents for lighting and acoustic studies were done to develop preliminary understandings in lighting and acoustic design. In validation of research, literature reviews were done to deliver basic terminologies and knowledge for students, which helps in evaluate the building's lighting and acoustic design. Measured drawings were prepared to ease in data collection. Images were taken during site visit for documentation purpose. Observations on lighting scenario and acoustic quality of the space are recorded. On lighting aspect, natural light and artificial light are the factors which need to consider. Besides that, light types, lighting effects and different material used to create different kind of atmosphere are noted to examine the lighting condition. Calculations were done to determine the adequacy of lighting and aid in evaluate the performance. On the other hand, studies on acoustic performance are carried out. By determine the sound sources and the materials' characteristics, solutions for better acoustic quality can be identified. The spatial arrangement also is taken in account to evaluate the acoustic's performance. Diagrams and calculations were done to aid in analysis and provide better understandings. The lighting and acoustic condition of the case study building was presented in a thorough manner. Suggestions and improvements were included base on knowledge and analysis, to provide better solutions for a comfortable environment.

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1.0 INTRODUCTION

1.1 Aims and Objectives

The aims and objectives of this report are listed as below:

- To analyse and evaluate the lighting and acoustic performance of chosen case study building.
- To determine the characteristics and function of daylighting and artificial lighting. In addition, characteristics and function of sound and acoustic are also determined within the chosen space.
- To identify the planning and installation of chosen case study space in order to establish the limitation or acceptable level of lighting and noise level.
- To explore and analyse the factors that affects the lighting and noise level of the selected space.
- Able to produce in-depth documentation of lighting and acoustic installation planning layout illustration by using drawings, sketches and pictures
- To implement basic understanding into the analysis of lighting layout and acoustic arrangements by using certain methods or calculations.
- To tabulate or draw graphs and diagrams to illustrate relevant topics.
- To identify technical issues regarding lighting and acoustic design and suggest improvements to enhance the quality of design solution.

1.2 Standard MS 1525 Lux Recommendation

Lighting Standard MS 1525: 2007

Lighting must provide a suitable visual environment within a particular space following the Code of Practice on Energy Efficiency and Use of Energy.

Sufficient and suitable lighting should be provided to a restaurant in order to achieve the desired atmosphere and appearance.

Type of Interior, task or activity	Maintained Illuminance (Lux)	Limiting Glare Rating	Minimum Colour Rendering (Ra)	Remarks
1. General Building Area				
Entrance Hall	100	22	60	
Lounge	200	22	80	
Circulation areas, corridors	100	28	40	Provide a transition zone to avoid sudden change at exit and entrance
Stairs, Escalator and Travelators	150	25	40	
Loading areas, ramps and bays	150	25	40	
Canteen	200	22	80	
Restroom	100	22	80	
Room of Physical exercise	300	22	80	
Cloakrooms, washroom, bathroom, toilet	200	25	80	
2. Restaurant and Hotel				
Reception and cahier desk	500	19	80	Localised lighting may be appropriate
Kitchen	500	22	80	There should be a transition zone between restaurant and kitchen
Restaurant, Dining room	200	22	80	
Self-service Restaurant	200	22	80	
Buffet	300	22	80	
Corridors	100	25	80	Lower levels are acceptable during night time
Multipurpose hall	300	22	80	

Table 1.2.1: Recommendation for lighting at respective area (Source: Code of Lighting, 2002)

1.3 Standard MS1525 dB Recommendation

Acoustic Standard ANSI (2008) S12.2-2008

Acoustic must provide a favourable environment within a particular space comply with American National Standard Institute ANSI (2008) S12.2-2008 Criteria for Evaluation Room Noise. This Standard provides three primary methods for evaluating room noise: a survey method that employs the A-weighted sound level; an engineering method that employs expanded noise criteria (NC) curves; and a method for evaluating low-frequency fluctuating noise using room noise criterion (RNC) curves. (Acoustical Society of America, 2008)

Type of interior, task or activity	Sound Level (dB)
Small Auditorium (<500 seats)	35-39
Large Auditorium (>500 seats)	30-35
Open Plan Classroom	35
Meeting Room	35-44
Office (Small, Private)	40-48
Corridors	44-53
Movie Theatres	39-48
Small Churches	39-44
Courtrooms	39-44
Restaurants	**48-52**
Shops and Garage	57-67
Circulation Path	48-52
Computer Room	48-53
Hotel Room	39-44
Open Plan Office	35-39

Table 1.3.1: Recommendation sound level at respective area (Source: ANSI 2008, S12.2-2008)

As shown as table 1.3.1, recommendation sound level for restaurant falls on the range 48-52dB.

1.4 Site Introduction

Figure 1.4.1: Entrance view of Ploy Restaurant

The Ploy Restaurant (Figure 1.4.1) is chosen as our case study. It is a modern Asian fusion restaurant located in a high rise office building, Work @ Clearwater at Damansara. The building is orientated such a way that it facing the main road, Jalan Changkat Sematan (Diagram 1.4.1). Although the restaurant is located at ground floor but it is not visible from the pedestrian and vehicular route, to provide a more secluded dining experience.

Diagram 1.4.1: Site Plan

'Ploy' means gem in Thai. It serves good quality of Japanese and Thai cuisine. Base on its fine dining concept, it has utilize sleek furniture and lighting in its interior design to achieve the splendid and classy ambiance. One of the most remarkable feature of the restaurant is it has an entrance area with angular timber panels and furniture, welcoming the customers at the first sight.

The Ploy Restaurant opens daily except on weekends and public holidays. The opening hours for lunch time is 12pm-3pm, (Monday-Friday) whereas dinner time is 6pm-12am (Monday-Saturday). During day time the customers are usually working class and residents nearby, the crowd usually swamps in after working hours. Moreover, it also house private events occasionally, there are usually parties, corporate presentation, talks held upon request.

1.4.1 Reason of selection for case study

As one of the best restaurants in Kuala Lumpur area recommended by trip advisor, the Ploy restaurant has unique interior design and attracted many customers by its dining environment. Therefore, it is chosen as our case study and we will approach the studies from two aspects:

<u>Lighting Performance</u>

Figure 1.4.1.1: Indoor and outdoor dining area

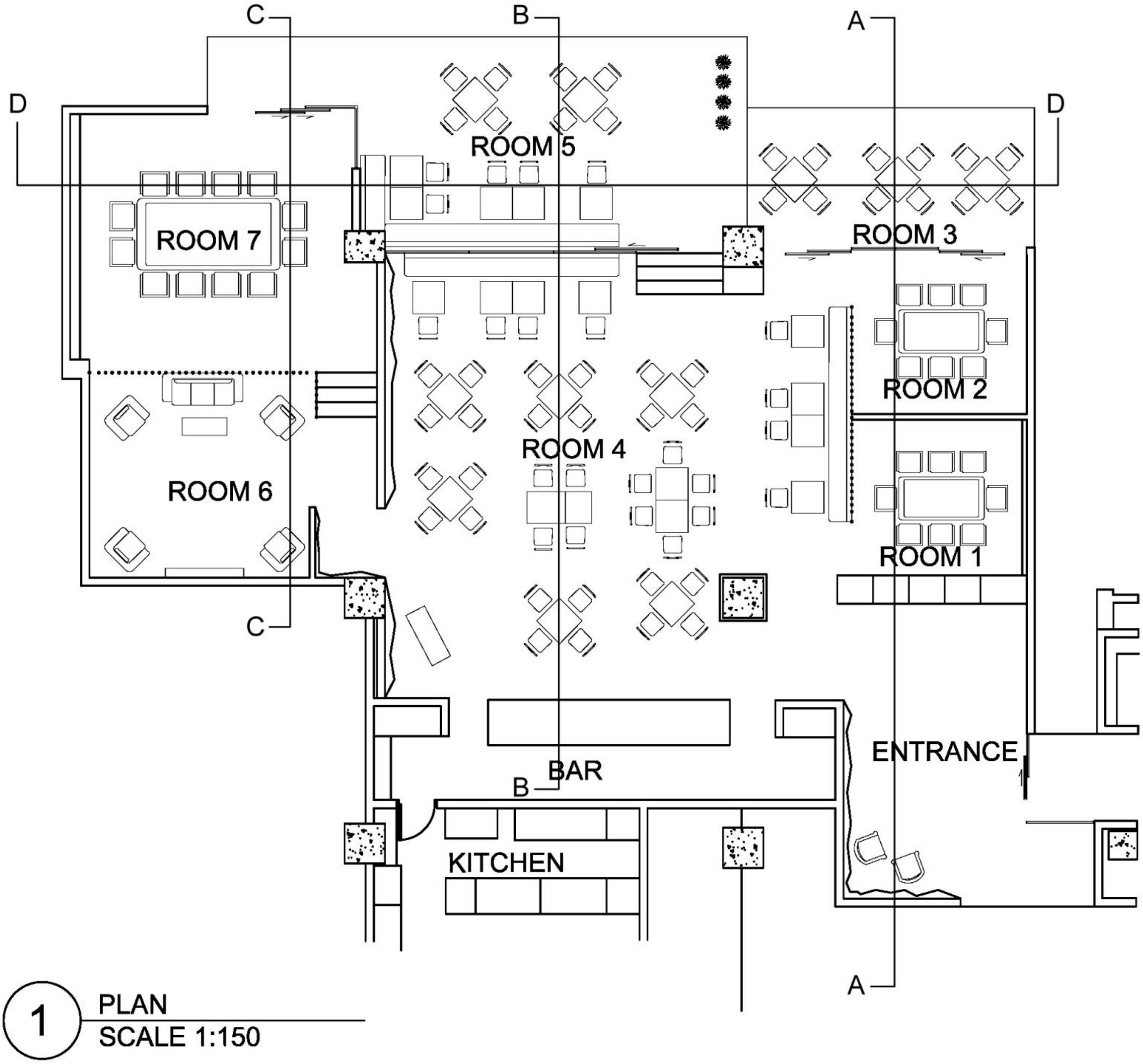
The Ploy Restaurant has indoor and outdoor dining zone which adopt different light source for day time. (Figure 1.4.1.1) That would be interesting study how natural lighting and artificial lighting complement each other and provide different kind of experiences to the occupants. Besides there, the restaurant utilize plenty types of light fittings which enhanced the interior ambiance by giving distinct lighting effect. However, some amendments and improvements on lighting can be made to achieve a more desirable dining environment.

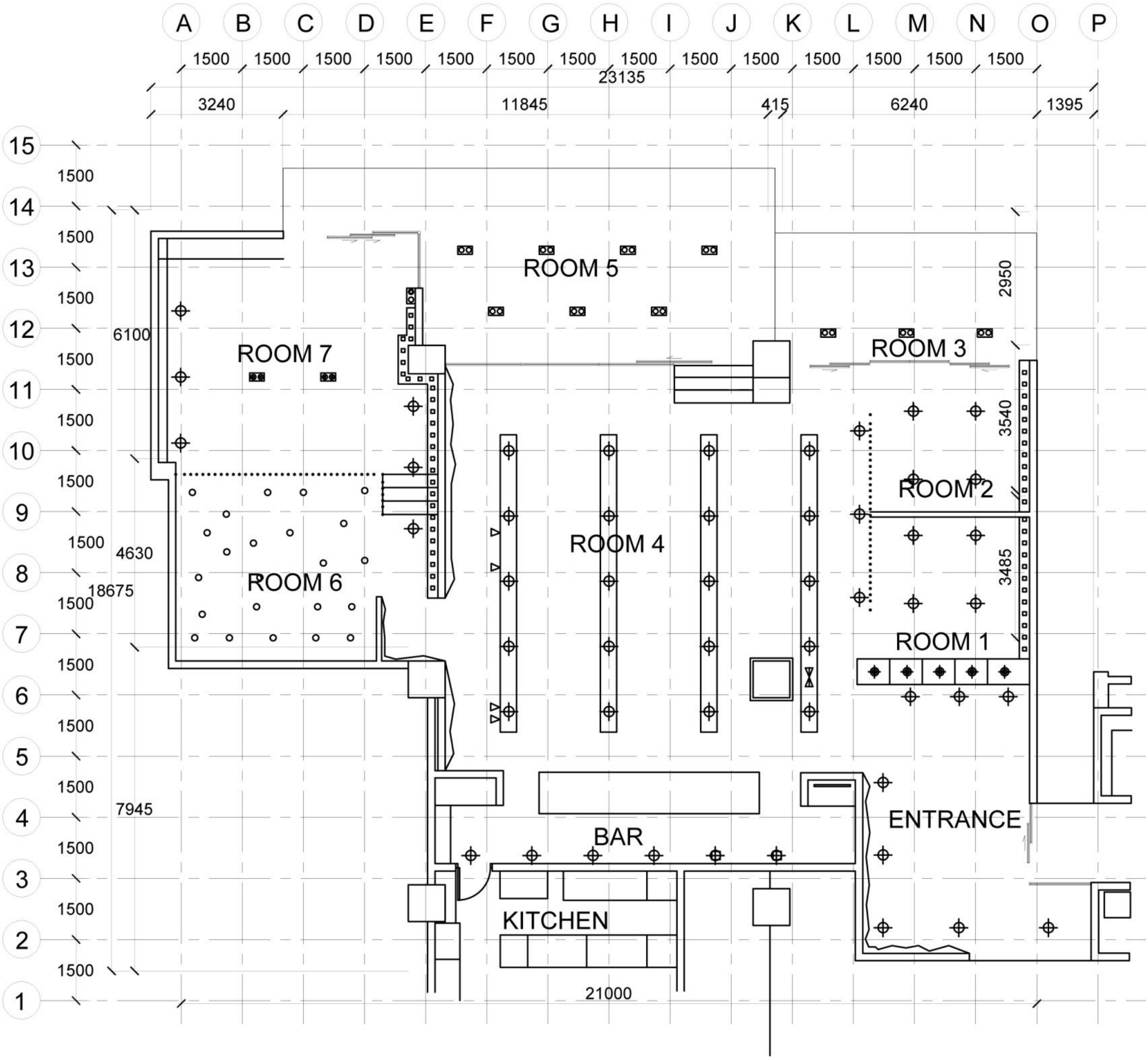
Acoustic Performance

Figure 1.4.1.2: Private event held in the restaurant (Source: PLOY Restaurant, 2014)

Setting of the Ploy Restaurant which situated beside Lebuhraya Sprint has made it an interesting case study for Acoustic. Of how it achieve tranquil environment for its fine dining concept, and also to deal with the sound sources from all the surrounding context such as Clearwater residences and Wisma Antah. The Ploy restaurant utilize different kind of materials and furniture such as carpet that play important role in maintaining acoustic comfort. Due to the restaurant caters for private events (Figure 1.4.1.2), there are microphones, speakers and projector which also contribute to sound sources. Hence, there can be alterations for acoustic performance too.

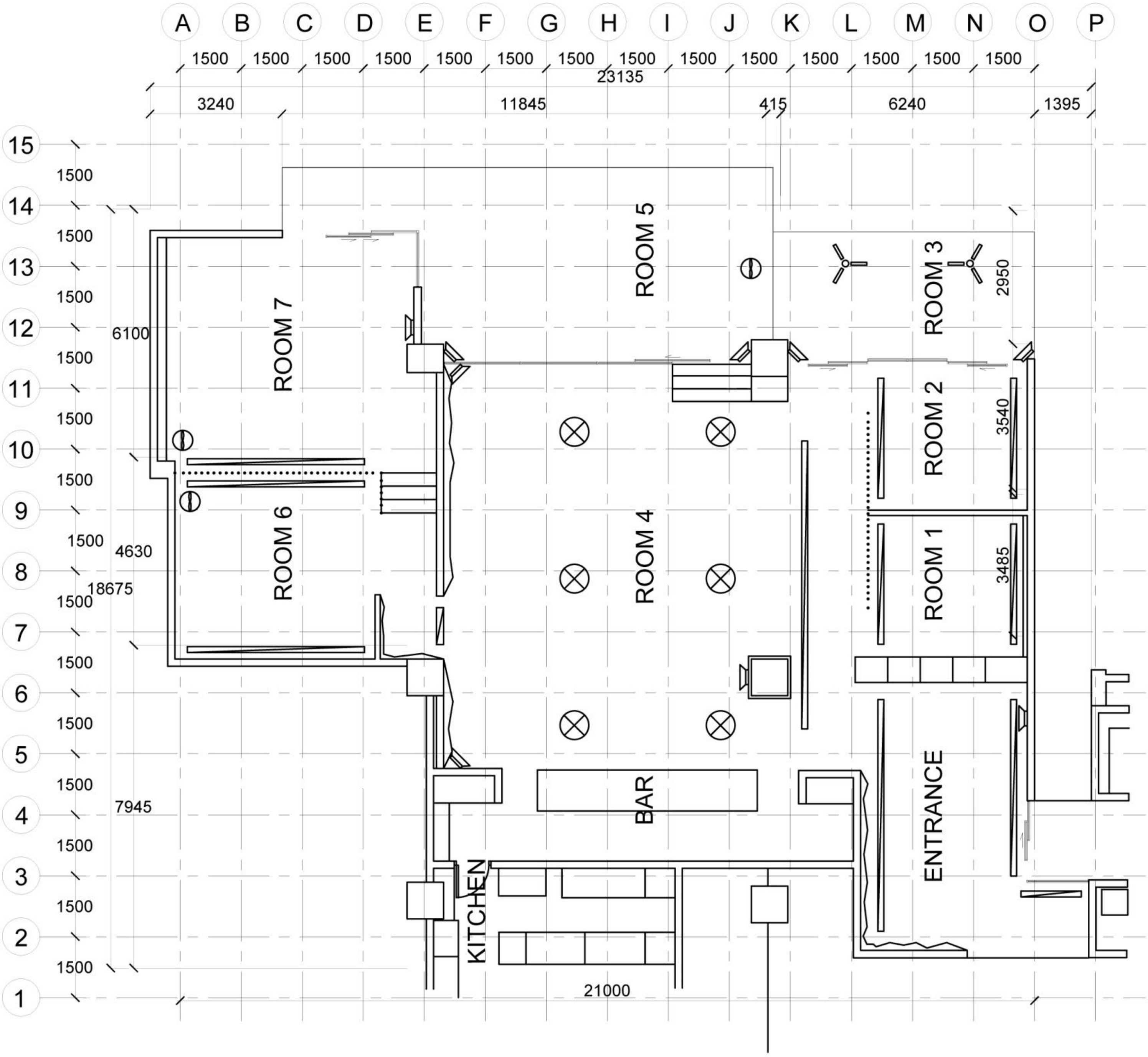
1.5 Measured Drawing





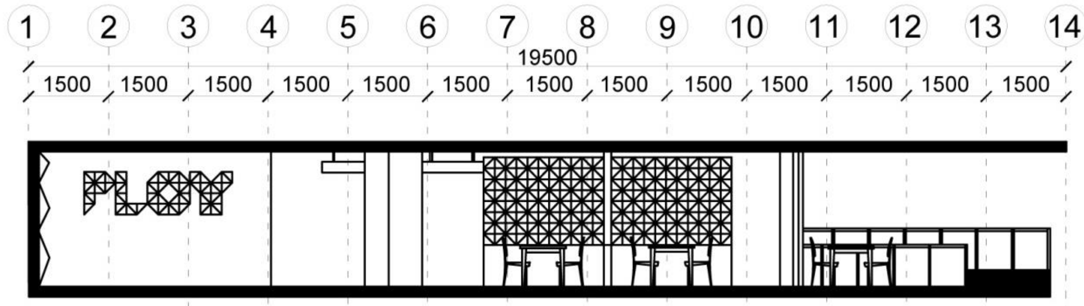
2 REFLECTED CEILING PLAN
SCALE 1:150

RECESSED LIGHT
TUNGSTEN HALOGEN LOW VOLTAGE DOWN LIGHT
HALOGEN DOWN LIGHT
UNDER CABINET HALOGEN DOWN LIGHT
INCANDESCENT LIGHT BULB
TRACK LIGHT
FLUORESCENT LIGHT
EMERGENCY LIGHT

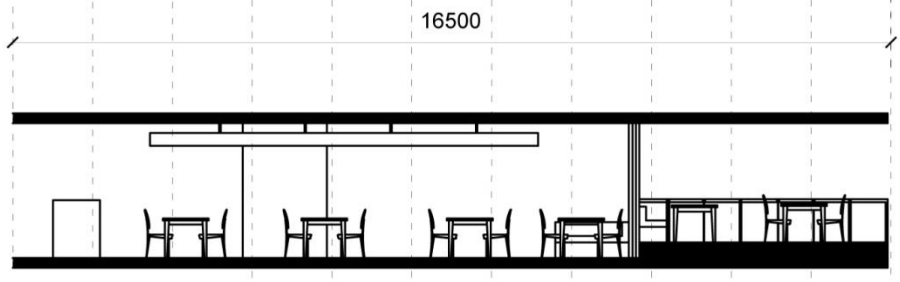


3 REFLECTED CEILING PLAN
SCALE 1:150

- LINEAR DIFFUSER
- CIRCULAR DIFFUSER
- SPEAKER
- CEILING FAN
- STAND FAN



SECTION A-A
SCALE 1:150
4



SECTION B-B
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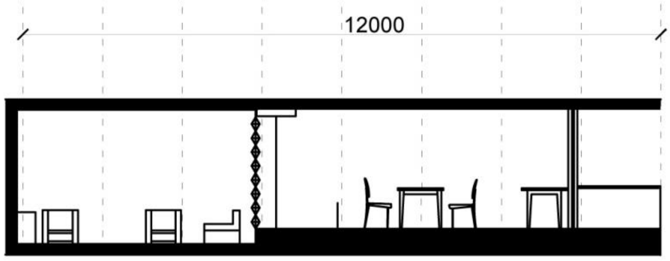
5



SECTION C-C
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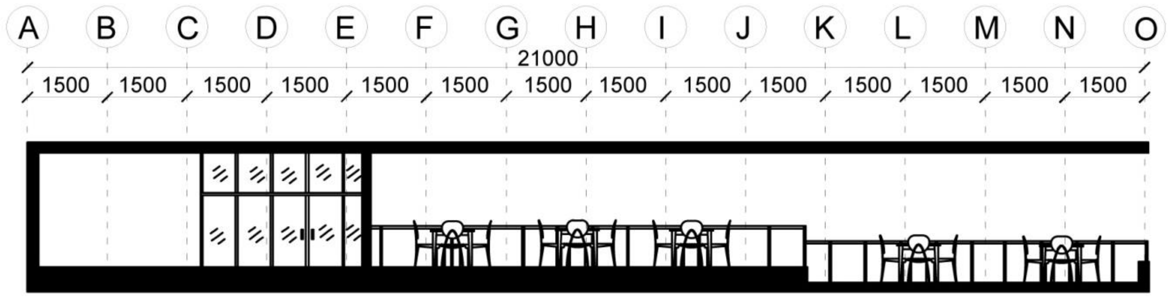


SECTION D-D
SCALE 1:150
7

2.0 LIGHTING STUDY

We find beauty not in the thing itself, but in the patterns of shadows, the light and the darkness, that one thing against another creates.

- Junichiro Tanizaki

2.0.1 Lighting Design in Architecture (The Six Basic Principles)

Illuminance

Illuminance is described as the quantity of light emitted by a light source that lands on a given surface area, measured in footcandles or, in the metric system, lux. In the built environment, illuminance can bring shape and clarity to a nuanced spatial composition, of its capability of controlling the intensity of visual extremes, allowing us to navigate our way through or perform tasks within a space.

Light can provide welcomed visibility, but it can also overstimulate or blind. Thus, it is crucial in the careful control of illuminance levels across spatial trajectories to ensure visual and spatial continuity, comfort and one's ability to see. Together with built form, light and dark as well as the gradients in between form a powerful palette which can further construct the understanding of an architectural space.

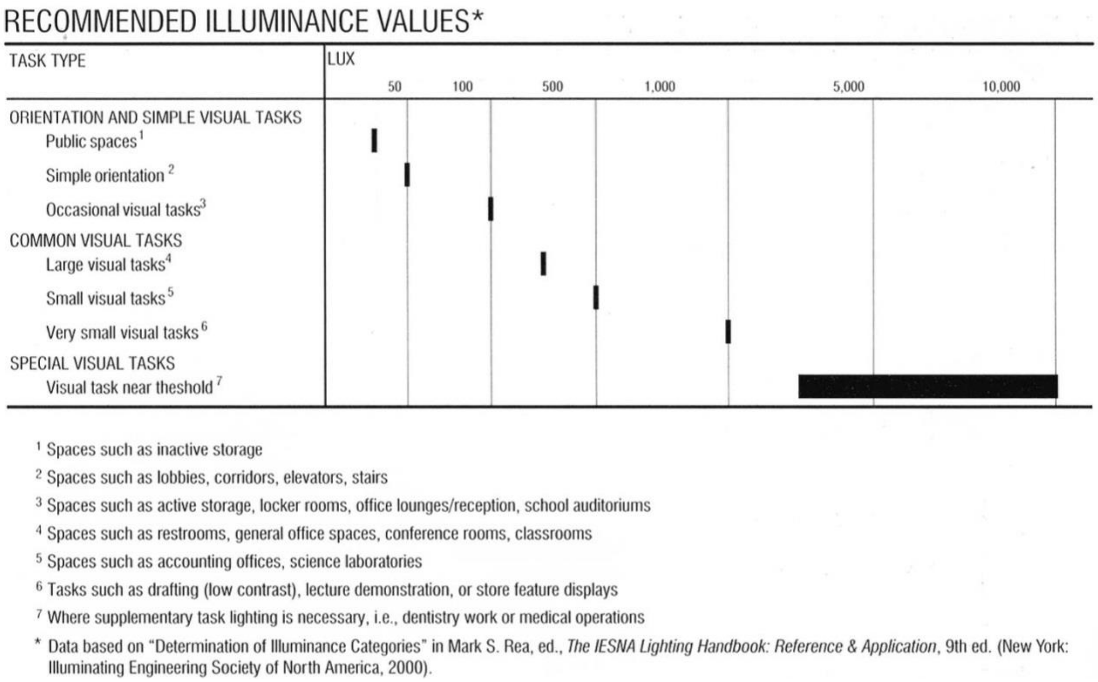


Figure 2.0.1: Recommended illuminance values (Source: Descottes, 2011)

Luminance

Luminance is measured in footlambert or candela per square meter whereas luminance ratios describe the difference in the brightness between two objects or areas in a given environment. The visual property of luminance aims to quantify the intensity of emitted light from a given surface.

Glare is the sensation of discomfort caused when high levels of luminance are misdirected toward the eye. It is a condition that lighting designers must control in their quest to create a visually tolerable and programmatically functional space. Often, the glare of an unshielded light source within plain view can overwhelm the viewer, preventing him from seeing what the light source aims to highlight. For this reason, recessed fixtures, shields and other disguises are often employed to minimize glare, enabling the human eye to focus and adapt to the visual effect of light upon the surface or object they illuminate, as shown in Figure 2.0.1.

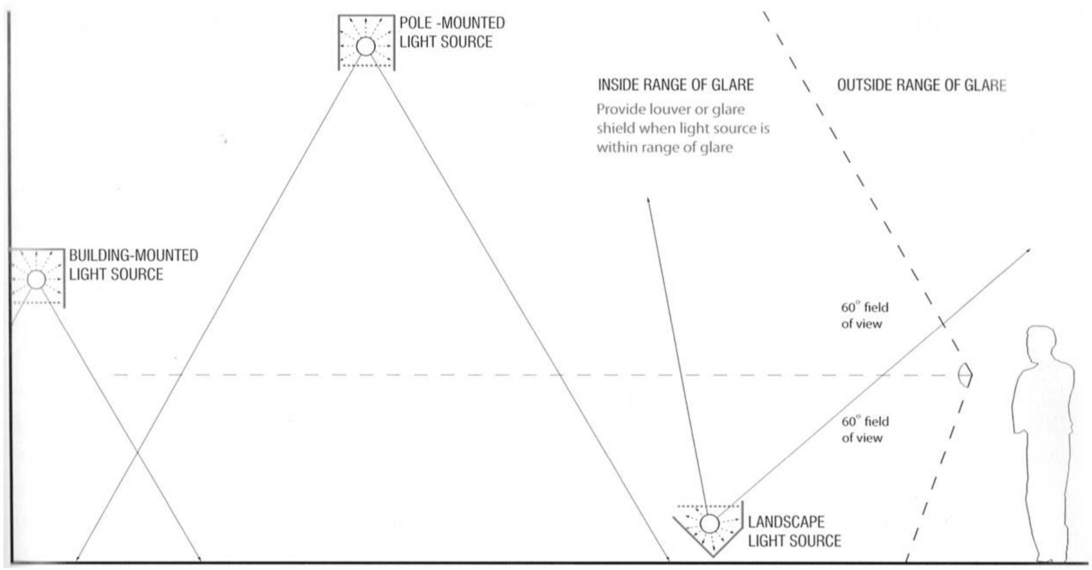


Figure 2.0.1: Glare prevention: Exterior fixtures situated within 60 degrees above eye level generally require shielding to prevent uncomfortable glare (Source: Descottes, 2011)

Color and Temperature

With artificial electric light as well as with mediated natural light, we have the opportunity to manipulate the cycle of colour and introduce other kinds of time and forms of duration. In interior lighting, it is often effective to vary the colour, hue and saturation of light throughout the course of a night in order to give a sense of atmospheric movement and the passing of time. Similarly, the selection of lighting types, the range of frequencies, and the colour temperature of light emitted are essential to staging an appropriate mood and scene.

Height

The example of hierarchy of height of light as shown in Figure 2.0.2 can serves as a model for spaces of both larger and smaller architectural scales. As humans are inclined to adjust the height of a light source to correspond to a desired level of intimacy, different readings of public and private space are created through the variation of light height.

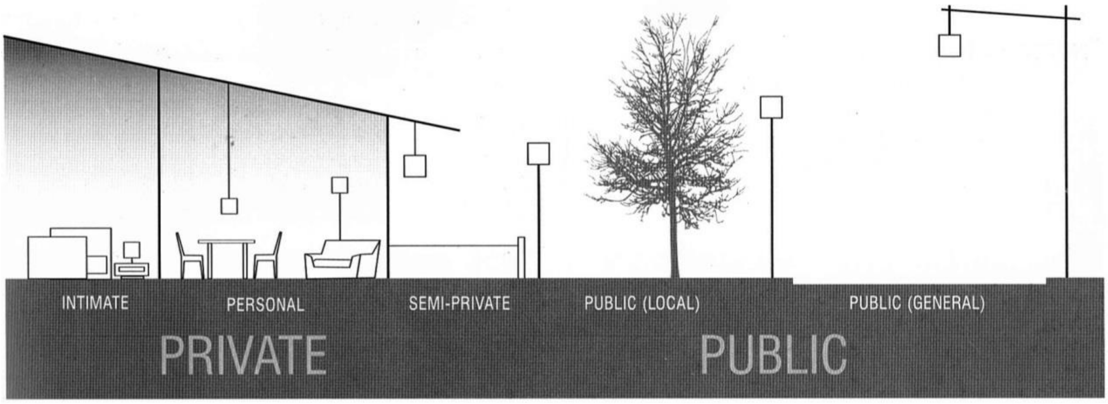


Figure 2.0.2: Height of light relative to degree of intimacy (Source: Descottes, 2011)

Besides intimacy, the height of a lighting fixture is also one of several variables that affect the intensity, spread and perceived brightness of a given light source. The visual principle of height is also essential in ensuring the functionality of a space.

Density

The visual principle of density can be defined by two parameters: the number of fixtures in a given area and the organizational character of a grouping of fixtures. In lighting design, the concept of power in density could be applied to give hierarchy and order, navigation and depth, as well as rhythm and movement to a space. It has both quantifiable science and subjective judgement, and ultimately, our visual understanding of the effects of densities in a given space can vary by project, program, or emotion.

Direction and Distribution

The directionality of light is generally described in one of three directions— up, down or multidirectional, and its resultant application on an object or area as direct or indirect. The distribution of light is generally either concentrated, where light is focused on a narrow area, or diffuse, where light is dispersed over a wide area. The pairing of differing directionalities and distributions provides a lighting designer with any possibilities for rendering an object or space to differing effect.

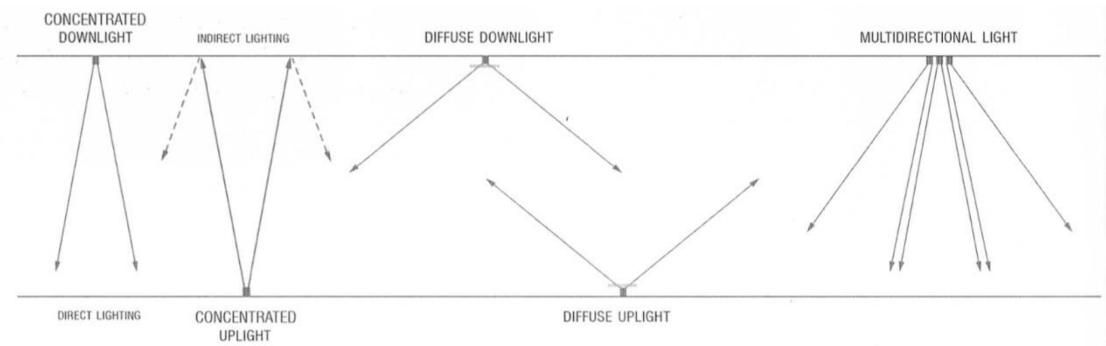


Figure 2.0.3: Direction and distribution of lights (Source: Descottes, 2011)

2.0.2 Lighting Design in Restaurant

The ambiance of a restaurant will be informed by the lighting design and a good lighting design is crucial for a patron to view food under the best possible light. Frable (1995) suggested that the color temperature of the lighting relates directly to the accurate color of the food. Low-level mood lighting is typical of fine dining, while bright lighting offers a more casual dining experience. Another reason why lighting is such a crucial element within restaurant design is because incorrect lighting can prevent the effectiveness of all other elements.

Over the course of a day, restaurants can change the lighting to suggest different moods. Most restaurants lighting is incandescent because of the warm tones that the lamps provide; however, fluorescent lighting is more energy efficient and may be more appropriate in the kitchen areas.

The followings are considerations and factors affecting lighting design:

- Purpose of the building or space
- Size
- Standard of visual comfort
- Times of day the space is in use
- Required illumination levels
- Distribution of light for adequate performance
- Choice of illuminance
- Amount of permissible/desirable distraction
- Contrast of lighting equipment and its background
- General contrast throughout the space between task and general surroundings

2.1 Precedent Study

Le Jules Verne

Figure 2.1.1: Exterior perspective of Le Jules Verne (Source: Top Hotels, 2014)

<u>Building Fast Facts</u>

Name : Le Jules Verne
Project Completion: 2004
Function : Restaurant
Location : Eiffel Tower, Paris, France
Interior Designer : AgencePatrick Jouin
Client : Alain Ducasse

Situated at the second platform of Paris' iconic Eiffel Tower, the Jules Verne restaurant offers fine dining with unparalleled views of the city. It is clear that in order to enhance the dining experience while at the same time enabling the visibility of the spectacular panoramic views of the City of Lights, the challenge in illuminating this restaurant interior lay in the need to introduce functional and iconic lighting. In achieving this fine balance, L'Observatoire International opted to create a predominantly dark space, where strategic lighting was only placed over the dining table and points of services (L'Obervatoire International, 1993). As a result, the diners have an unobstructed vistas out of the restaurant while the lights of Paris seemed to glow within.

2.1.1 Lighting Analysis

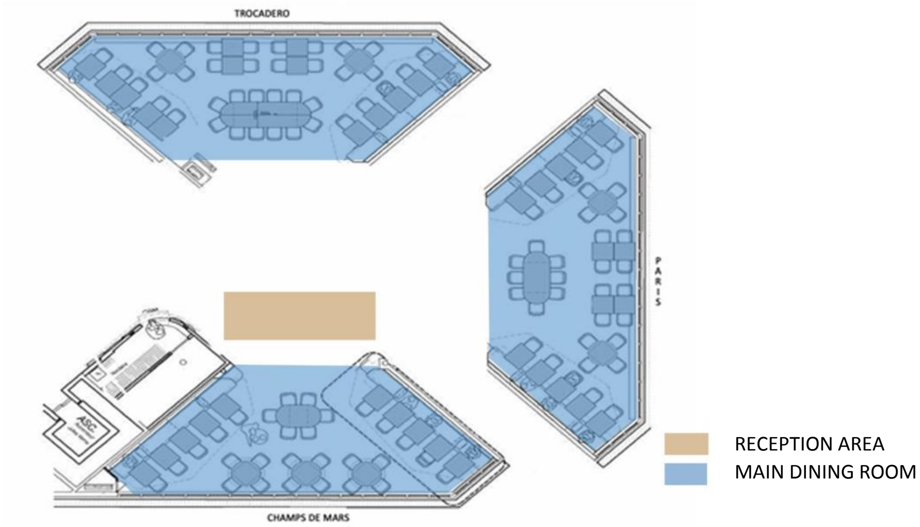


Figure 2.1.1.1: Reception area and main dining room are highlighted in floor plan (Source: Le Jules Verne, 2013)

Referring to Figure 2.1.1.1, the man dining room is organized by having three dining spaces radiating outwards from the a central which composed of bar and service area. This layout of a series of counter spaces and bar surfaces wrap around the core provides a horizon line and visual backdrop to the dining areas.

Reception Area

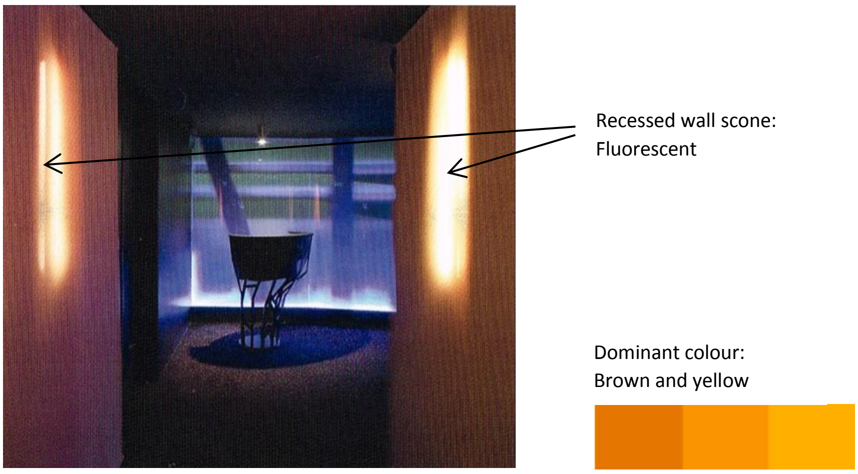


Figure 2.1.1.2: View through entrance corridor toward reception area: The corridor is illuminated by light scones concealed behind mesh curtain walls (Source: Descottes, 2011).

Upon exiting Le Jules Verne's private elevator, one emerges into the reception area. The dimly lit hallway where reception resides has two low-voltage halogen downlight recessed into the ceiling to illuminate this passage. A secondary rhythm of light added into the space by the four fluorescent tubes hidden behind curtains and staggered on either side of the hallway, illustrated in Figure 2.1.1.2. The strategy of locating fluorescent tubes just above the eye level brings a feeling of immediate intimacy to the space, which visually appear as soft, elongated sources of light emanating from behind the curatin. Furthermore, the warm colour temperatures of both light sources rener the atmosphere in rich hues of brown and yellow, allowing the eyes to adjust to a neutral pallete before entering into the main dining room. As the restaurant operates only for reservations and elevator access is reserved exclusively for guests, thus the experience of passage towards reception area is accentuated for linearity through the organized pattern and relatively high density of light fixtures.

	LIGHT SOURCE	ILLUMINANCE	LUMINANCE	COLOR	HEIGHT	DENSITY	DIRECTION / DISTRIBUTION
RECEPTION AREA	CORRIDOR DOWNLIGHTS: LOW-VOLTAGE HALOGEN	0–70 LUX	MEDIUM	WARM	2.3 M (7 FT 6 IN) (CEILING RECESSED)	RANDOM	DIRECT DOWN NARROW BEAM
	RECESSED WALL SCONCE: FLUORESCENT	0–50 LUX	MEDIUM	WARM	1.5 M (5 FT) O.C.	1 M (3 FT) O.C. ORGANIZED PATTERN	DIRECT DOWN CONCENTRATED

Table 2.1.1.1: Artificial light implementation table of reception area (Source: Descottes, 2011)

Figure 2.1.1.3: Low-voltage halogen down light (Source: Downlight, 2014)

Figure 2.1.1.4: Fluorescent wall scone (Source: Visa Lighting, 2014)

Main Dining Room

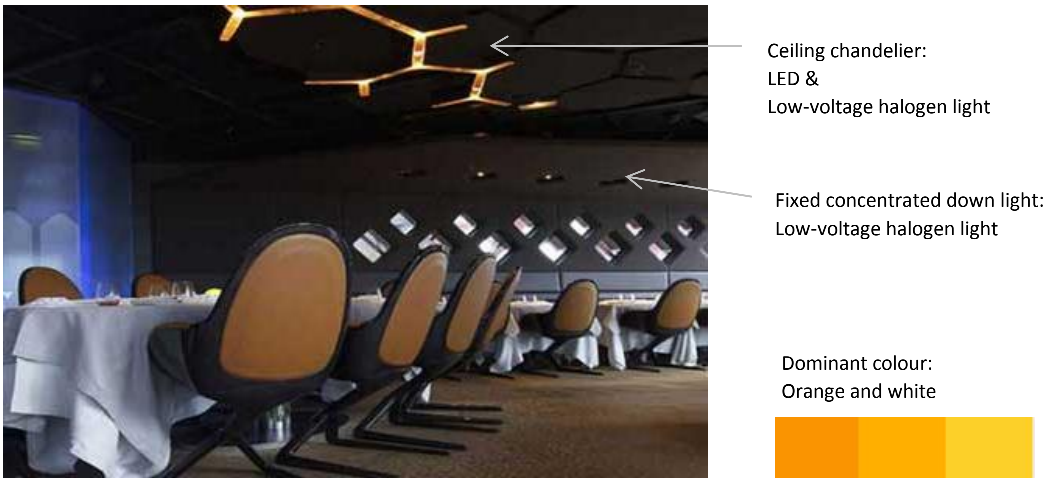


Figure 2.1.1.5: Dining table illuminated by a custom ceiling chandelier (Source: L'Obervatoire International, 1993)

The dominant light source in the main dining area is a custom chandelier system, which draws lines of structure light on the ceiling and the surrounding glass window planes that which the light is reflected upon. The shape of the chandelier derived from the intricate weave of the structural elements of the Eiffel Tower, a motif that also inspired the design of plates, forks and bar stools in the restaurant.

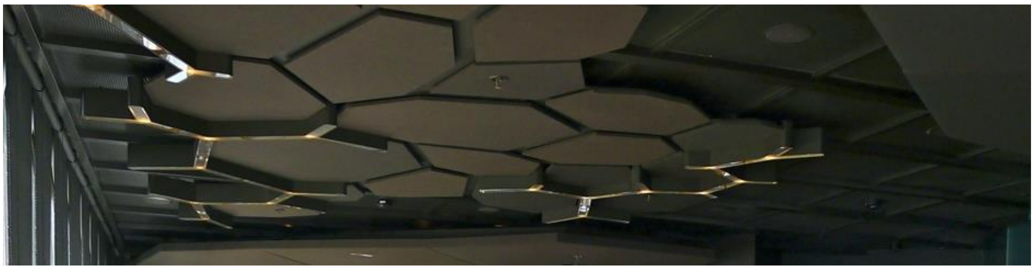


Figure 2.1.1.6: Chandelier lighting system on ceiling.

Figure 2.1.1.7: Plates resembles the design of chandelier.

Figure 2.1.1.8: Bar stool resembles the design of chandelier.

The concept of the seemingly radom-looking chandlier arose from the need to have light in the areas of the dining room where tabes are not in fixed position, enabling a wide variation of layouts according to varying functions and needs. Descottes (2011) outlined "in order to accommodate the rearrangement of furnitures, a light source is needed that coud evenly illuminate a greater area and whose formal logic is independent of any singular table arrangement," referred to Figure 2.1.1.10.

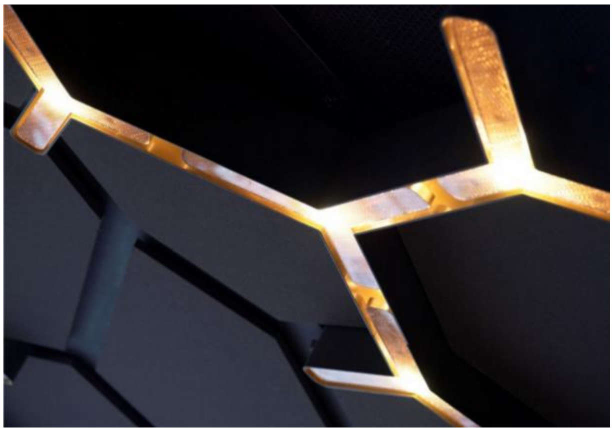


Figure 2.1.1.9: Detail on ceiling chandelier (Source: Jouin, 2014)

As shown in Figure 2.1.1.9, the chandelier contains both LED and low-voltage halogen lights recessed within. The formal structure of light is formed by the LEDs lining the perimeter of the linear openings, while the low-voltage halogen lights scattered throughout provide a more diffuse glow. Both light sources are controlled by a dimmer and the illuminance levels can be adjusted depending on the time and mood desired. The warm colour temperature of the chandelier complements the glow of the city's night sky.

Figure 2.1.1.10: Movable dining table (Source: Jouin, 2014)

Figure 2.1.1.11: Fixed banquet table (Source: Jouin, 2014)

The fixed banquet tables illustrated in Figure 2.1.1.11 are individually illuminated by recessed low-voltage halogen lights installed in the ceiling. These concentrated downlights illuminate te tabletops and are virtually invisible at the ceiling level so that their effect is perceived solely at the table level. The medium luminance levels of these lights result from the reflected light produced by the bright white cloths. Operated same as the chandelier, the banquet table lights can be increased or reduced by dimmers.

Figure 2.1.1.12: The specular surfaces of the periphery windows subtly superimpose the reflection of the interior over the exterior scene (Source: Jouin, 2014)

	LIGHT SOURCE	ILLUMINANCE	LUMINANCE	COLOR	HEIGHT	DENSITY	DIRECTION / DISTRIBUTION
MAIN DINING ROOM	TABLE ACCENT LIGHT: LOW-VOLTAGE HALOGEN	0–100 LUX	MEDIUM	WARM	2.5 M (8 FT) (CEILING RECESSED)	ORGANIZED PATTERN (1 PER TABLE)	DIRECT DOWN NARROW BEAM
	CEILING CHANDELIER GLOWING EFFECT: LED	N/A	LOW	WARM	2.5 M (8 FT) (CEILING MOUNTED)	RANDOM	DIRECT DIFFUSE
	CEILING CHANDELIER CONCENTRATED EFFECT: LOW-VOLTAGE HALOGEN	0–100 LUX	MEDIUM	WARM	2.5 M (8 FT) (CEILING MOUNTED)	RANDOM	DIRECT DOWN NARROW BEAM

Table 2.1.1.2: Artificial light implementation table of main dining room (Source: Descottes, 2011)

Figure 2.1.1.13: Comparisons of constrasting atmosphere between day and night.

Lounge and Bar

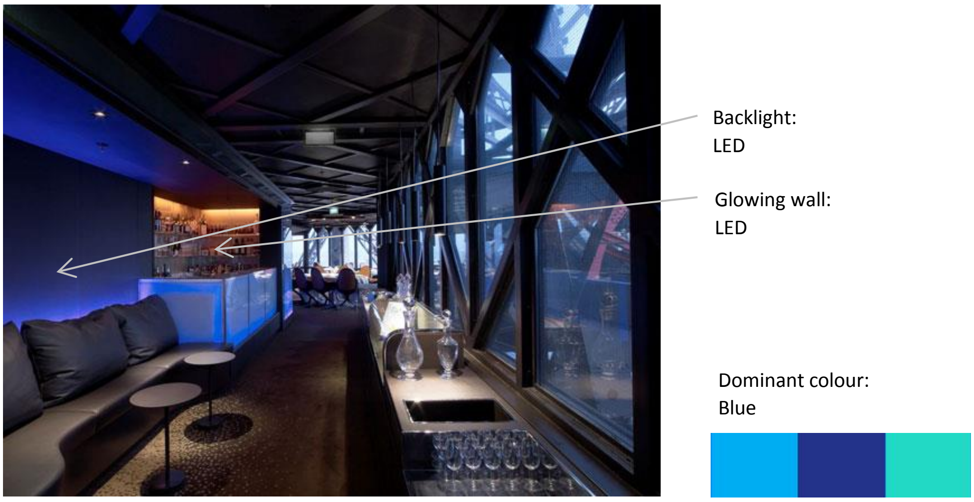


Figure 2.1.1.14: A lounge and bar surrounded by a glowing blue service counter (Source: L'Obervatoire International, 1993)

As a mean to create a visual unity to the fragmented element of spaces while simultaneously imply a continuity of circulation, linear LED lights of an intense blue colour and glowing effect are installed to illuminate the bar-height wall along its perimeter, as shown in Figure 2.1.1.15. Throughout the course of the night, the blue colour transforms into a deep amber colour as a way signalling the passing of time. As the furniture pieces of the restaurant are custom-designed to evoke the spindly structure of the Eiffel Tower, the backlight behind the cushioned seating calls attention to the intricacies of their wavelike patterns and boldness of form. The contrast between glowing wall and the silhouettes of objects and people before it adds a graphic element and drama to the space.

Radwan (2006) stressed that blue and purple can result in loss of appettite, thus they are always not common of a choice of colour adopted in restaurant. However, Le Jules Verne intelligently implemented blue as the dominant colour at the lounge and bar, knowing the colour psychology that blue does not evoke a feeling of hunger, but more of thirst. From another perspective, the change in colour tone stimulates a different and fresh atmosphere within the space.

	LIGHT SOURCE	ILLUMINANCE	LUMINANCE	COLOR	HEIGHT	DENSITY	DIRECTION / DISTRIBUTION
LOUNGE & BAR	GLOWING WALL: LED	N/A	LOW	COLOR CHANGING	0.8 M (3 FT) (FLOOR MOUNTED)	LINEAR	UP DIFFUSE

Table 2.1.1.3: Artificial light implementation table of lounge and bar (Source: Descottes, 2011)

Figure 2.1.1.15: Glowing wall lined along the bar perimeter (Source: Jouin, 2014)

2.1.2 Conclusion

The varying types of lighting displayed in Le Jules Verne has shown the practice of lighting in providing diverse moods of dining establishment, based on different functions and occasions. It is also vital to note the surrounding setting of a space for lighting design, in order to enhance the atmosphere as a whole.

Within a restaurant environment, customers should be able to experience excitement, pleasure, and a sense of personal well-being, while the dining establishment should be able to provide both physical and culinary services. Thus, there is a need within the hospitality community for a study to be done that looks at the correlation between lighting design and comfort levels within a restaurant setting. Baraban (1947) stated "space feel expansive or intimate, subdued or exciting, friendly or hostile, quiet or full of electrifying energy."

2.2 Research Methodology

2.2.1 Description of Equipment

The equipments used for data collection:

Figure 2.2.1.1: LX-101 Lux Meter

Figure 2.2.1.2: Pentax K-r DSLR camera

The Lux meter is a device for measuring the intensity of light. It measures illumination in terms of luxes (lux). A lux is equal to the total intensity of light that falls on a one square meter surface that is one foot away from the point source of light.

Lux Meter Specifications

GENERAL SPECIFICATIONS			
Display	13 mm (0.5") LCD.	Power Supply	DC 9V battery. 006P, MN1604 (PP3) or equivalent.
Ranges	0-50,000 Lux. 3 Ranges.		
Zero adjustment	Internal adjustment .	Power Consumption	Approx. DC 2 mA.
Over-input	Indication of " 1 ".		
Sampling time	0.4 second .	Dimension	*Main Instrument :* 108x73x23 mm (4.3x2.9x0.9 inch
Sensor structure	The exclusive photo diode & color correction filter.		*Sensor probe:*
Operating Temp.	0 to 50℃ (32 to 122 ℉).		82x55x7 mm (3.2x2.2x0.3 inch).
Operating Humidity	Less than 80% R.H.	Weight	160g (0.36 LB) with batteries.
		Accessories Included	Instruction manual............1 PC. Carrying case ....1 PC.

Table 2.2.1.1: General Specifications of LX-101 lux meter. (Source: Lutron, n.d.)

ELECTRICAL SPECIFICATIONS (23± 5 ℃)		
Range	Resolution	Accuracy
2,000 Lux	1 Lux	± (5 % + 2 d)
20,000 Lux	10 Lux	± (5 % + 2 d)
50,000 Lux	100 Lux	± (5 % + 2 d)
Note : Accuracy tested by a standard parallel light tungsten lamp of 2856K temperature.		

Table 2.2.1.2: Electrical Specifications of LX-101 lux meter (Source: Lutron, n.d.)

DSLR Camera is used to take evidences of identified artificial and natural light source. Besides that, light patterns that are formed are also recorded by taking photos.

2.2.2 Data Collection Method

Lighting data of daytime (3pm - 5pm) and night time (8pm - 10pm) is measured by a Lux meter as shown in Figure 1 according to the 1.5m x 1.5m grid line system. The grid line system was established earlier before site visit to aid the collection of data.

The Lux meter is held 1 meter and 1.5 meter above ground level due to the consideration of human activity range. As the restaurant is usually for dining purpose, we assumed that 1 meter is the sitting level of people while 1.5 meter height from ground is assumed to be average human eye level. These levels are the range that will influence human comfort for lighting while dining. After getting lux meter readings, they were noted down carefully on the floor plan with gridlines to aid for in-depth study and calculation.

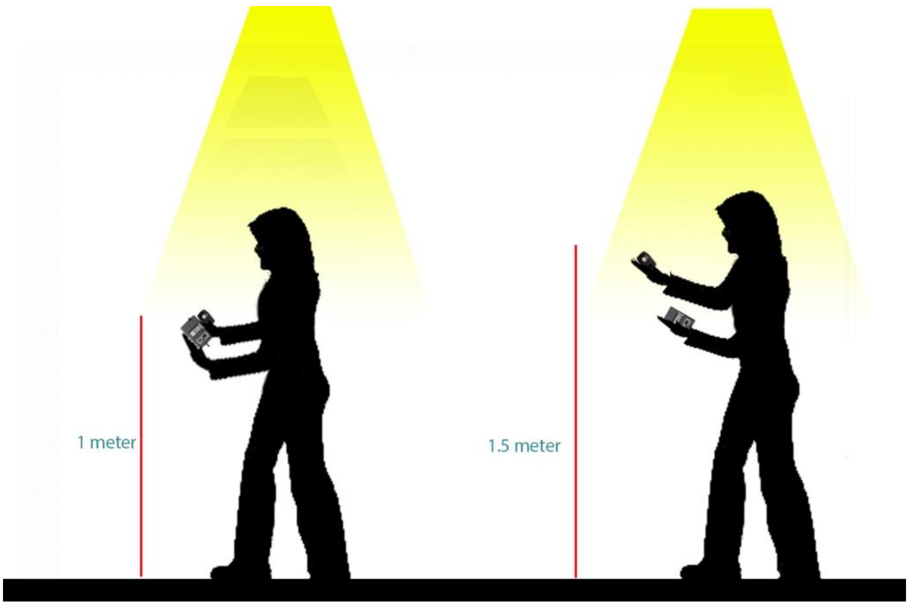


Figure 2.2.2.1: The Lux meter is hold 1 meter and 1.5 meter above ground

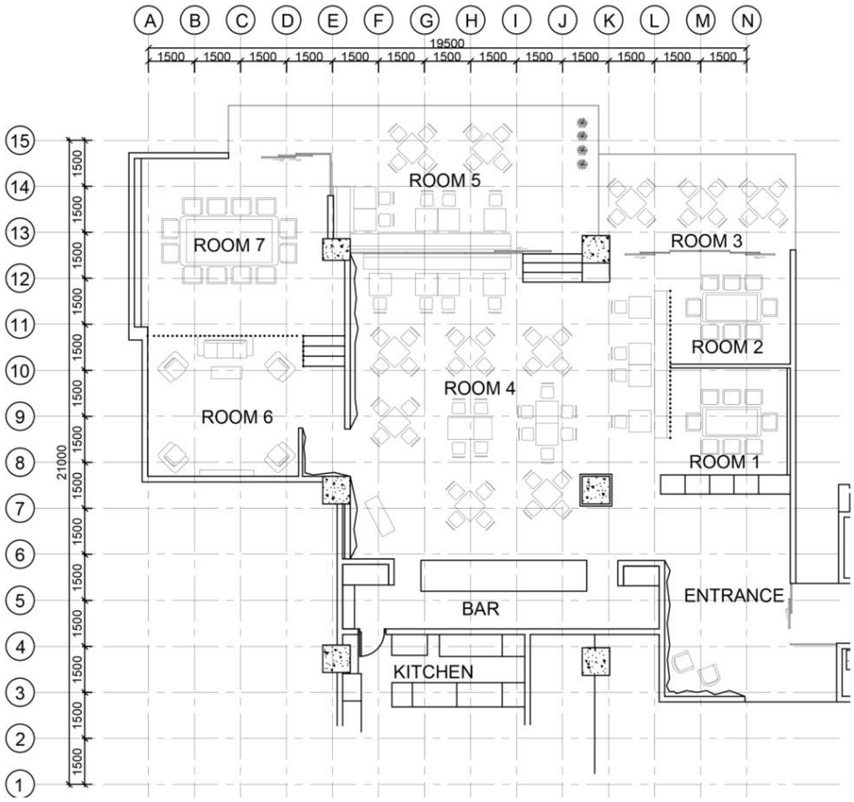


Figure 2.2.2.2: The floor plan is divided into 1.5 meter grid lines for both light and acoustic measurement.

By the way, Ploy Restaurant has different dining zone to provide different dining experience for clients. Hence, the floor plan is separated into respective zones is shown in Figure 2.2.2.3 in order to ease the organization of lighting studies.

Figure 2.2.2.3: Floor plan divided into different zones

2.2.3 Lighting Analysis Calculation Method

Daylighting Factor

The ratio of work plane illuminance (at a given point) to the outdoor illuminance on a horizontal plane in percentage.

$$DF = \frac{Ei\ indoor\ illuminance,\ \ at\ a\ given\ point}{EH\ outdoor\ illuminance}$$

Where,

Ei : illuminance due to daylight at a point on the indoor's working plane

E_H : the unobstructed horizontal exterior illuminance, average day light level in Malaysia (E_H) is assumed to be 20000 lux.

Lumen Method Calculation

Step 1:

Find out the light reflectance (%) for celling, wall, floor in the overall space based on the reflectance table. For example,

Reflectance Table			
Colors	**%**	**Materials**	**%**
White	70-80	Plaster - white	80
Light cream	70-80	White porcelain	65-75
Light yellow	55-65	Glazed white tile	60-75
		Limestone	35-70
Light green	45-50	Marble	30-70
Pink	45-50	Sandstone	20-40
Sky - blue	40-45	Concrete - gray	15-40
Light gray	40-45	Granite	20-25
		Brick - red	10-20
Beige	25-35	Carbon - black	2-10
Yellow ocher	25-35		
Light brown	25-35	Mirror	95
Olive green	25-35	Clear glass	6-8
Orange	20-25		
Vermillion red	20-25	Maple (Natural)	60
Medium gray	20-25	Birch (Natural)	35-50
		Oak - light	25-35
Dark green	10-15	Cherry (Natural)	15-30
Dark blue	10-15	Oak - dark	10-15
Dark red	10-15	Mahogany	6-12
Dark gray	10-15	Walnut - dark	5-10
Ideal Ceilings	**60-90**	Tin	67-72
Ideal Walls	**35-60**	Stainless steel	50-60
Ideal Countertops	**30-50**	Aluminum	55-58

Table 2.2.3.1: Light Reflectance Table (Source: LightCalc, n.d.)

Step 2:

Find the Room Index (RI). Room Index is the ratio of room plan area to half the wall area between the working and luminaires planes.

$$RI = \frac{L \times W}{H_m \times (L + W)}$$

Where,

RI=Room Index

L=Length of room

W=Width of room

Hm=Mounting height (vertical distances between the working plane and luminaire, refer to Figure 2.2.2.4)

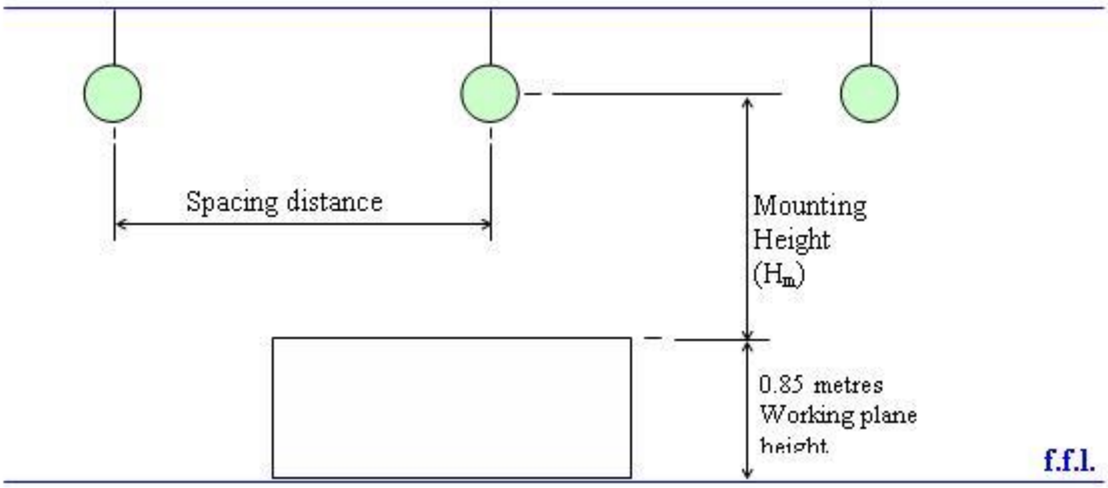


Figure 2.2.2.4: Illustration to identify Mounting Height (Source: Studentnotes, n.d.)

Step 3:

Identify Utilization Factor (UF) from table. The utilization factor table indicates how much of the luminous flux produced by the lamp in the fixture enters the work plane under a variety of condition. For example,

Utilization factor										Fixture efficiency
Ceiling(%)		70			50			30		
Walls(%)		50	30	10	50	30	10	50	30	10
Floor(%)		30 10	30 10	30 10	30 10	30 10	30 10	30 10	30 10	30 10
Room index	0.60	.27 .26	.22 .22	.19 .19	.26 .24	.22 .21	.19 .18	.26 .25	.21 .21	.19 .18
	0.80	.33 .31	.28 .27	.23 .23	.32 .30	.27 .26	.24 .23	.31 .30	.27 .26	.23 .23
	1.00	.38 .36	.32 .30	.28 .28	.36 .35	.32 .31	.29 .27	.35 .34	.31 .30	.28 .27
	1.25	.43 .40	.37 .35	.33 .32	.41 .39	.36 .35	.33 .32	.39 .37	.35 .34	.32 .31
	1.50	.47 .43	.41 .39	.37 .35	.44 .42	.40 .37	.36 .35	.42 .40	.39 .37	.36 .35
	2.00	.52 .47	.47 .44	.43 .41	.49 .46	.45 .43	.42 .40	.47 .45	.44 .42	.41 .40
	2.50	.56 .50	.51 .47	.48 .44	.53 .49	.49 .46	.46 .44	.50 .48	.47 .45	.45 .43
	3.00	.59 .52	.55 .49	.51 .47	.55 .52	.52 .48	.49 .46	.52 .50	.50 .48	.47 .46
	4.00	.62 .55	.59 .52	.56 .51	.58 .53	.56 .52	.53 .50	.55 .52	.53 .51	.51 .49
	5.00	.64 .56	.62 .55	.59 .53	.60 .55	.58 .53	.56 .52	.57 .54	.55 .52	.52 .51

Table 2.2.3.2: Utilization factor table (Source: Light by line a, 2014)

Step 4:

Calculate existing average illuminance level, E

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

Where,

E=average illuminance over the horizontal working plane (lx)

n=number of lamps in each luminaire

N=number of luminaire

F=Lamps luminous flux (lm)

UF=Utilization factor

MF=Maintenance factor

A=Area of horizontal working plane

Step 5:

Find the number of fittings required, N

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

2.3 Case Study

2.3.1 Existing Lighting Condition

Located in Damansara Heights, Ploy Restaurant is set in a high rise condominium, Clearwater Residence as refer to Figure 2.3.1.1. Therefore, it has only one façade faces outdoor. Referring to Figure 2.3.1.1.1, outdoor space is facing to the north and there is a high rise building, Wisma Antah next to it. The feature of local climate, sun path and appearances of Wisma Antah such as its height, colour tone and shadows will be taken into consideration while conducting lighting analysis.

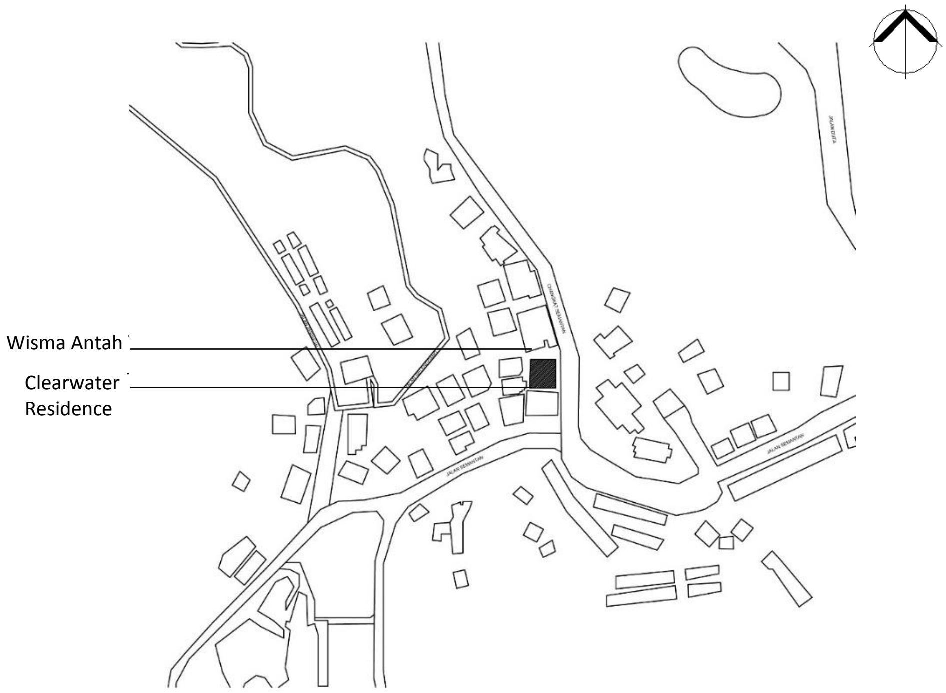


Figure 2.3.1.1: Site Plan

2.3.1.1 Site Context

Neighbouring Context

As Ploy Restaurant is operating in Clearwater Residence, Damansara Heights, north façade of it is facing to Wisma Antah (as shown in Figure 2.3.1.1.1), which is a high rise building with light colour tone on its façade. Although the outdoor dining area is shaded by ceiling, retractable roof, and shadows of Wisma Antah, it is still an uncomfortable zone for diners due to its neighbouring building. As shown in Figure 2.3.1.1.2, smooth surface with white colour façade of Wisma Antah is facing towards the outdoor dining area of Ploy Restaurant that creates sun glares and increases reflectance which will make the users undergo uncomfortable visualization experience.

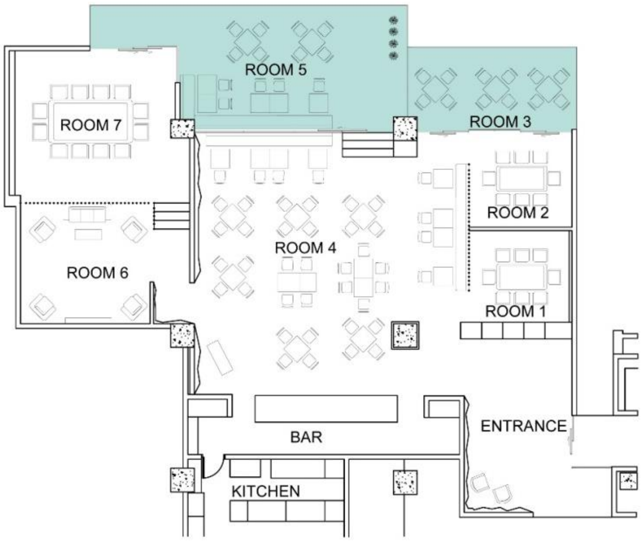


Figure 2.3.1.1.1: Outdoor spaces of Ploy Restaurant

Figure 2.3.1.1.2: Façade of Wisma Antah

Figure 2.3.1.1.3: Outdoor dining area

Referring to Figure 2.3.1.1.3, north façade of Ploy Restaurant is facing towards Wisma Antah, other façades are attached to Clearwater Residence. Therefore, north facade may accept natural daylight mostly from the transparent glass panel. Other spaces are severely affected by natural daylighting.

Local Climate

Located in the equatorial region, Malaysia possesses typical tropical climate characteristics. McKnight et al (2000) stated that, variation in temperature of tropical region is relatively constant and seasonal changes is dominantly affected by precipitation. Moreover, solar radiation is closely related to the sunshine duration. Its seasonal and spatial variations are thus very much the same as in the case of sunshine. (MOSTI, 2013) Refer to Figure 2.3.1.1.4, local sun path diagram is shown to illustrate the sun path pattern throughout a year.

As illustrated in Figure 2.3.1.1.5, shading patterns are shown in three different time, which are 10:00 am, 12:00pm and 4:00pm.With this illustration, performance of shading device is investigated.

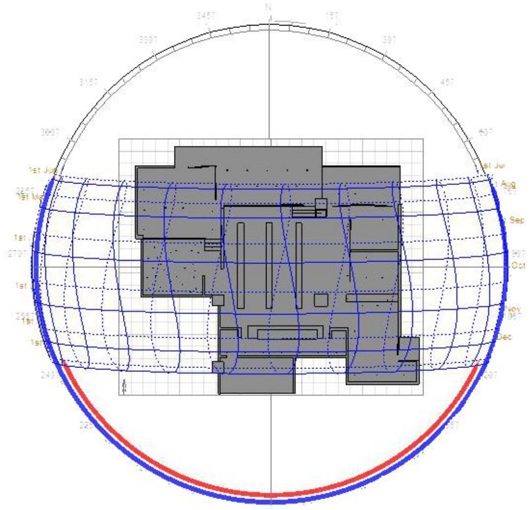


Figure 2.3.1.1.4: Sun path diagram of Kuala Lumpur

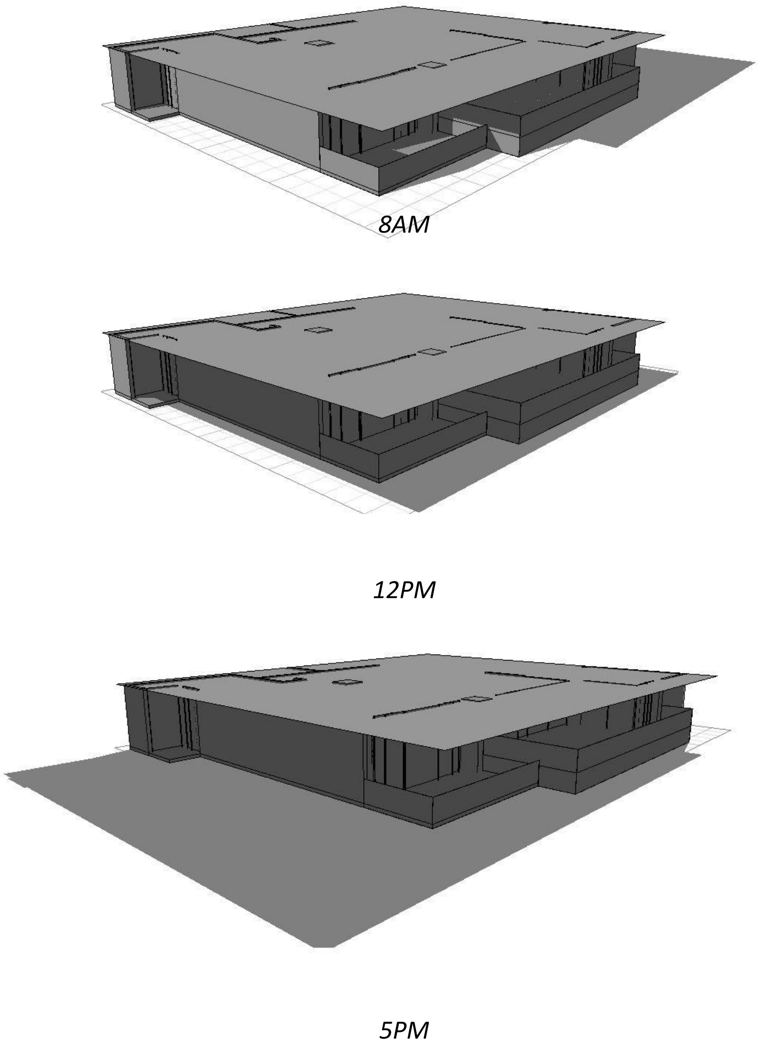


Figure 2.3.1.1.6: Shadow pattern of different time

Sky Condition

Being a maritime country close to the equator, Malaysia naturally has abundant sunshine and solar radiation. However, even in periods of severe drought, it is extremely rare to have a full day with completely clear sky without clouds. The cloud cover cuts off a substantial amount of sunshine and thus solar radiation. As stated by MOSTI (2013), on the average, Malaysia receives about 6 hours of sunshine per day. This will be a main consideration while designing the restaurant to minimize solar heat gain and sun glare.

Duration of daylighting in Kuala Lumpur

Referring to Table 2.3.1.1.1, hours of sunshine in Kuala Lumpur range between 4:54 hours for every day in November and 7:23 hours for each day in February. The longest day of the year is 12:10 long and the shortest day is 11:49 long, which the longest day is 0:21 hours longer than the shortest day. Moreover, there is an average of 2228 hours of sunlight per year (of a possible 4383) with an average of 6:06 hours of sunlight per day. It is sunny 50.8% of daylight hours. The remaining 49.2% of daylight hours are likely cloudy or with shade, haze or low sun intensity.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Sunlight Hours/ Day	06:11	07:23	06:30	06:18	06:17	06:36	06:30	06:17	05:36	05:17	04:54	05:23	06:06
Average Daylight Hours & Minutes/ Day	11:57	12:01	12:05	12:11	12:15	12:17	12:16	12:12	12:07	12:02	11:58	11:56	12:00
Sunny & (Cloudy) Daylight Hours (%)	52 (48)	62 (38)	54 (46)	52 (48)	52 (48)	54 (46)	54 (46)	52 (48)	47 (53)	44 (56)	41 (59)	46 (54)	51 (49)
Sun altitude at solar noon on the 21st day (°).	66.8	75.9	86.6	81.3	72.9	69.7	72.6	80.9	87.1	75.7	66.7	63.5	75

Table 2.3.1.1.1: Sunshine & Daylight Hours in Kuala Lumpur, Malaysia (Source: climatemps, n.d.)

2.3.1.2 Natural Daylighting

According to MS 1525, in order to take advantage of daylighting, the emission of transmittance of the daylight fenestration system should not be less than 50%. During the day, natural sunlight penetrates through glass panels of Room 5, which is the outdoor dining area. Indoor spaces of Room 2, 4 and 7 are illuminated by sunlight directly through fenestrations with single glazing glass as material. Furthermore, other spaces are not illuminated by natural sunlight during daytime.

Figure 2.3.1.2.1: Room 4 is severely illuminated by natural sunlight

Figure 2.3.1.2.2: Room 2 under natural light illumination

Referring to Figure 2.3.1.2.3 and 2.3.1.2.4, there is a vast difference of brightness between indoor and outdoor spaces during daytime. This is an undesirable lighting effect for human as eyes cannot adapt to the vast difference of illumination in a short time.

Therefore, artificial light fixtures are installed to provide sufficient brightness for the spaces and decrease the difference of brightness between indoor and outdoor space. Halogen down light with 150lm is used in most of the space in Ploy Restaurant to create an effect of dimly lit because it is aimed to create a soft lighting atmosphere for diners.

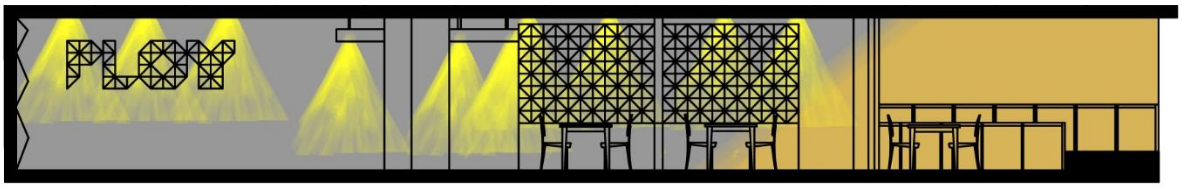


Figure 2.3.1.2.3: Lighting effect illustration of Section A-A

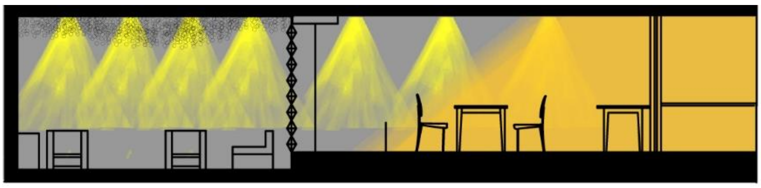


Figure 2.3.1.2.4: Lighting effect illustration of Section B-B

2.3.1.3 Artificial lighting

Various type of artificial light fixtures are installed in Ploy Restaurant to provide sufficient brightness for dining activities to be conducted. As refer to Figure 2.3.1.3.1, 2.3.1.3.2 and 2.3.1.3.3, artificial light fixtures are fully used throughout the restaurant during night time. It remains soft lighting to suit for the atmosphere of restaurant.

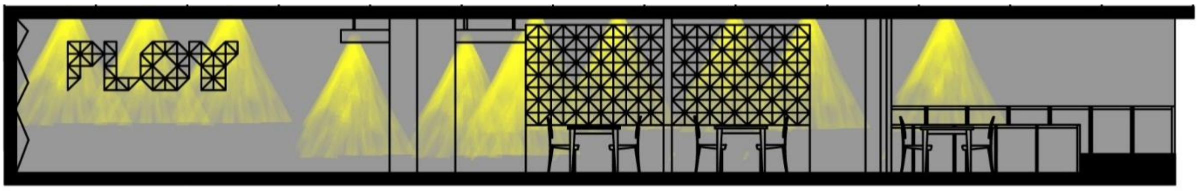


Figure 2.3.1.3.1: Artificial lighting effect illustration of Section A-A

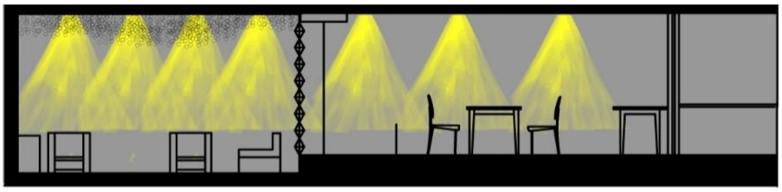


Figure 2.3.1.3.2: Artificial lighting effect illustration of Section A-A

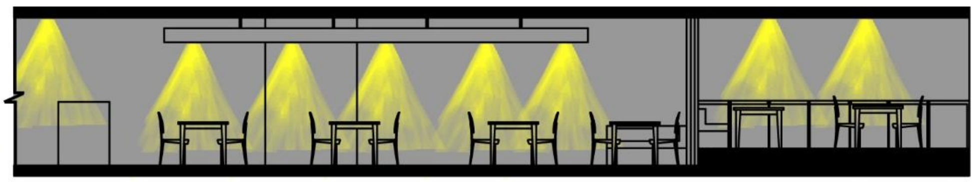


Figure 2.3.1.3.3: Artificial lighting effect illustration of Section D-D

Existing Light Specification

1. Fluorescent Light

Fluorescent lights are used in kitchen of Ploy Restaurant mainly. Figure 2.3.1.3.4 and 2.3.1.3.5 shows the distribution of fluorescent light and situation in kitchen. In this case, fluorescent light T8 is used because of its optimal lamp size and it is commercial building energy-saving lamp with electronic ballast.

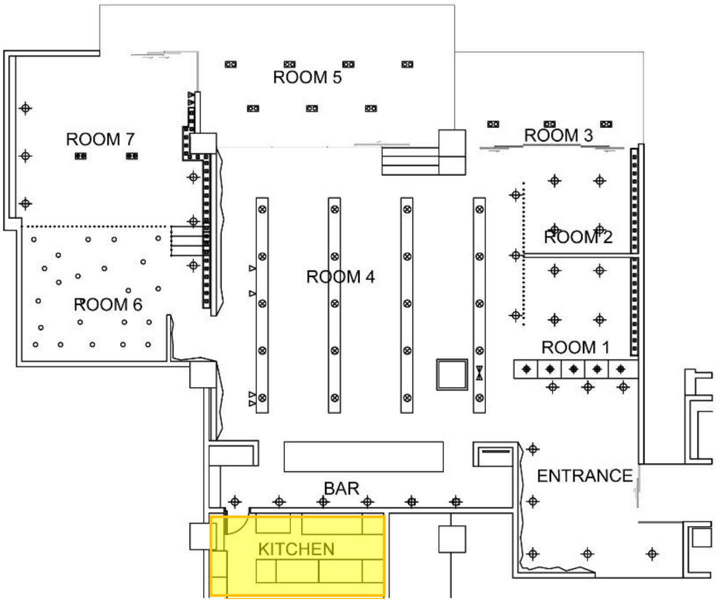


Figure 2.3.1.3.4: Distribution of Fluorescent Light

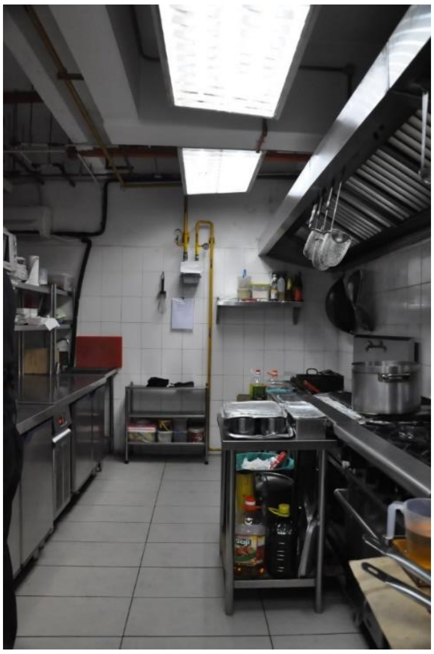
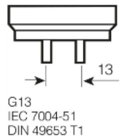


Figure 2.3.1.3.5: Fluorescent lights in Kitchen

Product Specification:

<table>
<tr><td>Product name</td><td>LUMILUX XXT T8</td><td rowspan="5"></td></tr>
<tr><td>Size</td><td>Tubular fluorescent
26mm diameter</td></tr>
<tr><td>Wattage</td><td>18 W</td></tr>
<tr><td>Luminous Flux</td><td>1350 lm</td></tr>
<tr><td>Colour Temperature</td><td>3000 K</td></tr>
<tr><td>Colour Rendering Index</td><td>≥80 Ra</td><td rowspan="4">
</td></tr>
<tr><td>Bulb finish</td><td>Warm White</td></tr>
<tr><td>Placement</td><td>Ceiling</td></tr>
<tr><td>Rated ambient temperature</td><td>25°C</td></tr>
</table>

2. Under Cabinet Light

As shown in Figure 2.3.1.3.6, series of under cabinet lights are installed in the wine rack at the entrance of Ploy Restaurant. Halogen light of 48mm diameter is used for this series of lighting to provide soft lighting pattern.

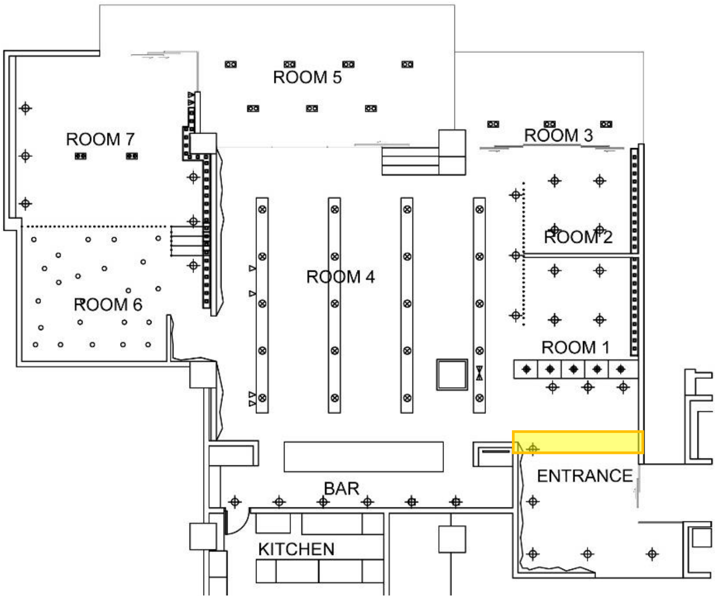


Figure 2.3.1.3.6: Distribution of under cabinet light

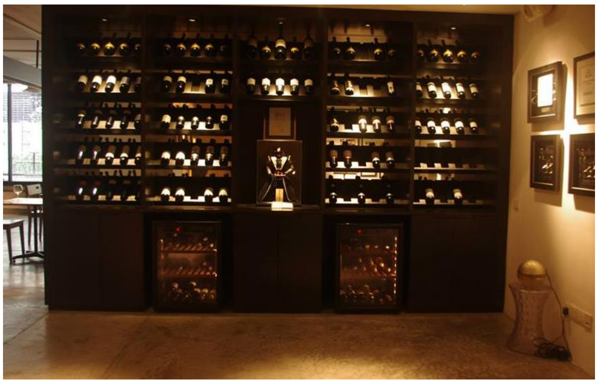


Figure 2.3.1.3.7: Under Cabinet Halogen Light at entrance of Ploy Restaurant

Product Specification:

Product name	HALOSPOT 48	
Size	48mm diameter	
Wattage	20W	
Luminous Flux	150 lm	
Colour Temperature	2800 K	
Colour Rendering Index	100 Ra	
Bulb finish	Warm White	
Placement	Under Cabinet	

3. Halogen Down Light (Baffle)

Due to its ability in producing light of a higher luminous efficacy and colour temperature, majority of area in Ploy Restaurant is illuminated by Halogen Light and they are distributed in a large area throughout the restaurant as shown in Figure 2.3.1.3.8.

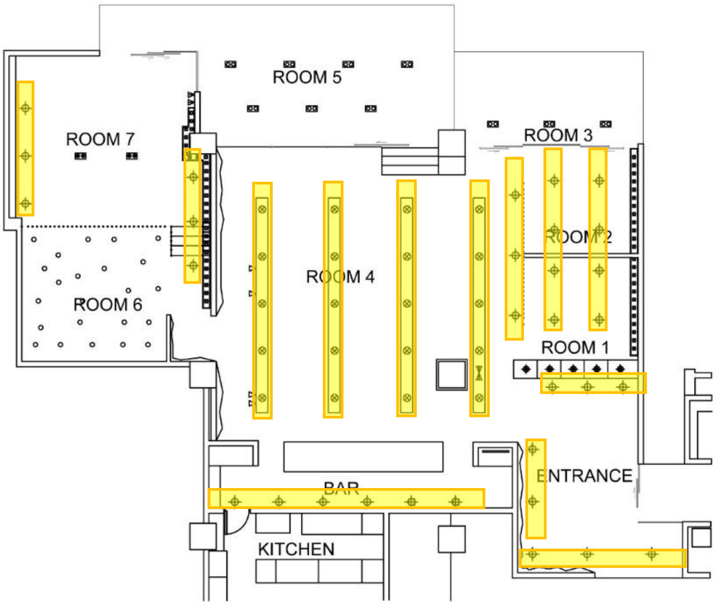


Figure 2.3.1.3.8: Distribution of Halogen down light

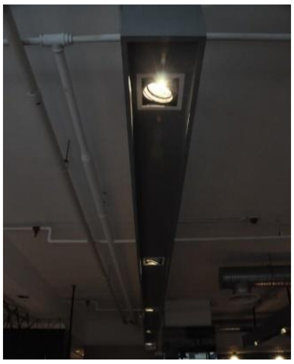
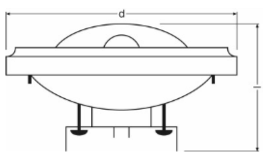


Figure 2.3.1.3.9: Halogen down light in dining

Product Specification:

Product name	HALOSPOT 111	
Size	111mm diameter	
Wattage	35 W	
Luminous Flux	350 lm	
Colour Temperature	3000 K	
Colour Rendering Index	100 Ra	
Beam Angle	4 °	
Bulb finish	Warm White	
Placement	Ceiling	
Rated ambient temperature	25°C	

4. Incandescent Light Bulb

Incandescent lights with mercury filled to direct the lights upwards are installed in Room 6 (Refer to figure 2.3.1.3.10) with large amount in a designated pattern. The purpose of having this light is for lighting and aesthetical decoration as shown in Figure 2.3.1.3.11.

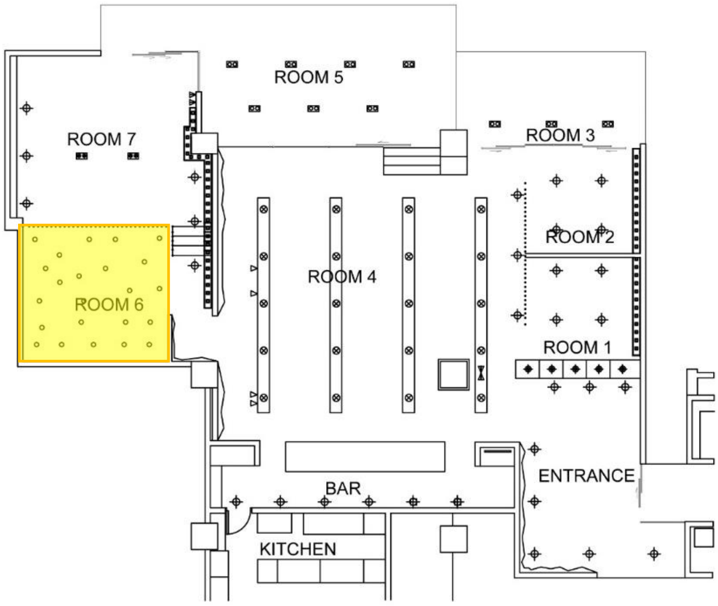
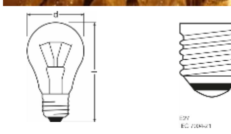


Figure 2.3.1.3.10: Distribution of Incandescent light bulb

Figure 2.3.1.3.11: Incandescent light bulb in lounge with designated pattern

Product Specification:

Product name	CLASSIC A 25 W 230 V E27	
Size	55mm diameter	
Wattage	25 W	
Luminous Flux	220 lm	
Colour Temperature	2800 K	
Colour Rendering Index	100 Ra	
Beam Angle	4 °	
Bulb finish	Soft White	
Placement	Ceiling	

5. Tungsten Halogen Low Voltage Down Light (Baffle)

Low voltage halogens down lights are installed at outdoor dining areas, Room 3, 5 and 7 (As shown in Figure 2.3.1.3.12). They are cool to the touch and minimally contribute heat to its surrounding. Therefore, its soft illumination is pleasing to the eyes.

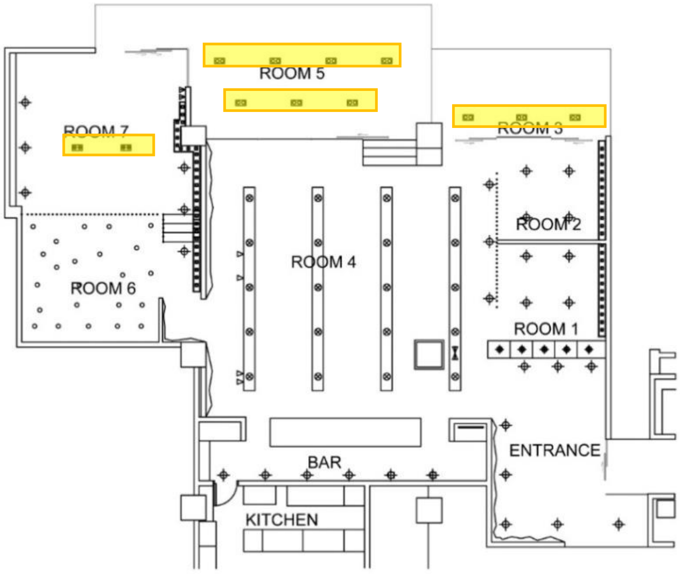
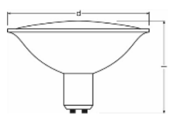


Figure 2.3.1.3.12: Distribution of Tungsten Halogen Low Voltage Down Light

Figure 2.3.1.3.13: Room 5

Product Specification:

Product name	HALOSPOT 70 20 W 12 V 8° BA15D	
Size	70.5mm diameter	
Wattage	20 W	
Luminous Flux	150 lm	
Colour Temperature	3000 K	
Colour Rendering Index	100 Ra	
Beam Angle	8 °	
Bulb finish	Warm White	
Placement	Ceiling	

6. Track Light (Incandescent Light Bulb)

Incandescent Light bulb of track lights are installed at a side of Room 4 (Refer to Figure 2.3.1.3.14) to provide enhancement lighting to a small coffee making area to draw attraction of customers.

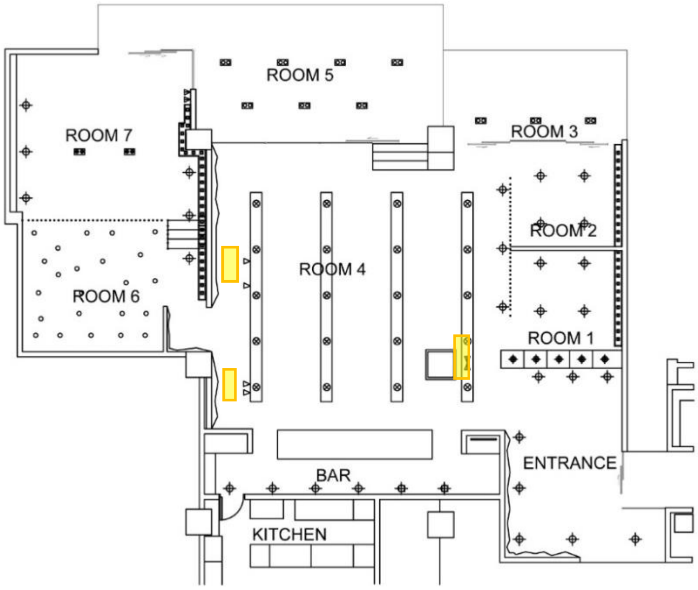


Figure 2.3.1.3.14: Distribution of Track Light

Figure 2.3.1.3.15: Incandescent Track Light

Product Specification:

Product name	CLASSIC A 25 W 230 V E27	
Size	55mm diameter	
Wattage	25 W	
Luminous Flux	220 lm	
Colour Temperature	2800 K	
Colour Rendering Index	100 Ra	
Bulb finish	Soft White	
Placement	Ceiling	

7. Recessed Lighting (L.E.D strip light)

Recessed Light with L.E.D strip light is installed along the wall in Room 1, Room 2, Room 6 and Room 7 (Refer to Figure 2.3.1.3.16) which are private dining rooms and lounge area to provide wall washing pattern of soft lighting in order to suit the atmosphere of these rooms as shown in Figure 2.3.1.3.17.

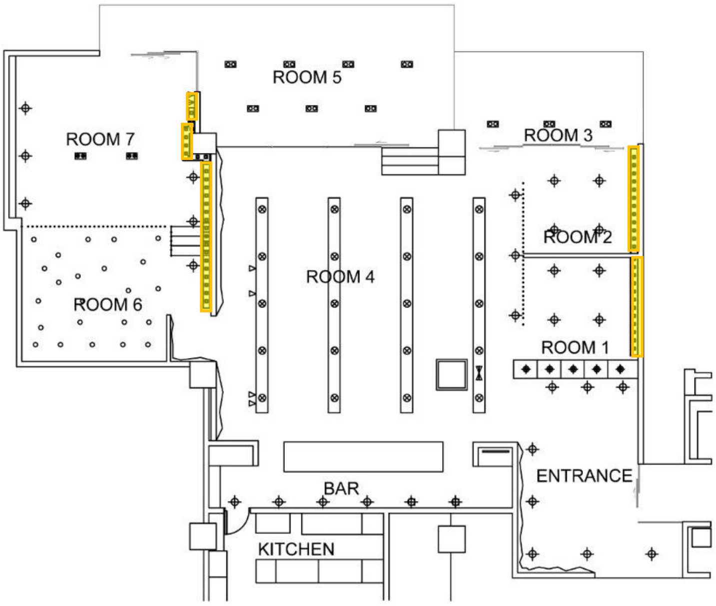


Figure 2.3.1.3.16: Distribution of Recessed light

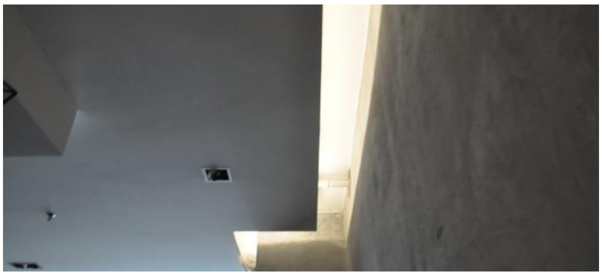


Figure 2.3.1.3.17: Recessed light installed on ceiling to make it invisible

Product Specification:

Product name	LK LED 40 CW	
Size	5mm diameter	
Wattage	2.8 W	
Luminous Flux	240 lm	
Colour Temperature	7500 K	
Colour Rendering Index	100 Ra	
Beam Angle	120°	
Bulb finish	Cool White	
Placement	Ceiling(Recessed)	
Ambient temperature range	-20...+40 °C	

8. Emergency Light (Incandescent Bulb)

An emergency light is a battery-backed lighting device that comes on automatically when a building experiences a power outage. Emergency light is installed in Ploy Restaurant to provide lighting during emergency blackout. (Refer to Figure 2.3.1.3.18).

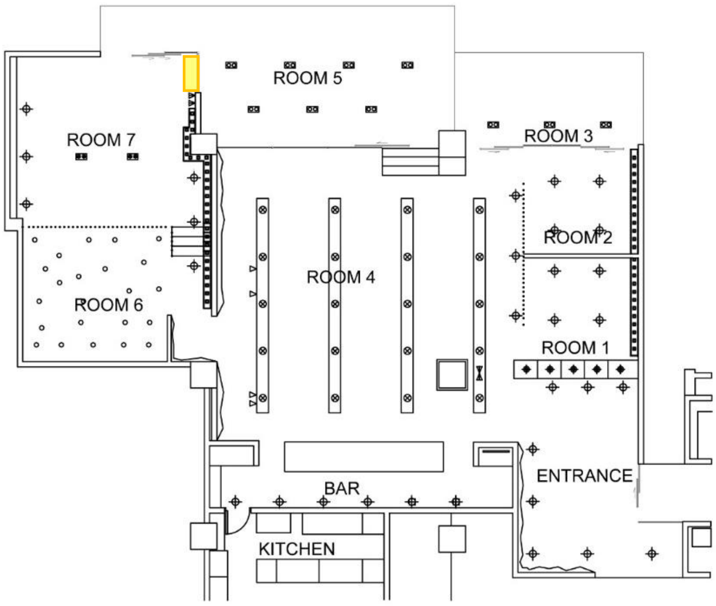


Figure 2.3.1.3.18: Distribution of Emergency Light

Product Specification:

Product name	PNE TEL-30 Incandescent Light Bulb	
Size	295L x 150W x 76H	
Light Source	2 x 6 W Incandescent	
Colour Temperature	SIRIM MS 619, Jabatan Bomba	
Placement	Surface mounting direct to wall	

Overall Summary of Types of light

Type	**Placement**	**Wattage (W)**	**Luminous Flux (lm)**	**Colour**	**Location**
Fluorescent Light	Ceiling	18	1350	Warm White	Kitchen
Under Cabinet Light	Under Cabinet	20	150	Warm White	Entrance
Halogen Down Light	Ceiling	35	350	Warm White	Entrance, All Dining Area
Incandescent Light Bulb	Ceiling	25	220	Soft White	Room 6
Tungsten Halogen Low Voltage Down Light	Ceiling	20	150	Warm White	Room 3, 5, 7
Track Light	Ceiling	25	220	Soft White	Room 4
Recessed Lighting	Ceiling	2.8	240	Cool White	Room 1, 2, 6, 7
Emergency Light	Surface mounting direct to wall	2x6 W	-	-	Room 7

2.3.2 Design Strategies That Affected Lighting Condition

Passive building design is important in a space to maximise the usage of daylight without causing heating or glare problem but increase the lighting efficiency of the building and achieve the best lighting experience and ambience. A key component of good daylighting, which essentially eliminates commonly used view windows, is the elimination of uncontrolled, direct beam light (Nicklas, 2008) . This can be achieve in different ways:

(a) Orientation

(b) Ceiling height

(c) Overhang and shading

(a) Orientation

Elongating the building on an east-west axis and locating high priority spaces on the north and south exposures can enhance cost-effective daylighting. Hence the only facade that allows for openings is the North facade which minimises the glares from East and West direction. Other than North facade, the other parts of the restaurant are shaded from the other spaces in the building block which artificial lights are needed.

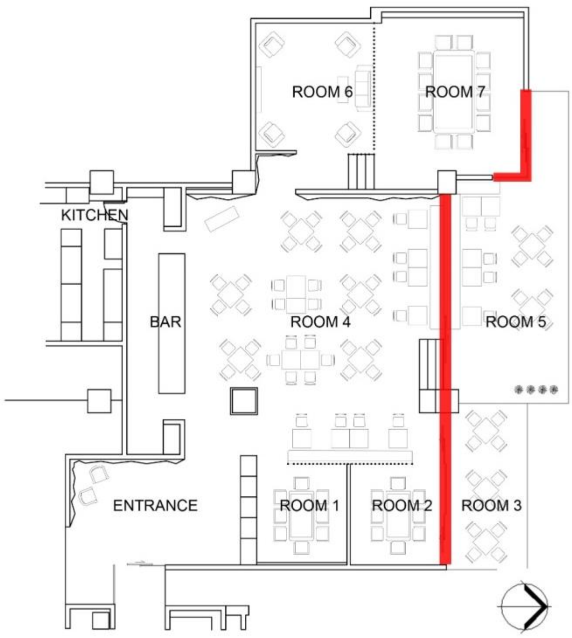


Figure2.3.2.1 East-orientated openings due to the restrictions within an office building block.

Although North-facing windows provide good daylight penetration in the morning and evening, excessive glares might cause eye discomfort as shown in Figure 2.3.2.2 due to the sliding glass doors. To provide human comfort level in the space, penetration of heat through the openings during daytime increases energy consumption for mechanical ventilation which is higher than artificial lights (Southface Energy Institute et.al, 2012). This two problems can be solved by some other alternative design strategies such as enlarging the roof overhang and choosing the right materials for wall and floor finishing.

Figure2.3.2.2 Excessive glares penetrate into the dining area which cause eyes discomfort.

(b) Ceiling Height

To reduce heat gain from openings, a space with relatively low floor-to-ceiling height is able to reduce direct exposure to sunlight (Robertson, n.d).
For our case study building, to avoid excessive glares penetrate into the restaurant, the ceiling height of opened dining area is rather lower so as to provide indirect sunlight penetrating through the windows into the space (as shown in Figure 2.3.2.3). The aim is to provide adequate light levels but not excessively into the dining area.

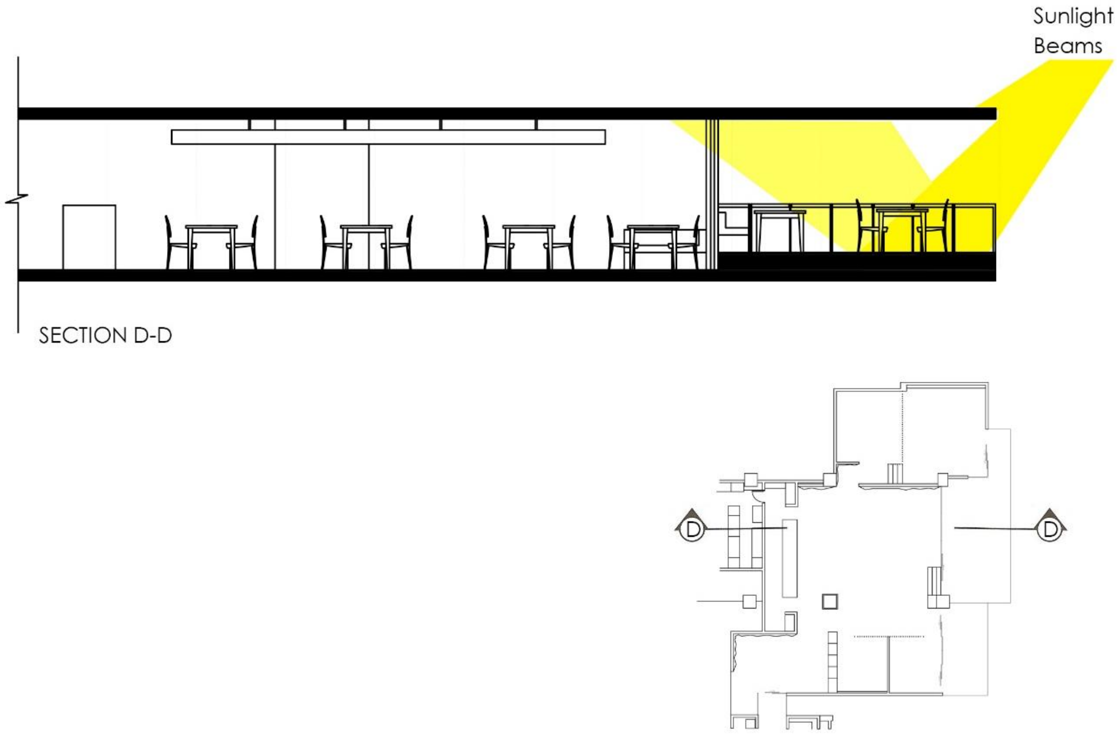


Figure 2.3.2.3 Sectional drawings show the reflection of direct sunlight shaded from the lower ceiling height of opened dining area into the space.

(c) Overhang and shading

Overhang of the balcony area acts as a buffering zone to filter the direct sunlight. It is shaded by the opposite high rise building. Obstructions can have a significant effect on the daylighting potential of a site. For low-to mid-rise projects, obstructions usually arise from buildings, terrain or trees. For larger buildings the obstructions are usually other large buildings (Robertson, n.d).

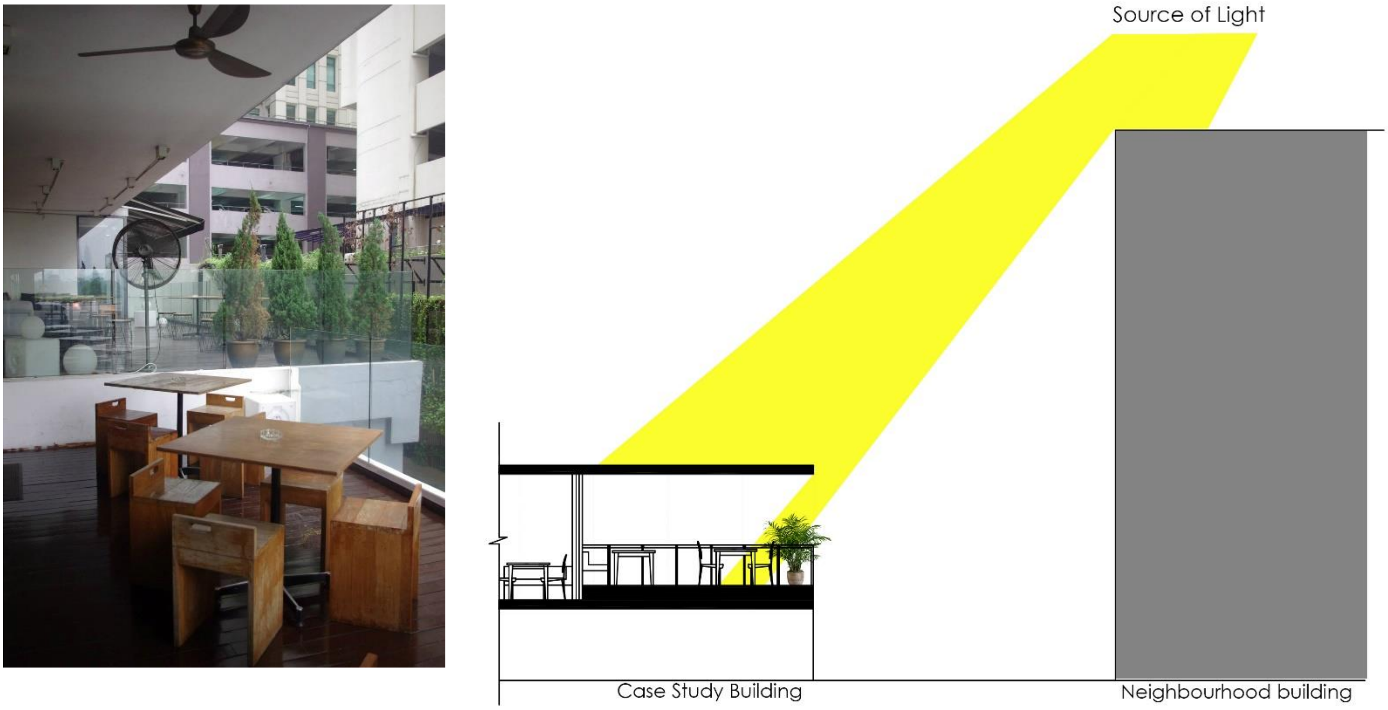


Figure 2.3.2.4 Shading from neighbourhood buildings and plants.

2.3.3 Lighting Reflectance of Material

Light, in accordance with the law of reflection, reflects off surfaces in a very predictable manner. Once a normal to the surface at the point of incidence is drawn, the angle of incidence can then be determined. The light ray will then reflect in such a manner that the angle of incidence is equal to the angle of reflection. A light beam can be thought of as a bundle of individual light rays and each individual light ray of the bundle follows the law of reflection. If the bundle of light rays is incident upon a smooth surface, as a mirror, then the light rays reflect and remain parallel and concentrated in a bundle upon leaving the surface. On the other hand, if the surface is microscopically rough, as in the case of paper, the light rays will reflect and diffuse in many different directions, even if each individual ray follows the law of reflection, producing a diffuse light. Most objects that we see are visible thanks to the diffuse reflection generated by their surfaces. (PAF, n.d.)

As refer to figure below, Figure2.3.3.1 shows the overall materiality of Ploy Restaurant while Figure 2.3.3.1 gives a perspective of sectional view.

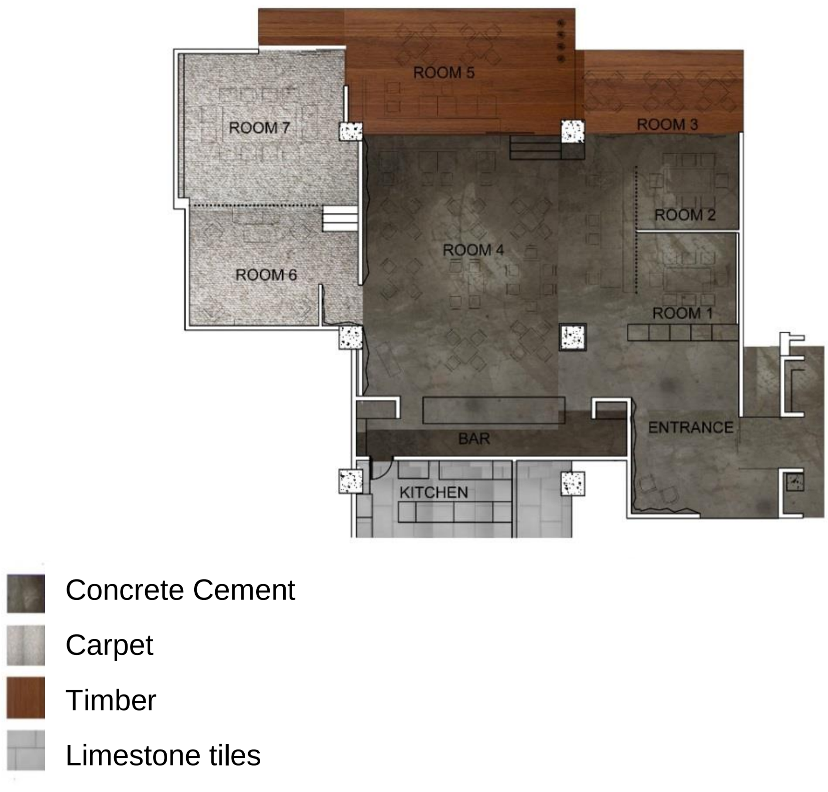


Figure 2.3.3.1: Materiality

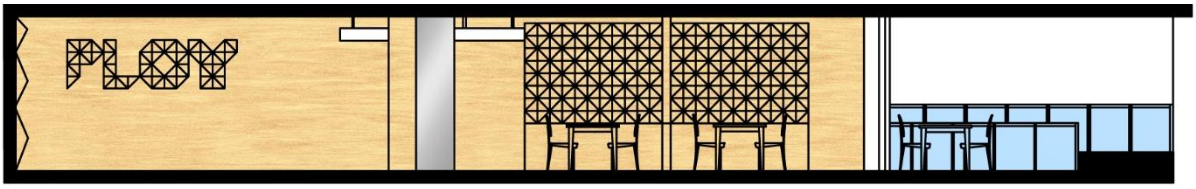


Figure 2.3.3.2: Material distribution of Section A-A

Figure 2.3.3.3: Material distribution of Section B-B

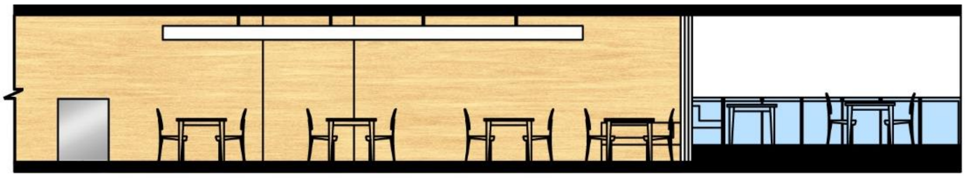
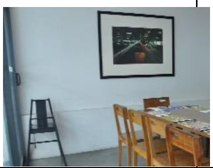


Figure 2.3.3.3: Material distribution of Section D-D

- Concrete Cement
- Timber
- Plaster Brick
- Glass
- Mirror

Categories	Function	Material	Colour	Area(m2)	Surface Type	Reflectance
Ceiling	Ceiling Finish	Plaster Board 	White	360	Reflective	40-45%
Wall	Wall	Reinforced Concrete 	Grey	43.49	Reflective	30-50%
	Wall	Plaster Brick 	White	40.15	Reflective	78%
	Decoration	Timber Finish 	Light Brown	40.15	Absorptiv e	25-35%
Partition	Partition	Glass Panel 	Trans parent	8.66	Reflective	8-12%
	Decoration / Partition	Steel 	Black	-	Absorptiv e	3-7%
Openings	Door	Glass 	Trans parent	11.1	Reflective	6-10%
	Door	Timber 	White	2.8	Absorptiv e	45-50%
	Door frame	Anodised Aluminium 	Black	-	Reflective	75-95%
Floor	Floor	Concrete Cement	Grey	55.4	Reflective	30-50%

						
	Floor	Limestone Tiles 	White	27.9	Absorptiv e	30-50%
	Floor Finish	Polished Timber 	Dark Brown	66.4	Absorptiv e	25-35%
	Carpet	Fabric 	Brown	11.6	Absorptiv e	10-20%
Furniture	Chair	Timber Veneer 	Brown	-	Absorptiv e	10-20%
	Sofa Chair	Fabric 	Blue	-	Absorptiv e	18%
	Table	Timber Veneer 	Brown	-	Absorptiv e	10-20%
	Sofa	Fabric 	Beige	-	Absorptiv e	80%
			Dark Brown	-	Absorptiv e	25%
	Bar (Decoration)	Polished Steel 	Reflec t	-	Reflective	60-80%
	Wine Rack	Timber	Dark Brown	-	Absorbtiv e	10-20%

Material Categorization According to Zone

Entrance

Ceiling	Plasterboard
Wall	Plaster Brick
Wall Decoration	Timber Finishes
Floor	Concrete Cement
Door	Glass Panel
Furniture	
Wine Rack	Timber
Sign Board	Steel

Figure 2.3.3.4: Entrance

Bar

Ceiling	Plasterboard
Wall	Reinforced Concrete
Wall Decoration	Timber Finishes
Floor	Concrete Cement
Furniture	
Wine Rack	Timber
Bar counter	Polished Steel

Figure 2.3.3.5: Bar

Kitchen

Ceiling	Plasterboard
Wall	Plaster Brick
Wall Finish	White Tile
Floor	Limestone Floor Tile
Door	White Timber
Furniture	
Countertop	Aluminium

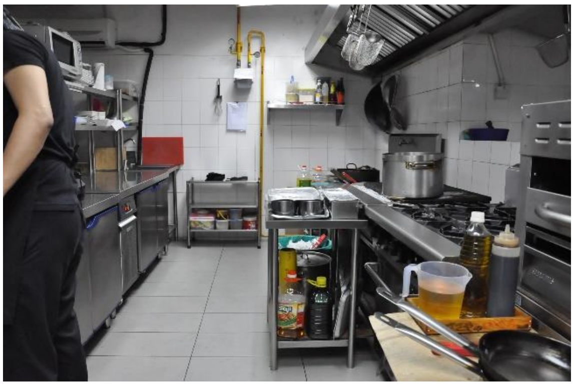


Figure 2.3.3.6: Kitchen

Room 1: Private Dining Area

Ceiling	Plasterboard
Wall	Plaster Brick
	Reinforced Concrete
Floor	Concrete Cement
Partition	Steel
Furniture	
Wine Rack	Timber
Chair	Timber Veneer
Table	Timber Veneer

Figure 2.3.3.7: Room 1

Room 2: Private Dining Area

Ceiling	Plasterboard
Wall	Plaster Brick
	Reinforced Concrete
Floor	Concrete Cement
Partition	Steel
Door	Glass
Door Frame	Anodised Aluminium
Furniture	
Chair	Timber Veneer
Table	Timber Veneer

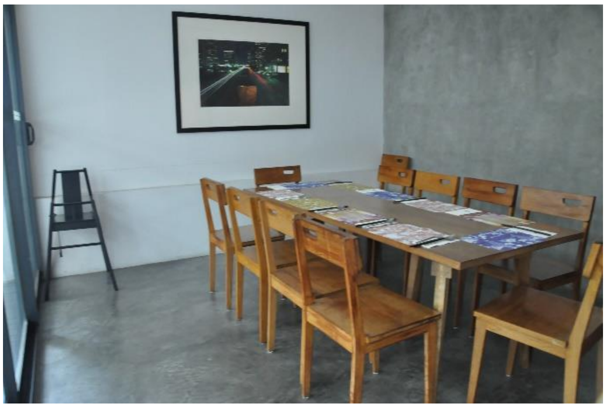


Figure 2.3.3.8: Room 2

Room 3: Outdoor Dining Area

Ceiling	Plasterboard
Wall	Plaster Brick
Floor	Polished Timber
Partition	Glass Panel
Door	Glass
Door Frame	Anodised Aluminium
Furniture	
Chair	Timber Veneer
Table	Timber Veneer

Figure 2.3.3.9: Room 3

Room 4: Public Dining Area

Ceiling	Plasterboard
Wall	Plaster Brick
Wall Decoration	Timber Finishes
	Polished Steel
Floor	Concrete Cement
Window	Glass
Door	Glass
Door/Window Frame	Anodised Aluminium
Furniture	
Chair	Timber Veneer
Sofa	Fabric
Table	Timber Veneer

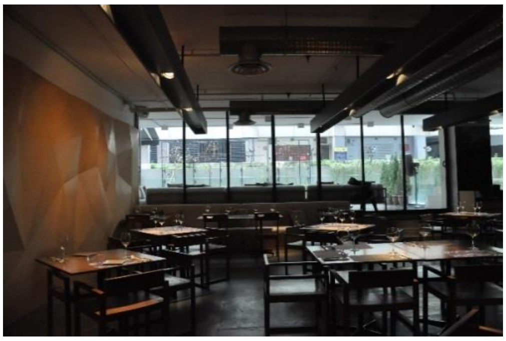


Figure 2.3.3.10: Room 4

Room 5: Outdoor Dining Area

Ceiling	Plasterboard
Wall	Plaster Brick
Floor	Polished Timber
Partition	Glass Panel
Window	Glass
Door	Glass
Door/Window Frame	Anodised Aluminium
Furniture	
Chair	Timber Veneer
Sofa	Fabric
Table	Timber Veneer

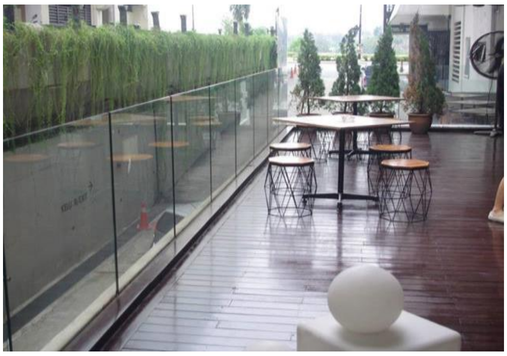


Figure 2.3.3.11: Room 5

Room 6: Lounge Area

Ceiling	Plasterboard
Wall	Plaster Brick
	Reinforced Concrete
Floor	Concrete Cement
Partition	Steel
Furniture	
Sofa	Fabric
Table	Timber Veneer
Carpet	Fabric

Figure 2.3.3.12: Room 6

Room 7: Lounge Area

Ceiling	Plasterboard
Wall	Reinforced Concrete
Floor	Concrete Cement
Partition	Steel
Door	Glass
Window	Glass
Door/Window Frame	Anodised Aluminium
Furniture	
Sofa	Fabric
Table	Timber Veneer
Carpet	Fabric

Figure 2.3.3.13: Room 7

2.4 Lighting Analysis

2.4.1 Data of lighting

2.4.1.1 Daytime lux readings

	17/9/2014	
TIME	3pm-5pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
A1	1	4
A2	2	3
A3	2	3
A4	1	2
B1	5	4
B2	4	6
B3	4	4
B4	1	3
C1	17	10
C2	8	8
C3	6	9
C4	248	54
C5	26	15
C6	10	15
C7	10	20
C8	12	24
C9	18	26
C10	125	49
D1	16	13
D2	15	12
D3	18	10
D4	35	8
D5	18	18
D6	4	7
D7	8	7
D8	9	10
D9	15	34
D10	26	51
D11	40	93
E1	25	710
E2	30	30
E3	25	35
E4	15	31
E5	23	64
E6	11	11
E7	11	8
E8	989	2279
E9	35	36
E10	80	114
E11	46	73
F1	30	48
F2	20	39
F3	8	17
F4	12	16
F5	10	9

	17/9/2014	
TIME	3pm-5pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
F6	13	11
F7	13	9
F8	350	1570
F9	28	33
F10	44	49
F11	29	35
F12	7	14
F13	9	12
F14	9	12
F15	5	6
G1	258	522
G2	60	61
G3	426	942
G4	37	28
G5	18	23
G6	189	23
G7	13	10
G8	20	25
G9	23	26
G10	34	44
G11	20	15
G12	18	20
G13	20	24
G14	19	18
G15	8	13
H1	124	87
H2	75	64
H3	862	944
H4	83	37
H5	20	15
H6	26	19
H7	15	11
H8	495	2212
H9	59	25
H10	281	323
H11	22	25
H12	22	20
H13	20	25
H14	19	26
H15	7	11
I1	2009	2013
I2	2007	2009
I3	2008	2006
I4	67	64
I5	36	31

	17/9/2014	
TIME	3pm-5pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
I6	47	27
I7	31	23
I8	42	47
I9	37	18
I10	52	45
I11	30	34
I12	12	10
I13	10	9
I14	11	9
I15	20	25
J1	2014	2017
J2	2007	2012
J3	2007	2008
J4	189	82
J5	97	75
J6	433	55
J7	36	28
J8	40	92
J9	46	45
J10	43	35
J11	236	417
J12	12	13
J13	16	13
J14	20	15
J15	20	36
K1	2118	2080
K2	2071	2056
K3	2068	2045
K4	2673	2700
K5	83	62
K6	2019	2002
K7	2009	2009
K8	2018	2017
K9	2005	2004
K10	2012	2010
K11	27	16
K12	30	22
K13	82	89
K14	41	42
K15	50	57
L1	2235	2633
L2	2463	2713
L3	2578	2778
L4	2138	2036
L5	260	150

	17/9/2014	
TIME	3pm-5pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
L6	2017	2016
L7	2020	2015
L8	2024	2018
L9	2070	2063
L10	2033	2017
L11	177	144
L12	130	114
L13	160	67
L14	74	24
L15	65	55
M6	2434	2455
M7	2312	2307
M8	2188	2113
M9	2213	2314
M10	2292	2328
M11	2188	2247
M12	2130	2074
M13	2031	2017
M14	37	58
M15	25	39
N6	2481	2515
N7	2460	2501
N8	2331	2436
N9	2319	2412
N10	2275	2392
N11	2210	2321
N12	2151	2074
N13	2096	2035

- Entrance Area
- Services Area
- Public Dining Area
- Private Dining Area
- Lounge Area
- Outdoor Dining Area

2.4.1.2 Daytime Light Contour Diagram

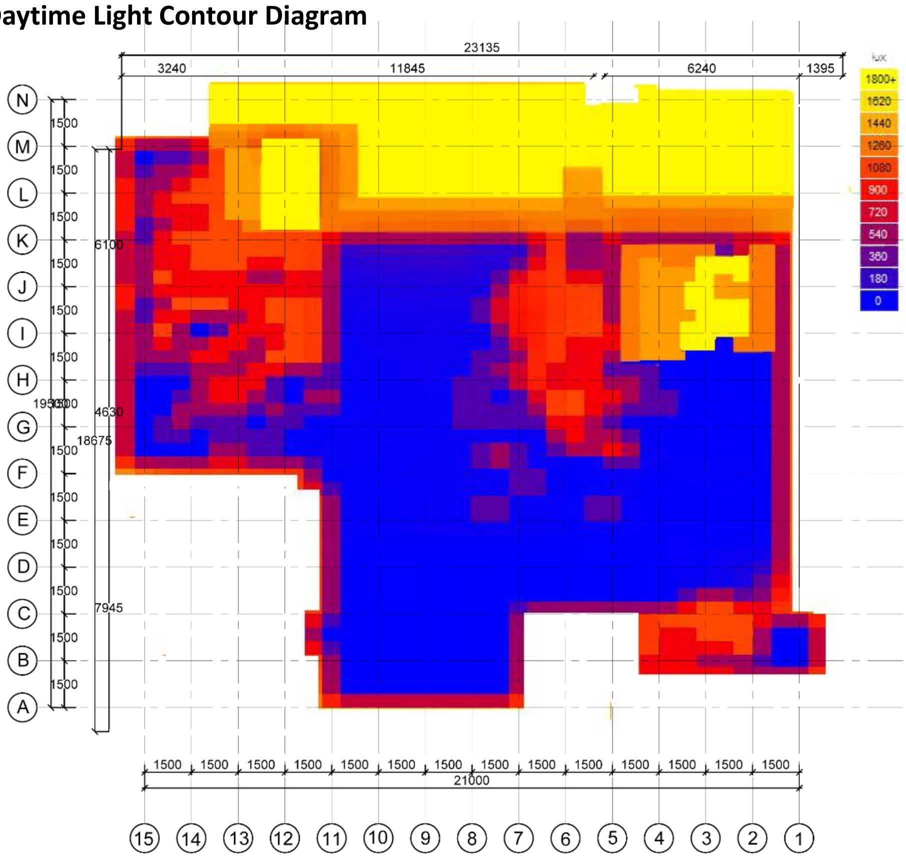


Figure 2.4.1.2.1: Day time light contour diagram at 1 meter height

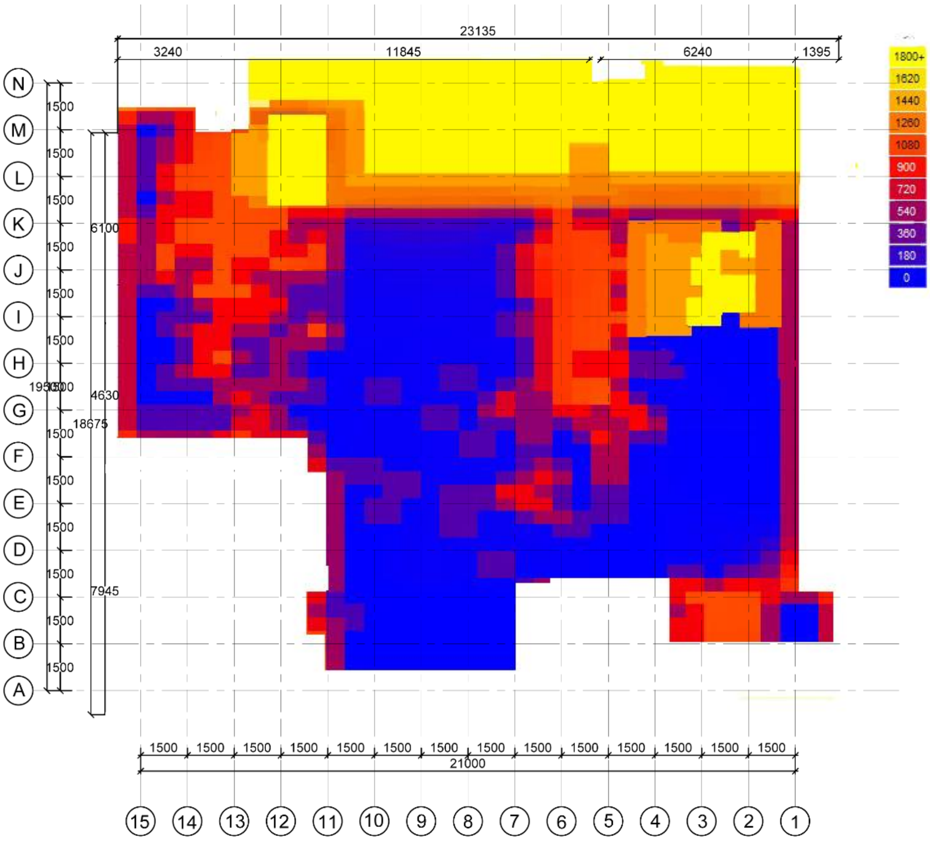


Figure 2.4.1.2.2: Day time light contour diagram at 1.5 meter height

As refer to figures above, daylighting effect is simulated at different level. The areas that are close to fenestrations will receive more natural daylighting as compare to other area. As such, daylighting is provided sufficiently to the outdoor dining areas (Room 3 and 5) for diners. Moreover, private dining area (Room 3) and entrance area also partly illuminated by daylight through glass door and windows. Instead, other spaces such as indoor dining areas (Room 1, 2, 4 and 6), bar and kitchen are totally out of natural daylighting provision.

Besides, daylighting factor level is simulated at 1m and 1.5m of height respectively. From the figures above, daylighting levels are not in vast difference at both levels but only different in a small area. Area at 1.5m height will receive a higher level of daylighting effect.

Overall Light Contour Diagram

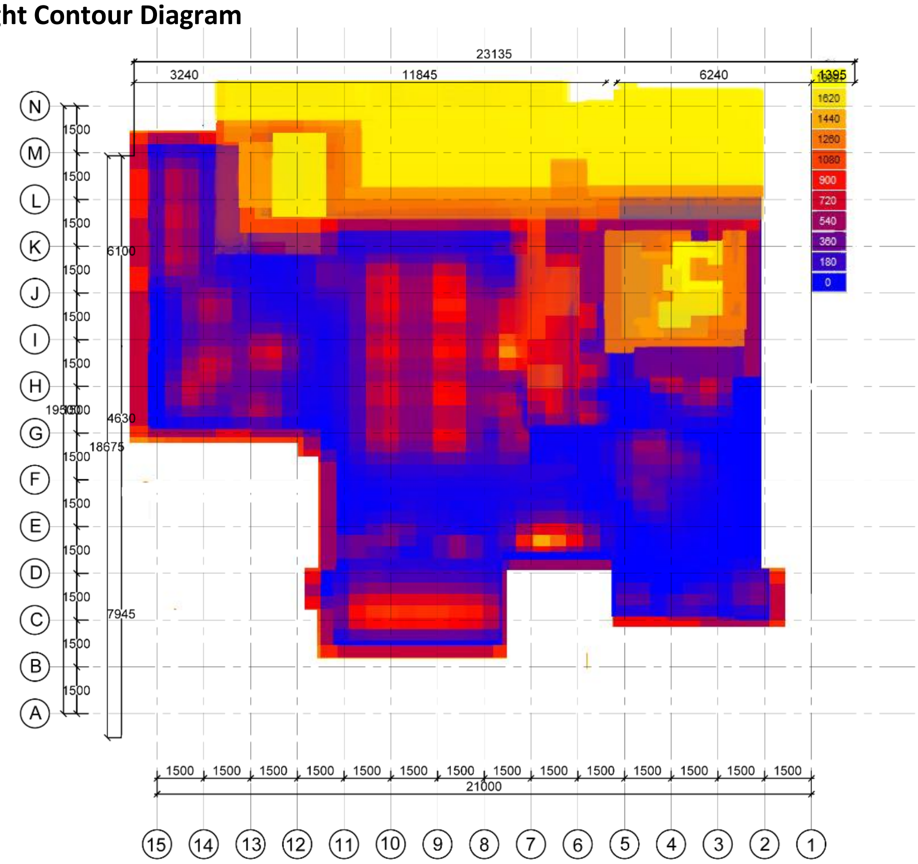


Figure 2.4.1.2.3: Overall lighting contour diagram at 1m height

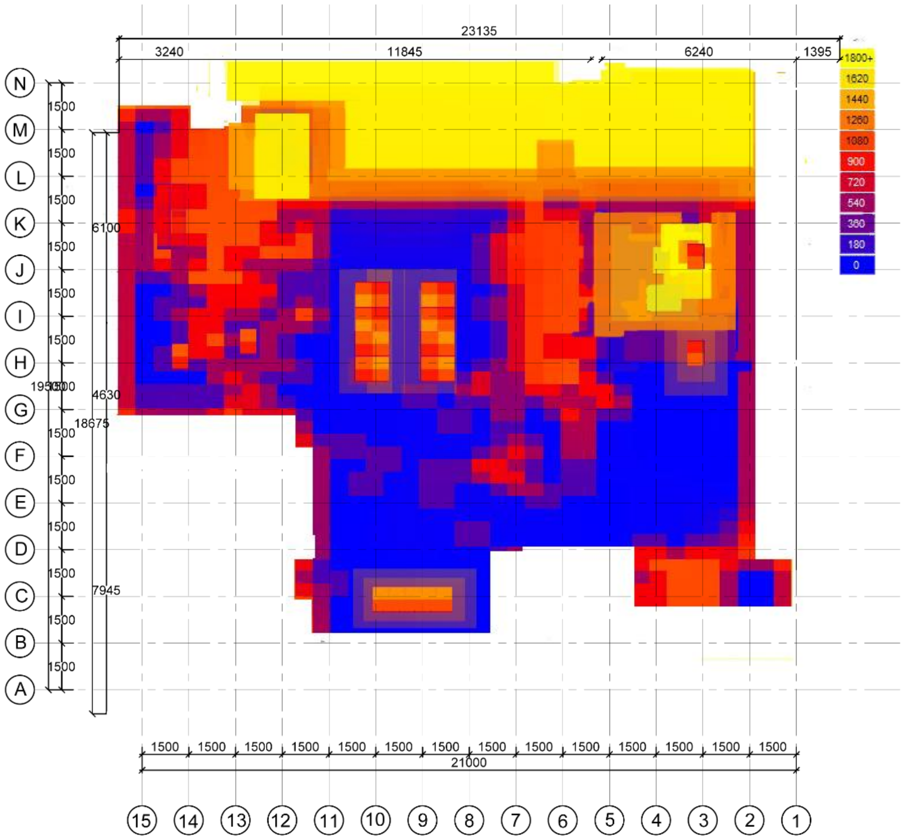


Figure 2.4.1.2.4: Overall lighting contour diagram at 1.5m height

Overall lighting contour diagrams (Figure 2.4.1.2.3 and 2.4.1.2.4) show the lighting levels of Ploy Restaurant with daylighting and artificial lighting effect. These diagrams reflect the actual lighting situation of the restaurant while it is operating in daytime. Artificial lighting fixtures are installed at areas which doesn't have enough daylight. Halogen down light with 320 lumen is generally used in Ploy Restaurant to provide dim lit atmosphere to let people to dine in. Instead, kitchen is illuminated by fluorescent light of 1350 lumens all the time.

Overall lighting levels at 1m and 1.5m height are simulated. In 1.5m height, lighting level is higher in compare with 1m height. This is crucial because it provides a better vision for diners while they are dining in these spaces.

2.4.1.3 Daylighting Factor

Daylight factor (DF) is defined as the ratio of interior illuminance (E_i) to available outdoor illuminance:

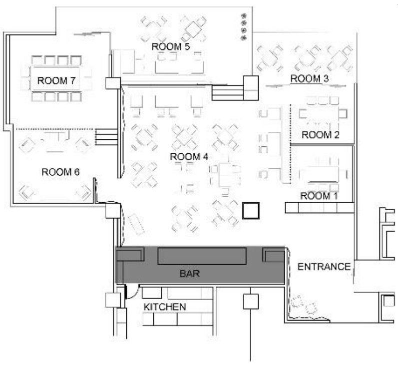
$$DF = \frac{\textit{Ei indoor illuminance, at a given point}}{\textit{EH outdoor illuminance}}$$

Where E_H is the unobstructed horizontal exterior illuminance. The daylight factor concept is applicable only where the sky luminance distribution is known or can reasonably be estimated. In this case, the average day light level in Malaysia (E_H) is assumed to be 20000 lux.

<u>Daylight Factor at Entrance Area</u>

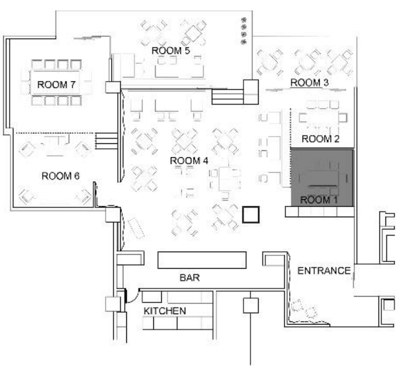
Average Lux Reading at Zone (E_i) = 3.33lux
Day Light Level in Malaysia (E_H) = 20000lux
Day Light Factor = (E_i/E_H)×100%
= 0.017%

<u>Daylight Factor at Bar Area</u>



Average Lux Reading at Zone (E_i) = 5.5lux
Day Light Level in Malaysia (E_H) = 20000lux
Day Light Factor = (E_i/E_H) ×100%
= 0.028%

<u>Daylight Factor at Private Dining Room 1</u>



Average Lux Reading at Zone (E_i) = 61lux
Day Light Level in Malaysia (E_H) = 20000lux
Day Light Factor = (E_i/E_H) ×100%
= 0.305%

Daylight Factor at Private Dining Room 2

Average Lux Reading at Zone (E_i) = 157.5lux
Day Light Level in Malaysia (E_H) = 20000lux
Day Light Factor = (E_i/E_H) ×100%
= 0.788%

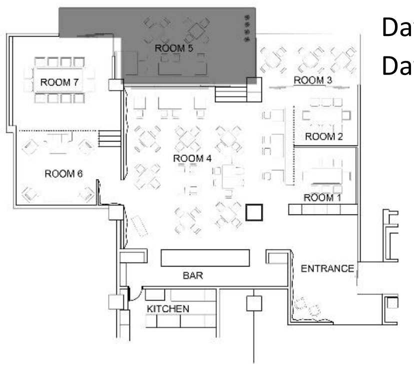
Daylight Factor at Outdoor Dining Room 3

Average Lux Reading at Zone (E_i) = 1955.33lux
Day Light Level in Malaysia (E_H) = 20000lux
Day Light Factor = (E_i/E_H) ×100%
= 9.777%

Daylight Factor at Public Dining Room 4

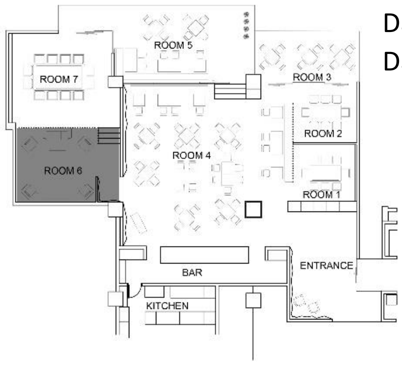
Average Lux Reading at Zone (E_i) = 23.57lux
Day Light Level in Malaysia (E_H) = 20000lux
Day Light Factor = (E_i/E_H) ×100%
= 0.118%

Daylight Factor at Outdoor Dining Room 5



Average Lux Reading at Zone (E_i) = 820.89lux
Day Light Level in Malaysia (E_H) = 20000lux
Day Light Factor = (E_i/E_H) ×100%
= 4.104%

Daylight Factor at Private Dining Room 6



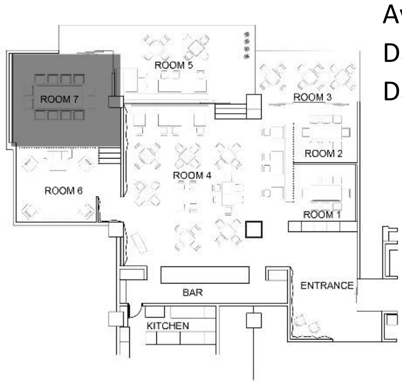
Average Lux Reading at Zone (E_i) = 3.43lux

Day Light Level in Malaysia (E_H) = 20000lux

Day Light Factor = $(E_i/E_H) \times 100\%$

= 0.017%

Daylight Factor at Private Dining Room 7



Average Lux Reading at Zone (E_i) = 67.3lux

Day Light Level in Malaysia (E_H) = 20000lux

Day Light Factor = $(E_i/E_H)\times 100\%$

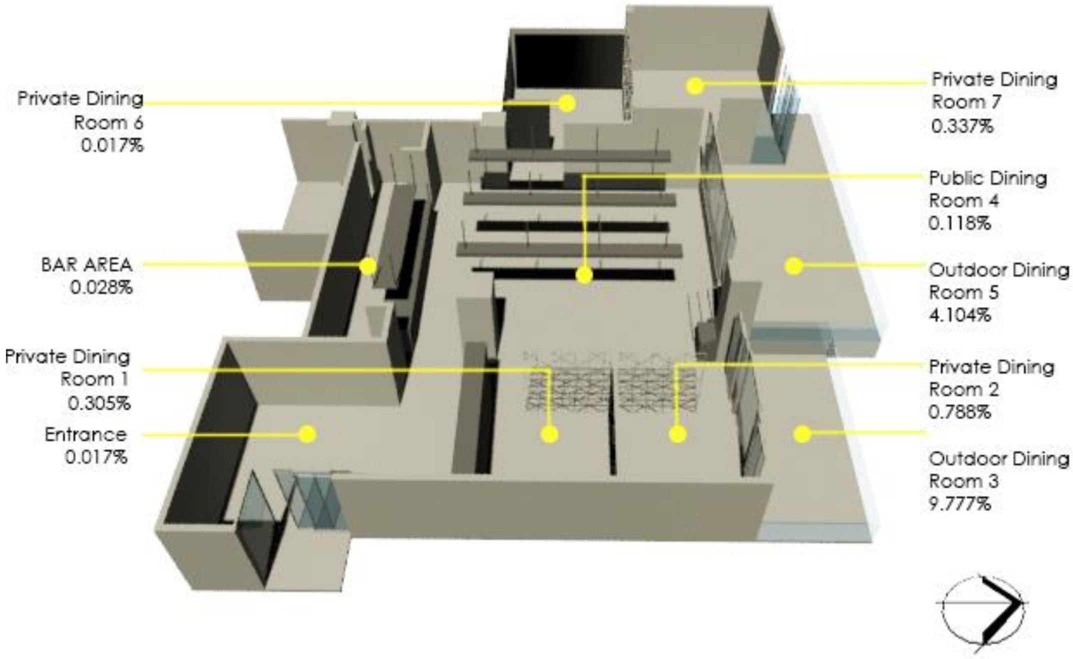
= 0.337%

The CIBSE Lighting Guide 10 (LG10-1999) broadly bands average daylight factors into the following categories:

- <2 – Not adequately lit – artificial lighting will be required.
- 2-5 – Adequately lit but artificial lighting may be in use for part of the time.
- >5 – Well lit – artificial lighting generally not required except at dawn and dusk – but glare and solar gain may cause problems.

Zone	Day Light Factor	Day Light Condition
Entrance Area	0.017	Fairly dim
Bar Area	0.028	Fairly Dim
Private Dining Room 1	0.305	Fairly Dim
Private Dining Room 2	0.788	Fairly Dim
Outdoor Dining Room 3	9.777	Glare and thermal problem

Public Dining Room 4	0.118	Fairly Dim
Outdoor Dining Room 5	4.104	Adequately lit
Private Dining Room 6	0.017	Fairly Dim
Private Dining Room 7	0.337	Fairly Dim



2.4.1.4 Night Time Lux Reading

TIME	17/9/2014 8pm-10pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
A1	43	32
A2	21	21
A3	19	18
A4	34	44
B1	586	345
B2	504	578
B3	49	20
B4	37	32
C1	78	158
C2	58	54
C3	298	425
C4	8	21
C5	8	25
C6	24	25
C7	15	21
C8	13	22
C9	8	24
C10	24	28
D1	63	50
D2	73	86
D3	54	63
D4	11	6
D5	18	21
D6	4	9
D7	4	10
D8	74	11
D9	10	11
D10	19	13
D11	30	24
E1	163	75
E2	189	188
E3	29	34
E4	15	15
E5	19	18
E6	8	8
E7	9	11
E8	8	15
E9	8	9
E10	36	25
E11	42	31
F1	28	31
F2	16	18
F3	9	14
F4	74	143
F5	19	14

TIME	17/9/2014 8pm-10pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
F6	9	14
F7	11	16
F8	12	15
F9	15	9
F10	11	9
F11	9	11
F12	19	15
F13	17	22
F14	17	18
F15	6	10
G1	218	574
G2	254	569
G3	24	21
G4	328	178
G5	24	32
G6	32	18
G7	28	15
G8	214	378
G9	19	11
G10	21	32
G11	17	18
G12	28	21
G13	28	32
G14	20	24
G15	8	15
H1	124	48
H2	32	42
H3	298	284
H4	652	512
H5	24	28
H6	28	38
H7	20	18
H8	26	18
H9	24	16
H10	32	34
H11	159	218
H12	17	18
H13	25	21
H14	24	28
H15	16	15
I1	96	124
I2	152	128
I3	98	118
I4	108	123
I5	35	98

TIME	17/9/2014 8pm-10pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
I6	68	41
I7	39	32
I8	74	158
I9	52	28
I10	22	28
I11	41	92
I12	14	10
I13	24	18
I14	16	21
I15	8	11
J1	109	125
J2	128	162
J3	96	186
J4	186	127
J5	38	95
J6	71	46
J7	47	47
J8	37	36
J9	78	139
J10	54	48
J11	128	168
J12	25	18
J13	9	10
J14	21	14
J15	8	13
K1	59	102
K2	58	125
K3	68	101
K4	47	95
K5	85	102
K6	49	84
K7	54	95
K8	68	86
K9	56	92
K10	62	91
K11	67	96
K12	25	38
K13	105	132
K14	58	250
K15	92	98
L1	45	105
L2	65	98
L3	58	85
L4	52	105
L5	57	102

TIME	17/9/2014 8pm-10pm	
HEIGHT	17/9/2014	1.5m
GRID/ZONE	LUX METER READING (lx)	
L6	60	89
L7	64	94
L8	68	82
L9	59	92
L10	68	84
L11	62	88
L12	328	308
L13	186	114
L14	71	35
L15	84	98
M6	68	91
M7	62	96
M8	63	85
M9	59	92
M10	65	96
M11	58	116
M12	62	108
M13	68	91
M14	57	95
M15	54	87
N6	65	89
N7	62	97
N8	69	95
N9	58	105
N10	54	85
N11	69	98
N12	58	89
N13	53	84

- Entrance Area
- Services Area
- Public Dining Area
- Private Dining Area
- Lounge Area
- Outdoor Dining Area

2.4.1.5 Night Time Light Contour Diagram

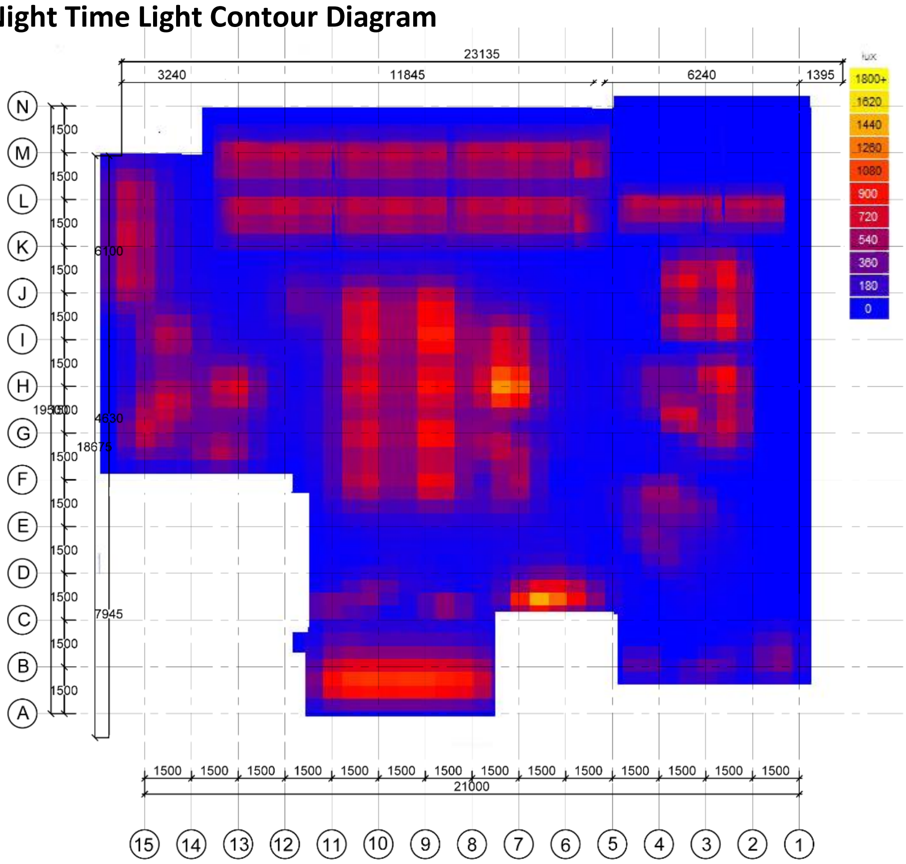


Figure 2.1.4.2.1: Night time light contour diagram at 1 meter height

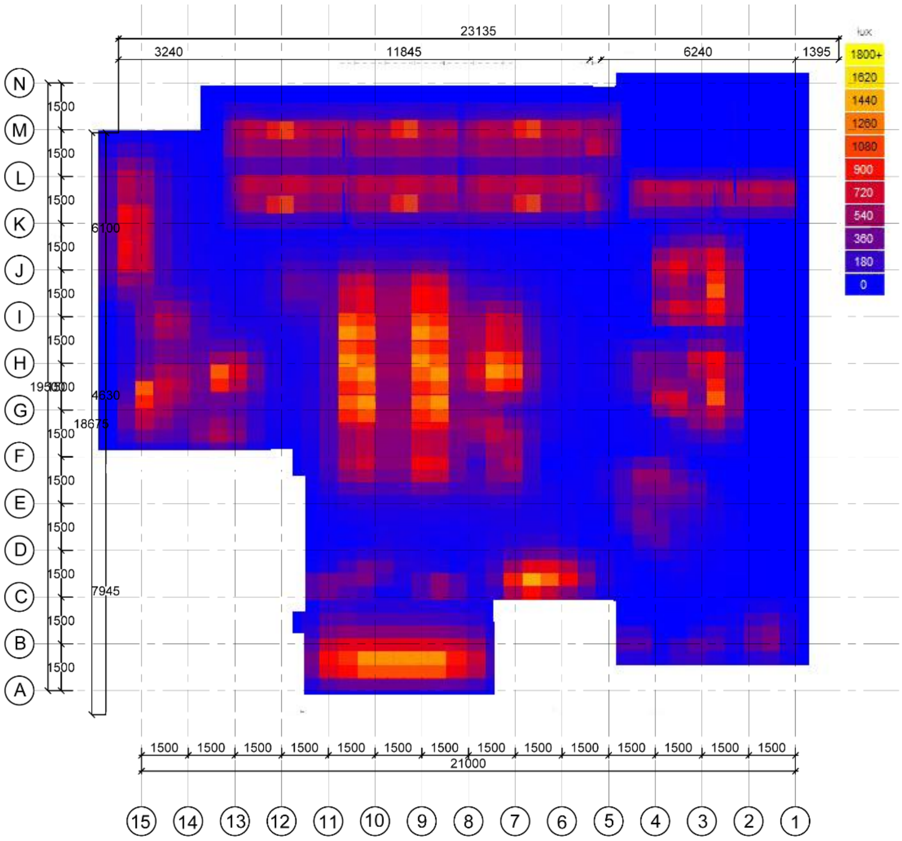


Figure 2.1.4.2.2: Night time light contour diagram at 1.5 meter height

During night time, Ploy Restaurant is illuminated by artificial light fixtures entirely. As shown in Figure 2.1.4.2.1 and 2.1.4.2.2, artificial lighting levels are demonstrated at 1m and 1.5m height. It is obvious to see the change of lighting level in the two heights. In the night time, Ploy Restaurant is still remains at the atmosphere of dimly lit in most of the dining area. Kitchen is the only space with higher average lux readings because of the use of fluorescent lights.

2.4.2 Analysis and Calculations

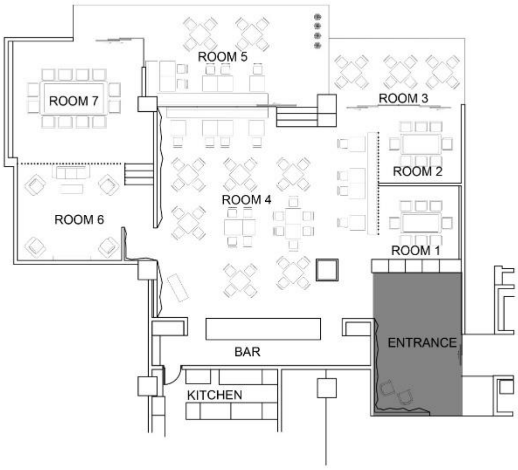
(Refer to 1.2 Standard MS 1525 Lux Recommendation)

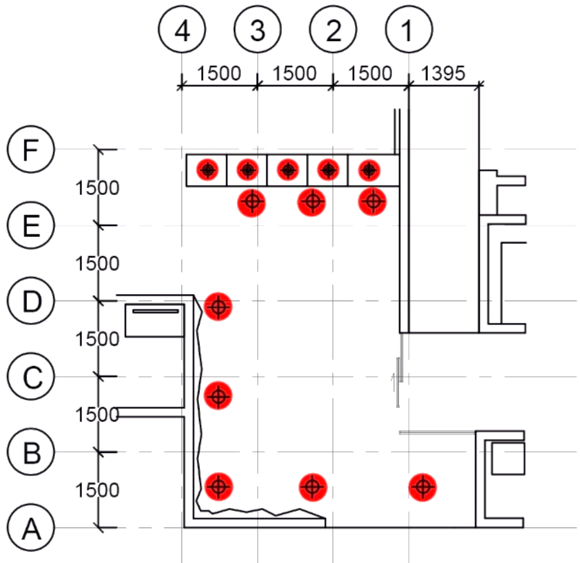
Utilization factor										Fixture efficiency
Ceiling(%)		70			50			30		
Walls(%)		50	30	10	50	30	10	50	30	10
Floor(%)		30 10	30 10	30 10	30 10	30 10	30 10	30 10	30 10	30 10
Room index	0.60	.27 .26	.22 .22	.19 .19	.26 .24	.22 .21	.19 .18	.26 .25	.21 .21	.19 .18
	0.80	.33 .31	.28 .27	.23 .23	.32 .30	.27 .26	.24 .23	.31 .30	.27 .26	.23 .23
	1.00	.38 .36	.32 .30	.28 .28	.36 .35	.32 .31	.29 .27	.35 .34	.31 .30	.28 .27
	1.25	.43 .40	.37 .35	.33 .32	.41 .39	.36 .35	.33 .32	.39 .37	.35 .34	.32 .31
	1.50	.47 .43	.41 .39	.37 .35	.44 .42	.40 .37	.36 .35	.42 .40	.39 .37	.36 .35
	2.00	.52 .47	.47 .44	.43 .41	.49 .46	.45 .43	.42 .40	.47 .45	.44 .42	.41 .40
	2.50	.56 .50	.51 .47	.48 .44	.53 .49	.49 .46	.46 .44	.50 .48	.47 .45	.45 .43
	3.00	.59 .52	.55 .49	.51 .47	.55 .52	.52 .48	.49 .46	.52 .50	.50 .48	.47 .46
	4.00	.62 .55	.59 .52	.56 .51	.58 .53	.56 .52	.53 .50	.55 .52	.53 .51	.51 .49
	5.00	.64 .56	.62 .55	.59 .53	.60 .55	.58 .53	.56 .52	.57 .54	.55 .52	.52 .51

Table 2.4.2.1: Utilization Factor Table (Source: Summarized from SynthLight Handbook, Chapter 3)

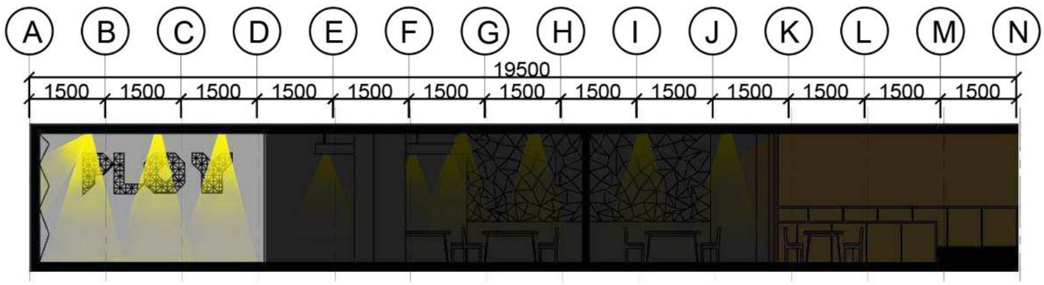
Lumen method is used in investigating the lighting condition of the space following the zones of restaurant as shown in figure below.

2.4.2.1 Entrance Area





ENTRANCE AREA SCALE 1:150



The light distribution at Entance Area is direct lighting. The downward focused light directly cast onto the target surface without reflection from other object.

Data Tabulation: Lux Meter Reading

	17/9/2014			
TIME	**3pm-5pm**		**8pm-10pm**	
HEIGHT	**1m**	**1.5m**	**1m**	**1.5m**
GRID/ZONE	**LUX METER READING (lx)**			
A1	1	4	43	32
A2	2	3	21	21
A3	2	3	19	18
A4	1	2	34	44
B1	5	4	586	345
B2	4	6	504	578
B3	4	4	49	20
B4	1	3	37	32
C1	17	10	78	158
C2	8	8	58	54
C3	6	9	298	425
C4	6	6	8	21
D1	16	13	63	50
D2	15	12	73	86
D3	18	10	54	63
D4	35	8	11	6
E1	25	710	163	75
E2	30	30	189	188
E3	25	35	29	34
E4	15	31	15	15

Table 2.4.2.1.1: Data tabulation of Entrance area.

	Daytime (3pm-5pm)		Night Time (8pm-10pm)	
	1m	**1.5m**	**1m**	**1.5m**
Lowest Reading	1 (Grid A1)	2 (Grid A4)	8 (Grid C3)	6 (Grid D4)
Highest Reading	35 (Grid D4)	710 (Grid E1)	586 (Grid B1)	578 (Grid B2)
Average Reading	11.8	45.55	116.6	113.25

Table 2.4.2.1.2: Highest reading, lowest reading and average reading of Entrance Area.

The readings collected during daytime fluctuate due to the indirect sun light penetrating into the area. The highest reading at 1m and 1.5m circulates around grid point C1 and D2 because of the outdoor light penetrating through the front automatic glass door while the other parts of area illuminated by the direct light fixtures.

Referring to MS1525, the required illuminance for a lounge is 100 lux. As compared to our collected data, this area is not meeting the requirement of sufficient lux. However, the highest lux reading collected in this area during daytime exceeds the MS1525 requirement.

The highest and lowest reading points during the night are almost similar to the reading during the day. The overall readings collected at the entrance area during the night are much higher at certain point than in the day due to the turning on of the light fixtures at night time. However, according to MS1525, the average lux of the space during the night is still sufficient to meet the standard illuminance requirements.

Types of Light and Materials

Types of Light	Light Specification	Luminous Flux (F)	Quantity (N)
Halogen Down Light	HALOSPOT 48	150 lm	5
	HALOSPOT 111	320 lm	8

Table 2.4.2.1.3: Types of light located in Entrance Area.

Component	Material	Function	Colour	Area (m^2)	Surface Type	Reflectance Value (%)
Ceiling	Plaster Finish	Ceiling	White	67	Reflective	40-45
Wall	Timber	Decorative wall	Brown	40.15	Absorptive	25-35
	Reinforced Concrete	Wall	White	43.49	Reflective	30-50
	Glass	Partition	Transparent	8.66	Reflective	8-12
Opening	Glass	Door	Transparent	11.1	Reflective	6-10
Floor	Concrete Cement	Floor	Grey	55.4	Reflective	30-50
	Fabric	Carpet	Brown	11.6	Absorptive	25-35
Furniture	Fabric	Sofa	Blue	8	Absorptive	18

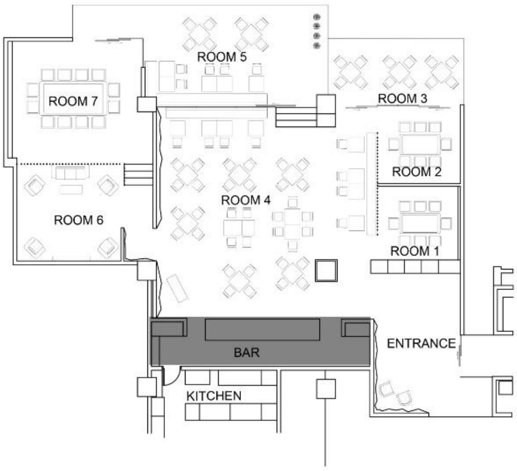
Table 2.4.2.1.4: Materials available in Entrance Area.

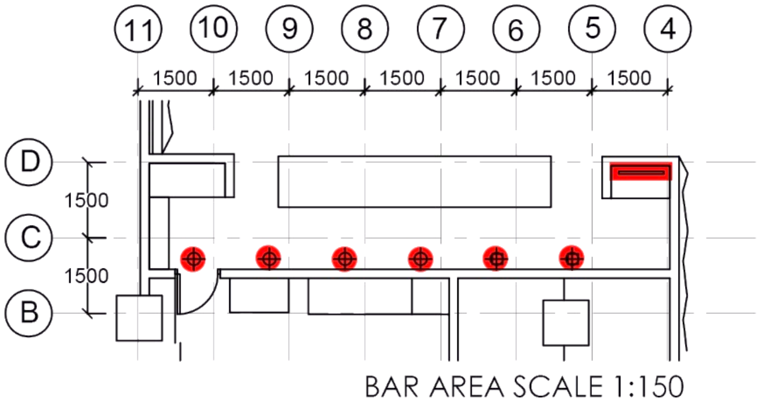
Lumen Method

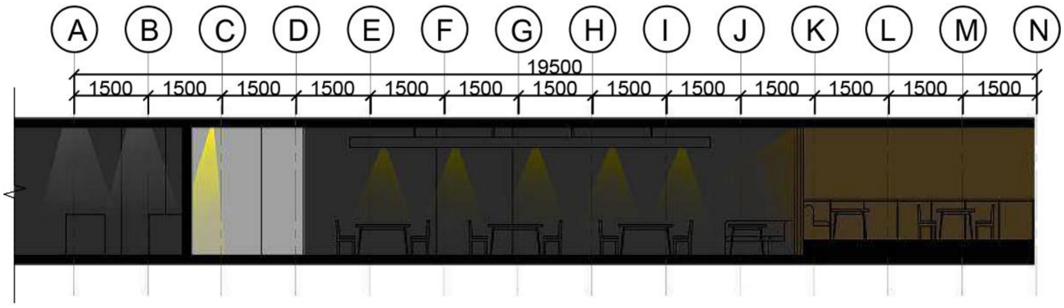
Location	Entrance Area
Dimension of Room, LxW	7.40 x 4.42
Total Floor Area (m^2)	32.71
Mounting Height , h_m (m)	3.8 - 0.9 = 2.9
Room Index, K	$K = \frac{L \; x \; W}{(L+W)hm}$ $= \frac{7.40 \; x \; 4.42}{(7.40+4.42) \; x \; 2.9}$ = 0.95
Room Reflectance (%)	C:50, W:50, F:30
Utilisation Factor (UF)	0.36
Maintenance Factor (MF)	0.75
Standard Illuminance Level Required (lux)	100
Existing Illuminance Level, E	$E=\frac{NxFxUFxMF}{A}$ $= \frac{5x150x0.36x0.75}{32.71} + \frac{8x350x0.36x0.75}{32.71}$ = 6.19+23.11 = 29.3 lux According to MS 1525, standard illuminance for entrance area is 100 lux. 100lux – 29.3lux = 70.7lux Entrance Area lacks of 70.7lux illuminance level.

Number of Fittings Required, N'	Since HALOSPOT48 is used mainly for lighting up wine display in the cabinet, hence to light up the space, number of 35W Halogen Down Light HALOSPOT111 with luminous flux of 320lm shall be indicated. For 35W HALOSPOT111, N'= $\frac{E\ x\ A}{F\ x\ UF\ x\ MF}$ = $\frac{100\ x\ 32.71}{350\ x\ 0{,}36\ x\ 0.75}$ = 34.6 ≈ 35 Halogen Down Lights needed to meet the standard illuminance required in Entrance Area.
Conclusion	According to MS 1525, standard illuminance for restaurant is 100 lux. Existing illuminance for Entrance Area, 29.3 lux does not meet the standard requirement. To meet standard requirement of an Entrance Area, 27 more Halogen Down Lights are required.

2.4.2.2 Bar Area







Data Tabulation: Lux Meter Reading

	17/9/2014			
TIME	3pm-5pm		8pm-10pm	
HEIGHT	1m	1.5m	1m	1.5m
GRID/ZONE	LUX METER READING (lx)			
C4	248	54	8	21
C5	26	15	8	25
C6	10	15	24	25
C7	10	20	15	21
C8	12	24	13	22
C9	18	26	8	24
C10	125	49	24	28
D4	35	8	11	6
D5	18	18	18	21
D6	4	7	4	9
D7	8	7	4	10
D8	9	10	74	11
D9	15	34	10	11
D10	26	51	19	13

Table 2.4.2.2.1: Data tabulation of Bar area.

	Daytime (3pm-5pm)		Night Time (8pm-10pm)	
	1m	1.5m	1m	1.5m
Lowest Reading	4	7	4	6
Highest Reading	248	54	74	28
Average Reading	40.29	24.14	17.14	17.64

Table 2.4.2.2.2: Highest reading, lowest reading and average reading of Bar Area.

Types of Light and Materials

Types of Light	Light Specification	Luminous Flux (F)	Quantity (N)
Halogen Down Light	HALOSPOT 111	350 lm	6

Table 2.4.2.2.3: Types of light located in Bar Area.

Component	Material	Function	Colour	Area (m^2)	Surface Type	Reflectance Value (%)
Ceiling	Plaster Finish	Ceiling	White	23.12	Reflective	40-45
Wall	Timber	Decorative wall	Brown	21.89	Absorptive	25-35
	Reinforced Concrete	Wall	Grey	41.04	Reflective	30-50
Opening	Timber	Door	White	2.8	Absorptive	45-50
Floor	Concrete Cement	Floor	Grey	55.4	Reflective	30-50
Furniture	Steel	Bar Table	Silver	7.78	Reflective	79-90

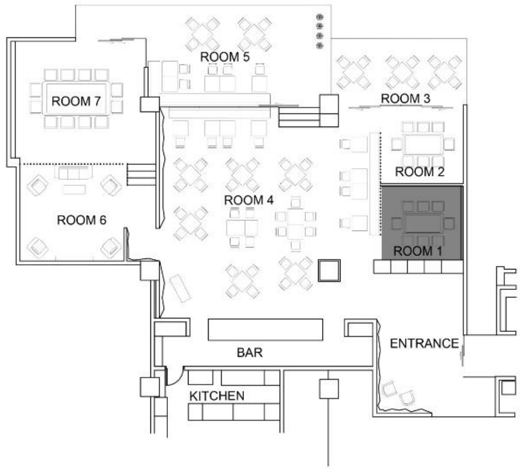
Table 2.4.2.2.4: Materials available in Bar Area.

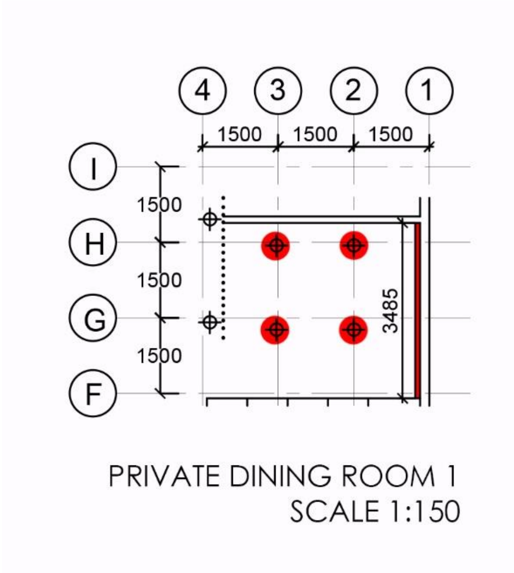
Lumen Method

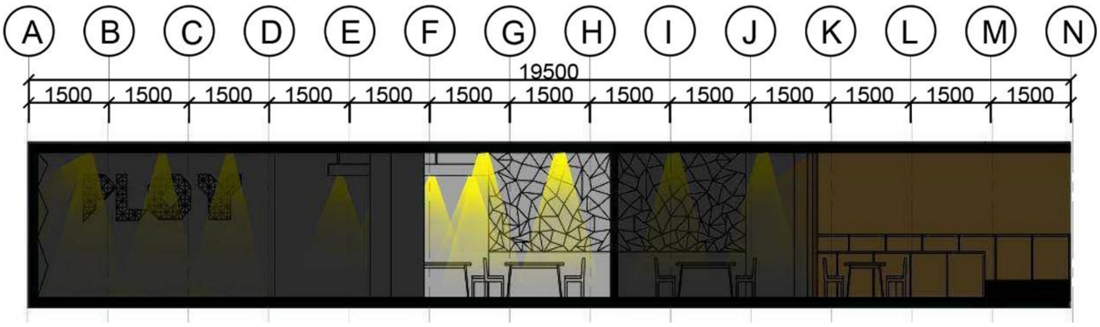
Location	Bar Area
Dimension of Room, LxW	10.32 x 2.28
Total Floor Area (m^2)	23.53
Mounting Height , h_m (m)	3.8 - 0.9 = 2.9
Room Index, K	$K = \frac{L \times W}{(L+W)hm}$ $= \frac{10.32 \times 2.28}{(10.32+2.28) \times 2.9}$ = 0.64
Room Reflectance (%)	C:50, W:50, F:30
Utilisation Factor (UF)	0.26
Maintenance Factor (MF)	0.75
Standard Illuminance Level Required (lux)	500

Existing Illuminance Level, E	$E = \frac{NxFxUFxMF}{A}$ $= \frac{6x350x0.26x0.75}{23.53}$ = 17.4 lux According to MS 1525, standard illuminance for bar or cooking area is 500 lux. 500lux – 17.4lux = 482.6lux Bar Area lacks of 482.6lux illuminance level.
Number of Fittings Required, N’	For 35W Halogen Down Light, $N' = \frac{E\ x\ A}{F\ x\ UF\ x\ MF}$ $= \frac{500\ x\ 23.53}{350\ x\ 0{,}26\ x\ 0.75}$ = 172.4 ≈ 173 Halogen Down Lights needed to meet the standard illuminance required in bar area.
Conclusion	According to MS 1525, standard illuminance for cooking area of restaurant is 500 lux. Existing illuminance for Bar Area, 23.53 lux does not meet the standard requirement. To meet the standard illuminance requirement of a bar area, 167 more Halogen Down Lights are required in the space which is not applicable. Hence lights with higher luminous flux level shall be used in cooking area.

2.4.2.3 Private Dining Room 1







Data Tabulation: Lux Meter Reading

TIME	17/9/2014			
	3pm-5pm		8pm-10pm	
HEIGHT	1m	1.5m	1m	1.5m
GRID/ZONE	LUX METER READING (lx)			
F1	30	48	28	31
F2	20	39	16	18
F3	8	17	9	14
G1	258	522	218	574
G2	60	61	254	569
G3	426	942	24	21
H1	124	87	124	48
H2	75	64	32	42
H3	862	944	298	284

Table 2.4.2.3.1: Data tabulation of Private Dining Room 1.

	Daytime (3pm-5pm)		Night Time (8pm-10pm)	
	1m	1.5m	1m	1.5m
Lowest Reading	8	17	9	14
Highest Reading	862	944	298	574
Average Reading	11.8	302.67	111.44	177.89

Table 2.4.2.3.2: Highest reading, lowest reading and average reading of Private Dining Room 1.

The light distribution at Private Dining Area has both direct and indirect lighting. The downward focused light directly cast onto the target surface without reflection from other source whereas the LED strip light is hidden on the ceiling to create the diffuse light effect.

The highest reading recorded in this dining area is grid point G1, G3 and H3. This is caused by the direction and position of the artificial lighting in the space. The lighting condition of this area is considered an ideal space for dining because it fulfils the requirement of MS1525 which states the illuminance of 200 lux for a restaurant area.

Types of Light and Materials

Types of Light	Light Specification	Luminous Flux (F)	Quantity (N)
Halogen Down Light	HALOSPOT 111	350 lm	4
LED Strip Light	LK LED 40 CW	240 lm	1

Table 2.4.2.3.3: Types of light located in Private Dining Room 1.

Component	Material	Function	Colour	Area (m^2)	Surface Type	Reflectance Value (%)
Ceiling	Plaster Finish	Ceiling	White	28.44	Reflective	40-45
Wall	Timber	Decorative wall	Brown	24.11	Absorptive	25-35
	Reinforced Concrete	Wall	Grey	21.26	Reflective	30-50
Floor	Concrete Cement	Floor	Grey	28.44	Reflective	30-50
Furniture	Timber	Table	Brown	2.68	Absorptive	10-20
	Timber	Chair	Brown	2.16	Absorptive	10-20

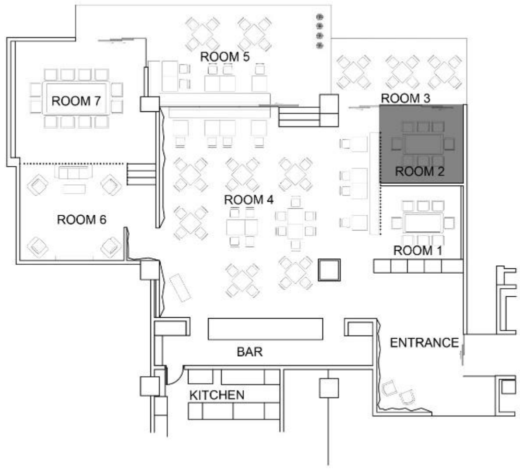
Table 2.4.2.3.4: Materials available in Private Dining Room 1.

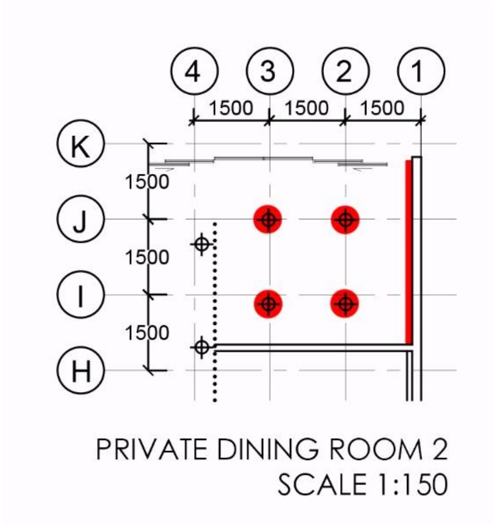
Lumen Method

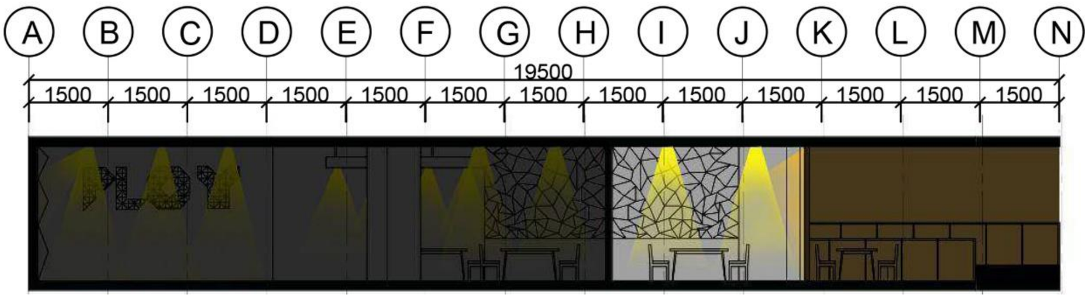
Location	Private Dining Room 1
Dimension of Room, LxW	3.63 x 3.49
Total Floor Area (m^2)	12.67
Mounting Height , h_m (m)	3.8 - 0.9 = 2.9
Room Index, K	$K = \frac{L \, x \, W}{(L+W)hm}$

	$=\frac{3.63 \; x \; 3.49}{(3.63+3.49) \; x \; 2.9}$ = 0.61
Room Reflectance (%)	C:50, W:30, F:30
Utilisation Factor (UF)	0.22
Maintenance Factor (MF)	0.75
Standard Illuminance Level Required (lux)	200
Existing Illuminance Level, E	$E=\frac{NxFxUFxMF}{A}$ $=\frac{4x350x0.22x0.75}{12.67}+\frac{1x240x0.22x0.75}{12.67}$ = 18.23 + 3.13 = 21.36 According to MS 1525, standard illuminance for cashier or dining area is 200 lux. 200lux – 21.36lux = 178.64lux Private Dining Room 1 lacks of 178.64 lux illuminance level.
Number of Fittings Required, N'	Since the LED strip light act as the diffused light hidden in the ceiling, only 2 more strips can be added in the private dining area. Hence for 2.8 W LED strip light, $E=\frac{NxFxUFxMF}{A}$ $=\frac{3x240x0.22x0.75}{12.67}$ = 9.38 lux 200 lux – 9.38 lux = 190.62 lux For 35W Halogen Down Light, $N'=\frac{E \; x \; A}{F \; x \; UF \; x \; MF}$ $=\frac{190.62 \; x \; 12.67}{350 \; x \; 0,22 \; x \; 0.75}$ = 41.8 ≈ 42 Halogen Down Lights needed to meet the standard illuminance required in Private Dining Room 1.
Conclusion	According to MS 1525, standard illuminance for dining area is 200 lux. Existing illuminance for Private Dining Room 1, 21.36 lux does not meet the standard requirement. To meet the standard illuminance requirement of a dining area, 38 more Halogen Down Lights are required in the space.

2.4.2.4 Private Dining Room 2







Data Tabulation: Lux Meter Reading

TIME	17/9/2014			
	3pm-5pm		8pm-10pm	
HEIGHT	1m	1.5m	1m	1.5m
GRID/ZONE	LUX METER READING (lx)			
I1	2009	2013	96	124
I2	2007	2009	152	128
I3	2008	2006	98	118
J1	2014	2017	109	125
J2	2007	2012	128	162
J3	2007	2008	96	186

Table 2.4.2.4.1: Data tabulation of Private Dining Room 2.

	Daytime (3pm-5pm)		Night Time (8pm-10pm)	
	1m	1.5m	1m	1.5m
Lowest Reading	2007	2006	92	118
Highest Reading	2014	2017	152	186
Average Reading	2008.67	2010.83	113.17	140.5

Table 2.4.2.4.2: Highest reading, lowest reading and average reading of Private Dining Room 2.

The light distribution at Private Dining Area has both direct and indirect lighting. The downward focused light directly cast onto the target surface without reflection from other source whereas the LED strip light is hidden on the ceiling to create the diffuse light effect.

Together with natural daylighting due to the glass sliding door at the North side, it provides sufficient lighting for the space. Hence the lux readings at this area during daytime are averagely high. Referring to MS1525, this space meets the requirement of 200 lux for a dining area.

In the night, the illuminance of the space decreases due to the absence of day light. However, Grid I2 and J2 has the higher reading due to the direct exposure of artificial lighting.

Types of Light and Materials

Types of Light	Light Specification	Luminous Flux (F)	Quantity (N)
Halogen Down Light	HALOSPOT 111	350 lm	4
LED Strip Light	LK LED 40 CW	240 lm	1

Table 2.4.2.4.3: Types of light located in *Private Dining Room 2.*

Component	Material	Function	Colour	Area (m^2)	Surface Type	Reflectance Value (%)
Ceiling	Plaster Finish	Ceiling	White	28.44	Reflective	40-45
Wall	Timber	Decorative wall	Brown	24.11	Absorptive	25-35
	Reinforced Concrete	Wall	Grey	21.26	Reflective	30-50
	Fabric	Curtain	White	9.1	Absorptive	11-20
Floor	Concrete Cement	Floor	Grey	28.44	Reflective	30-50
Furniture	Timber	Table	Brown	2.68	Absorptive	10-20
	Timber	Chair	Brown	2.16	Absorptive	10-20

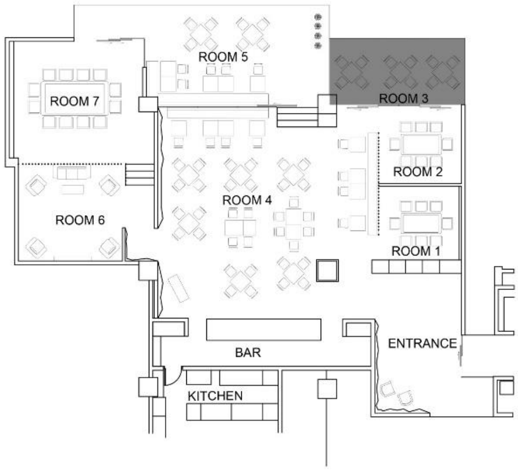
Table 2.4.2.4.4: Materials available in *Private Dining Room 2.*

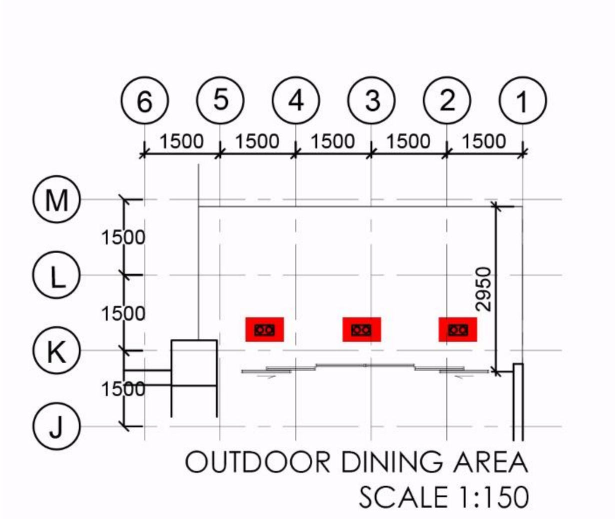
Lumen Method

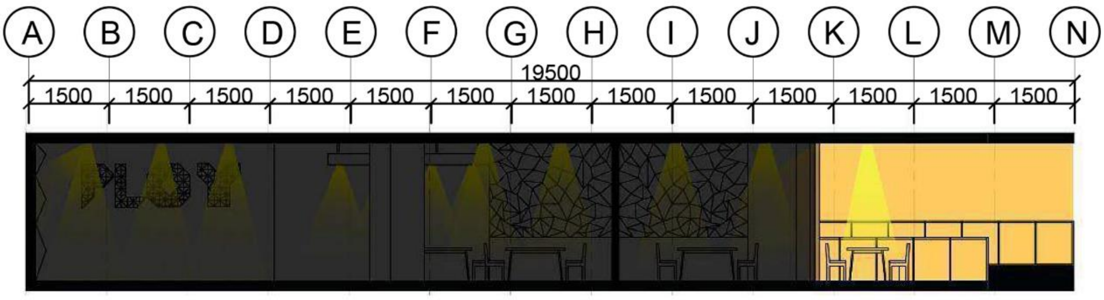
Location	Private Dining Room 2
Dimension of Room, LxW	3.63 x 3.54
Total Floor Area (m^2)	12.85
Mounting Height , h_m (m)	3.8 - 0.9 = 2.9
Room Index, K	$K = \frac{L \, x \, W}{(L+W)hm}$

	$=\frac{3.63\ x\ 3.54}{(3.63+3.54)\ x\ 2.9}$ = 0.62
Room Reflectance (%)	C:50, W:30, F:30
Utilisation Factor (UF)	0.22
Maintenance Factor (MF)	0.75
Standard Illuminance Level Required (lux)	200
Existing Illuminance Level, E	$E=\frac{NxFxUFxMF}{A}$ $=\frac{4x350x0.22x0.75}{12.85}+\frac{1x240x0.22x0.75}{12.85}$ = 17.98 + 3.08 = 21.06 According to MS 1525, standard illuminance for cashier or dining area is 200 lux. 200lux – 21.06lux = 178.94lux Private Dining Room 2 lacks of 178.94 lux illuminance level.
Number of Fittings Required, N'	Since the LED strip light act as the diffused light hidden in the ceiling, only 2 more strips can be added in the private dining area. Hence for 2.8 W LED strip light, $E=\frac{NxFxUFxMF}{A}$ $=\frac{3x240x0.22x0.75}{12.67}$ = 9.38 lux 200 lux – 9.38 lux = 190.62 lux For 35W Halogen Down Light, $N=\frac{E\ x\ A}{F\ x\ UF\ x\ MF}$ $=\frac{190.62\ x\ 12.85}{350\ x\ 0,22\ x\ 0.75}$ = 42.4 ≈ 43 Halogen Down Lights needed to meet the standard illuminance required in Private Dining Room 2.
Conclusion	According to MS 1525, standard illuminance for dining area is 200 lux. Existing illuminance for Private Dining Room 2, 21.06 lux does not meet the standard requirement. To meet the standard illuminance requirement of a dining area, 39 more Halogen Down Lights are required in the space.

2.4.2.5 Outdoor Dining Room 3







Data Tabulation: Lux Meter Reading

TIME	17/9/2014			
	3pm-5pm		8pm-10pm	
HEIGHT	1m	1.5m	1m	1.5m
GRID/ZONE	LUX METER READING (lx)			
K2	2071	2056	58	125
K3	2068	2045	68	101
K4	2673	2700	47	95
K5	83	62	85	102
L2	2463	2713	65	98
L3	2578	2778	58	85
L4	2138	2036	52	105
L5	260	150	57	102

Table 2.4.2.5.1: Data tabulation of Outdoor Dining Room 3.

	Daytime (3pm-5pm)		Night Time (8pm-10pm)	
	1m	1.5m	1m	1.5m
Lowest Reading	83	62	47	85
Highest Reading	2673	2778	85	125
Average Reading	1791.75	1817.5	61.25	101.63

Table 2.4.2.5.2: Highest reading, lowest reading and average reading of Outdoor Dining Room 3.

The light distribution at Outdoor Dining Area is direct lighting. The downward focused light directly cast onto the target surface without reflection from other source. The daylighting at outdoor is also providing lighting for the space. Therefore the space is having sufficient lighting.

The lowest readings collected in this outdoor corner dining area are below 1000 lux at grid point K5. This points is located at the inner side of the space which is less exposed to the direct sunlight. Other grids at this area are very much affected by the direct sunlight resulting in a reading of over 1000 lux. During the day, the illuminance in this area is very high, exceeding the requirement of MS1525 for a dining area.

During the night, the illuminance of this area could go as low as below 100 lux because of the absence of daylighting. However, with the presence of outdoor artificial lights and neighbouring street light, the readings collected in this space are still able to meet averagely 100 lux.

Types of Light and Materials

Types of Light	Light Specification	Luminous Flux (F)	Quantity (N)
Tungsten Halogen Low Voltage Down Light	HALOSPOT 70 20 W 12 V 8° BA15D	150 lm	6

Table 2.4.2.5.3: Types of light located in Outdoor Dining Room 3.

Component	Material	Function	Colour	Area (m^2)	Surface Type	Reflectance Value (%)
Ceiling	Plaster Finish	Ceiling	White	39.04	Reflective	40-45
Wall	Glass	Railing	Transparent	21.26	Reflective	6-10
Opening	Glass	Door	Transparent	16.54	Reflective	6-10
Floor	Timber	Decking	Brown	39.4	Absorptive	25-35
Furniture	Timber	Table	Brown	2.68	Absorptive	10-20
	Timber	Chair	Brown	2.16	Absorptive	10-20

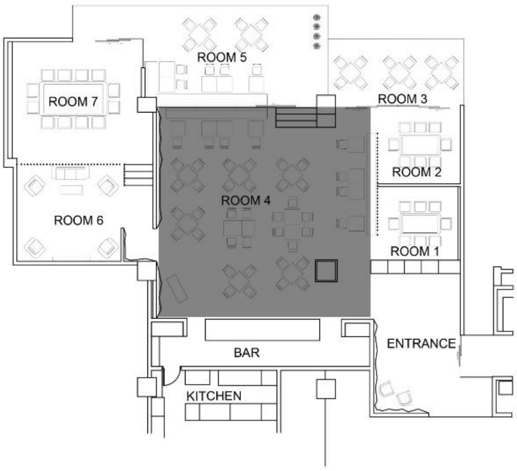
Table 2.4.2.5.4: Materials available in Outdoor Dining Room 3.

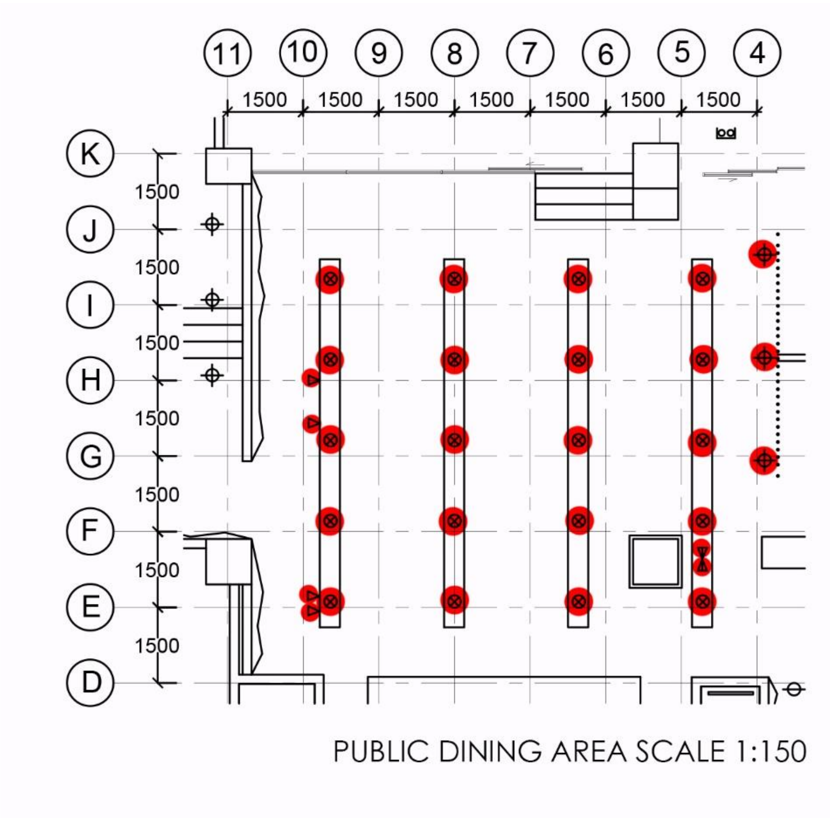
Lumen Method

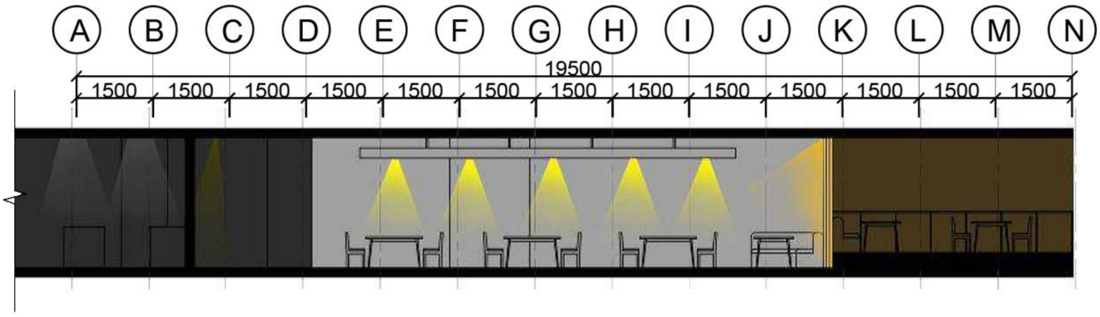
Location	Outdoor Dining Area
Dimension of Room, LxW	6.24 x 2.95

Total Floor Area (m^2)	18.41
Mounting Height , h_m (m)	3.8 - 0.9 = 2.9
Room Index, K	$K = \frac{L \, x \, W}{(L+W)hm}$ $= \frac{6.24 \, x \, 2.95}{(6.24+2.95) \, x \, 2.9}$ = 0.69
Room Reflectance (%)	C:50, W:30, F:30
Utilisation Factor (UF)	0.19
Maintenance Factor (MF)	0.75
Standard Illuminance Level Required (lux)	200
Existing Illuminance Level, E	$E = \frac{NxFxUFxMF}{A}$ $= \frac{6x150x0.19x0.75}{18.41}$ = 6.97 According to MS 1525, standard illuminance for dining area is 200 lux. 200lux – 6.97lux = 193.03lux Outdoor Dining Area lacks of 193.03 lux illuminance level.
Number of Fittings Required, N’	For 20 W Tungsten Halogen Low Voltage Down Light, $N = \frac{E \, x \, A}{F \, x \, UF \, x \, MF}$ $= \frac{200 \, x \, 18.41}{150 \, x \, 0{,}19 \, x \, 0.75}$ = 172.3 ≈ 173 Tungsten Halogen Low Voltage Down Light needed to meet the standard illuminance required in Outdoor Dining Area.
Conclusion	According to MS 1525, standard illuminance for dining area is 200 lux. Existing illuminance for Outdoor Dining Area, 6.97 lux does not meet the standard requirement. To meet the standard illuminance requirement of a dining area, 167 more Tungsten Halogen Low Voltage Down Light are required in the space. Since the Outdoor Dining Area is exposed to natural daylight during daytime and exposed to neighbourhood street light during night time. Hence the number of lights required is not necessary to be 173.

2.4.2.6 Public Dining Room 4







Section showing the Main dining with method of light distribution

Data Tabulation: Lux Meter Reading

	17/9/2014			
TIME	3pm-5pm		8pm-10pm	
HEIGHT	1m	1.5m	1m	1.5m
GRID/ZONE	LUX METER READING (lx)			
E4	15	31	15	15
E5	23	64	19	18
E6	11	11	8	8
E7	11	8	9	11
E8	989	2279	8	15
E9	35	36	8	9
E10	80	114	36	25
F4	12	16	74	143
F5	10	9	19	14
F6	13	11	9	14
F7	13	9	11	16
F8	350	1570	12	15
F9	28	33	15	9
F10	44	49	11	9
G4	37	28	328	178
G5	18	23	24	32
G6	189	23	32	18
G7	13	10	28	15
G8	20	25	214	378
G9	23	26	19	11
G10	34	44	21	32
H4	83	37	652	512
H5	20	15	24	28
H6	26	19	28	38
H7	15	11	20	18
H8	495	2212	26	18
H9	59	25	24	16
H10	281	323	32	34
I4	67	64	108	123
I5	36	31	35	98
I6	47	27	68	41
I7	31	23	39	32
I8	42	47	74	158
I9	37	18	52	28
I10	52	45	22	28
J4	189	82	186	127
J5	97	75	38	95
J6	433	55	71	46
J7	36	28	47	47

J8	40	92	37	36
J9	46	45	78	139
J10	43	35	54	48

Table 2.4.2.6.1: Data tabulation of Public Dining Room 4.

	Daytime (3pm-5pm)		*Night Time (8pm-10pm)*	
	1m	1.5m	1m	1.5m
Lowest Reading	10	8	8	8
Highest Reading	989	2279	652	512
Average Reading	98.64	184	62.5	63.9

Table 2.4.2.6.2: Highest reading, lowest reading and average reading of Public Dining Room 4.

The light distribution at Public Dining Area is direct lighting. The downward focused light directly cast onto the target surface without reflection from other source. It providing sufficient lighting for the space. Also with the indirect daylight from the side, the space is brighter during the day.

The highest and lowest reading collected in this main dining area space differs drastically. Certain areas have a high lux reading because the artificial light is directed at it while other areas with low lux reading are because of the absence of artificial lighting.

According to the requirements of 200 lux for a dining area in MS1525, certain areas of this dining space meet the requirement while some others fail.

The environment of this space in the night becomes dimmer due to the absence of day light through the glass panel. Certain areas are still bright due to the use of artificial light. Whereas the other parts of this dining area is very dim. The overall average lux reading of this dining area does not meet the requirement of MS1525.

Types of Light and Materials

Types of Light	Light Specification	Luminous Flux (F)	Quantity (N)
Halogen Down Light	HALOSPOT 111	350	23
Incandescent Light Bulb	CLASSIC A 25 W 230 V E27	220	6

Table 2.4.2.6.3: Types of light located in Public Dining Room 4.

Component	Material	Function	Colour	Area (m^2)	Surface Type	Reflectance Value (%)
Ceiling	Plaster Finish	Ceiling	White	102.85	Reflective	40-45
Wall	Timber	Decorative wall	Brown	31.88	Absorptive	25-35
Opening	Glass	Door	Transparent	36.26	Reflective	6-10
Floor	Concrete Cement	Floor Finish	Grey	102.85	Reflective	30-50
Furniture	Timber	Table	Brown	12.57	Absorptive	10-20
	Timber	Chair	Brown	17.28	Absorptive	10-20
	Fabric	Sofa	Dark Brown	4.59	Absorptive	25

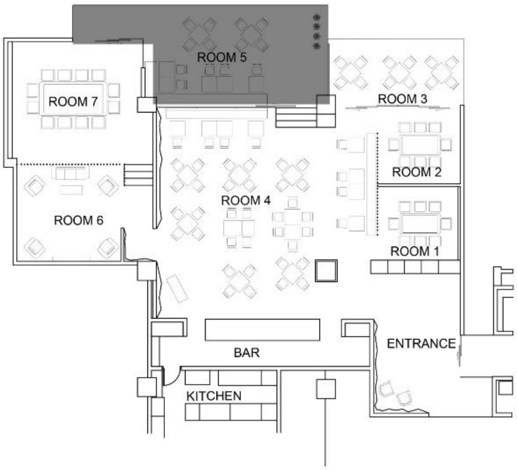
Table 2.4.2.6.4: Materials available in Public Dining Room 4.

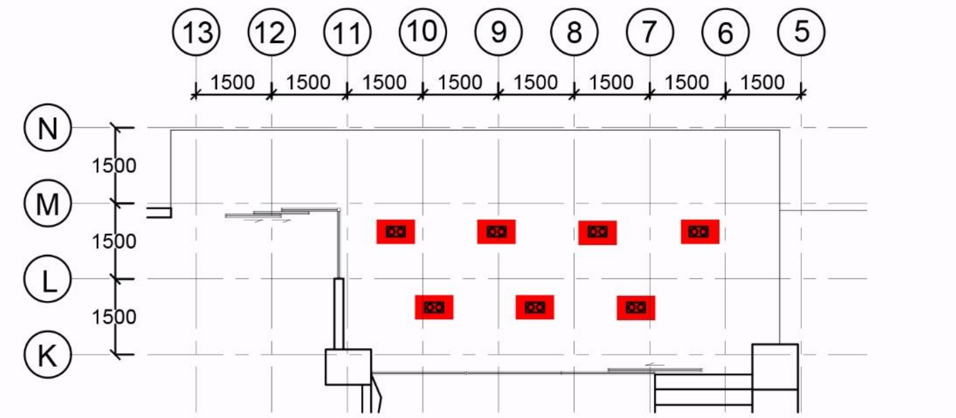
Lumen Method

Location	Public Dining Area
Dimension of Room, LxW	10.43 x 9.95
Total Floor Area (m^2)	103.78
Mounting Height , h_m (m)	3.8-0.9 = 2.9
Room Index, K	$K = \frac{L \, x \, W}{(L+W)hm}$ $= \frac{10.43 \text{ x } 9.95}{(10.43+ 9.95\ ) \, x \, 2.9}$ = 1.76
Room Reflectance (%)	C:50, W:30, F:30
Utilisation Factor (UF)	0.4
Maintenance Factor (MF)	0.75
Standard Illuminance Level Required (lux)	200
Existing Illuminance Level, E	$E=\frac{NxFxUFxMF}{A}$ $= \frac{23x350x0.4x0.75}{103.78} + \frac{6x220x0.4x0.75}{103.78}$ = 23.27 + 3.82 = 27.09 According to MS 1525, standard illuminance for dining area is 200 lux. 200lux – 27.09lux = 172.91lux Public Dining Area lacks of 172.91 lux illuminance level.

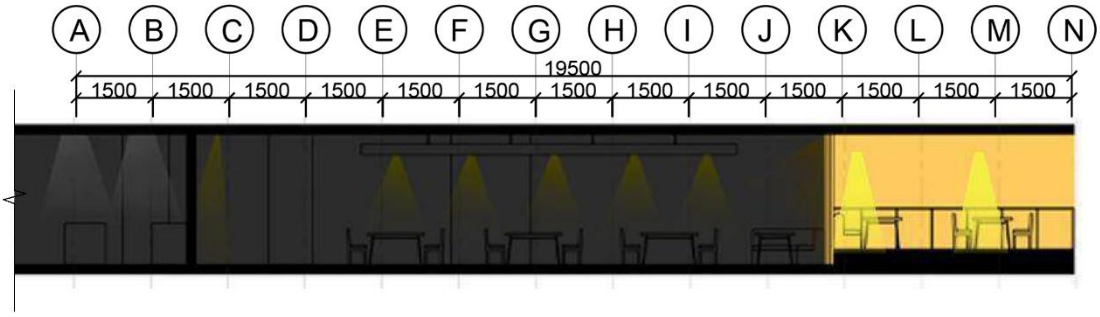
Number of Fittings Required, N'	(i) Assume the number of Incandescent Light Bulb remain as 6, $E=\frac{NxFxUFxMF}{A}$ $=\frac{6x220x0.4x0.75}{103.78}$ = 3.82 200 lux – 3.82 lux = 196.18 lux For 35 W Halogen Down Light, $N=\frac{E\ x\ A}{F\ x\ UF\ x\ MF}$ $=\frac{196.18\ x\ 103.78}{350\ x\ 0,4\ x\ 0.75}$ = 193.9 ≈ 194 Halogen Down Lights needed to meet the standard illuminance required in Public Dining Area. (ii) Assume the number of Halogen Down Light remain as 23, $E=\frac{NxFxUFxMF}{A}$ $=\frac{23x350x0.4x0.75}{103.78}$ = 23.27 200 lux – 23.27 lux = 176.73 lux For 25 W Incandescent Light Bulb, $N=\frac{E\ x\ A}{F\ x\ UF\ x\ MF}$ $=\frac{176.73\ x\ 103.78}{220\ x\ 0,4\ x\ 0.75}$ =277.9 ≈ 278 Halogen Down Lights needed to meet the standard illuminance required in Public Dining Area.
Conclusion	According to MS 1525, standard illuminance for dining area is 200 lux. Existing illuminance for Public Dining Area, 27.09 lux does not meet the standard requirement. To meet the standard illuminance requirement of a dining area, 171 more Halogen Down Light or 272 more Incandescent Light Bulb are required in the space which is not practical in meeting requirement of the space. Hence light fixtures with higher luminous flux level could be considered when designing the lighting.

2.4.2.7 Outdoor Dining Room 5





OUTDOOR DINING AREA SCALE 1:150



Data Tabulation: Lux Meter Reading

TIME	17/9/2014			
	3pm-5pm		8pm-10pm	
HEIGHT	1m	1.5m	1m	1.5m
GRID/ZONE	LUX METER READING (lx)			
K6	2019	2002	49	84
K7	2009	2009	54	95
K8	2018	2017	68	86
K9	2005	2004	56	92
K10	2012	2010	62	91
K11	27	16	67	96
L6	2017	2016	60	89
L7	2020	2015	64	94
L8	2024	2018	68	82
L9	2070	2063	59	92
L10	2033	2017	68	84
L11	177	144	62	88
M6	2434	2455	68	91
M7	2312	2307	62	96
M8	2188	2113	63	85
M9	2213	2314	59	92
M10	2292	2328	65	96
M11	2188	2247	58	116
M12	2130	2074	62	108
M13	2031	2017	68	91
N6	2481	2515	65	89
N7	2460	2501	62	97
N8	2331	2436	69	95
N9	2319	2412	58	105
N10	2275	2392	54	85
N11	2210	2321	69	98
N12	2151	2074	58	89
N13	2096	2035	53	84

Table 2.4.2.7.1: Data tabulation of Outdoor Dining Room 5.

	Daytime (3pm-5pm)		Night Time (8pm-10pm)	
	1m	1.5m	1m	1.5m
Lowest Reading	27	16	49	82
Highest Reading	2481	2501	69	116
Average Reading	2019.36	2031.14	61.82	89

Table 2.4.2.7.2: Highest reading, lowest reading and average reading of Outdoor Dining Room 5.

The light distribution at Outdoor Dining Area is direct lighting. The downward focused light directly cast onto the target surface without reflection from other source. The daylighting at outdoor is also providing lighting for the space. Therefore the space is having sufficient lighting.

This Al-fresco inspired dining area receives a high amount of direct sunlight during the day. According to MS1525, this area far exceeds the requirement of a dining area which is 200 lux.

During the night, the illuminance drastically decreases due to the absence of daylight. The artificial lighting in the area is able to reach an average about 100 lux which does not meet the MS1525 requirement of a dining area of 200 lux. However, this space is more comfortable at night than in the day as during the day it is directly exposed to heat transmission from the sunlight.

Types of Light and Materials

Types of Light	Light Specification	Luminous Flux (F)	Quantity (N)
Tungsten Halogen Low Voltage Down Light	HALOSPOT 70 20 W 12 V 8° BA15D	150 lm	14

Table 2.4.2.7.3: Types of light located in Outdoor Dining Room 5.

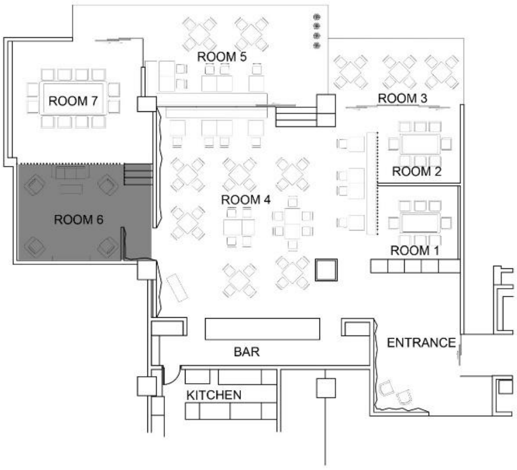
Component	Material	Function	Colour	Area (m^2)	Surface Type	Reflectance Value (%)
Ceiling	Plaster Finish	Ceiling	White	99.7	Reflective	40-45
Wall	Glass	Railing	Transparent	31.07	Reflective	6-10
	Glass	Partition wall	Transparent	34.06	Reflective	6-10
	Reinforced Concrete	Wall	White	8.22	Reflective	30-50
Opening	Glass	Door	Transparent	9.83	Reflective	6-10
Floor	Timber	Decking	Brown	94.23	Absorptive	25-35
Furniture	Timber	Table	Brown	3.84	Absorptive	10-20
	Timber	Chair	Brown	0.47	Absorptive	10-20
	Fabric	Sofa	Dark Brown	4.76	Absorptive	25

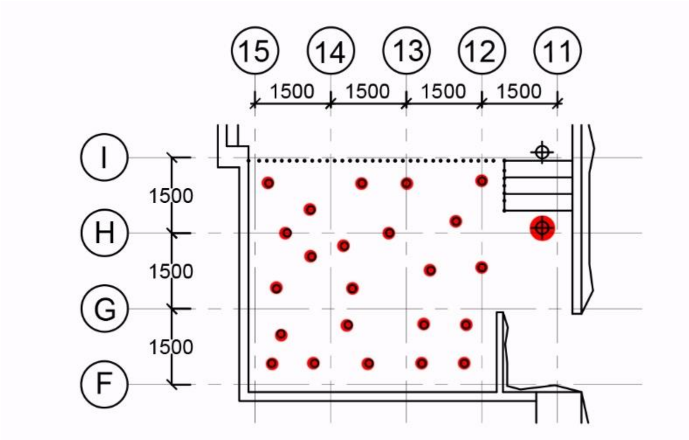
Table 2.4.2.7.4: Materials available in Outdoor Dining Room 5.

Lumen Method

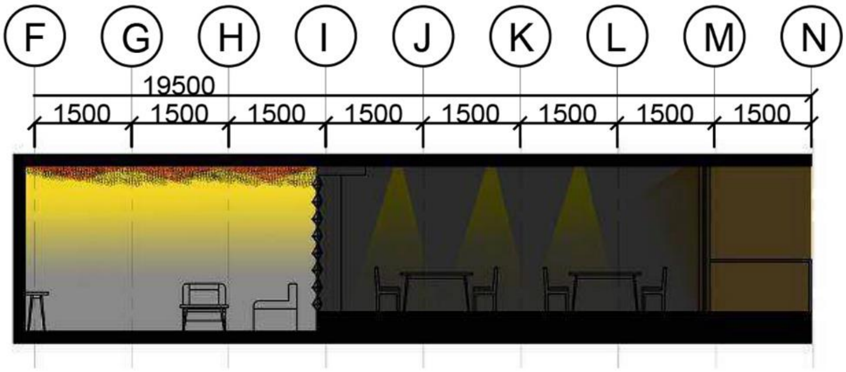
Location	Outdoor Dining Area
Dimension of Room, LxW	4.54 x 9.4
Total Floor Area (m^2)	42.68
Mounting Height , h_m (m)	3.8 – 0.68 – 0.9 = 2.22
Room Index, K	$K = \frac{L\,x\,W}{(L+W)hm}$ $= \frac{4.54 \text{ x } 9.4}{(4.54+ 9.4\,)\,x\,2.22}$ = 1.38
Room Reflectance (%)	C:50, W:30, F:30
Utilisation Factor (UF)	0.36
Maintenance Factor (MF)	0.75
Standard Illuminance Level Required (lux)	200
Existing Illuminance Level, E	$E=\frac{NxFxUFxMF}{A}$ $= \frac{14x150x0.36x0.75}{42.68}$ = 13.28 According to MS 1525, standard illuminance for dining area is 200 lux. 200 lux – 13.28 lux = 186.72 lux Outdoor Dining Area lacks of 186.72 lux illuminance level.
Number of Fittings Required, N’	For 20 W Tungsten Halogen Low Voltage Down Light, $N= \frac{E\,x\,A}{F\,x\,UF\,x\,MF}$ $= \frac{200\,x\,42.68}{150\,x\,0{,}36\,x\,0.75}$ = 210.77 ≈ 211 Tungsten Halogen Low Voltage Down Light needed to meet the standard illuminance required in Outdoor Dining Area.
Conclusion	According to MS 1525, standard illuminance for dining area is 200 lux. Existing illuminance for Outdoor Dining Area, 13.28 lux does not meet the standard requirement. To meet the standard illuminance requirement of a dining area, 197 more Tungsten Halogen Low Voltage Down Light are required in the space. Since the Outdoor Dining Area is exposed to natural daylight during daytime and exposed to neighbourhood street light during night time. Hence the number of lights required is not necessary to be 211.

2.4.2.8 Private Dining Room 6





LOUNGE AREA SCALE 1:150



Data Tabulation: Lux Meter Reading

TIME	17/9/2014			
	3pm-5pm		8pm-10pm	
HEIGHT	1m	1.5m	1m	1.5m
GRID/ZONE	LUX METER READING (lx)			
F11	29	35	9	11
F12	7	14	19	15
F13	9	12	17	22
F14	9	12	17	18
F15	5	6	6	10
G11	20	15	17	18
G12	18	20	28	21
G13	20	24	28	32
G14	19	18	20	24
G15	8	13	8	15
H11	22	25	159	218
H12	22	20	17	18
H13	20	25	25	21
H14	19	26	24	28
H15	7	11	16	15

Table 2.4.2.8.1: Data tabulation of Lounge Area.

	Daytime (3pm-5pm)		Night Time (8pm-10pm)	
	1m	1.5m	1m	1.5m
Lowest Reading	5	6	6	10
Highest Reading	29	35	159	218
Average Reading	15.6	18.4	27.33	32.4

Table 2.4.2.8.2: Highest reading, lowest reading and average reading of Lounge Area.

The light distribution at Lounge Area is Indirect Lighting since the artificial light is being reflected onto the ceiling by putting mercury at the bottom of the bulb which also helps to reduce the glares. The average illuminance of this area is generally low hence it does not meeting the requirement of MS1525.

The artificial lighting provided in this lounge space is 100% adjustable. During the night, the lights will be turned brighter, resulting in a higher lux reading compared to in the day.

Types of Light and Materials

Types of Light	Light Specification	Luminous Flux (F)	Quantity (N)
Incandescent Light Bulb	CLASSIC A 25 W 230 V E27	220	23
Halogen Down Light	HALOSPOT 111	350	1

Table 2.4.2.8.3: Types of light located in Lounge Area.

Component	Material	Function	Colour	Area (m^2)	Surface Type	Reflectance Value (%)
Ceiling	Plaster Finish	Ceiling	White	21.98	Reflective	40-45
Wall	Timber	Decorative wall	Brown	11.91	Absorptive	25-35
	Reinforced Concrete	Wall	Grey	35.64	Reflective	30-50
Floor	Timber	Decking	Brown	29.54	Absorptive	30-50
	Fabric	Carpet	Brown/Red	6.13	Absorptive	10-20
Furniture	Timber	Table	Brown	0.91	Absorptive	10-20
	Fabric	Sofa	White/Black	2.16	Absorptive	25

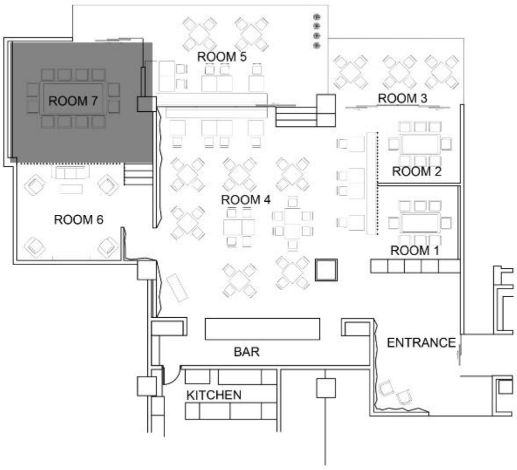
Table 2.4.2.8.4: Materials available in Lounge Area.

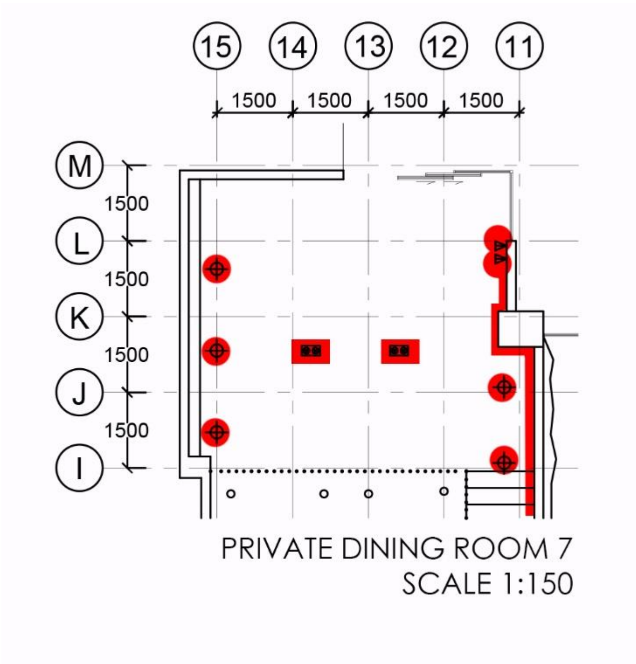
Lumen Method

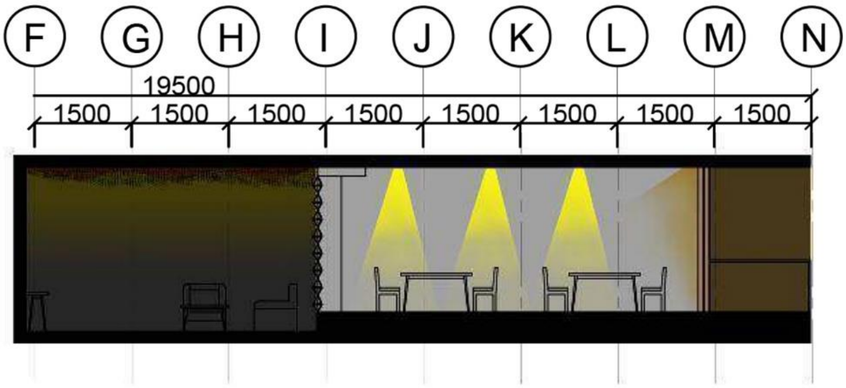
Location	Private Lounge Area
Dimension of Room, LxW	6.43 x 4.45
Total Floor Area (m^2)	28.61
Mounting Height , h_m (m)	3.8-0.9 = 2.9
Room Index, K	$K = \frac{L \times W}{(L+W)hm}$ $= \frac{6.43 \times 4.45}{(6.43 + 4.45) \times 2.9}$ = 0.91
Room Reflectance (%)	C:50, W:30, F:30
Utilisation Factor (UF)	0.32
Maintenance Factor (MF)	0.75
Standard Illuminance Level Required (lux)	200
Existing Illuminance Level, E	$E = \frac{N x F x UF x MF}{A}$ $= \frac{23 x 220 x 0.32 x 0.75}{28.61} + \frac{1 \, x \, 350 x 0.32 x 0.75}{28.61}$ = 42.25 + 2.94 = 45.19 According to MS 1525, standard illuminance for dining area is 200 lux. 200 lux – 45.19 lux = 154.81 lux Public Dining Area lacks of 154.81 lux illuminance level.

Number of Fittings Required, N'	Since the Incandescent Light Bulbs act as decoration of the ceiling where some of the light bulbs case are left empty without lighting function on it. Hence more functioning light bulbs could be added into the space. Assume the number of Halogen Down Light remain as 1, E=$\frac{NxFxUFxMF}{A}$ = $\frac{1\ x\ 350x0.32x0.75}{28.61}$ = 2.94 200 lux – 2.94 lux = 197.06 lux For 25 W Incandescent Light Bulb, N= $\frac{E\ x\ A}{F\ x\ UF\ x\ MF}$ = $\frac{197.06\ x\ 28.61}{220\ x\ 0,32\ x\ 0.75}$ = 106.78 ≈ 107 Incandescent Light Bulbs needed to meet the standard illuminance required in Lounge Area.
Conclusion	According to MS 1525, standard illuminance for lounge area is 200 lux. Existing illuminance for Lounge Area of the restaurant, 45.19 lux does not meet the standard requirement. To meet the standard illuminance requirement of a dining area, 84 more Incandescent Light Bulb are required in the space.

2.4.2.9 Private Dining Room 7







Data Tabulation: Lux Meter Reading

	17/9/2014			
TIME	3pm-5pm		8pm-10pm	
HEIGHT	1m	1.5m	1m	1.5m
GRID/ZONE	LUX METER READING (lx)			
I11	30	34	41	92
I12	12	10	14	10
I13	10	9	24	18
I14	11	9	16	21
I15	20	25	8	11
J11	236	417	128	168
J12	12	13	25	18
J13	16	13	9	10
J14	20	15	21	14
J15	20	36	8	13
K11	27	16	67	96
K12	30	22	25	38
K13	82	89	105	132
K14	41	42	58	250
K15	50	57	92	98
L11	177	144	62	88
L12	130	114	328	308
L13	160	67	186	114
L14	74	24	71	35
L15	65	55	84	98

Table 2.4.2.9.1: Data tabulation of Private Dining Room 7.

	Daytime (3pm-5pm)		Night Time (8pm-10pm)	
	1m	1.5m	1m	1.5m
Lowest Reading	10	9	8	10
Highest Reading	236	417	328	308
Average Reading	61.15	60.55	68.6	81.6

Table 2.4.2.9.2: Highest reading, lowest reading and average reading of Private Dining Room 7.

The light distribution at Private Dining Room 7 is direct lighting together with the indirect lighting. The downward focused light directly cast onto the target surface without reflection from other source whereas the LED strip light is hidden on the ceiling to create the diffuse light effect.

Together with natural daylighting due to the glass sliding door at the North side, it provides sufficient lighting for the space. Hence the lux readings near the glass sliding door area are slightly higher than the standard requirement of 200 lux.

In the night, the illuminance reading decreases due to the absence of indirect sunlight. However, with more lighting fixtures turned on during night time, the average reading barely reach 100 lux.

Types of Light and Materials

Types of Light	Light Specification	Luminous Flux (F)	Quantity (N)
Halogen Down Light	HALOSPOT 111	350	5
Tungsten Halogen Low Voltage Down Light	HALOSPOT 70 20 W 12 V 8° BA15D	150	4
L.E.D strip light	LK LED 40 CW	240	1
Emergency Light	PNE TEL-30 Incandescent Light Bulb	200	1

Table 2.4.2.9.3: Types of light located in Private Dining Room 7.

Component	Material	Function	Colour	Area (m^2)	Surface Type	Reflectance Value (%)
Ceiling	Plaster Finish	Ceiling	White	37.4	Reflective	40-45
Wall	Reinforced Concrete	Wall	Grey	41.99	Reflective	30-50
	Glass	Partition wall	Transparent	10.64	Reflective	8-12
Opening	Glass	Door	Transparent	11.55	Reflective	6-10
Floor	Fabric	Carpet	Blue	37.4	Absorptive	10-20
Furniture	Timber	Table	Brown	4.83	Absorptive	10-20
	Timber	Chair	Brown	8.64	Absorptive	10-20

Table 2.4.2.9.4: Materials available in Private Dining Room 7.

Lumen Method

Location	Private Lounge Area
Dimension of Room, LxW	6.1 x 8.21
Total Floor Area (m^2)	50.08
Mounting Height , h_m (m)	3.8 - 0.68 - 0.9 = 2.22
Room Index, K	$K = \frac{L \times W}{(L+W)hm}$ $= \frac{6.1 \times 8.21}{(6.1+8.21) \times 2.22}$ = 1.58
Room Reflectance (%)	C:50, W:50, F:30
Utilisation Factor (UF)	0.44
Maintenance Factor (MF)	0.75
Standard Illuminance Level Required (lux)	200
Existing Illuminance Level, E	$E = \frac{NxFxUFxMF}{A}$ $= \frac{5 \times 350 \times 0.44 \times 0.75}{50.08} + \frac{4 \times 150x0.44x0.75}{50.08} + \frac{1 \times 240 \times 0.44 \times 0.75}{50.08} + \frac{1 \times 200 \times 0.44 \times 0.75}{50.08}$ = 11.53 + 3.96 + 1.58 + 1.32 = 18.39 According to MS 1525, standard illuminance for dining area is 200 lux. 200 lux – 18.39 lux = 181.61 lux Public Dining Area lacks of 181.61 lux illuminance level.
Number of Fittings Required, N’	(i) Assume the number of Tungsten Halogen Low Voltage Down Light, L.E.D strip light, Emergency Light remain, $E = \frac{NxFxUFxMF}{A}$ $= \frac{4 \times 150x0.44x0.75}{50.08} + \frac{1 \times 240 \times 0.44 \times 0.75}{50.08} + \frac{1 \times 200 \times 0.44 \times 0.75}{50.08}$ = 3.96 + 1.58 + 1.32 = 6.86 200 lux – 6.86 lux = 193.14 lux For 35 W Halogen Down Light, $N' = \frac{E \times A}{F \times UF \times MF}$ $= \frac{193.14 \times 50.08}{350 \times 0{,}44 \times 0.75}$ = 83.7 ≈ 84 Halogen Down Lights needed to meet the standard illuminance required in Private Dining Area.

	(ii) Assume the number of Halogen Down Light, L.E.D strip light, Emergency Light remain, $E=\frac{NxFxUFxMF}{A}$ $=\frac{5\ x\ 350\ x\ 0.44\ x\ 0.75}{50.08}+\frac{1\ x\ 240\ x\ 0.44\ x\ 0.75}{50.08}+\frac{1\ x\ 200\ x\ 0.44\ x\ 0.75}{50.08}$ = 11.53 + + 1.58 + 1.32 = 14.43 200 lux – 14.43 lux = 185.57 lux For 20W Tungsten Halogen Low Voltage Down Light, $N'=\frac{E\ x\ A}{F\ x\ UF\ x\ MF}$ $=\frac{185.57\ x\ 50.08}{150\ x\ 0{,}44\ x\ 0.75}$ = 187.7 ≈ 188 Tungsten Halogen Low Voltage Down Light s needed to meet the standard illuminance required in Private Dining Area.
Conclusion	According to MS 1525, standard illuminance for dining area is 200 lux. Existing illuminance for Private Dining Area of the restaurant, 18.39 lux does not meet the standard requirement. To meet the standard illuminance requirement of a dining area, 79 more Halogen Down Lights or 184 more Tungsten Halogen Low Voltage Down Lights are required in the space.

2.5 Conclusion

A critical analysis was conducted through observation of surrounding context, collecting data with appropriate instruments and methods, generating analysis data through analytic software such as Ecotect, and finally calculating it using appropriate methods and calculations. Based on the analytical data and information, it can be concluded that the lighting of Ploy Restaurant does not meet the requirements set of MS1525.

In order to achieve better luminance level to meet the requirement of MS1525 2007, almost all the spaces in the restaurant required additional lighting features. Nevertheless, it is reasonable as the main sole purpose of the middle dining restaurant is to provide a cozy and romantic ambience for the occupants so that it falls in place with the overall aesthetic of the design. However the design of lighting shall be considered properly to avoid leaving certain areas terribly dark.

The other areas of the restaurant which do not serve as dining zone but serve as working and servicing zone shall have better lighting condition to provide a safer working environment for the workers and ensure a smooth operation when preparing food and other services. To enhance the lighting performance at the restaurant, while at the same time to maintain the desired ambience, it is suggested to prepare more artificial lighting such as table lamp or standing lamp at certain areas which is unreachable by the ceiling lighting. Other than that, adjustable lights shall also be applied in the dining area to control the lighting condition at day or night time accordingly. By doing this, diners may adjust the luminance level according to individual needs and personal perception of comfort. At the same time they do not affect the overall light intensity greatly as a controlled environment is created.

3.0 ACOUSTIC STUDY

The great problem of the concert hall is that the shoebox is the ideal shape for acoustics but that no architect worth their names to build a shoebox.

- Rem Koolhaas

3.0.1 Acoustic Design in Architecture

Frequency of Sound

The frequency of sound wave is simply the number of complete vibrations occurring per unit of time. The unit o measure is the hertz (Hz). Most of the sounds around us generally contain energy to some degree over rather wide ranges of the audible frequency range.

Magnitude of Sound

In addition to the character of a sound, intensity and magnitude of acoustical energy contained in the sound wave in also concerned. Sound intensity is proportional to the amplitude of the pressure disturbance above and below the undisturbed atmospheric pressure. Because of the wide range, as well as the fact that the human ear responds roughly in a logarithmic way to sound, a logarithm-based measurement unit called the decibel (dB) has been adopted for sound level measurements.

	CRITERIA	
TYPE OF SPACE OR ACTIVITY	RECOMMENDED NC CURVE	SOUND LEVEL, dBA
Workspaces in which continuous speech communication and telephone use are not required	60–70	65–75
Shops, garages, contract equipment rooms	45–60	52–65
Kitchens, laundries	45–60	52–65
Light maintenance shops, computer rooms	45–55	52–61
Drafting rooms, shop classrooms	40–50	47–56
General business and secretarial offices	40–50	47–56
Laboratories, clinics, patient waiting spaces	40–50	47–56
Public lobbies, corridors, circulation spaces	40–50	47–56
Retail shops, stores, restaurants, cafeterias	35–45	42–52
Large offices, secretarial, relaxation areas	35–45	42–52
Residential living, dining rooms	30–40	38–47
General classrooms, libraries	30–40	38–47
Private, semiprivate offices	30–40	38–47
Bedrooms, hotels, apartments with air conditioning	30–40	38–47
Bedrooms, private residences, hospitals	25–35	34–42
Executive offices, conference spaces	25–35	34–42
Small general-purpose auditoriums (less than about 500 seats), conference rooms, function rooms	30 (max)	40 (max)
Small churches and synagogues	25 (max)	35 (max)
Radio, TV, recording studios (close microphone pickup)	25 (max)	35 (max)
Churches, synagogues (for serious liturgical music)	20 (max)	30 (max)
Large auditoriums for unamplified music and drama	20 (max)	30 (max)
Radio, recording studios (remote microphone pickup)	15 (max)	25 (max)
Opera performance halls	15 (max)	25 (max)
Music performance and recital halls	15 (max)	25 (max)

Table 3.0.1: Recommended criteria for steady background sound in typical building spaces (Source: Cavanaugh, 2010)

<u>Direct and Reverberant Sound</u>

The sound filed at any point in a room consists of two components: direct and reverberant sound. The direct component reduces with the distance from the source whereas the reverberant component (all possible reflections and interreflections) is taken as homogeneous throughout the room, and is dependent on the room surfaces.

The direct field of a sound source is defined as that part of the sound field which has not suffered any reflection from any room surfaces or obstacles, while the reverberant field of a source is defined as that part of the sound field radiated by a source which has experienced at least one reflection from a boundary of the room or enclosure containing the source (Hanson, n.d.).

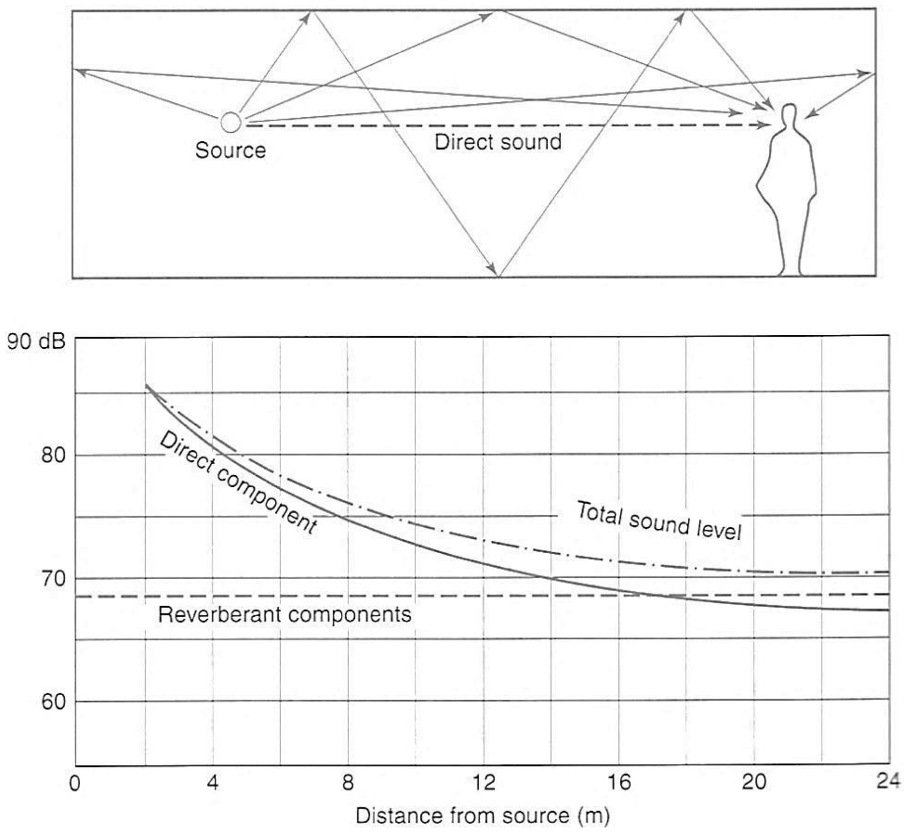


Figure 3.0.1: Direct and reverberant sound in a room (Szokolay, 2008)

Reverberation in Rooms

The reverberation period (time in seconds for the sound to decay 60 dB after the source is turned off) is directly proportional to the cubic volume of the space and inversely proportional to the total sound absorption, refer to formula in 3.2.3: RT. For most typical rooms in buildings, the expressions can yield a good estimate of the reverberation period. As the sound absorption coefficients of most building materials vary with frequency, the reverberation calculations must be carried out at representative low-, mid- and high-frequency ranges (in octaves band from 125 through 4000 Hz).

Noise Reduction Coefficient

An industry-wide accepted methods of describing the' average' sound absorption characteristics of an acoustic material is the noise coefficient (NRC). NRC is the arithmetic average of the measured sound absorption coefficient at 250-, 500-, 1000-, and 2000- Hz test frequencies, rounded off to the nearest 0.05. In general, effective sound absorption is achieved when the sound absorption coefficients exceed about 0.4, as 40% of incident sound is absorbed and 60% is reflected back into the room. In contrast, materials having coefficients of 0.8 or greater are considered very effective absorbers.

3.0.2 Acoustic Design in Restaurant

The acoustics in a restaurant go hand-in-hand with the concept. In some restaurants, for example, the reverberation of hard surfaces adds to the desired effect of the dining experience. There are a number of ways to control the acoustic in an environment, as long as the desired effect is understood. The simplest way to control acoustics is through sound-absorptive materials. These can range from carpet on the floor to panelling on the walls to sound-absorptive tiles in the ceiling. Another strategy worth considering is to compartmentalize the restaurant into different types of rooms with different noise levels to suit the various patrons.

Regardless of dining style, the sounds in many restaurants are higher than conversational noise levels, making it difficult for patrons to speak without extra effort. Indeed, surveys recently repeatedly confirm patron's dissatisfaction with noisy dining rooms. However, younger patrons tend to enjoy loud and lively eating environments. Furthermore, contemporary architectural trends and modern restaurant designs often include harder surfaces such as tile, glass, concrete and metals that sound bounces off of versus more traditional materials that inherently have greater sound-absorption qualities. Thus, it is a great challenge nowadays of restaurant's design to control the noise level so that it comes in right below the conversational sound level while keeping the environment lively and exciting.

The followings are considerations and factors affecting lighting design:

- Sound frequencies
- Sound sources
- Volatility of noise in space
- Horizontal layout of space
- Ceiling height
- Volume of space
- Equipment in use within the space
- Outdoor sound issues
- Architectural materials
- Fabrics and finishes

3.1 Precedent Study

Quaker Steak & Lube

Figure 3.1.1: Exterior perspective of Quaker Steak & Lube (Source: Welcome to Quaker Steak & Lube, 2014)

<u>Building Fast Facts</u>

Name	: Quaker Steak & Lube
Founded	: 1974
Founders	: George "Jig" Warren & Gary "Mo" Meszaros
Function	: Casual dining restaurant
Location	: Sharon, Pennsylvania

Situated in Sharon, Pennsylvania, Quaker steak & Lube is a casual dining restaurant built in 1974 over an abandoned gas station in downtown. Its exterior is famously stereotyped with the license plates and old automobiles as decorations. The name is a play on that of the motor oil company Quaker State. With the unique location of a large room and high ceilings, many life entertainment events are planned to be included. Noise control solution is the main approach to handle the problems determining sound proofing within the space. The echoes from all sides of walls and ceiling have made the sound quality unbearable in the room. Thus, a solution is much needed to sound proofing the restaurant in order to utilize the space for year-round entertainment, not just in the summer when they could open their doors.

3.1.1 Acoustic Analysis

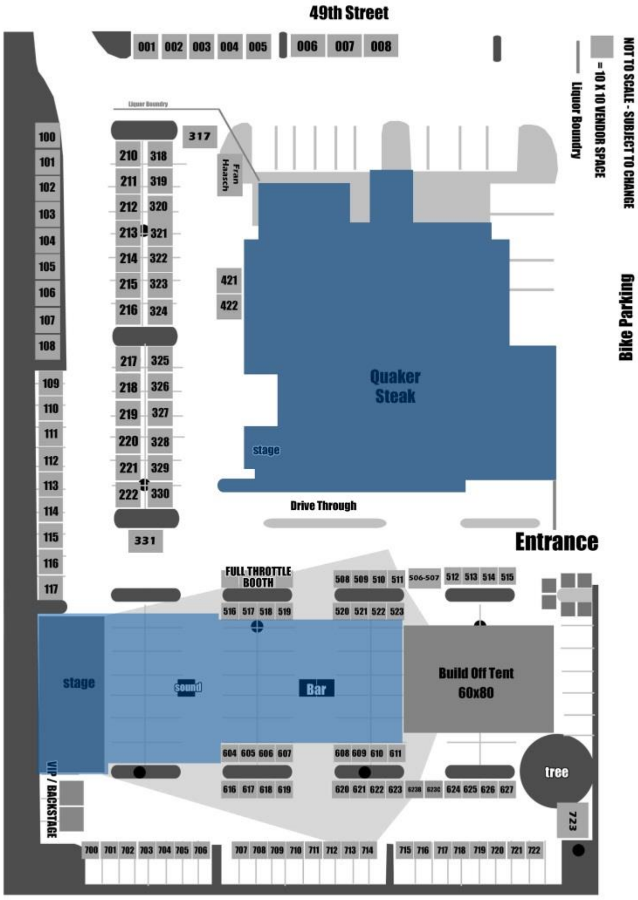


Figure 3.1.1.1: Site plan of Quaker Steak and Lube along Satterfield Road (Source: Info Notice, 2014)

Referring to Figure 3.1.1.1, the organization of space is splitted using a linear street as the main entrance. The dining restaurant is located on the right from the entrance, whereas stage and bar occupy the space on its left where the life entertainment events would take place.

Figure 3.1.1.2: High metal ceilings and glass panels make the room a sound man's nightmare (Source: Quaker Steak & Lube)

Sound Treatment

Figure 3.1.1.3: Before treatment, performance stage with concrete wall as backdrop (Source: Soundproofing a Restaurant Case Study: Quaker Steak & Lube, 2014)

Figure 3.1.1.4: After treatment, concrete wall surface is covered with acoustical backdrop (Source: Soundproofing a Restaurant Case Study: Quaker Steak & Lube, 2014)

Quaker Steak and Lube's stage was initially surrounded by concrete walls and other hard surfaces that wrecked the sound of bands and other performances making the room uncomfortable for restaurant clientele. To eliminate the overpowering high frequencies and control reverberation bringing balance to the sound in the room, a large amount of Eco-C-Tex noise control material is installed as the acoustical backdrop to cover the wall’s surfaces surrounding the stage. As shown in Figure 3.1.5, the same look and feel was brought to the stage, the focal point of the room, using a black and white checkerboard pattern made of coated eco-C-tex. This look was enhanced by a custom shaped and framed eco-C-tex panel made to look like a guitar pick.

Maintaining the restaurant's signature decor is the high priority when sound proofing the restaurant. To provide a hidden noise control solution custom, coated eco-C-tex panels in The Lube's signature green were concealed in the ceiling trusses and on the walls, referring to Figure 3.1.1.6.

Figure 3.1.1.5: Restaurant noises became unbearable when they reverberated in the unusually high, metal ceilings. (Source: Soundproofing a Restaurant Case Study: Quaker Steak & Lube, 2014)

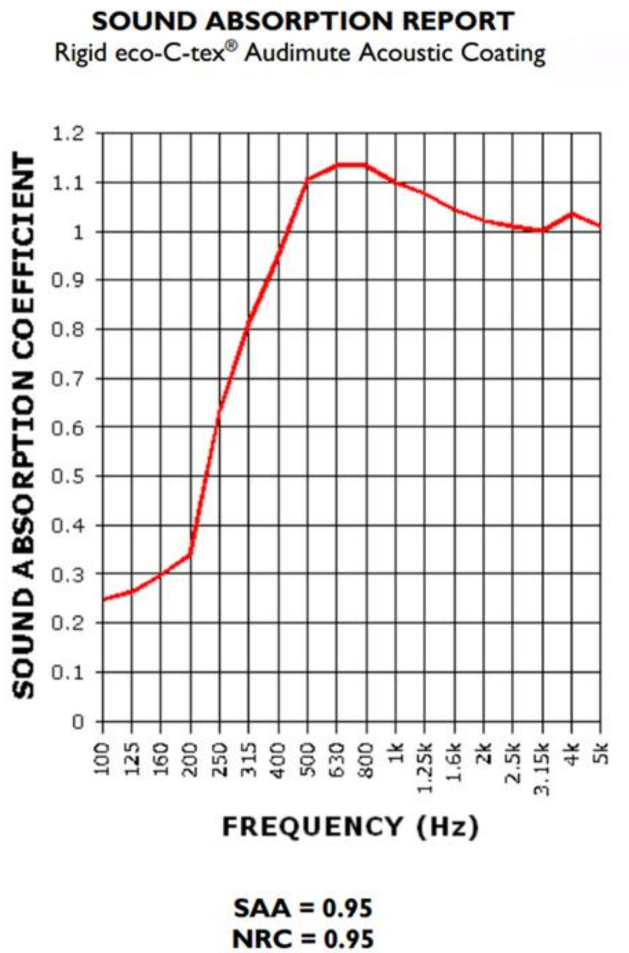
Figure 3.1.1.6: Custom coated Eco-C-Tex to match the ceiling was hidden within trusses to prevent disturbing the ceiling's unique look. (Source: Soundproofing a Restaurant Case Study: Quaker Steak & Lube, 2014)

2" Material	125 Hz	250 Hz	500 Hz	1K Hz	2K Hz	4K Hz	NRC
Audimute eco-C-tex - 2"	0.39	0.63	1.18	1.11	1.06	1.09	.95
Auralex Studiofoam Metro Foam Panels- 2"	0.13	0.23	0.68	0.93	0.91	0.89	0.70
Auralex Studiofoam Pyramids Foam Panels - 2"	0.13	0.18	0.57	0.96	1.03	0.98	0.70
Auralex Studiofoam Wedges Foam Panels - 2"	0.11	0.30	0.91	1.05	0.99	1.00	0.80
Sonex Classic Acoustical Foam Panels - 2"	0.17	0.33	0.85	1.03	1.08	1.06	0.80
Soft Sound Foam Panels - 2"	0.32	0.75	1.2	1.1	0.9	0.63	0.99
Owens-Corning 703 Fiberglass Paneling - 2"	0.17	0.86	1.14	1.07	1.02	0.98	1.00
Auralex SonoSuede Fiberglass Paneling - 2"	.59	0.76	0.91	0.85	0.80	0.76	0.85

Table 3.1.1.1: Comparison of nois reduction coefficient between Audimute eco-C-tex panels with fiberglass panels and foam panels (Source: Audimute, 2014)

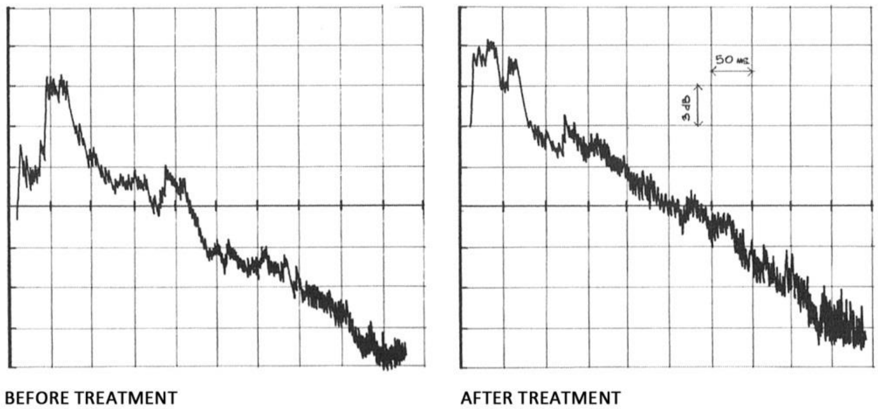
1/3 Octave Center Frequency (Hz)	Absorption Coefficient	Total Absorption In Sabins
100	0.25	17.82
** 125	0.26	18.95
160	0.30	21.38
200	0.34	24.56
** 250	0.63	45.57
315	0.82	58.74
400	0.95	68.29
** 500	1.11	79.62
630	1.13	81.60
800	1.13	81.67
** 1000	1.10	79.19
1250	1.08	77.61
1600	1.04	75.14
** 2000	1.02	73.54
2500	1.01	72.72
3150	1.00	72.10
** 4000	1.04	74.64
5000	1.01	72.74

Table 3.1.1.2: Test report for Audimute eco-C-tex panels (Source: Audimute Soundproofing Beachwood, 2013)



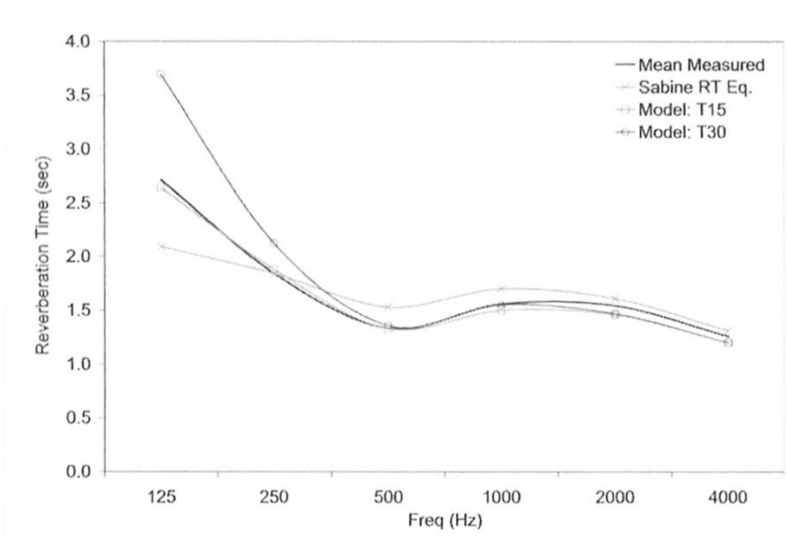
Graph 3.1.1.1: Sound absorption coefficient against frequency of sound absorption report for Audimute eco-C-tex panels (Source: Audimute Soundproofing Beachwood, 2013)

Results



Graph 3.1.1.2: Acoustic impulse measurement before and after treatment (Source: Cavanaugh, 2010)

The impulse response after the treatment with the eco-C-tex acoustic material (right) as shown in Graph 3.1.1.2 clearly demonstrates the significant reflected sound energy arriving at a listener's seat during the first 50 milliseconds of the delay, compared to the impulse response before treatment.



Graph 3.1.1.3: Comparison of measured and computer-simulated reverberation times (Source: Cavanaugh, 2010)

After installation, further reverberation time tests confirmed that the solution using eco-C-tex acoustic material had successfully achieved the target noise reduction, dramatically improving the way sound travelled in the room and the quality of the dining environment for diners as a result. This equated to reductions of up to 50% in frequency specific reverberation times. Finally, solution has found to reveal purer sound proofing that enabled the indoor performance space to be fully utilized without driving guests and bands away.

3.1.2 Conclusion

Installation of sound panels has provided extremely noticeable restaurant soundproofing results. The sound waves absorption provided by placement of the panels on both walls and ceiling helped to control the echoes and reverberant noise once bounced off the surfaces.

By using this acoustical panel absorbers, noise within the room can be control within the range of 500 Hz. This strategy aims to give an ambient feel for the patrons dining in terms of acoustically and aesthetically as it maintains the looks and overall interior of the restaurant. Using fabric, specifically a material with a blend of cotton and cellulose as a material for ceiling baffle and sound diffusors, the reverberation time of sound travelling in the restaurant can decrease to below 2 seconds which is the recommended reverberation time for speech in restaurant around 1.5-2 s. Thus, without altering the image of the restaurant interior, the sound can be controlled within the restaurant.

3.2 Research Methodology

3.2.1 Description of Equipment

Features:

Manually ranged

Measuring range: 30 to 130 dB

Power supply: 9V Battery

Figure 3.2.1.1: 01dB Sound level meter

Acoustic data is collected using 01dB Sound level meter. The sound level meter is an electronic device that can detect small variations in sound waves and provide decibel readings. Since data logger is not provided, collected data is jotted down manually for further analysis.

Figure 3.2.1.2: Pentax K-r DSLR camera

DSLR Camera is used to take evidences of identified internal and external sound sources. Besides that, materials and human activities going on in the restaurant which affect the acoustic performance of the space has also been recorded by taking photos.

3.2.2 Data Collection Method

Sound level of different time intervals is measured and recorded. There are non-peak hour (3pm-5pm) and peak hour (8pm-10pm).

To aid the data collection, 1.5m x 1.5m grid lines are set upon the floor plan (Diagram 3.2.2.1). The acoustic data is measured and collected at the intersection of gridlines during different time interval.

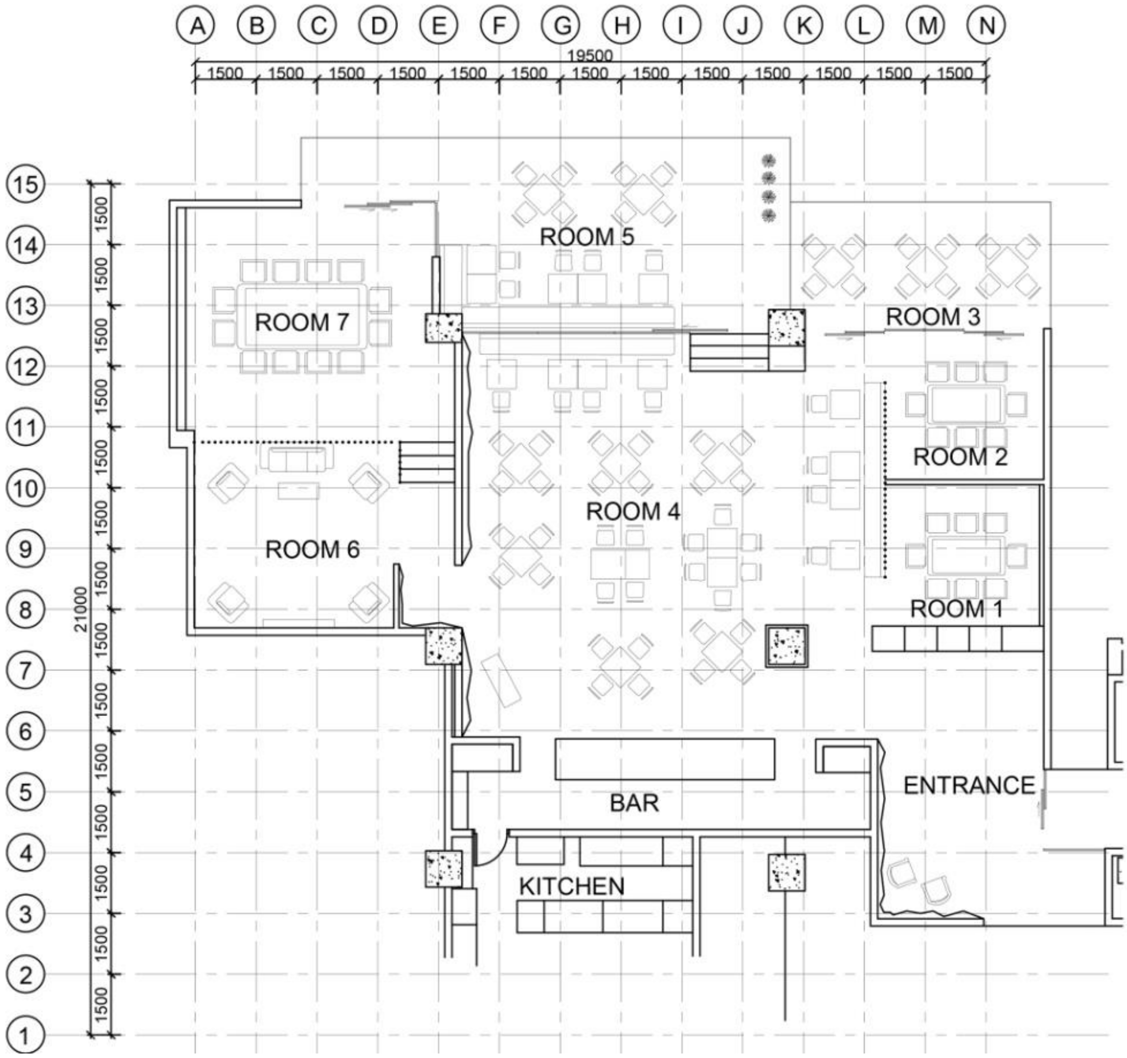


Diagram 3.2.2.1: Floor plan with 1.5m x 1.5m grids

Since the restaurant has different dining zones and service zone, the floor plan is divided into different zone (Diagram 3.2.2.2) to ease the acoustic studies. This helps to produce a more organized and precise outcome of analysis.

Diagram 3.2.2.2: Floor plan divideD to different zones

To ensure the consistency, each reading is taken 1m above floor level facing the same direction. (Diagram 3.2.2.3) The data collector are not allowed to make any noises to ensure accuracy of data.

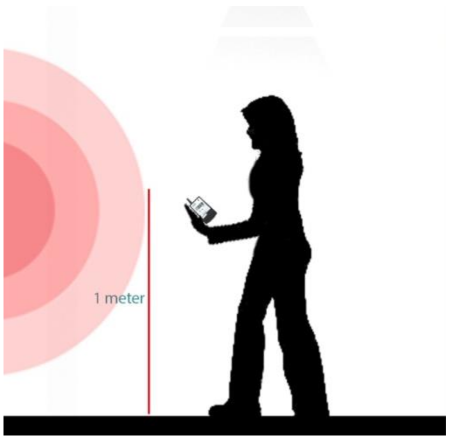


Diagram 3.2.2.3: Sound reading are taken 1 meter from the ground.

Then, the data being tabulated for further analysis.

ZONE ENTRANCE	Non-Peak Reading (dB)	Peak Reading (dB)	ZONE ROOM 3	Non-Peak Reading (dB)	Peak Reading (dB)	ZONE ROOM 4	Non-Peak Reading (dB)	Peak Reading (dB)	ZONE ROOM 4	Non-Peak Reading (dB)	Peak Reading (dB)	ZONE KITCHEN /BAR	Non-Peak Reading (dB)	Peak Reading (dB)
4O	59	61	13N	72	77	7L	64	75	9H	63	77	5K	60	71
5O	58	64	14N	74	80	8L	63	74	10H	61	79	6K	65	75
4N	58	62	15N	72	79	9L	63	73	11H	61	76	5J	60	72
5N	59	66	13M	72	76	10L	63	72	12H	60	75	6J	63	73
6N	60	67	14M	75	77	11L	64	73	7G	62	77	5I	62	72
7N	60	63	15M	72	77	12L	63	74	8G	63	68	6I	63	72
4M	59	62	13L	72	79	7K	63	70	9G	61	69	5H	63	73
5M	59	67	14L	75	76	8K	64	72	10G	60	66	6H	65	77
6M	60	69	15L	72	75	9K	63	69	11G	59	68	5G	63	76
7M	60	70	13K	73	75	10K	66	71	12G	59	67	6G	63	76
ROOM 1			14K	76	74	11K	64	70	7F	61	66	5F	66	77
8N	62	72	15K	75	73	12K	64	71	8F	63	65	**ROOM 7**		
9N	64	72	**ROOM 5**			7J	63	75	9F	63	63	11E	57	72
10N	62	68	14J	80	82	8J	63	74	10F	59	64	12E	52	68
8M	62	67	15J	73	81	9J	64	75	11F	59	62	11D	54	69
9M	64	69	14I	73	75	10J	63	75	12F	59	63	12D	53	70
10M	62	72	15I	72	76	11J	63	74	**ROOM 6**			13D	53	69
ROOM 2			14H	74	76	12J	62	74	8E	61	70	14D	53	71
11N	62	68	15H	73	75	7I	62	75	9E	58	69	11C	55	69
12N	65	70	14G	74	78	8I	63	76	10E	55	63	12C	52	69
11M	64	69	15G	73	77	9I	63	75	9D	47	64	13C	53	70
12M	64	71	13F	73	76	10I	61	77	10D	49	65	14C	53	72
			14F	72	75	11I	61	75	9C	47	65	11B	52	72
			15F	73	73	12I	60	74	10C	47	65	12B	49	71
			15E	71	74	7H	62	75	9B	47	64	13B	51	69
			15D	72	75	8H	63	77	10B	47	64	14B	52	68

Table 3.2.2.1: Data collected on 12/9/2014 during non-peak hour (3pm-5pm) and peak hour (8pm-10pm)

3.2.3 Acoustic Analysis Calculation Method

Sound Pressure Level (SPL)

Sound pressure level is the level differences in sound pressure achieved by sound waves. It can be calculated using the formula:

SPL = 10 log (I/I_0),

Where I = Sound Power Intensity (Watts)

I_0= Reference Power (1×10^{-12} Watts)

Reverberation Time (RT)

Reverberation time is defined as the time it takes for sound energy in an enclosed space to decay by a factor of one million or 60 dB. It is dependent on the volume and amount of acoustical absorption in the space. It can be calculated using the formula:

RT = (0.16xV) / A,

Where V = Volume of space

A = Total absorption ($s_1a_1+s_2a_2+\ldots+s_na_n$)

(s= surface area, a= absorption coefficient)

Sound Reduction Index (SRI)

Sound reduction index is an indication of sound transmission loss on materials. It can be calculated using the formula:

SRI = 10 log ($1/T_{av}$),

Where T_{av} = Average transmission coefficient of materials

SRI_n = 10 log ($1/T_n$), T_{av} = ($S_1xT_{c1}+S_2xT_{c2}\ldots+S_nxT_{cn}$)/Total Surface Area

Where S= surface area of material, T= transmission coefficient of material

3.3 Case study

3.3.1 Existing Acoustic Condition

3.3.1.1 External Noise Sources

Circulation around the building

As shown in diagram 3.3.1.1.1, the Ploy Restaurant is located at the corner of the office building, Work@Clearwater. The entrance of the building is facing a busy main road. The lane located at the side of the building is the only access to the car park. The traffic of the two following routes are the main contributor for external noise sources.

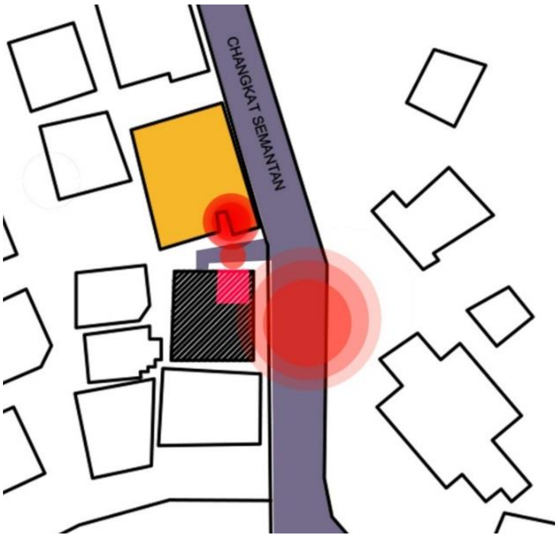


Diagram 3.3.1.1.1: External noise sources around Ploy Restaurant

Figure 3.3.1.1.1: Side lane of Ploy Restaurant is the only access to Work@Clearwater car park.

Neighbouring Context

Besides the traffic, neighbouring context around the site had also affect the noise level of the site. The adjacent building's machine room has generated significant amount of noise. (Figure 3.3.1.1.2) This had affected the noise level at the outdoor dining area of The Ploy Restaurant.

Figure 3.3.1.1.2: Outdoor dining area facing adjacent building's machine room

3.3.1.2 Indoor Noise Sources

General sources of noise from the indoor are whistling ducts, air supply fans, exhaust fans, air conditioning chillers are common objectionable noises. Beyond that, it is human activity that is contributing to the noise such as waiters walking around and the chattering of the customers.

Air Diffusers

Diagram 3.3.1.2.1: Location of air diffusers in Ploy restaurant

The air diffusers are used to ventilate the space to improve air quality. They are a mechanical device that is designed to evenly distribute air. As shown in the diagram 3.3.1.2.1, the cool air passes through the ducts from the generators.

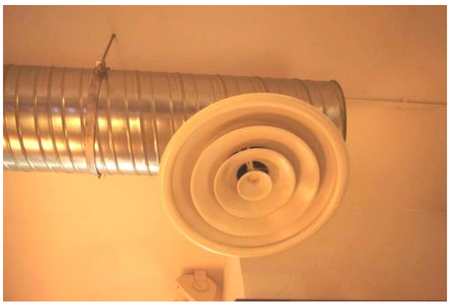


Figure 3.3.1.2.1: Circular Diffusers

Figure 3.3.1.2.2: Linear Diffusers

The linear diffusers (Figure 3.3.1.2.1) located at the sides are hidden under the ceiling while the circular diffusers (Figure 3.3.1.2.2) in the centre of the restaurant are left with their ducts exposed.

Speakers

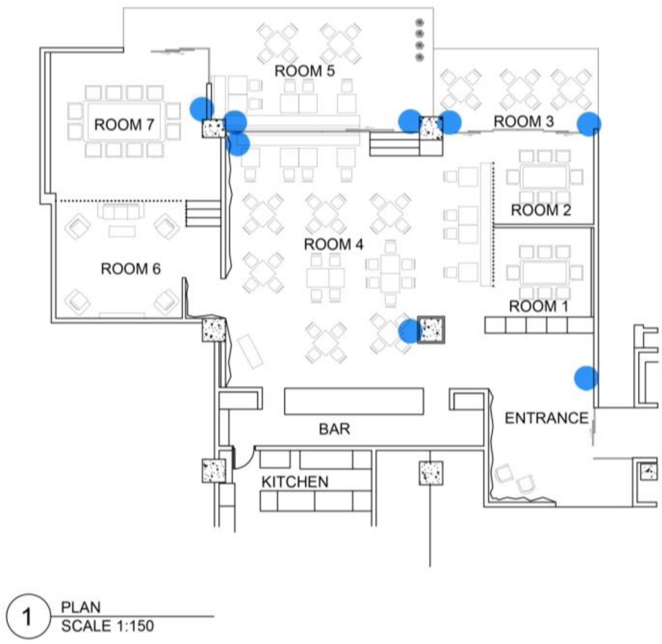


Diagram 3.3.1.2.2: Location of speakers in Ploy restaurant

There are speakers throughout the restaurant which are turned on during their operation time. The songs played on the speakers are mellow, giving a generally relaxed, soothing ambient environmental condition to its customers. However, the noise may be insignificant during peak hours as there would be crowd conversing.

Fans

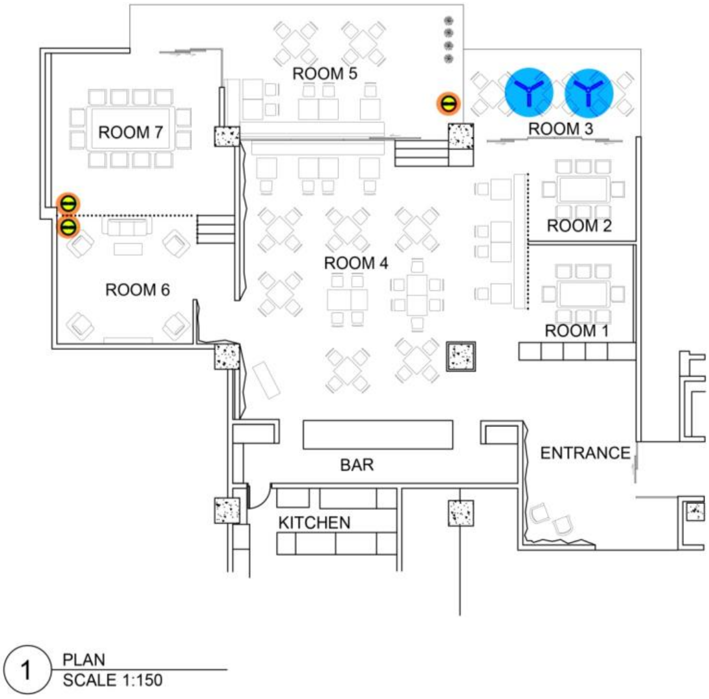


Diagram 3.3.1.2.3: Location of fans in Ploy restaurant

According to diagram 3.3.1.2.3, the restaurant uses fans as one of their ventilation devices. The ceiling fans (Figure 3.3.1.2.3) and the stand fans contribute significant amount of noises. The stand fans can be found at the outdoor seating area (Figure 3.3.1.2.4) and one each in Room 6 and Room 7. The stand fan at Room 5 is the main contributor to the noise that travels into the inside of the restaurant through the open door.

Figure 3.3.1.2.3:
Ceiling fan found in the outdoor seating area, Room 3.

Figure 3.3.1.2.4:
Stand fan which is main noise contributor at Room 5

Human Activities

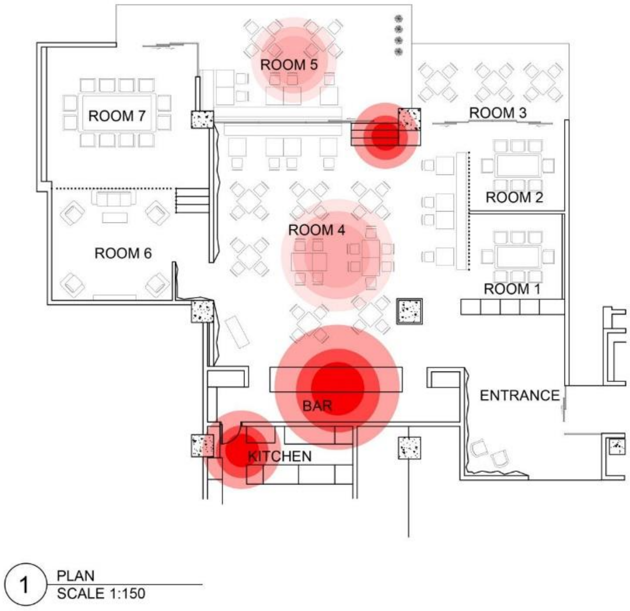


Diagram 3.3.1.2.4: Heavy noise area by human activities

Ungulate behaviour is observed while recording human activity and anthropogenic noises. As shown in diagram 3.3.1.2.4, it is found that the human activity coming from the kitchen and the bar is the most pronounced.

Due to it is the service zone, the kitchen and bar area is one of the highest usage area. The sounds that come from the bar are usually the clinking of glasses, the buzz of the coffee machine and the displacement of cutlery. While the sound that comes from the kitchen is the ventilation hood which is turned on during their operating hours and also noises created during food preparation process (Figure 3.3.1.2.5).

Besides that, the entrance towards outdoor dining zone has considerable amount of noises too. This is because the waiters walk to and forth to deliver foods to customer. The cashier counter is also located around the area, thus the frequent communication between customers and staffs create higher noise level in the particular zone.

Figure 3.3.1.2.5: Food preparation process going on in kitchen

Figure 3.3.1.2.6: Customer chattering

In addition to the noise from human activities, the main dining zone (figure3.3.1.2.6) and outdoor dining zone has significant amount of noise too since both the spaces cater most of the patrons. Example of noises include chatters of customers and noises produced by cutleries.

3.3.2 Acoustical Characteristics of Materials

As a fine dining restaurant, Ploy restaurant employs materials' acoustical characteristics to maintain sound level and create comfortable dining environment for users.

The majority components found in the restaurant is made up of timber. There are faceted wooden walls (Figure 3.3.2.1) in the main dining area. As shown in Figure 3.3.2.2, the furniture found in restaurant are also made up of timber. This is due to the high sound absorption coefficient of timber, which can absorb the noises created and reduce sound reflection, and thus decrease sound level in general.

Figure 3.3.2.1: Faceted wooden walls are found along the main dining area which act as sound insulators

Figure 3.3.2.2: Wooden tables and chairs found in the restaurant

The Ploy restaurant also utilizes fabric as part of the furniture as it is an excellent sound absorber. Example from figure 3.3.2.3, curtain set up as divider between main dining zone and private dining zone. Moreover, some of the seating are made up of sofa with cushions. (Figure 3.3.2.4)

Though concrete floor (Figure 3.3.2.5) does not has profound sound absorbing quality like timber do, there are alternative components to serve as sound absorber, such as carpet. Carpets are used to absorb sound in particular area where silent level is needed to be assure, such as private dining area. (Figure 3.3.2.6)

Figure 3.3.2.3: Private dining area is separated with decorated wire frames and curtain. (Source: The Star)

Figure 3.3.2.4:
Cushioned sofa seating

Figure 3.3.2.5:
Concrete floor with carpet on top of it

Figure 3.3.2.6:
The private dining room is carpeted to reduce noise in the space

3.4 Acoustic Analysis

3.4.1 Acoustic Data

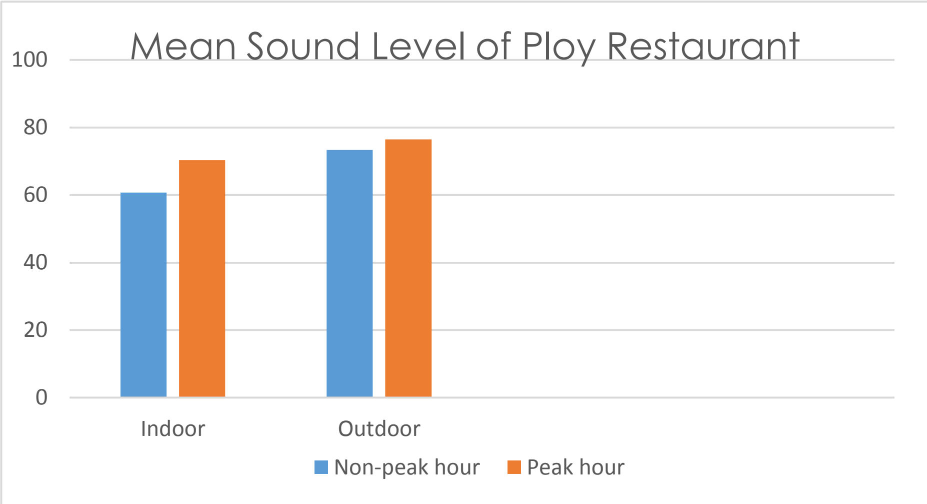


Diagram 3.4.1.1: Mean sound level of Ploy Restaurant in different hours on 12/9/14

According to data collected, diagram 3.4.1.1 is generated to show the mean sound level of Ploy Restaurant. It is showed that the indoor sound level are generally lower than outdoor sound level. During non-peak hour, the average indoor sound level is 60dB whereas during peak hour the average indoor sound level is 70dB.

The average outdoor sound level is slightly higher than indoor sound level but not much different during non-peak and peak hour, which is 73dB and 76dB respectively. This can be explained that the outdoor noise sources is constant whereas the indoor noise sources may cause by certain activities.

Source	SPL(dBA)
Faintest audible sound	0
Whisper	20
Quiet residence	30
Soft stereo in residence	40
Speech range	50-70
Cafeteria	80
Pneumatic jackhammer	90
Loud crowd noise	100
Accelerating motorcycle	100
Rock concert	120
Jet engine (75 feet away)	140

Diagram 3.4.1.2: Sound level of common sound sources (Source: Asa, n.d.)

Based on diagram 3.4.1.2, it is show that the mean sound level of Ploy Restaurant falls beyond the range of cafeteria sound level, which means Ploy has a generally quieter and more peaceful environment than other cafeterias do.

3.4.1.1 Non-Peak Time Noise Contour Diagram

	B	C	D	E	F	G	H	I	J	K	L	M	N	O
15			72	71	73	74	74	72	73	75	72	72	72	
14	52	53	54		73	73	74	73	80	76	75	75	74	
13	51	53	53		72					73	72	72	72	
12	49	52	53	52	59	59	60	60	62	63	64	64	65	
11	52	55	53	57	59	59	61	61	63	64	63	64	62	
10	47	47	49	55	59	60	61	62	64	63	63	62	62	
9	47	47	47	58	63	61	63	63	63	66	63	64	64	
8				61	63	61	63	63	63	64	64	62	62	
7					61	62	62	62	62	64	63	60	60	
6						63	65	63	63	65		60	60	
5					66	63	63	62	60	60		59	59	58
4												59	58	59
3														
2														
1														

Diagram 3.4.1.1.1: Data tabulation during non-peak hour

Diagram 3.4.1.1.2: Noise contour diagram during non-peak hour

Based on data tabulated in diagram 3.4.1.1.1, a noise contour diagram of non-peak hour is generated. (Diagram 3.4.1.1.2) As shown in the contour diagram, the darkest shade (above 75dB) indicated the greatest amount of sound level, which is at outdoor dining area. This is due to it is exposed to external noise sources generated by traffic and also the still machineries.

Followed by main dining area and service area, which has the same intensities (above 65dB), the food preparation process in kitchen, speakers and chattering of occupants are the main noise contributors to the areas during non-peak hour.

The noise level of entrance area is lower than the main dining area as during non-peak hour not much people hanging out at that area. The lounge area and private dining area (Room 7) has the lightest shade (45-55dB) as there are private spaces for function and during non-peak hours there are no occupants in it. Hence, the noise level are the lowest amongst the spaces.

3.4.1.2 Peak Time Noise Contour Diagram

	B	C	D	E	F	G	H	I	J	K	L	M	N	O
15			75	74	73	77	75	76	81	73	75	77	79	
14	68	72	71		75	78	76	75	82	74	76	77	78	
13	69	70	69		76					75	79	76	77	
12	71	69	70	68	63	67	75	74	74	71	74	71	70	
11	72	69	69	72	62	68	76	75	74	70	73	69	68	
10	64	65	65	63	64	66	79	77	75	72	72	72	68	
9	64	65	64	69	63	69	77	75	75	69	73	69	72	
8				70	65	68	77	76	74	72	74	67	72	
7					66	77	75	75	75	70	75	70	63	
6						76	77	72	73	75		69	67	
5					77	76	73	72	72	71		67	66	64
4												62	62	61
3														
2														
1														

Diagram 3.4.1.2.1: Data tabulation during peak hour

Diagram 3.4.1.2.2: Noise contour diagram during peak hour

Based on data tabulated in diagram 3.4.1.2.1, a noise contour diagram of peak hour is generated. (Diagram 3.4.1.2.2) As shown in the contour diagram, the darkest shade (above 80 dB) indicated the greatest amount of sound level, which is at outdoor dining area. Besides the traffic and external noise sources, human activities is the main noise contributor to the area during peak hour. This is because increasing number of patrons during dinner hour.

Same as non-peak hour's situation, the main dining area and service area which has the same intensities (above 70dB). Food preparation process in kitchen, barista working at bar area, speakers and chattering of occupants are the main noise contributors. However, the edge of wall has lower sound level as the material used has good acoustical quality and act as sound insulator. This has help in noise control hence the level at the edges are particular lowered.

The corner of entrance area has lowest sound level (60-65dB) as it is a narrow exhibition corner and seldom activities carry on at that corner. Lounge area and private dining area (Room 7) has particularly low reading as they are not opened for public hence no activity carry out in both of the areas.

3.4.2 Acoustic Ray Diagram

Acoustic ray diagrams are been generated to show how the sound travels in the space. Speakers as still noise source of the restaurant are taken as reference for study.

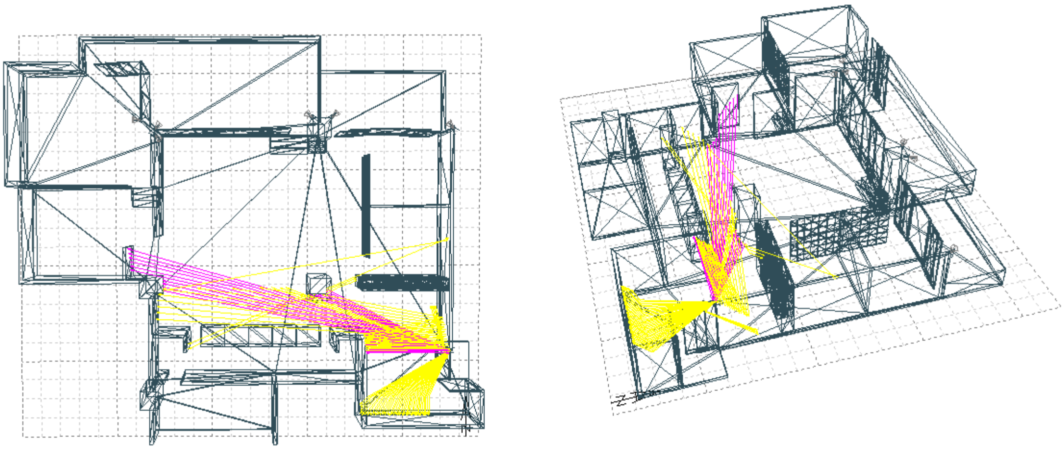


Diagram 3.4.2.1: Acoustic ray indicating the reflection depth of speaker1

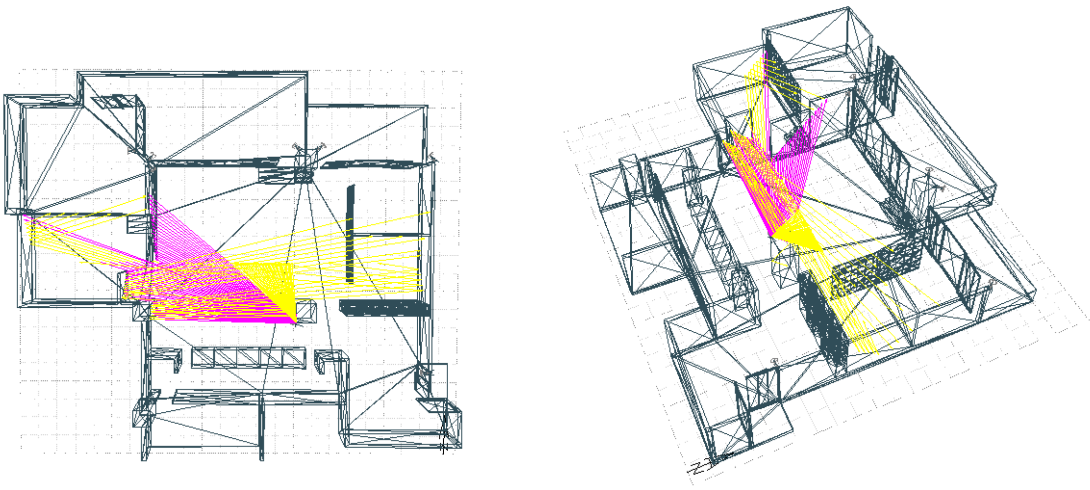
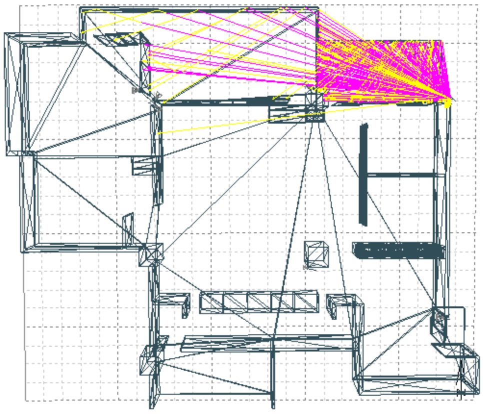


Diagram 3.4.2.2: Acoustic ray indicating the reflection depth of speaker2



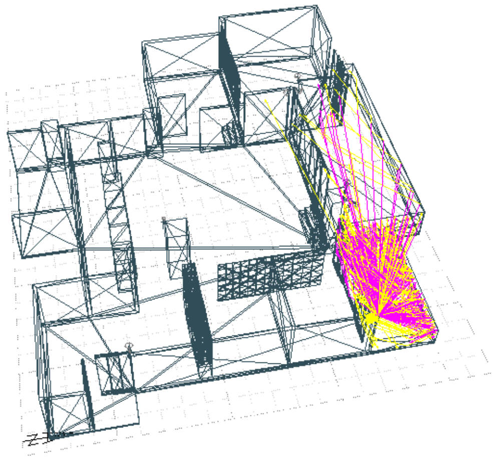
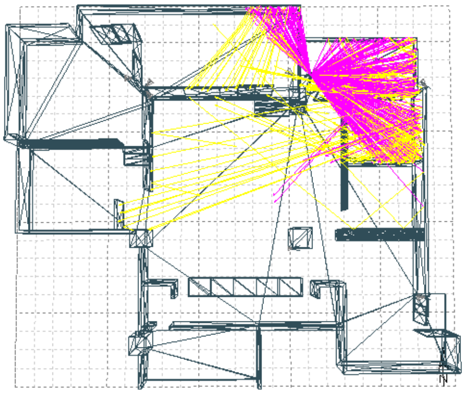


Diagram 3.4.2.3: Acoustic ray indicating the reflection depth of speaker 3



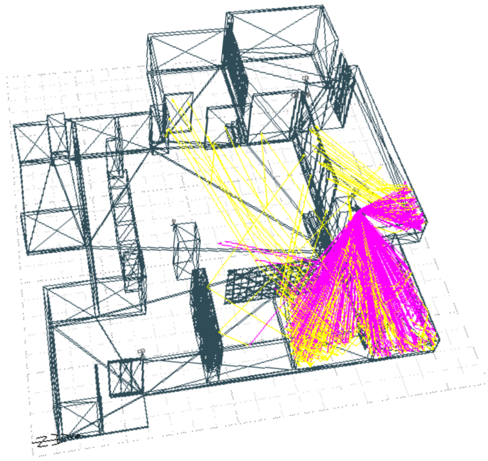
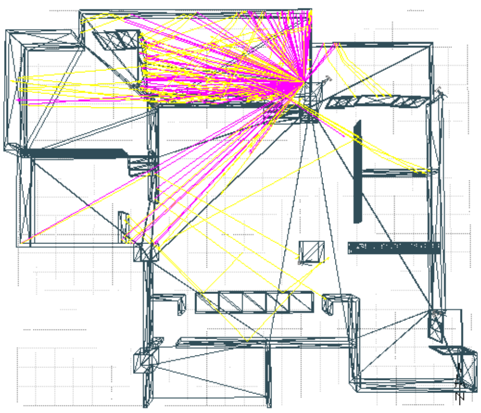


Diagram 3.4.2.4: Acoustic ray indicating the reflection depth of speaker 4



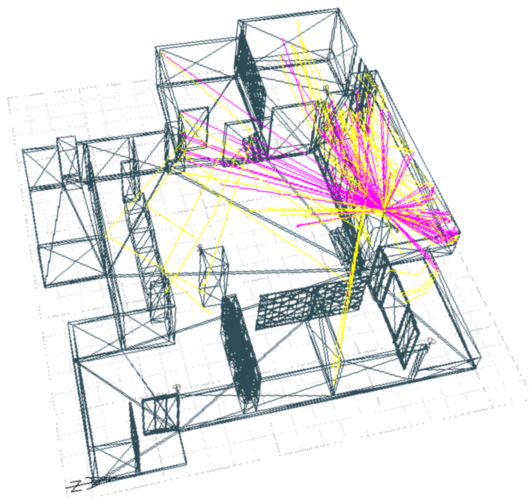


Diagram 3.4.2.5: Acoustic ray indicating the reflection depth of speaker 5

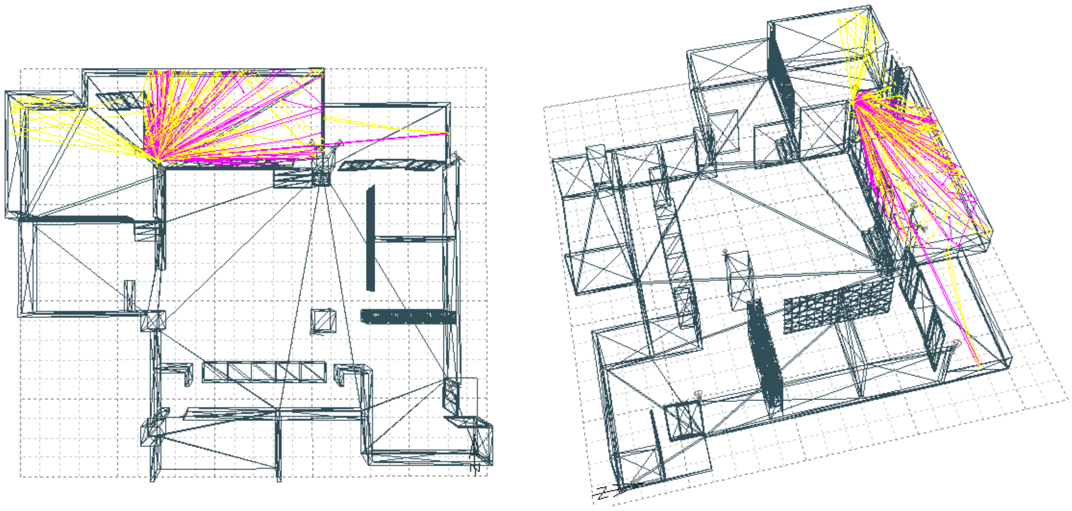


Diagram 3.4.2.6: Acoustic ray indicating the reflection depth of speaker 6

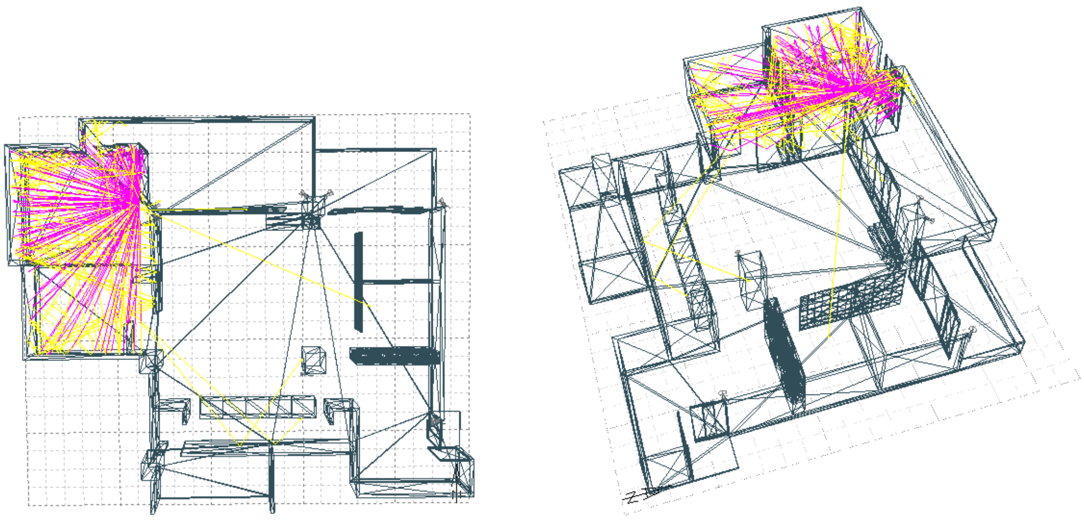


Diagram 3.4.2.7: Acoustic ray indicating the reflection depth of speaker 7

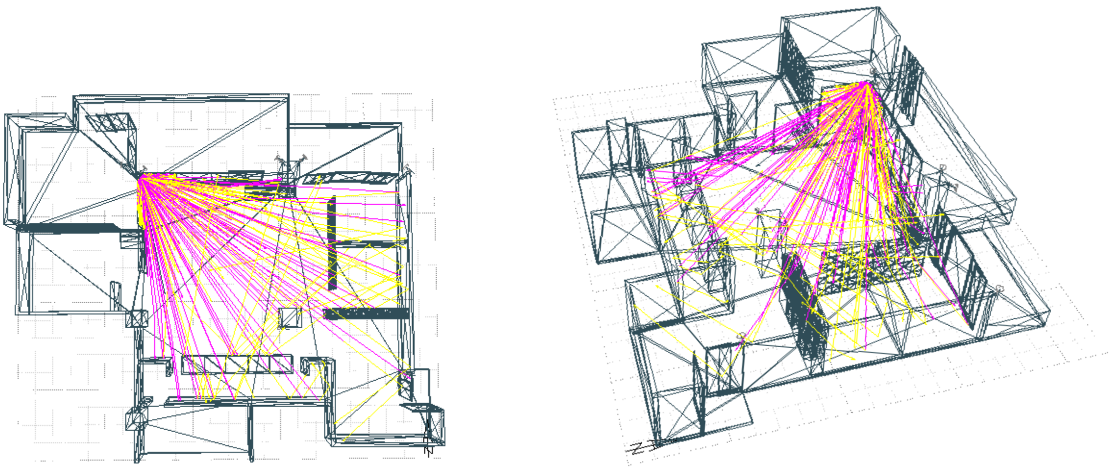


Diagram 3.4.2.8: Acoustic ray indicating the reflection depth of speaker 8

3.4.3 General Sound Pressure Level Calculations and Analysis

The general sound pressure level is the raw amount of sound level produced by still machineries or equipment that had not engaged with human activities and acoustic treatment by materials yet.

The power of main noise sources in Ploy restaurant which is speakers, diffusers and fans are being calculated to determine the total amount of sound decibels produced by each noise sources.

Using the formula **Swl = 10 log (I/I_0),**

Where I = Sound Power Intensity (Watts)

I_0= Reference Power ($1x10^{-12}$ Watts)

Noise Source:

(I) Speakers

Number of speakers found in Ploy Restaurant: 9

Estimated Noise level produced by 1 speaker: 85dB

85=10 log (I/Io)

Log ($I/1x10^{-12}$) =8.5

Log $^{-1}$ Log ($I/1x10^{-12}$)= log^{-1}8.5

($I/1x10^{-12}$)= $3.16x10^{8}$

$I_{speaker}$=$3.16x10^{-4}$ dB

Total sound intensity by speakers= 9 x 3.16 $x10^{-4}$

=**2.84×10^{-3} dB**

Combined SPL = 10 log (I_{total}/I_0)

=10 log ($2.84x10^{-3}$ / $1x10^{-12}$)

=**94.53 dB**

(II) Diffusers

Number of diffusers found in Ploy Restaurant: 14

Estimated Noise level produced by 1 diffuser: 50dB

50=10 log (I/Io)

Log $(I/1x10^{-12})$ =5

Log $^{-1}$ Log $(I/1x10^{-12})$= $\log^{-1}5$

$(I/1x10^{-12})$= $1.0x10^{5}$

$\mathbf{I_{diffuser} = 1.0 \times 10^{-7}}$ **dB**

Total sound intensity by speakers= 14 x 1.0 x 10^{-7}

=$\mathbf{1.4 \times 10^{-6}}$ **dB**

Combined SPL = 10 log $\mathbf{(I_{total}/I_0)}$

=10 log $(1.4 \times 10^{-6} / 1x10^{-12})$

=**61.46 dB**

(III) Fans

Number of fans found in Ploy Restaurant: 5

Estimated Noise level produced by 1 fan: 75dB

75=10 log (I/Io)

Log $(I/1x10^{-12})$ =7.5

Log $^{-1}$ Log $(I/1x10^{-12})$= $\log^{-1}7.5$

$(I/1x10^{-12})$= $3.1x10^{7}$

$\mathbf{I_{diffuser} = 3.1 \times 10^{-5}}$ **dB**

Total sound intensity by fans= 5 x 3.1 x 10^{-5}

=$\mathbf{1.55 \times 10^{-4}}$ **dB**

Combined SPL = 10 log $\mathbf{(I_{total}/I_0)}$

=10 log $(1.55 \times 10^{-4} / 1x10^{-12})$

=**81.90 dB**

General Sound Pressure Level according to zone

The sound intensity of speakers, diffusers and fans are taken as reference to determine the general sound level of a particular zone. Thus, the sound level of a particular zone can be calculated by using the following equation:

Total sound intensity, I_{Total}

= (Number of speakers x $I_{speaker}$) + (Number of diffusers x $I_{speaker}$) +

(Number of fans x I_{fans})

Combined SPL = 10 log (I_{total}/I_0) ,where

I_0= 1×10^{-12} Watts

$I_{speaker}$=3.16×10^{-4} dB

$I_{diffuser}$ = 1.0×10^{-7} dB

I_{fans}= 1.55×10^{-4} dB

(i) Entrance Area

Number of speaker: 1

Number of diffuser: 2

Number of fans: 0

Total sound intensity, I_{Total} = ($1 \times 3.16 \times 10^{-4}$) + ($2 \times 1.0 \times 10^{-7}$) + ($0 \times 1.55 \times 10^{-4}$)

= 3.16×10^{-4} dB

Combined SPL

= 10 log (I_{total}/I_0)

=10 log ($3.16 \times 10^{-4} / 1 \times 10^{-12}$)

=85 dB

Thus, total noise produced by speakers and diffusers in **Entrance Area** is **85dB.**

(ii) Public Dining Area

Number of speaker: 3

Number of diffuser: 6

Number of fans: 0

Total sound intensity, I_{Total} = $(3 \times 3.16 \times 10^{-4}) + (6 \times 1.0 \times 10^{-7}) + (0 \times 1.55 \times 10^{-4})$

$= 9.49 \times 10^{-4}$ dB

Combined SPL

= 10 log (I_{total}/I_0)

=10 log ($9.49 \times 10^{-4} / 1 \times 10^{-12}$)

=89.7 dB

Thus, total noise produced by speakers and diffusers in **Public Dining Area** is **89.7dB**.

(iii) Private Dining Area

Room 1 :

Number of speaker: 0

Number of diffuser: 1

Number of fans: 0

Total sound intensity, I_{Total} = $(0 \times 3.16 \times 10^{-4}) + (1 \times 1.0 \times 10^{-7}) + (0 \times 1.55 \times 10^{-4})$

$= 1.0 \times 10^{-7}$ dB

Combined SPL

= 10 log (I_{total}/I_0)

=10 log ($1.0 \times 10^{-7} / 1 \times 10^{-12}$)

=50 dB

Thus, total noise produced by diffusers in **Private Dining Area (Room 1)** is **50 dB**.

Room 2:

Number of speaker: 0

Number of diffuser: 1

Number of fans: 0

Total sound intensity, I_{Total} = $(0 \times 3.16 \times 10^{-4}) + (1 \times 1.0 \times 10^{-7}) + (0 \times 1.55 \times 10^{-4})$

= 1.0×10^{-7} dB

Combined SPL

= 10 log (I_{total} / I_0)

=10 log ($1.0 \times 10^{-7} / 1 \times 10^{-12}$)

=50 dB

Thus, total noise produced by diffusers in **Private Dining Area (Room 2)** is **50 dB**.

Room 7:

Number of speaker: 1

Number of diffuser: 1

Number of fans: 1

Total sound intensity, I_{Total} = $(1 \times 3.16 \times 10^{-4}) + (1 \times 1.0 \times 10^{-7}) + (1 \times 1.55 \times 10^{-4})$

= 4.71×10^{-4} dB

Combined SPL

= 10 log (I_{total} / I_0)

=10 log ($4.71 \times 10^{-4} / 1 \times 10^{-12}$)

=86.73 dB

Thus, total noise produced by speakers, diffusers and fans in **Private Dining Area (Room 7)** is **86.73 dB**.

(iv) Outdoor Dining Area

Room 3:

Number of speaker: 2

Number of diffuser: 0

Number of fans: 2

Total sound intensity, I_{Total} = $(2 \times 3.16 \times 10^{-4}) + (0 \times 1.0 \times 10^{-7}) + (2 \times 1.55 \times 10^{-4})$

= 9.42×10^{-4} dB

Combined SPL

= 10 log (I_{total}/I_0)

=10 log ($9.42 \times 10^{-4} / 1 \times 10^{-12}$)

=89.74 dB

Thus, total noise produced by speakers and fans in **Outdoor Dining Area (Room 3)** is **89.74 dB**.

Room 5:

Number of speaker: 2

Number of diffuser: 0

Number of fans: 1

Total sound intensity, I_{Total} = $(2 \times 3.16 \times 10^{-4}) + (0 \times 1.0 \times 10^{-7}) + (1 \times 1.55 \times 10^{-4})$

= 7.87×10^{-4} dB

Combined SPL

= 10 log (I_{total}/I_0)

=10 log ($7.87 \times 10^{-4} / 1 \times 10^{-12}$)

=88.96 dB

Thus, total noise produced by speakers and fans in **Outdoor Dining Area (Room 5)** is **88.96 dB**.

(v) Lounge Area

Number of speaker: 0

Number of diffuser: 1

Number of fans: 1

Total sound intensity, I_{Total} = $(0 \times 3.16 \times 10^{-4}) + (1 \times 1.0 \times 10^{-7}) + (1 \times 1.55 \times 10^{-4})$

= 1.55×10^{-4}dB

Combined SPL

= $10 \log (I_{total}/I_0)$

=$10 \log (1.55 \times 10^{-4} / 1 \times 10^{-12})$

=81.9 dB

Thus, total noise produced by diffusers and fans in **Lounge Area** is **81.9 dB**.

(vi) Services Area

Number of speaker: 0

Number of diffuser: 1

Number of fans: 1

Total sound intensity, I_{Total} = $(0 \times 3.16 \times 10^{-4}) + (1 \times 1.0 \times 10^{-7}) + (0 \times 1.55 \times 10^{-4})$

= 1.55×10^{-4}dB

Combined SPL

= $10 \log (I_{total}/I_0)$

=$10 \log (1.55 \times 10^{-4} / 1 \times 10^{-12})$

= 81.9 dB

Thus, total noise produced by diffusers and fans in **Service area** is **81.9 dB**.

3.4.3.1 Summary and Analysis

Zone	General Sound Pressure Level (dB)
Entrance Area	85
Public Dining Area	89.7
Private Dining Area (Room1,2)	50
Private Dining Area (Room7)	86.73
Outdoor Dining Area (Room3)	89.74
Outdoor Dining Area (Room5)	88.96
Lounge Area	81.9
Service Area	81.9

Table 3.4.3.1.1 General Sound Level Produce by Still Machineries

According to the calculations above showed that the speakers and fans produced significant amount of noises to the space whereas noised produced by diffusers are relatively soft.

From table 3.4.3.1.1, the dining area are generally loud where the sound pressure level falls on the range between 86-90dB, mainly caused by speakers or fans. It shows that there are not a suitable environment for dining, study and have normal conversation.

Private dining area, Room1 & Room2 are comparatively more favorable than the other areas as it has no other interference and the noise produced by air diffusers can be neglected.

Acoustical treatments or sound insulator may need to apply in certain areas that is loud to ensure acoustical comfort.

3.4.4 Space Acoustical Analysis

Space acoustical analysis is presented according to different zones when human activities and materials are taken account into it.

3.4.4.1 Entrance Zone

Diagram 3.4.4.1.1: Entrance zone showed in floor plan

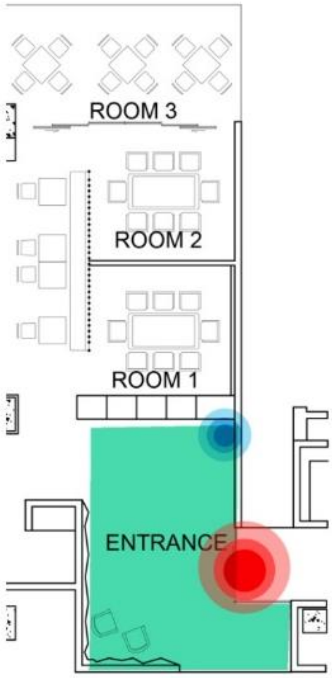


Diagram 3.4.4.1.2: Noises coming from sliding door and speaker

Figure 3.4.4.1.1: Entrance of Ploy Restaurant (Source: Lo, 2012)

Data tabulation of sound level:

	Non-peak	Peak
Lowest Reading	58	65
Highest Reading	60	66

According to diagram 3.4.4.1.2, the entrance receives the most noise from the outside. Separated by a glass automated sliding door, right in front of the entrance is the lobby lift. During peak hours, the usage of the automated sliding door increases. (Figure 3.4.4.1.2) The sliding of the door creates a certain amount of sound. Also, this allows the outside sound to transmit into space, therefore, the data obtained shows a higher sound reading. Further front of the entrance is the lobby and the main door leading to the main road. The lobby adjacent (Figure3.4.4.1.3) to the restaurant entrance is also one of the noise contributor as people are walking in and out of the building.

Figure 3.4.4.1.2: Automated door

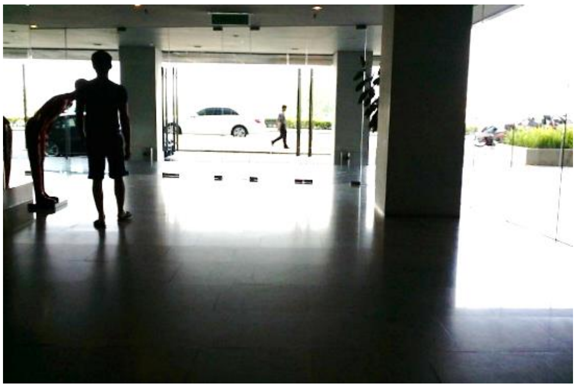


Figure 3.4.4.1.3: Entrance facing lobby

During non-peak hours, the results obtained shows that the function of the surrounding wall of the entrance was able to absorb some of the sound. The walls are mostly faceted with wood which helped reduce the sound. There is also a wooden cupboard with wine bottle displays (Figure 3.4.4.1.4) placed at the entrance. Although there is a speaker at the entrance, the data has no significant differences. This may be because the music is played as a background sound and the entrance has carpeted floor (Figure 3.4.4.1.5) and insulated concrete wall which helps absorb transmitted sound.

Figure 3.4.4.1.4: Wooden cupboard with wine bottle display acted as a sound barrier.

Figure 3.4.4.1.5: The entrance with a thick carpet

Average Sound Pressure Level

The sound pressure level is the average sound level at a space.

Using **SPL = 10 log (I/I_0)**

Where I= sound power (intensity) (watts), I_0 = reference power 1.0 x 10^{-12} watts

Non-peak hour:

Highest reading: 60

60 =10 log (I/Io)

Log ($I/1x10^{-12}$) =6

Log $^{-1}$ Log ($I/1x10^{-12}$) = $\log^{-1}6$

($I/1x10^{-12}$)= $1.0x10^{6}$

I_H= $1.0x10^{-6}$

Lowest reading: 58

58 =10 log (I/Io)

Log ($I/1x10^{-12}$) =5.8

Log $^{-1}$ Log ($I/1x10^{-12}$) = $\log^{-1}5.8$

($I/1x10^{-12}$)= $6.3x10^{5}$

I_L= $6.3x10^{-7}$

Total intensities, I_{Total} = $1.0x10^{-6} + 6.3x10^{-7}$

= $1.63x10^{-6}$

SPL=10 log (I_{Total}/I_0)

= 10 log ($1.63x10^{-6}$ / $1x10^{-12}$)

=**62.12 dB**, Average sound pressure level in **Entrance zone** during **non-peak hour**.

Peak hour:

Highest reading: 66

66 =10 log (I/Io)

Log $(I/1x10^{-12})$ =6.6

$Log^{-1} Log (I/1x10^{-12}) = log^{-1}6.6$

$(I/1x10^{-12})= 4.0x10^{6}$

$I_H= 4.0x10^{-6}$

Lowest reading: 65

65=10 log (I/Io)

Log $(I/1x10^{-12})$ =6.5

$Log^{-1} Log (I/1x10^{-12}) = log^{-1}6.5$

$(I/1x10^{-12})= 3.1x10^{6}$

$I_L= 3.1x10^{-6}$

Total intensities, $I_{Total} = 4.0x10^{-6} + 3.1x10^{-6}$

$= 7.1x10^{-6}$

$SPL=10 \log (I_{Total}/I_0)$

$= 10 \log (7.1x10^{-6}/ 1x10^{-12})$

=**68.51 dB**, Average sound pressure level in **Entrance zone** during **peak hour**.

3.4.4.2 Private Dining Zone

Diagram 3.4.4.2.1: Private dining zone showed in floor plan

Figure 3.4.4.2.1: Enclosed dining area as Room 1 and Room 2.

From figure 3.4.4.2.1, Room 1 and Room 2 are reserved area for dinners to have more privacy. It is an enclosed room for a group of customers that prefers more privacy. The entrance to this space is an open door, with decorative wire partition that separates the room from the main dining area.

<u>Room 1</u>

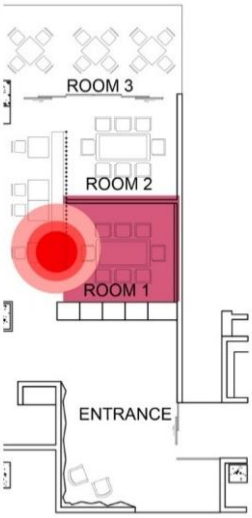


Diagram 3.4.4.2.2:
Sound source coming from Public dining zone

Figure 3.4.4.2.2: Room 1 has bare concrete and the back of a wooden cupboard as the surrounding walls.

Data tabulation of sound level:

	Non-peak	Peak
Lowest Reading	62	67
Highest Reading	64	74

During non-peak hours, the reading obtained may be different due to the furniture. The reading along the walls are lower, and the reading at the centre of Room 1 is higher. The device is placed above the table, the sound may reflect off the table which cause a higher reading in the centre of the Room 1. This can be explained as the furniture might be reflecting sound, while the walls are absorbing sound. There were no curtains present on the partition at the time of the reading.

During peak hours, the reading are higher as the sound can be transmitted from public dining zone into Room 1 through the decorative wire partition (Diagram 3.4.4.2.2). This has space for the sound a way to travel into Room 1. The material used in the space is bare concrete (Figure 3.4.4.2.2) which has a higher tendency to reflect sound. The hard surface of the concrete is likely to cause a significant reverberation effect.

ROOM 2

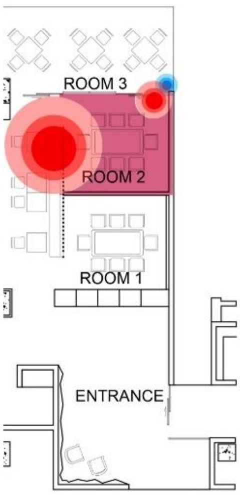


Diagram 3.4.4.2.3:
Sound source coming from Public dining zone and speaker

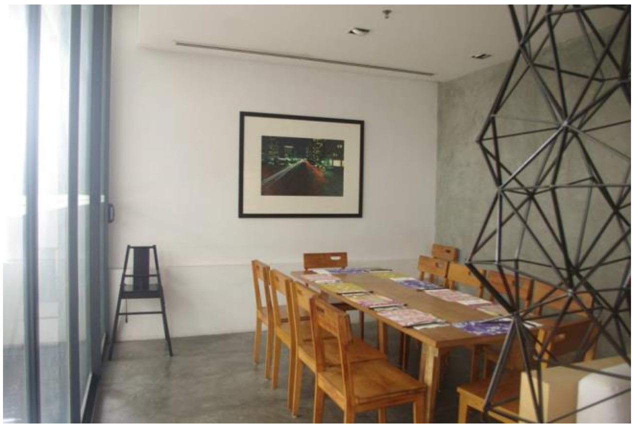


Figure 3.4.4.2.3: Room 2 has bare concrete and glass panels as surrounding walls.

Data tabulation of sound level:

	Non-peak	Peak
Lowest Reading	62	70
Highest Reading	65	73

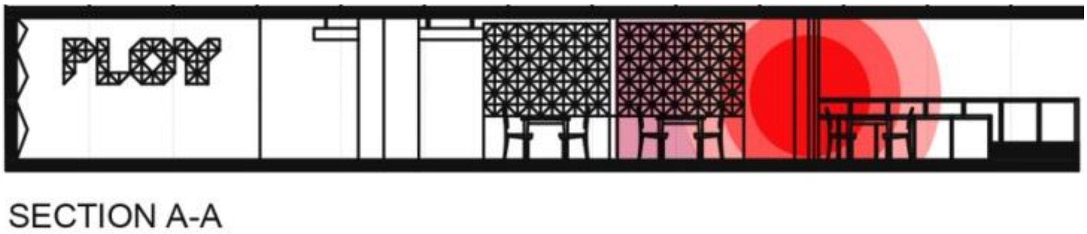


Diagram 3.4.4.2.4: Sound transmitted from the outside to the interior through glass door

Diagram 3.4.4.2.3 and Diagram 3.4.4.2.4 shows the noise from outside transmitting to Room 2. There is also a speaker just outside Room 2 but the sound is mostly drown by the open space and the traffic.

During non-peak hours, the highest reading obtained is nearby the glass door located along the glass panels of Room 2 (Figure 3.4.4.2.4). Although the door is closed, the higher reading obtained may be due to leaking of sound from the outside. Overall, the reading obtained is slightly higher than Room 1. This is due to the material used as one side of the room is replaced with glass panels. The sound is transmitted through the glass panels which has lower Sound Transmission Class (STC).

During peak hours, the reading obtained is higher due to the increase of crowd. In addition to that, the windows and doors are usually the major sound-leaking and transmission problem.

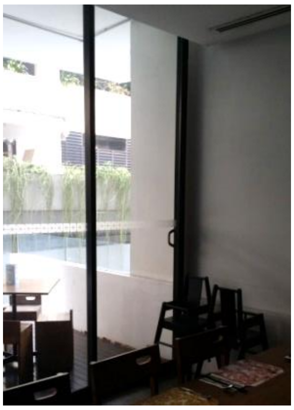


Figure 3.4.4.2.4: The glass panels located in Room 2

ROOM 7

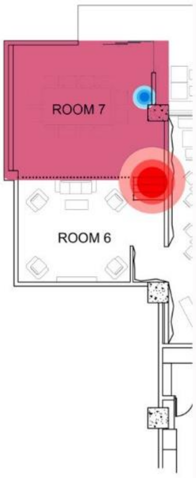


Diagram 3.4.4.2.4:
Sound source coming from Lounge area and speaker

Figure 3.4.4.2.5: Room 7 located at corner of the restaurant, which glass sliding provided to ease circulation

Data tabulation of sound level:

	Non-peak	Peak
Lowest Reading	49	56
Highest Reading	57	63

Room 7 is a private dining area which is usually reserved for a larger crowd with preference of a more enclosed and private dining. There are a glass sliding door (Figure 3.4.4.2.5) which is used mostly by customers if they want to exit the room without making a big round in the restaurant. The sliding door does leak sound from the outside but only to a minimal level, the reading taken at the glass panels has no significant differences most likely due to the thick carpet which drown out most of the noise.

During non-peak hours, the highest data reading was taken around the stairs. (Diagram 3.4.4.2.4) The stairs leads customers from the lounge area (Room 6) to the private dining area (Room 7). The stairs is adjacent to the door way that leads into the main dining area. Therefore, the reading is higher at the stairs as it is a pathway for the noise to travel into Room 7.

During peak hours, the data taken is higher due to the increase of crowd in the main dining area. However, the noise is not significant and it does not cause any discomfort as Room 7 is fully carpeted.

Average Sound Pressure Level

Room 1

Non-peak hour:

Highest reading: 64

64 =10 log (I/Io)

Log $(I/1x10^{-12})$ =6.4

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}6.4$

$(I/1x10^{-12})$= $2.51x10^{6}$

I_H= $2.51x10^{-6}$

Lowest reading: 62

62 =10 log (I/Io)

Log $(I/1x10^{-12})$ =6.2

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}6.2$

$(I/1x10^{-12})$= $1.58x10^{6}$

I_L= $1.58x10^{-6}$

Total intensities, I_{Total} = $2.51x10^{-6}$+ $1.58x10^{-6}$

= $4.09x10^{-6}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(4.09x10^{-6}/ 1x10^{-12})$

=**66.12 dB**, Average sound pressure level in **Private Dining Zone (Room 1)** during **non- peak hour**.

Peak hour:

Highest reading: 74

74 =10 log (I/Io)

Log $(I/1x10^{-12})$ =7.4

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}7.4$

$(I/1x10^{-12})$= $2.51x10^{7}$

I_H= $2.51x10^{-5}$

Lowest reading: 67

67 =10 log (I/Io)

Log $(I/1x10^{-12})$ =6.7

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}6.7$

$(I/1x10^{-12})$= $5.01x10^{6}$

I_L= $5.01x10^{-6}$

Total intensities, I_{Total} = $2.51x10^{-5}$+ $5.01x10^{-6}$

= $3.01x10^{-5}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(3.01x10^{-5}/ 1x10^{-12})$

=**74.79 dB**, Average sound pressure level in **Private Dining Zone (Room 1)** during **peak hour**.

Room 2

Non-peak hour:

Highest reading: 65

65 =10 log (I/Io)

Log $(I/1x10^{-12})$ =6.5

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}6.5$

$(I/1x10^{-12})$= $3.16x10^{6}$

I_H= $3.16x10^{-6}$

Lowest reading: 62

62 =10 log (I/Io)

Log $(I/1x10^{-12})$ =6.2

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}6.2$

$(I/1x10^{-12})$= $1.58x10^{6}$

I_L= $1.58x10^{-6}$

Total intensities, I_{Total} = $3.16x10^{-6}$+ $1.58x10^{-6}$

= $4.74x10^{-6}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(4.74x10^{-6}/ 1x10^{-12})$

=**66.76 dB**, Average sound pressure level in **Private Dining Zone (Room 2)** during **non- peak hour**.

Peak hour:

Highest reading: 73

73 =10 log (I/Io)

Log $(I/1x10^{-12})$ =7.3

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}7.3$

$(I/1x10^{-12})$= $2.0x10^{7}$

I_H= $2.0x10^{-5}$

Lowest reading: 70

70 =10 log (I/Io)

Log $(I/1x10^{-12})$ =7

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}7$

$(I/1x10^{-12})$= $1.0x10^{7}$

I_L= $1.0x10^{-5}$

Total intensities, I_{Total} = $2.0x10^{-5}$+ $1.0x10^{-5}$

= $3.0x10^{-5}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(3.0x10^{-5}/ 1x10^{-12})$

=**74.77 dB**, Average sound pressure level in **Private Dining Zone (Room 2)** during **peak hour**.

Room 7

Non-peak hour:

Highest reading: 57

57 =10 log (I/Io)

Log $(I/1x10^{-12})$ =5.7

Log $^{-1}$ Log $(I/1x10^{-12})$ = log^{-1}5.7

$(I/1x10^{-12})$= $5.01x10^5$

I_H= $5.01x10^{-7}$

Lowest reading: 49

49 =10 log (I/Io)

Log $(I/1x10^{-12})$ =4.9

Log $^{-1}$ Log $(I/1x10^{-12})$ = log^{-1}4.9

$(I/1x10^{-12})$= $7.94x10^4$

I_L= $7.94x10^{-8}$

Total intensities, I_{Total} = $5.01x10^{-7}$+ $7.94x10^{-8}$

= $5.80x10^{-7}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(5.80x10^{-7}/ 1x10^{-12})$

=**57.63 dB**, Average sound pressure level in **Private Dining Zone (Room 7)** during **non- peak hour**.

Peak hour:

Highest reading: 63

63 =10 log (I/Io)

Log $(I/1x10^{-12})$ =6.3

Log $^{-1}$ Log $(I/1x10^{-12})$ = log^{-1}6.3

$(I/1x10^{-12})$= $2.0x10^6$

I_H= $2.0x10^{-6}$

Lowest reading: 56

56 =10 log (I/Io)

Log $(I/1x10^{-12})$ =5.6

Log $^{-1}$ Log $(I/1x10^{-12})$ = log^{-1}5.6

$(I/1x10^{-12})$= $4.0x10^5$

I_L= $4.0x10^{-7}$

Total intensities, I_{Total} = $2.0x10^{-6}$+ $4.0x10^{-7}$

= $2.4x10^{-6}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(2.4x10^{-6}/ 1x10^{-12})$

=**63.8 dB**, Average sound pressure level in **Private Dining Zone (Room 7)** during **peak hour**.

3.4.4.3 Outdoor Dining Area

The outdoor dining area is located at the ground floor level. (Diagram 3.4.4.3.1) As shown in figure 3.4.4.3.1, it is exposed to the sound produced from the main road traffic. It is also exposed to a lane which is the entrance and exit of the underground car park.

Diagram 3.4.4.3.1:
Outdoor dining zone showed in floor plan

Figure 3.4.4.3.1:
Outdoor dining area is exposed to sound produced from traffic

<u>Room 3</u>

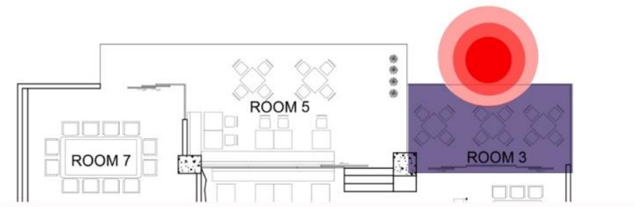


Diagram 3.4.4.3.2:
Traffic is the main noise contributor to Room 3

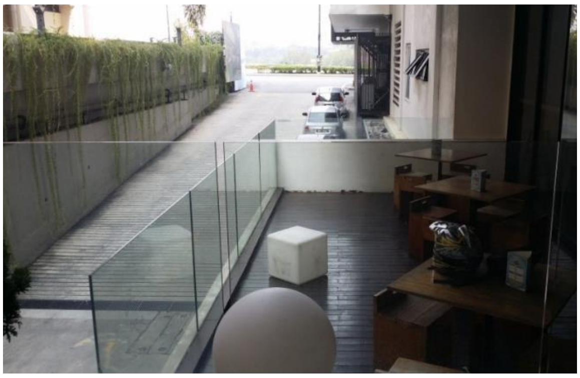
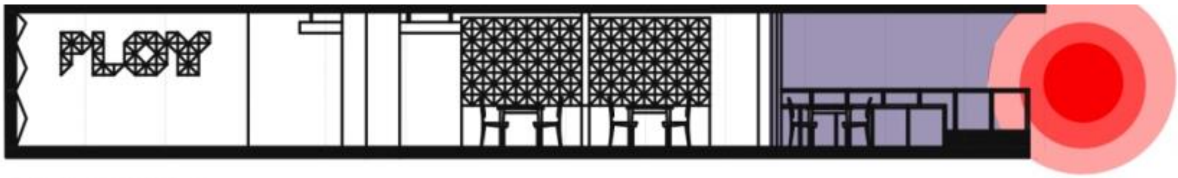


Figure 3.4.4.3.2:
Room 3 is located beside a back lane that leads to the underground car park.

Data tabulation of sound level:

	Non-peak	Peak
Lowest Reading	72	78
Highest Reading	76	79



SECTION A-A

Diagram 3.4.4.3.3 Outdoor noise sources is being transmit to the exposed dining area

During non-peak hours, the reading is still quite high even though the seating area is small as it is exposed to the outside traffic. The timber material used as the flooring may help to absorb some noise. (Figure 3.4.4.3.2) Besides that, there are ceiling fans (Figure 3.4.4.3.3) which possibly serve as noise contributor in room3. However, it is not turned on during non-peak hour. The advantages of an outdoor seating area is that it can disperse sound better compared to an enclosed area.

During peak hours, there are more traffic coming in and out of the basement, resulting in higher sound reading.

Figure 3.4.4.3.3: There are 2 ceiling fan in Room 3 but they are turned off at the time of the reading as this outdoor seating area is less preferable.

Room 5

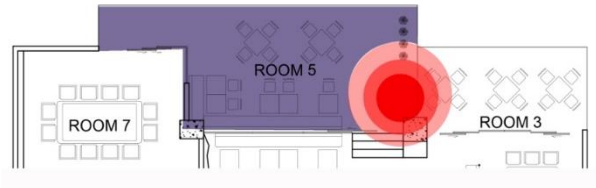


Diagram 3.4.4.3.3:
Stand fan is the main noise source for Room 5

Figure 3.4.4.3.4:
Room 5 is a bigger outdoor seating area

Data tabulation of sound level:

	Non-peak	Peak
Lowest Reading	71	80
Highest Reading	80	87

The highest reading taken in Room 5 is significantly higher due to the stand fan (Figure 3.4.4.3.5) placed near the door way. During peak hours, the opening and closing of the sliding door and the sound produced by working staffs increases the noise level. The conversation of the customers when they are dining also contributes to the noise reading.

Figure 3.4.4.3.5: The stand fan is the main contributor of the noise.

Average Sound Pressure Level

Room 3

Non-peak hour:

Highest reading: 76

76 =10 log (I/Io)

Log $(I/1x10^{-12})$ =7.6

Log $^{-1}$ Log $(I/1x10^{-12})$ = $log^{-1}7.6$

$(I/1x10^{-12})$= $3.98x10^{7}$

I_H= $3.98x10^{-5}$

Lowest reading: 72

72 =10 log (I/Io)

Log $(I/1x10^{-12})$ =7.2

Log $^{-1}$ Log $(I/1x10^{-12})$ = $log^{-1}7.2$

$(I/1x10^{-12})$= $1.58x10^{7}$

I_L= $1.58x10^{-5}$

Total intensities, I_{Total} = $3.98x10^{-5}$+ $1.58x10^{-5}$

= 5.56 $x10^{-5}$

SPL=10 log (I_{Total}/I_0)

= 10 log (5.56 $x10^{-5}$ / $1x10^{-12}$)

=**77.45 dB**, Average sound pressure level in **Outdoor Dining Zone (Room 3)** during **non-peak hour**.

Peak hour:

Highest reading: 79

79 =10 log (I/Io)

Log $(I/1x10^{-12})$ =7.9

Log $^{-1}$ Log $(I/1x10^{-12})$ = $log^{-1}7.9$

$(I/1x10^{-12})$= $7.94x10^{7}$

I_H= $7.94x10^{-5}$

Lowest reading: 78

78 =10 log (I/Io)

Log $(I/1x10^{-12})$ =7.8

Log $^{-1}$ Log $(I/1x10^{-12})$ = $log^{-1}7.8$

$(I/1x10^{-12})$= $6.31x10^{7}$

I_L= 6.31 $x10^{-5}$

Total intensities, I_{Total} = 7.94 $x10^{-5}$+ $6.31x10^{-5}$

= 1.43 $x10^{-4}$

SPL=10 log (I_{Total}/I_0)

= 10 log (1.43 $x10^{-4}$/ $1x10^{-12}$)

=**81.55 dB**, Average sound pressure level in **Outdoor Dining Zone (Room 3)** during **peak hour**.

Room 5

Non-peak hour:

Highest reading: 80

80 =10 log (I/Io)

Log $(I/1x10^{-12})$ =8

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}8$

$(I/1x10^{-12})$= $1.0x10^{8}$

I_H= $1.0x10^{-4}$

Lowest reading: 71

71 =10 log (I/Io)

Log $(I/1x10^{-12})$ =7.1

Log $^{-1}$ Log$(I/1x10^{-12})$ = $\log^{-1}7.1$

$(I/1x10^{-12})$= $1.26x10^{7}$

I_L= $1.26x10^{-5}$

Total intensities, I_{Total} = $1.0x10^{-4}$+ $1.26x10^{-5}$

= $1.13 x10^{-4}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(1.13 x10^{-4}/ 1x10^{-12})$

= **80.53 dB**, Average sound pressure level in **Outdoor Dining Zone (Room 5)** during **non-peak hour**.

Peak hour:

Highest reading: 87

87 =10 log (I/Io)

Log $(I/1x10^{-12})$ =8.7

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}8.7$

$(I/1x10^{-12})$= $5.01 x10^{8}$

I_H= $5.01x10^{-4}$

Lowest reading: 80

80 =10 log (I/Io)

Log $(I/1x10^{-12})$ =8

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}8$

$(I/1x10^{-12})$= $1.0x10^{8}$

I_L= $1.0x10^{-4}$

Total intensities, I_{Total} = $5.01x10^{-4}$+ $1.0x10^{-4}$

= $6.01 x10^{-4}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(6.01x10^{-4}/ 1x10^{-12})$

= **87.79 dB**, Average sound pressure level in **Outdoor Dining Zone (Room 5)** during **peak hour**.

3.4.4.4 Public Dining Area

Diagram 3.4.4.4.1:
Public dining zone showed in floor plan

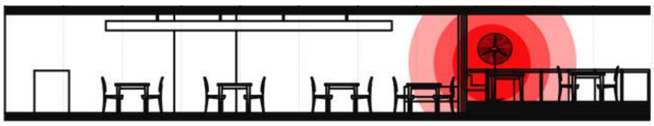
Figure 3.4.4.4.1:
Public dining zone caters most of the crowd

The public dining area (Figure 3.4.4.4.1) is the main area where customers dine. It has the most floor area which can cater to a large crowd. (Diagram 3.4.4.4.1)

Data tabulation of sound level:

	Non-peak	Peak
Lowest Reading	60	82
Highest Reading	66	86

Diagram 3.4.4.4.2:
Despite the noise from the crowd of the main dining area, the bar and the outdoor noise are the secondary contributors.



SECTION D-D

Diagram 3.4.4.4.3:
Noise of the stand fan from the outdoor seating area is able to leak through the door and into the main dining space.

During non-peak time, the reading along the bar is higher because of the reflective material of the bar counter (Figure 3.4.4.4.2). The hard and smooth surface of the reflective material of the bar counter top causes the sound to bounce off. In addition to that, the works that take place behind the bar also contributes to the higher sound reading. On the other hand, the reading along the cushioned seating area (Figure 3.4.4.4.3) is lower. The cushioned bench has high sound absorption which results in lower reading along the cushioned bench. This is due to the absorptive materials of the cushion which reduces the sound level. The reading along the faceted wooden wall (Figure 3.4.4.4.4) is also slightly lower due to the excellent sound absorption quality of wood.

Figure 3.4.4.4.2: The reflective bar counter top

Figure 3.4.4.4.3: Cushion seating area

Figure 3.4.4.4.4: Faceted wooden wall maintained acoustical quality of the space

During peak hours, the readings increases significantly due to the increased number of customers which increases the activity of working staffs, more preparations going on in the kitchen and the increased number of chattering of customers. Moreover, the sliding door (indicated red) has most of the sound leakage (Figure 3.4.4.4.5). The reading obtained adjacent to the door is higher due to the exterior sound that is produced by the ongoing traffic and the stand fan, especially during peak hours.

Figure 3.4.4.4.5: The glass sliding door leads to the outdoor seating area.

Another significant noise source comes from the air diffusers. The public dining area is fixed with a total number of 6 circular air diffusers (Figure 3.4.4.4.6) which are switched on throughout their operating hours regardless whether it is during peak or non-peak hours.

Figure 3.4.4.4.6: Circular and rectangular diffusers are found in the main dining area.

Average Sound Pressure Level

Non-peak hour:

Highest reading: 66

66 =10 log (I/Io)

Log $(I/1x10^{-12})$ =6.6

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}6.6$

$(I/1x10^{-12})$= $3.98x10^{6}$

I_H= $3.98x10^{-6}$

Lowest reading: 60

6 =10 log (I/Io)

Log $(I/1x10^{-12})$ =6

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}6$

$(I/1x10^{-12})$= $1.0x10^{6}$

I_L= $1.0x10^{-6}$

Total intensities, I_{Total} = $3.98x10^{-6}$+ $1.0x10^{-6}$

= $4.98 x10^{-6}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(4.98 x10^{-6}/ 1x10^{-12})$

= **66.97 dB**, Average sound pressure level in **Public Dining Zone** during **non-peak hour**.

Peak hour:

Highest reading: 86

86 =10 log (I/Io)

Log $(I/1x10^{-12})$ =8.6

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}8.6$

$(I/1x10^{-12})$= $3.98x10^{8}$

I_H= $3.98x10^{-4}$

Lowest reading: 82

82 =10 log (I/Io)

Log $(I/1x10^{-12})$ =8.2

Log $^{-1}$ Log $(I/1x10^{-12})$ = $\log^{-1}8.2$

$(I/1x10^{-12})$= $1.58x10^{8}$

I_L= $1.58x10^{-4}$

Total intensities, I_{Total} = $3.98x10^{-4}$+ $1.58x10^{-4}$

= $5.56 x10^{-4}$

SPL=10 log (I_{Total}/I_0)

= 10 log $(5.56 x10^{-4}/ 1x10^{-12})$

= **87.45 dB**, Average sound pressure level in **Public Dining Zone** during **peak hour**.

3.4.4.5 Lounge Area

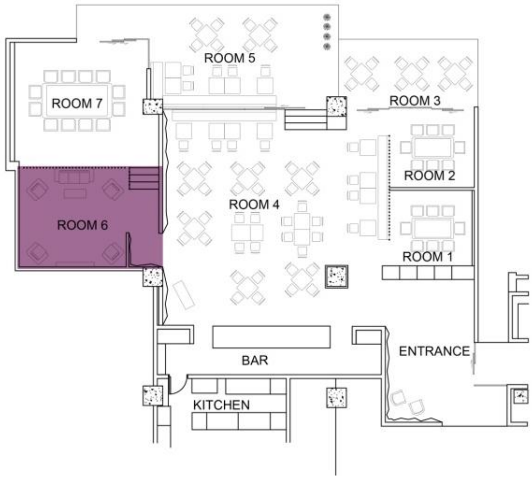


Diagram 3.4.4.5.1:
Lounge area showed in floor plan

Figure 3.4.4.5.1:
Lounge area (Source: Lo,2012)

As shown in diagram 3.4.4.5.1, the lounge area is an enclosed space which is connected to a private dining room, Room 7. It is set lower than Room 7. The lounge area is a room (Figure 3.4.4.5.1) in the restaurant for customers to sit and relax. It has a big coffee table, a few individual sofas, a long sofa and a cow hide rug.

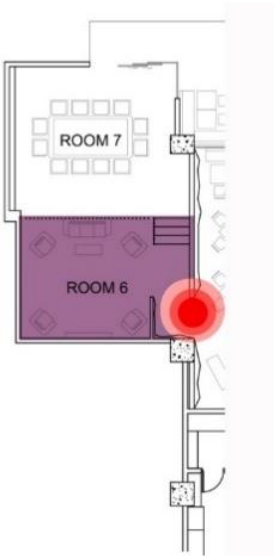
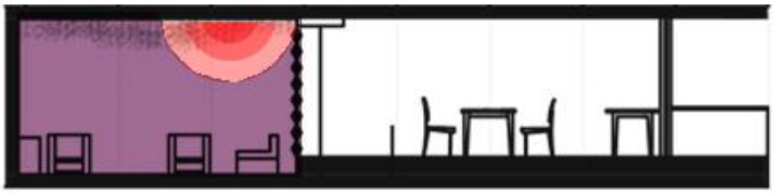


Diagram 3.4.4.5.2:
The noise sources come from air diffuser and entrance for lounge area

Figure 3.4.4.5.2:
The corner of lounge area has relatively lower readings

Data tabulation of sound level:

	Non-peak	Peak
Lowest Reading	47	67
Highest Reading	61	69



SECTION B-B

Diagram 3.4.4.5.3: Diffuser is the main noise source in Lounge area.

During non-peak hours, the lounge area is the quietest zone in the restaurant. As shown in figure 3.4.4.5.4, there was no one present at the lounge area when the reading was taken. The main source of the noise is identified which is the speakers and the diffuser. There is a rectangular diffuser place right on top of the door way. (Diagram 3.4.4.5.3) It is switched on through the whole operating time of the restaurant. The diffuser is one of the noise contributor of the lounge area as it transmits airborne sounds. The open walkway that leads into the lounge area has the highest reading as there is where the sound travel into the space. However, the exterior of the lounge area has faceted wood as aesthetics and acoustic properties. This helps reduce the noise from bouncing off the walls which can cause more reverberation time.

During peak hours, there were faint conversations from the crowd at the main dining area. However, due to the distance, the data collected has no significant differences. The lower readings of the room taken are along the walls of the lounge area.

Even though the lounge area has bare concrete as its surrounding walls, it is still the quietest area in the restaurant. This is because there are components of the room that are acting as a sound absorber The decorative lights (Figure 3.4.4.5.3) sits above the lounge area act as a sound absorber as it is grouped together with some spaces in between the light bulbs. The noise is dispersed as it pass through the decorative light bulbs. The cow hide rug is also a sound absorber found here. Also, the cushioned seats and sofas shown in figure 3.4.4.5.4 can absorb sound which leads to a low data reading.

Figure 3.4.4.5.3: Large amount of decorative lights serve as sound absorber in the space

Figure 3.4.4.5.4: Cushioned seats and sofas are excellent sound absorber

Average Sound Pressure Level

Non-peak hour:

Highest reading: 61

61 =10 log (I/Io)

$\text{Log}(I/1\times10^{-12}) = 6.1$

$\text{Log}^{-1}\,\text{Log}(I/1\times10^{-12}) = \log^{-1}6.1$

$(I/1\times10^{-12}) = 1.26\times10^{6}$

$I_H = 1.26\times10^{-6}$

Lowest reading: 47

47 =10 log (I/Io)

$\text{Log}(I/1\times10^{-12}) = 4.7$

$\text{Log}^{-1}\,\text{Log}(I/1\times10^{-12}) = \log^{-1}4.7$

$(I/1\times10^{-12}) = 5.01\times10^{4}$

$I_L = 5.01\times10^{-8}$

Total intensities, $I_{Total} = 1.26\times10^{-6} + 5.01\times10^{-8}$

$= 1.31\times10^{-6}$

$SPL = 10 \log (I_{Total}/I_0)$

$= 10 \log (1.31\times10^{-6} / 1\times10^{-12})$

= **61.17 dB**, Average sound pressure level in **Lounge Area** during **non-peak hour**.

Peak hour:

Highest reading: 69

69 =10 log (I/Io)

$\text{Log}(I/1\times10^{-12}) = 6.9$

$\text{Log}^{-1}\,\text{Log}(I/1\times10^{-12}) = \log^{-1}6.9$

$(I/1\times10^{-12}) = 7.94\times10^{6}$

$I_H = 7.94\times10^{-6}$

Lowest reading: 67

67 =10 log (I/Io)

$\text{Log}(I/1\times10^{-12}) = 6.7$

$\text{Log}^{-1}\,\text{Log}(I/1\times10^{-12}) = \log^{-1}6.7$

$(I/1\times10^{-12}) = 5.01\times10^{6}$

$I_L = 5.01\times10^{-6}$

Total intensities, $I_{Total} = 7.94\times10^{-6} + 5.01\times10^{-6}$

$= 1.30\times10^{-5}$

$SPL = 10 \log (I_{Total}/I_0)$

$= 10 \log (1.30\times10^{-5} / 1\times10^{-12})$

= **71.14 dB**, Average sound pressure level in **Lounge Area** during **peak hour**.

3.4.4.6 Service Area

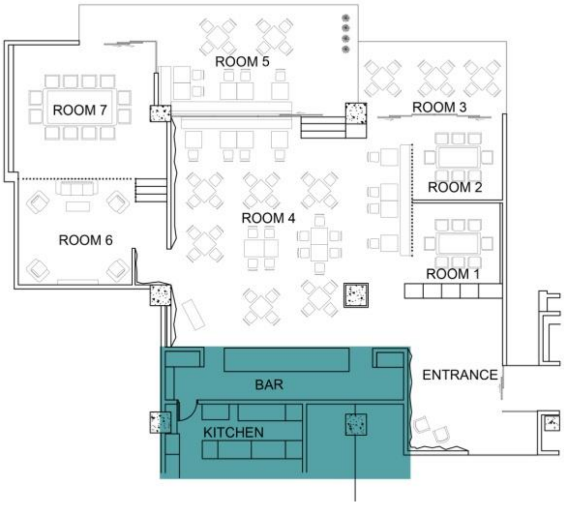


Diagram 3.4.4.6.1:
Service area showed in floor plan

Figure 3.4.4.6.1:
Drinks prepared in bar area cause noises

The bar is a service area where the restaurant staff prepares drinks from brewing coffee to mixing cocktails (Figure 3.4.4.6.1). The noise at this area is quite high as there is a lot of staff movements and operating of equipment. Only authorizes personal are allowed to enter the bar area.

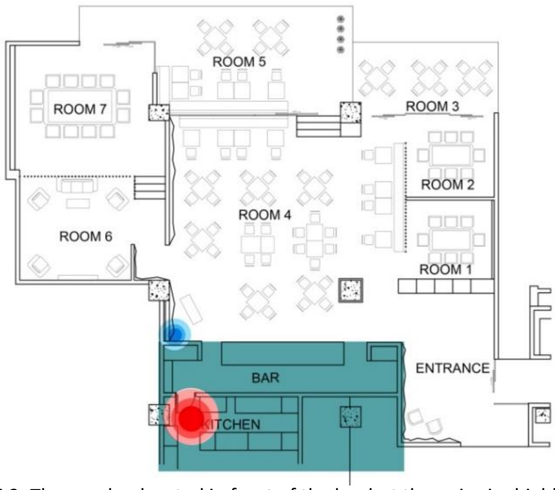
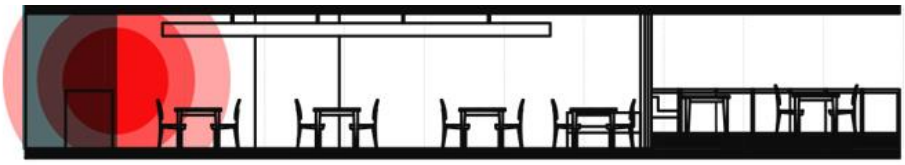


Diagram 3.4.4.6.2: The speaker located in front of the bar but the noise is shielded off by a partition.

Data tabulation of sound level:

	Non-peak	Peak
Lowest Reading	60	69
Highest Reading	66	79



SECTION D-D

Diagram 3.4.4.6.3: Noise from the bar that is directly influencing the noise at the main dining area

During non-peak hours, the reading is relatively low as there is minimal operation of the bar. As shown in diagram 3.4.4.6.2, although there is a speaker in front of the bar, there is no difference in the data taken as it is shielded off by a partition. The speaker is also directed at the main dining area which allows the sound to disperse in that direction.

During peak hours, the noise reading significantly increases. The machinery operated at the bar such as the coffee machine is at use. There is many clinking of glasses and plates as the waiters serve food and bring in used tableware.

According to diagram 3.4.4.6.3, the main dining area directly disrupts the noise of the bar as there is no partition to separate them both. The main sound contributor of the bar other than from the bar itself is the noise from the kitchen. (Diagram 3.4.4.6.1) The waiters constantly bring food in and out of the kitchen which allow the noise to transmit through the kitchen door, directly affecting the noise of the bar area. (Figure 3.4.4.6.2) The lowest reading is located at the side of the bar (Figure 3.4.4.6.3) where there is limited space with a desk, a space to keep documents.

Figure 3.4.4.6.2:
Kitchen activities is the main noise sources of service zone

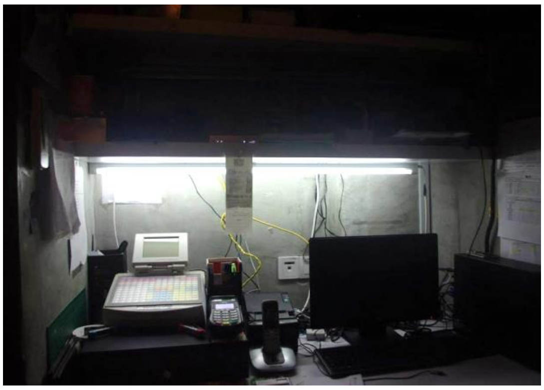


Figure 3.4.4.6.3:
Working area which has lowest sound reading

Average Sound Pressure Level

Non-peak hour:

Highest reading: 66

66 =10 log (I/Io)

$\text{Log}\,(I/1\text{x}10^{-12}) = 6.6$

$\text{Log}^{-1}\,\text{Log}\,(I/1\text{x}10^{-12}) = \log^{-1}6.6$

$(I/1\text{x}10^{-12}) = 3.98\text{x}10^{6}$

$I_H = 3.98\text{x}10^{-6}$

Lowest reading: 60

60 =10 log (I/Io)

$\text{Log}\,(I/1\text{x}10^{-12}) = 6$

$\text{Log}^{-1}\,\text{Log}\,(I/1\text{x}10^{-12}) = \log^{-1}6$

$(I/1\text{x}10^{-12}) = 6.0\text{x}10^{6}$

$I_L = 6.0\text{x}10^{-6}$

Total intensities, $I_{Total} = 3.98\text{x}10^{-6} + 6.0\text{x}10^{-6}$

$= 9.98 \text{ x } 10^{-6}$

$\text{SPL} = 10 \log (I_{Total}/I_0)$

$= 10 \log (9.98 \text{ x}10^{-6} / 1\text{x}10^{-12})$

= **70.00 dB**, Average sound pressure level in **Service Zone** during **non-peak hour**.

Peak hour:

Highest reading: 79

79 =10 log (I/Io)

$\text{Log}\,(I/1\text{x}10^{-12}) = 7.9$

$\text{Log}^{-1}\,\text{Log}\,(I/1\text{x}10^{-12}) = \log^{-1}7.9$

$(I/1\text{x}10^{-12}) = 7.94\text{x}10^{7}$

$I_H = 7.94\text{x}10^{-5}$

Lowest reading: 69

69 =10 log (I/Io)

$\text{Log}\,(I/1\text{x}10^{-12}) = 6.9$

$\text{Log}^{-1}\,\text{Log}\,(I/1\text{x}10^{-12}) = \log^{-1}6.9$

$(I/1\text{x}10^{-12}) = 7.94\text{x}10^{6}$

$I_L = 7.94\text{x}10^{-6}$

Total intensities, $I_{Total} = 7.94\text{x}10^{-5} + 7.94\text{x}10^{-6}$

$= 8.73 \text{ x}10^{-5}$

$\text{SPL} = 10 \log (I_{Total}/I_0)$

$= 10 \log (8.73 \text{ x}10^{-5} / 1\text{x}10^{-12})$

= **79.41dB**, Average sound pressure level in **Service Zone** during **peak hour**.

3.4.4.7 Summary and Analysis

The study shows that during **non-peak hour**, Room 7 in **Private Dining area** has the lowest sound level, which is **57.63 dB,** this is because of lack of human activities going on in the space and the use of acoustical materials which absorb sound, such as thick carpet (Diagram 3.4.4.7.1). A private dining area should always have good acoustic quality to maintain the ambiance for comfort dining. Other than material approach, the location of the private dining area is at the corner of restaurant and is isolated by concrete wall and wooden faceted wall, therefore the noise created by human activities from public dining area would not travel to the space so easily.

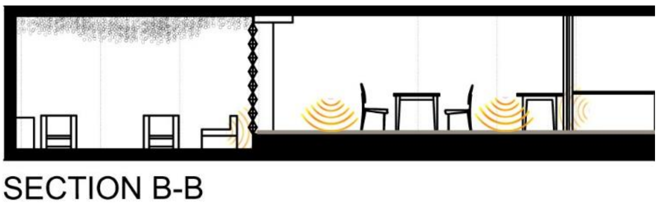


Diagram3.4.4.7.1: Noises from outdoor and lounge area is absorbed by the carpet

The highest sound level can be obtained at Room 5 in **Outdoor Dining area**, which is **80.53dB.** Main noise contributors to outdoor dining area during non-peak hour are the external noise sources from neighboring context. (Diagram 3.4.4.7.2) That is the noises from adjacent building's machine room, and also traffic noises caused by circulation around the building. Since it is open air dining area, sounds from different direction can transmit easily to the space without any obstacles. Other than that, the operation of stand fan also brought significant amount of noise to the space. Thus, it is not an ideal place for private conversations and study at outdoor dining area.

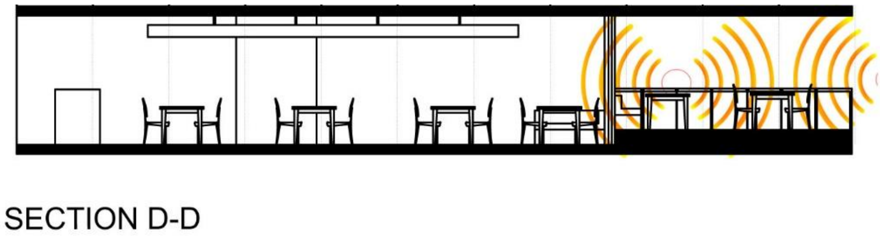


Diagram3.4.4.7.2: Outdoor dining area is exposed to external noise sources, sound disperse easily

During **peak hour**, Room 7 in **Private Dining area** remains the quietest room too, with the sound level **63.8dB**. Due to it only caters for private function, during peak hour it has no occupants too. However, due to the increasing of patrons dining at the adjacent outdoor dining area, the noise from outdoor area has transmit to the private dining space through glass door.

Room 5 of **Outdoor Dining Area** remains the noisiest room during peak hour (Diagram 3.4.4.7.3) with the sound level of **87.79dB**. This is due to the increase amount of patrons dining in the restaurant. The chattering of customers, and the speakers playing music during peak hours are the main noise contributor. The traffic at the side lane and movement of staffs and customers had generate significant amount of noises too. Moreover, the waiter coming to-and-forth through the glass sliding door caused the noises from **Main Dining area** transmit through it. The stand fans still operating and all sources of noises all together generate a greater amount of noise than non-peak hour.

Diagram 3.4.4.7.3: Noise contributors of Outdoor dining area during peak hour

3.4.5 Reverberation Time

Reverberation is one of the most pronounced hearing reactions in an enclosed space. It is the persistence of sound after the sound has ceased, and through that it gives subjective impression of liveliness or deadness to a space, as a scale to determine human perceptual comfort.

Reverberation time is a fundamental quantity in architectural acoustics. It can be calculated at preliminary design stage. This is beneficial in determining how well a space will function for its intended use and if more or less absorption is need within a space.

(i) Volume of space:

The reverberation time of main enclosed zone in Ploy Restaurant is calculated. (Diagram 3.4.5.1) Main enclosed zone includes: entrance area, public dining area, private dining area (Room 1 & Room 2) and bar area.

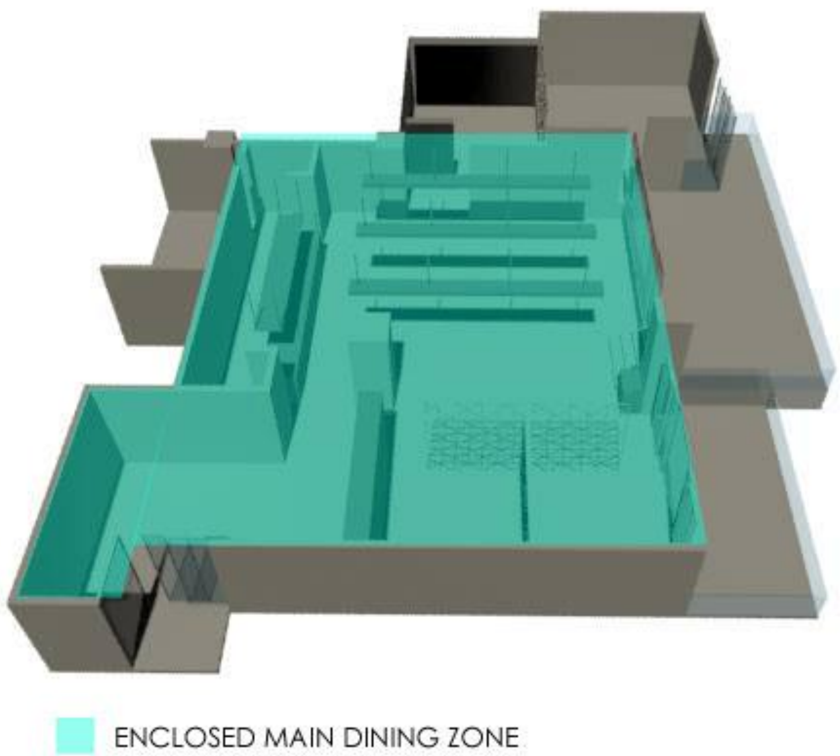


Diagram 3.4.5.1: Main Dining zone

Volume of main enclosed zone

=Area of entrance zone + Area of public dining zone+ Area of semi-private dining+ Area or bar area

= ($32.71m^2$ x 3.8m) + ($103.78m^2$ x 3.8m) + ($25.87m^2$ x 3.8m) + ($23.53m^2$ x 3.8m)

= $706.38m^3$

(ii) Acoustical absorption in the space

Materials has different absorption coefficient in different frequencies. Acoustical absorption of materials in the following frequencies: 500Hz, 2000Hz and 4000Hz is taken as reference to calculate reverberation time.

As shown in diagram 3.4.5.2, the optimum reverberation time for cafeteria is between 0.8-1.3s.

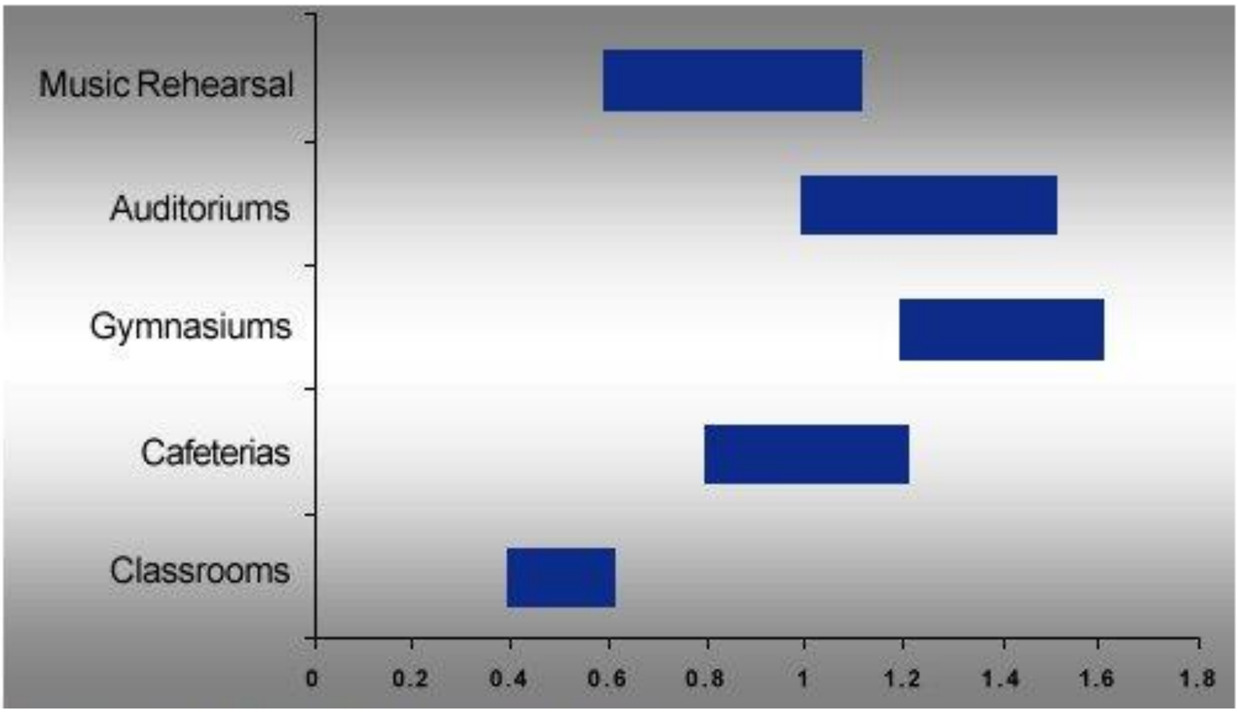


Diagram 3.4.5.2: Optimum reverberation time for different spaces (Source: Spectra Tect, n.d.)

Material	Function	Area [A] (m2)	Absorption Coefficient in 500 Hz[S]	Sound Absorption [SA]
Plaster	Ceiling	236.21	0.02	4.72
Timber	Wall Panel	62.04	0.10	6.20
	Door	2.80	0.10	0.28
	Floor	24.11	0.10	2.41
	Furniture (Table)	39.53	0.10	3.95
	Partition	24.11	0.10	2.41
Concrete Cement	Wall	54.49	0.02	1.09
	Floor	244.29	0.02	4.89
Reinforced Concrete	Column	2.70	0.06	0.16
	Wall	43.49	0.06	2.61
Glass	Door	30.41	0.10	3.04
	Glass Panel	39.95	0.10	4.00
	Mirror	1.07	0.18	0.19
Steel	Furniture (Bar)	7.78	0.01	0.08
Fabric	Curtain	17.76	0.15	2.66
	Carpet	11.60	0.25	2.90
	Cushion	12.60	0.49	6.17
Total sound absorption by materials				47.77

Time	Number of people	Absorption Coefficient in 500Hz [S]	Sound Absorption [SA]
Non-peak hour	20	0.42	8.40
Peak hour	70	0.42	29.40

Table 3.4.5.1: Material Absorption Coefficient at 500 Hz

According to Table 3.4.5.1, the total sound absorption at **500Hz** during non-peak hour and peak hour are **56.17** and **77.17** respectively.

Reverberation time calculation:

Non-peak hour:

RT = (0.16xV) / A

= (0.16 x 706.38)/56.17

= 2.01s

The reverberation time for main dining zone in 500Hz of absorption coefficient during **non-peak** hour (20 people) is **2.01s**. According to MS1525, the standard comfort reverberation time falls between 0.8s-1.3s. Thus, the reverberation time of case study **does not fulfill** the standard. It is poor environment for speech however it is fairly acceptable for place with music playing along. During non-peak hour there are less occupants, longer reverberation time is acceptable for playing soothing music in the restaurant, hence the scenario is **acceptable.**

Peak hour:

RT = (0.16xV) / A

= (0.16 x 706.38)/77.17

= 1.46s

The reverberation time for main dining zone in 500Hz of absorption coefficient during **peak** hour (70 people) is **1.46s**. According to MS1525, the standard comfort reverberation time falls between 0.8s-1.3s. Thus, the reverberation time of case study **does not fulfill** the standard. During peak hour there are many dining patrons chattering, longer reverberation time is poor for conversation as the noises interfere other customers. Hence, the scenario is **unacceptable.** To improve this situation, temporary partition can be held during peak hours.

Material	Function	Area [A] (m2)	Absorption Coefficient in 2000 Hz[S]	Sound Absorption [SA]
Plaster	Ceiling	236.21	0.04	9.45
Timber	Wall Panel	62.04	0.10	0.00
	Door	2.80	0.10	0.28
	Floor	24.11	0.10	2.41
	Furniture (Table)	39.53	0.10	3.95
	Partition	24.11	0.10	2.41
Concrete Cement	Wall	54.49	0.02	1.09
	Floor	244.29	0.02	4.89
Reinforced Concrete	Column	2.70	0.10	0.27
	Wall	43.49	0.10	4.35
Glass	Door	30.41	0.07	2.13
	Glass Panel	39.95	0.07	2.80
	Mirror	1.07	0.07	0.07
Steel	Furniture (Bar)	7.78	0.01	0.08
Fabric	Curtain	17.76	0.70	12.43
	Carpet	11.60	0.70	8.12
	Cushion	12.60	0.70	8.82
Total sound absorption by materials				63.55

Time	Number of people	Absorption Coefficient in 2000Hz [S]	Sound Absorption [SA]
Non-peak hour	20	0.5	10.00
Peak hour	70	0.5	35.00

Table 3.4.5.2: Material Absorption Coefficient at 2000 Hz

According to Table 3.4.5.2, the total sound absorption at **2000Hz** during non-peak hour and peak hour are **73.55** and **98.55** respectively.

Reverberation time calculation:

Non-peak hour:

RT = (0.16xV) / A

= (0.16 x 706.38)/73.55

= 1.54s

The reverberation time for main dining zone in 2000Hz of absorption coefficient during **non-peak** hour (20 people) is **1.54s**. According to MS1525, the standard comfort reverberation time falls between 0.8s-1.3s. Thus, the reverberation time of case study **does not fulfill** the standard. It is poor environment for speech however it is fairly acceptable for place with music playing along. During non-peak hour there are less occupants, longer reverberation time is acceptable for playing soothing music in the restaurant, hence the scenario is **acceptable.**

Peak hour:

RT = (0.16xV) / A

= (0.16 x 706.38)/98.55

= 1.15s

The reverberation time for main dining zone in 2000Hz of absorption coefficient during **peak** hour (70 people) is **1.15s**. According to MS1525, the standard comfort reverberation time falls between 0.8s-1.3s. Thus, the reverberation time of case study **fulfill** the standard. Hence, this zone has designed based on sound absorption requirement.

Material	Function	Area [A] (m2)	Absorption Coefficient in 4000 Hz[S]	Sound Absorption [SA]
Plaster	Ceiling	236.21	0.02	4.72
Timber	Wall Panel	62.04	0.10	0.00
	Door	2.80	0.10	0.28
	Floor	24.11	0.10	2.41
	Furniture (Table)	39.53	0.10	3.95
	Partition	24.11	0.10	2.41
Concrete Cement	Wall	54.49	0.03	1.63
	Floor	244.29	0.03	7.33
Reinforced Concrete	Column	2.70	0.10	0.27
	Wall	43.49	0.10	4.35
Glass	Door	30.41	0.04	1.22
	Glass Panel	39.95	0.04	1.60
	Mirror	1.07	0.04	0.04
Steel	Furniture (Bar)	7.78	0.01	0.08
Fabric	Curtain	17.76	0.55	9.77
	Carpet	11.60	0.55	6.38
	Cushion	12.60	0.55	6.93
Total sound absorption by materials				53.37

Time	Number of people	Absorption Coefficient in 4000Hz [S]	Sound Absorption [SA]
Non-peak hour	20	0.5	10.00
Peak hour	70	0.5	35.00

Table 3.4.5.3: Material Absorption Coefficient at 4000 Hz

According to Table 3.4.5.3, the total sound absorption at **4000Hz** during non-peak hour and peak hour are **63.37** and **88.37** respectively.

Reverberation time calculation:

Non-peak hour:

RT = (0.16xV) / A

= (0.16 x 706.38)/63.37

= 1.78s

The reverberation time for main dining zone in 4000Hz of absorption coefficient during **non-peak** hour (20 people) is **1.78s**. According to MS1525, the standard comfort reverberation time falls between 0.8s-1.3s. Thus, the reverberation time of case study **does not fulfill** the standard. It is poor environment for speech however it is fairly acceptable for place with music playing along. During non-peak hour there are less occupants, longer reverberation time is acceptable for playing soothing music in the restaurant, hence the scenario is **acceptable.**

Peak hour:

RT = (0.16xV) / A

= (0.16 x 706.38)/88.37

= 1.28s

The reverberation time for main dining zone in 4000Hz of absorption coefficient during **peak** hour (70 people) is **1.28s**. According to MS1525, the standard comfort reverberation time falls between 0.8s-1.3s. Thus, the reverberation time of case study **fulfill** the standard. Hence, this zone has designed based on sound absorption requirement.

3.4.6 Sound Reduction Index (SRI)

The sound reduction index is a measure of the insulation against the direct transmission of air-borne sound. For the case study, the partition between outdoor dining area and indoor dining area is chose to study. Besides that, partition between private dining area, lounge area and public dining area is chose to study due to its good acoustic quality. It can be calculated using the formula:

$$SRI_n = 10 \log (1/T_n),\ T_{av} = (S_1 x T_{c1} + S_2 x T_{c2} \ldots + S_n x T_{cn})/\text{Total Surface Area}$$

Where S= surface area of material, T= transmission coefficient of material

3.4.6.1 Sound reduction index from outdoor to indoor

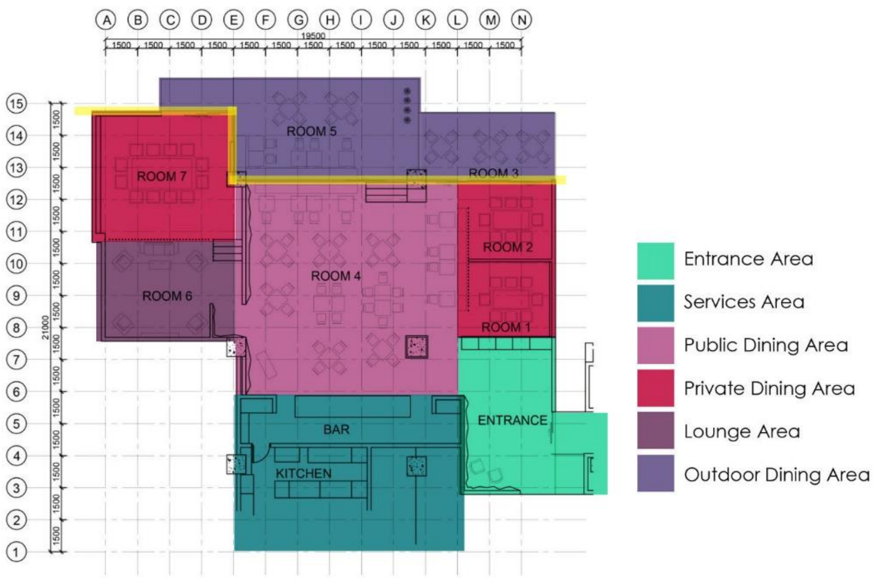


Diagram 3.4.6.1.1: Yellow line indicating divider between outdoor dining area and indoor dining area

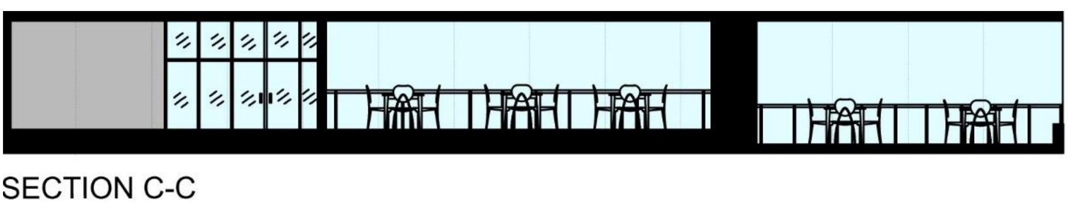


Diagram 3.4.6.1.2: Section with material properties shown

Wall type 1: Glass Panels / Windows

SRI = 10 log (1/T)

$SRI_{glass} = 26$

26 = 10 log (1/T)

2.6 = log (1/T)

Log^{-1} 2.6 = (1/T)

$T_{glass} = 2.51 \times 10^{-3}$

Wall type 2: Painted Concrete Wall

SRI = 10 log (1/T)

$SRI_{concrete} = 42$

42= 10 log (1/T)

4.2 = log (1/T)

Log^{-1} 4.2 = (1/T)

$T_{concrete} = 6.31 \times 10^{-5}$

Surface Material	Surface area (m^2)[S]	SRI (dB)	Transmission coefficient [T_{cn}]	Surface area x Transmission coefficient [ST]
Glass Panels	59.85	26	2.51×10^{-3}	1.50×10^{-1}
Painted Concrete Wall	24.15	42	6.31×10^{-5}	1.52×10^{-3}
Total	84			0.15152

T_{av} = (0.15152/84)

$= 1.80 \times 10^{-3}$

$SRI_{overall} = 10 \log (1/T_{av})$

$= 10 \log (1/ 1.80 \times 10^{-3})$

= 27.45 dB

As shown in calculations above, **27.45dB** of noise level had reduced during transmission from outdoor dining area to indoor dining area.

3.4.6.2 Sound reduction index from Public Dining area to Private Dining area

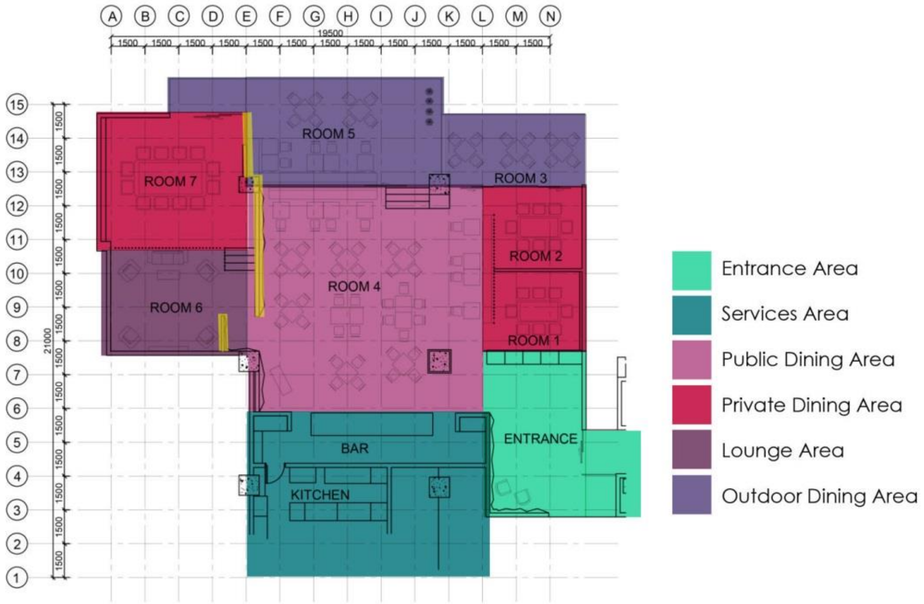


Diagram 3.4.6.2.1: Yellow line indicating divider between public dining area and private dining area

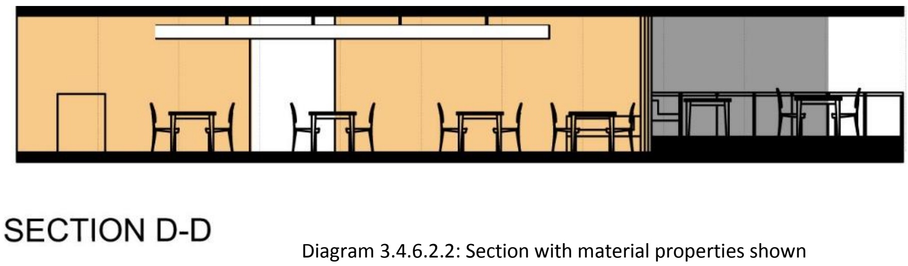


Diagram 3.4.6.2.2: Section with material properties shown

Wall type 1: Timber faceted wall

SRI = 10 log (1/T)

SRI_{timber} = 28

28 = 10 log (1/T)

2.8 = log (1/T)

Log^{-1} 2.8 = (1/T)

$T_{timber} = 1.58 \times 10^{-3}$

Wall type 2: Painted Concrete Wall

SRI = 10 log (1/T)

$SRI_{concrete}$ = 42

42= 10 log (1/T)

4.2 = log (1/T)

Log^{-1} 4.2 = (1/T)

$T_{concrete} = 6.31 \times 10^{-5}$

Surface Material	Surface area (m^2)[S]	SRI (dB)	Transmission coefficient [T_{cn}]	Surface area x Transmission coefficient [ST]
Timber Faceted Wall	26.25	28	1.58×10^{-3}	4.15×10^{-2}
Painted Concrete Wall	36.75	42	6.31×10^{-5}	2.32×10^{-3}
Total	63			0.04382

T_{av} = (0.04382/63)

$= 6.96 \times 10^{-4}$

$SRI_{overall} = 10 \log (1/T_{av})$

$= 10 \log (1/ 6.96 \times 10^{-4})$

= 31.57 dB

As shown in calculations above, **31.57 dB** of noise level had reduced during transmission from outdoor dining area to indoor dining area.

3.4.6.3 Summary and Analysis

STC Rating	Speech Heard Through Wall or Floor	Noise Control Level
25	Normal speech understandable	Poor
30	Loud speech understandable	Marginal
40	Loud speech audible as murmur but unintelligible	Good
50	Loud speech barely audible	Very Good
55 and up	Loud speech not heard	Excellent

NOTE: Assumes background noise of 30dB on the listening side.

Table 3.4.6.3.1: Sound Transmission class rating table (Source: Inspectapedia, n.d.)

According to table 3.4.6.3.1, it shows that the partition between Outdoor dining area and Indoor dining area which has SRI index **27.45dB** is **poor** in noise control. This is due to the partition are mostly glass panels or sliding doors where sound can be transmit easily. To improve the noise control quality, sound insulation such as sound attenuators can be install. Besides that, adding curtains to the partitions also help to absorb noises.

For partition between public dining area and private dining area (Room 7) and lounge area, it has SRI index of **31.57dB,** it falls under **marginal** level of noise control. The timber faceted wall (Figure 3.4.6.3.1) is an excellent sound absorber and it block most of the noises into the private dining area, creating a tranquil ambiance for the occupants inside.

Figure 3.4.6.3.1: Timber faceted wall serve as partition at the same time it has noise control function

3.5 Conclusion

Throughout the case study it can be conclude that the Ploy restaurant is suitable for fine dining and have soft conversation during non-peak hour, it is not really suitable for patrons to have fine dining during peak hour. The general sound level of each areas are similar as typical cafeteria whereas the reverberation time and sound transmission level are slightly over the standard but acceptable range. As a fine dining restaurant where peaceful ambiance is assured, acoustic qualities of the space is one of the vital considerations. The designer has put effort and employs materials that has good sound insulation characteristics in the restaurant. Moreover, there are furniture that complement the design at the same time help in improving acoustic performance in the space. The arrangement of spaces according different zone is done well and partitions had been installed in the appropriate locations. However, several aspects can be improve to achieve better acoustic quality, such as dealing with external noise sources, exhaust devices which are main noise contributors.

There are a few suggestions for The Ploy Restaurant to improve the overall acoustic performance. These are the several zones which has fall beyond comfort acoustic level and needed to be improve:

(i) Main Dining Zone:

The main dining zone caters most of the patrons. Human activities such as chattering, circulation within restaurant are the main noise contributors. Despite human activities, noises from open bar area, where food preparation take places produced significant amount of noises too. To improve the acoustic performance, partitions can be install. Main dining spaces are suggested to be compartmentalized into smaller space for better fine dining experience. Besides that, the volume of speakers are suggested to low down during peak-hour to ensure acoustic comfort.

(ii) Outdoor Dining Zone:

The outdoor dining zone receives noises mostly from neighboring context and the traffic. However, to maintain the openness and visual continuity of space it cannot be covered. The suggested solution is to having pot plants to absorb noise.

The stand fan which generate large amount of noise are suggested to be replace by other ventilation device that release minimal amount of noises

In conclusion, the Ploy Restaurant has achieve marginal level in overall acoustic performance and can be achieve higher level of acoustical comfort through minimal space adjusment and additional devices.

4.0 REFERENCE

Audimute Soundproofing Beachwood. (2013). Retrieved October 12, 2014, from Riverbank Acoustic Laboratories, Alion Science and Technology: http://www.audimutesoundproofing.com/Images/pdf/Coated%20Eco%20SW%20Standard.pdf

Bnya, J. R. (2005). *Benya Lighting Design.* Retrieved from Ligthing Design Basic.

Cavanaugh, W. (2010). *Architectural Acoustic.* New Jersey: John Wiley & Sons.

Ciani, A. E. (2010). A Study of How Lighting Can Affect a Guest's ining Experience. *Graduate Theses and Disserations*, 17.

Classroom Acoustics Boooklet. (n.d.). Retrieved fromhttp://asa.aip.org/classroom/booklet.html

Descottes, H. (2011). *Architectural Lighting Designing with Light and Space.* New York: Princeton Architectural Press.

Downlight. (2014). Retrieved October 8, 2014, from Lighting Specialist Est: http://www.mr-resistor.co.uk/item.aspx?i=7876

Frable, F. (1995). Choose Quality, Not Quantity for Food Service. *Nation's Restaurant News*, 90-91.

Grondzik, W. T. (2010). Mechanical and electrical equipment for buildings. Hoboken, NJ: Wiley.

Hanson, C. (n.d.). Fundamentals of Acoustics. Retrieved from http://www.who.int/occupational_health/publications/noise1.pdf

Info Notice. (2014). Retrieved October 12, 2014, from West Coast Photo Group: http://www.meetup.com/West-Coast-Photo-Group-of-Florida/events/101090472/

Jouin, P. (2014). *Le Jules Verne*. Retrieved October 8, 2014, from Jouin Manku: http://www.patrickjouin.com/fr/projets/jouin-manku/1377-le-jules-verne.html

Le Jules Verne. (n.d.). Retrieved October 7, 2014, from Allian Ducasse: http://www.lejulesverne-paris.com/en

Le Jules Verne. (2013, November 20). Retrieved October 8, 2014, from amearquitetura: http://www.amearquitetura.com/2013/11/20/le-jules-verne/

L'Obervatoire International. (1993). Retrieved October 7, 2014, from Lighting Designers and Concultants: http://www.lobsintl.com/Portfolio_JLV_01.html

Nicklas, M. (2008). *Daylighting Strategies That Maximise Benefits.* Retrieved from Innovative Design: http://www.innovativedesign.net/files/Download/HPB_Daylighting%20Strategies%20That%20Maximize%20Benefits.pdf

Projects. (2014). Retrieved from Lights by Linea: http://lightsbylinea.com/index.php?route=product/category&path=89

Quaker Steak & Lube. (n.d.). Retrieved October 12, 2014, from Suede and Chrome Extra: http://www.suede-and-chrome.com/2009/11/suede-and-chrome-extra-quaker-steak.html

Radwan, R. (2006). *Restaurant Colour Psychology*. Retrieved October 8, 2014, from Alexandria: http://www.2knowmyself.com/miscellaneous/Restaurant_color_psychology

Reverberation Time - Acoustics.com. (n.d.). Retrieved fromhttp://www.reverberationtime.com/

Robertson, K. (n.d). *Daylighting Guide for Building.* Retrieved from Canada Mortgage and Housing Corporation: http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/upload/Daylighting-Guide-for-Buildings.pdf

Sound Proofing. (2014). Retrieved October 12, 2014, from Audimute: http://www.audimutesoundproofing.com/home-recording-studio-music-recording-studio-music-recording-studios.aspx

Soundproofing a Restaurant Case Study: Quaker Steak & Lube. (2014). Retrieved October 12, 2014, from Audimute Soundproofing: http://www.audimutesoundproofing.com/soundproofing-a-restaurant.aspx

Sound Transmission Class - STC & Sound Reduction Index - SRI, Wall Sound Transmission Control. (n.d.). Retrieved fromhttp://inspectapedia.com/.../Sound_Transmission_Class_STC...Truesdale A, Absorption Coefficients of Material

Southface Energy Institute et.al. (2012, December). *Efficient Lighting Strategies.* Retrieved from http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/26467.pdf

Szokolay, S. (2008). *Introduction to Architectural Science* (2nd ed.). London: Elsevier.

Top Hotels. (2014). Retrieved October 7, 2014, from Paris Travel Club Guide: http://girlsguidetoparis.com/insider/view.php?list=restaurants&restaurantID=69

Visa Lighting. (2014). Retrieved October 8, 2014, from Autodesk Seek: http://seek.autodesk.com/product/latest/agg/visalighting/Visa-Lighting/17650

Welcome to Quaker Steak & Lube. (2014). Retrieved October 11, 2014, from Quaker Steak & Lube: http://thelube.com/locations/west-virginia/wheeling/

5.0 APPENDIX

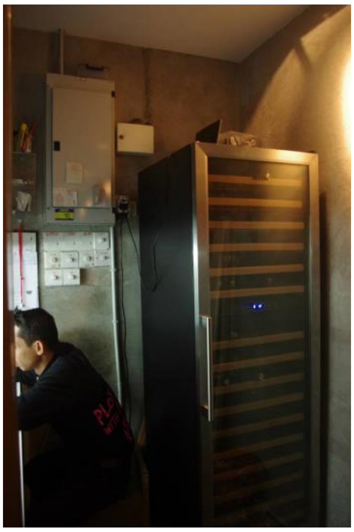


Figure 5.0.1: Staff working place beside bar area

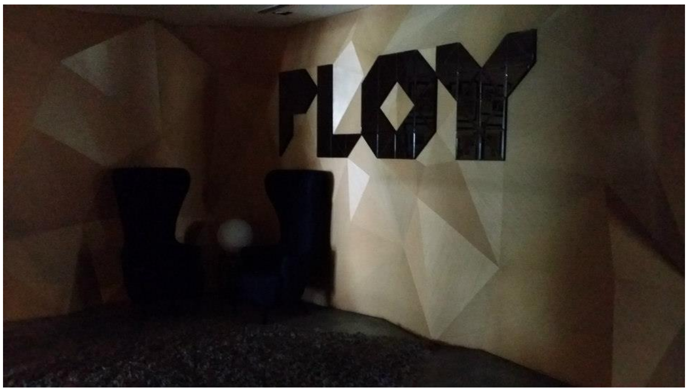


Figure 5.0.2: Lights off condition during non-working hour

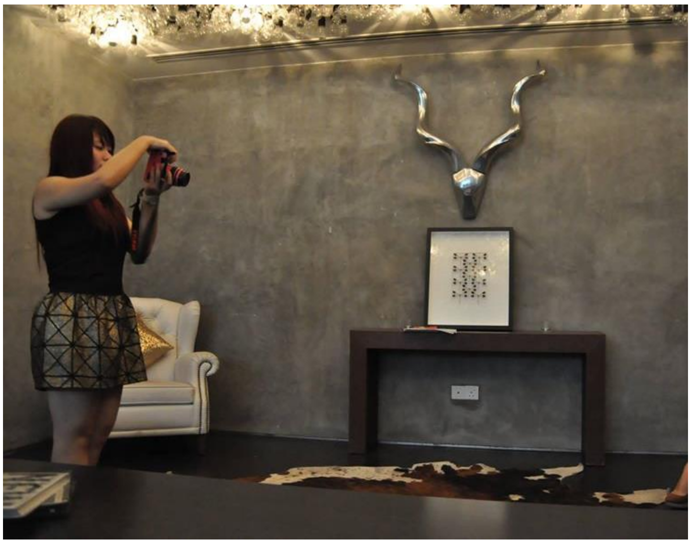


Figure 5.0.3: Photo of spaces were took for documentation purpose

Figure 5.0.4: Kitchen's condition

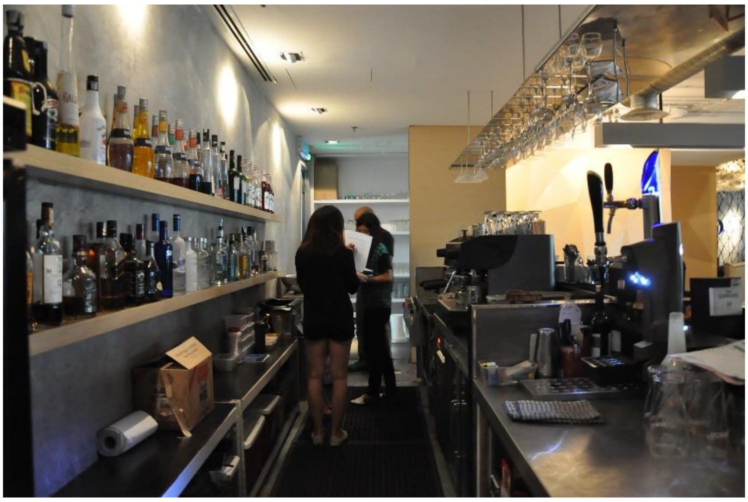


Figure 5.0.5: Information were jotted down

Figure 5.0.6: Group photo in lounge area

2.4 Lighting Analysis
2.4.1 Data of lighting
2.4.1.1 Daytime lux readings

TIME	17/9/2014	
	3pm-5pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
A1	1	4
A2	2	3
A3	2	3
A4	1	2
B1	5	4
B2	4	6
B3	4	4
B4	1	3
C1	17	10
C2	8	8
C3	6	9
C4	248	54
C5	26	15
C6	10	15
C7	10	20
C8	12	24
C9	18	26
C10	125	49
D1	16	13
D2	15	12
D3	18	10
D4	35	8
D5	18	18
D6	4	7
D7	8	7
D8	9	10
D9	15	34
D10	26	51
D11	40	93
E1	25	710
E2	30	30
E3	25	35
E4	15	31
E5	23	64
E6	11	11
E7	11	8
E8	989	2279
E9	35	36
E10	80	114
E11	46	73
F1	30	48
F2	20	39
F3	8	17
F4	12	16
F5	10	9

TIME	17/9/2014	
	3pm-5pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
F6	13	11
F7	13	9
F8	350	1570
F9	28	33
F10	44	49
F11	29	35
F12	7	14
F13	9	12
F14	9	12
F15	5	6
G1	258	522
G2	60	61
G3	426	942
G4	37	28
G5	18	23
G6	189	23
G7	13	10
G8	20	25
G9	23	26
G10	34	44
G11	20	15
G12	18	20
G13	20	24
G14	19	18
G15	8	13
H1	124	87
H2	75	64
H3	862	944
H4	83	37
H5	20	15
H6	26	19
H7	15	11
H8	495	2212
H9	59	25
H10	281	323
H11	22	25
H12	22	20
H13	20	25
H14	19	26
H15	7	11
I1	2009	2013
I2	2007	2009
I3	2008	2006
I4	67	64
I5	36	31

TIME	17/9/2014	
	3pm-5pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
I6	47	27
I7	31	23
I8	42	47
I9	37	18
I10	52	45
I11	30	34
I12	12	10
I13	10	9
I14	11	9
I15	20	25
J1	2014	2017
J2	2007	2012
J3	2007	2008
J4	189	82
J5	97	75
J6	433	55
J7	36	28
J8	40	92
J9	46	45
J10	43	35
J11	236	417
J12	12	13
J13	16	13
J14	20	15
J15	20	36
K1	2118	2080
K2	2071	2056
K3	2068	2045
K4	2673	2700
K5	83	62
K6	2019	2002
K7	2009	2009
K8	2018	2017
K9	2005	2004
K10	2012	2010
K11	27	16
K12	30	22
K13	82	89
K14	41	42
K15	50	57
L1	2235	2633
L2	2463	2713
L3	2578	2778
L4	2138	2036
L5	260	150

TIME	17/9/2014	
	3pm-5pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
L6	2017	2016
L7	2020	2015
L8	2024	2018
L9	2070	2063
L10	2033	2017
L11	177	144
L12	130	114
L13	160	67
L14	74	24
L15	65	55
M6	2434	2455
M7	2312	2307
M8	2188	2113
M9	2213	2314
M10	2292	2328
M11	2188	2247
M12	2130	2074
M13	2031	2017
M14	37	58
M15	25	39
N6	2481	2515
N7	2460	2501
N8	2331	2436
N9	2319	2412
N10	2275	2392
N11	2210	2321
N12	2151	2074
N13	2096	2035

Entrance Area
Services Area
Public Dining Area
Private Dining Area
Lounge Area
Outdoor Dining Area

Table 5.0.1: Daytime data tabulation for lighting analysis.

2.4 Lighting Analysis
2.4.1 Data of lighting
2.4.1.4 Night Time Lux Reading

TIME	17/9/2014 8pm-10pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
A1	43	32
A2	21	21
A3	19	18
A4	34	44
B1	586	345
B2	504	578
B3	49	20
B4	37	32
C1	78	158
C2	58	54
C3	298	425
C4	8	21
C5	8	25
C6	24	25
C7	15	21
C8	13	22
C9	8	24
C10	24	28
D1	63	50
D2	73	86
D3	54	63
D4	11	6
D5	18	21
D6	4	9
D7	4	10
D8	74	11
D9	10	11
D10	19	13
D11	30	24
E1	163	75
E2	189	188
E3	29	34
E4	15	15
E5	19	18
E6	8	8
E7	9	11
E8	8	15
E9	8	9
E10	36	25
E11	42	31
F1	28	31
F2	16	18
F3	9	14
F4	74	143
F5	19	14

TIME	17/9/2014 8pm-10pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
F6	9	14
F7	11	16
F8	12	15
F9	15	9
F10	11	9
F11	9	11
F12	19	15
F13	17	22
F14	17	18
F15	6	10
G1	218	574
G2	254	569
G3	24	21
G4	328	178
G5	24	32
G6	32	18
G7	28	15
G8	214	378
G9	19	11
G10	21	32
G11	17	18
G12	28	21
G13	28	32
G14	20	24
G15	8	15
H1	124	48
H2	32	42
H3	298	284
H4	652	512
H5	24	28
H6	28	38
H7	20	18
H8	26	18
H9	24	16
H10	32	34
H11	159	218
H12	17	18
H13	25	21
H14	24	28
H15	16	15
I1	96	124
I2	152	128
I3	98	118
I4	108	123
I5	35	98

TIME	17/9/2014 8pm-10pm	
HEIGHT	1m	1.5m
GRID/ZONE	LUX METER READING (lx)	
I6	68	41
I7	39	32
I8	74	158
I9	52	28
I10	22	28
I11	41	92
I12	14	10
I13	24	18
I14	16	21
I15	8	11
J1	109	125
J2	128	162
J3	96	186
J4	186	127
J5	38	95
J6	71	46
J7	47	47
J8	37	36
J9	78	139
J10	54	48
J11	128	168
J12	25	18
J13	9	10
J14	21	14
J15	8	13
K1	59	102
K2	58	125
K3	68	101
K4	47	95
K5	85	102
K6	49	84
K7	54	95
K8	68	86
K9	56	92
K10	62	91
K11	67	96
K12	25	38
K13	105	132
K14	58	250
K15	92	98
L1	45	105
L2	65	98
L3	58	85
L4	52	105
L5	57	102

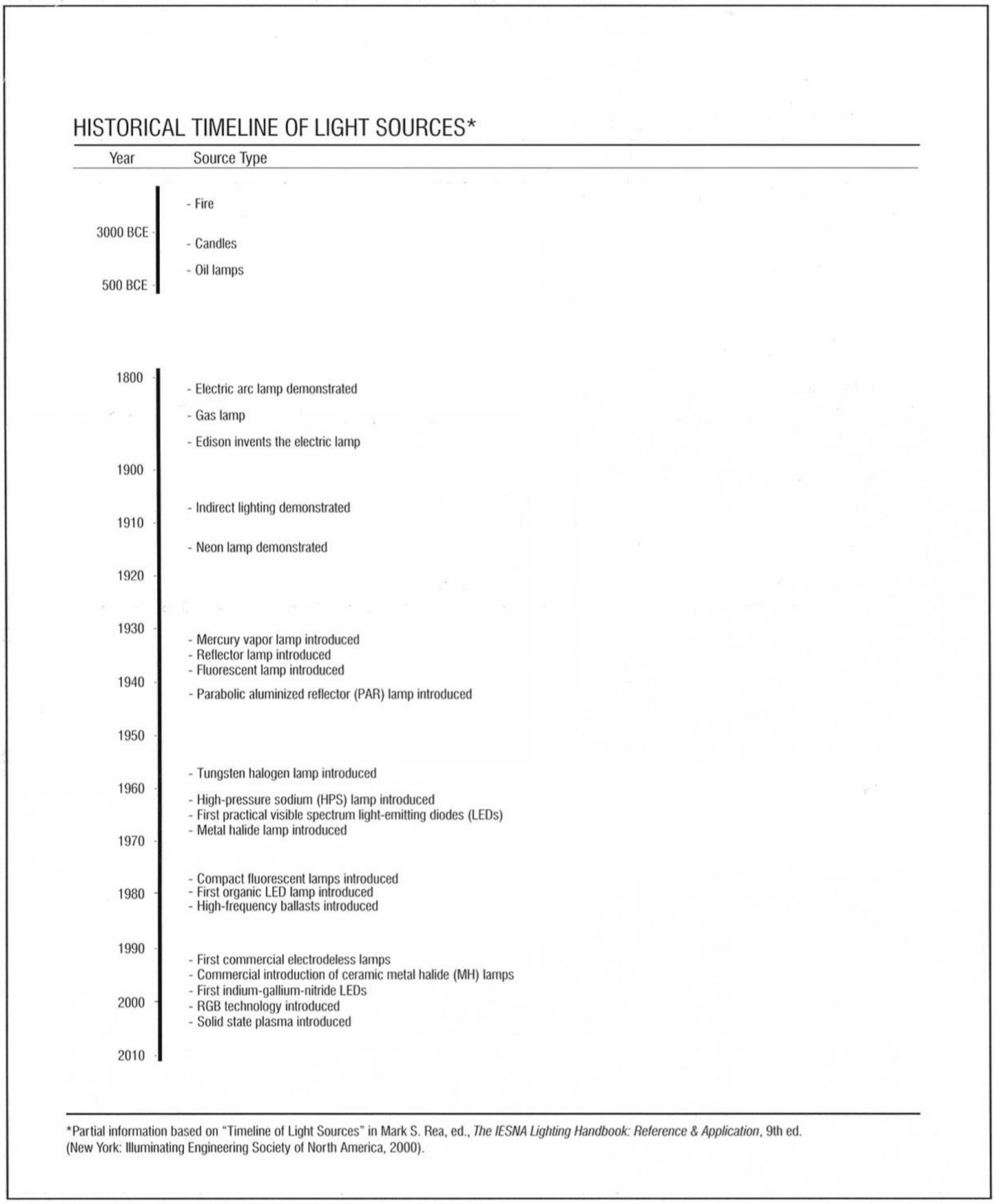
TIME	17/9/2014 8pm-10pm	
HEIGHT	17/9/2014	1.5m
GRID/ZONE	LUX METER READING (lx)	
L6	60	89
L7	64	94
L8	68	82
L9	59	92
L10	68	84
L11	62	88
L12	328	308
L13	186	114
L14	71	35
L15	84	98
M6	68	91
M7	62	96
M8	63	85
M9	59	92
M10	65	96
M11	58	116
M12	62	108
M13	68	91
M14	57	95
M15	54	87
N6	65	89
N7	62	97
N8	69	95
N9	58	105
N10	54	85
N11	69	98
N12	58	89
N13	53	84

- Entrance Area
- Services Area
- Public Dining Area
- Private Dining Area
- Lounge Area
- Outdoor Dining Area

Table 5.0.2: Nighttime data tabulation for lighting analysis.

ZONE ENTRANCE	Non-Peak Reading (dB)	Peak Reading (dB)	ZONE ROOM 3	Non-Peak Reading (dB)	Peak Reading (dB)	ZONE ROOM 4	Non-Peak Reading (dB)	Peak Reading (dB)	ZONE ROOM 4	Non-Peak Reading (dB)	Peak Reading (dB)	ZONE KITCHEN /BAR	Non-Peak Reading (dB)	Peak Reading (dB)
4O	59	61	13N	72	77	7L	64	75	9H	63	77	5K	60	71
5O	58	64	14N	74	80	8L	63	74	10H	61	79	6K	65	75
4N	58	62	15N	72	79	9L	63	73	11H	61	76	5J	60	72
5N	59	66	13M	72	76	10L	63	72	12H	60	75	6J	63	73
6N	60	67	14M	75	77	11L	64	73	7G	62	77	5I	62	72
7N	60	63	15M	72	77	12L	63	74	8G	63	68	6I	63	72
4M	59	62	13L	72	79	7K	63	70	9G	61	69	5H	63	73
5M	59	67	14L	75	76	8K	64	72	10G	60	66	6H	65	77
6M	60	69	15L	72	75	9K	63	69	11G	59	68	5G	63	76
7M	60	70	13K	73	75	10K	66	71	12G	59	67	6G	63	76
ROOM 1			14K	76	74	11K	64	70	7F	61	66	5F	66	77
8N	62	72	15K	75	73	12K	64	71	8F	63	65	**ROOM 7**		
9N	64	72	**ROOM 5**			7J	63	75	9F	63	63	11E	57	72
10N	62	68	14J	80	82	8J	63	74	10F	59	64	12E	52	68
8M	62	67	15J	73	81	9J	64	75	11F	59	62	11D	54	69
9M	64	69	14I	73	75	10J	63	75	12F	59	63	12D	53	70
10M	62	72	15I	72	76	11J	63	74	**ROOM 6**			13D	53	69
ROOM 2			14H	74	76	12J	62	74	8E	61	70	14D	53	71
11N	62	68	15H	73	75	7I	62	75	9E	58	69	11C	55	69
12N	65	70	14G	74	78	8I	63	76	10E	55	63	12C	52	69
11M	64	69	15G	73	77	9I	63	75	9D	47	64	13C	53	70
12M	64	71	13F	73	76	10I	61	77	10D	49	65	14C	53	72
			14F	72	75	11I	61	75	9C	47	65	11B	52	72
			15F	73	73	12I	60	74	10C	47	65	12B	49	71
			15E	71	74	7H	62	75	9B	47	64	13B	51	69
			15D	72	75	8H	63	77	10B	47	64	14B	52	68

Table 5.0.3: Data tabulation for acoustic analysis.

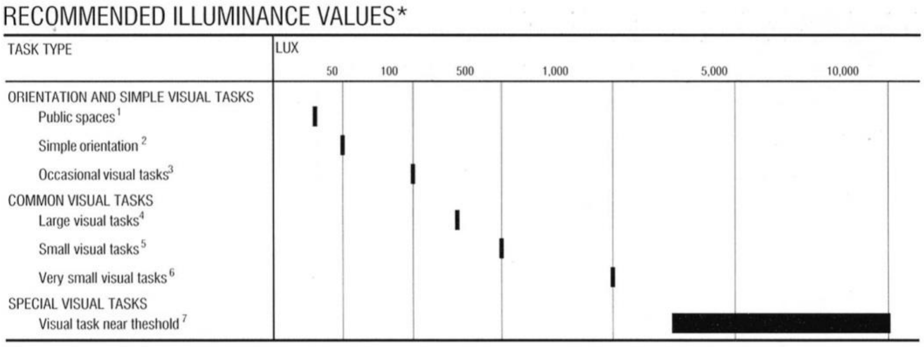


HISTORICAL TIMELINE OF LIGHT SOURCES*

Year	Source Type
	- Fire
3000 BCE	- Candles
	- Oil lamps
500 BCE	
1800	- Electric arc lamp demonstrated
	- Gas lamp
	- Edison invents the electric lamp
1900	
	- Indirect lighting demonstrated
1910	
	- Neon lamp demonstrated
1920	
1930	- Mercury vapor lamp introduced - Reflector lamp introduced - Fluorescent lamp introduced
1940	- Parabolic aluminized reflector (PAR) lamp introduced
1950	
	- Tungsten halogen lamp introduced
1960	- High-pressure sodium (HPS) lamp introduced - First practical visible spectrum light-emitting diodes (LEDs) - Metal halide lamp introduced
1970	
1980	- Compact fluorescent lamps introduced - First organic LED lamp introduced - High-frequency ballasts introduced
1990	- First commercial electrodeless lamps - Commercial introduction of ceramic metal halide (MH) lamps - First indium-gallium-nitride LEDs
2000	- RGB technology introduced - Solid state plasma introduced
2010	

*Partial information based on "Timeline of Light Sources" in Mark S. Rea, ed., *The IESNA Lighting Handbook: Reference & Application*, 9th ed. (New York: Illuminating Engineering Society of North America, 2000).

Figure 5.0.7: Historical timeline of light sources (Source: Descottes, 2011)



1 Spaces such as inactive storage
2 Spaces such as lobbies, corridors, elevators, stairs
3 Spaces such as active storage, locker rooms, office lounges/reception, school auditoriums
4 Spaces such as restrooms, general office spaces, conference rooms, classrooms
5 Spaces such as accounting offices, science laboratories
6 Tasks such as drafting (low contrast), lecture demonstration, or store feature displays
7 Where supplementary task lighting is necessary, i.e., dentistry work or medical operations
* Data based on "Determination of Illuminance Categories" in Mark S. Rea, ed., *The IESNA Lighting Handbook: Reference & Application*, 9th ed. (New York: Illuminating Engineering Society of North America, 2000).

Figure 5.0.8: Recommended illuminance values (Source: Descottes, 2011)

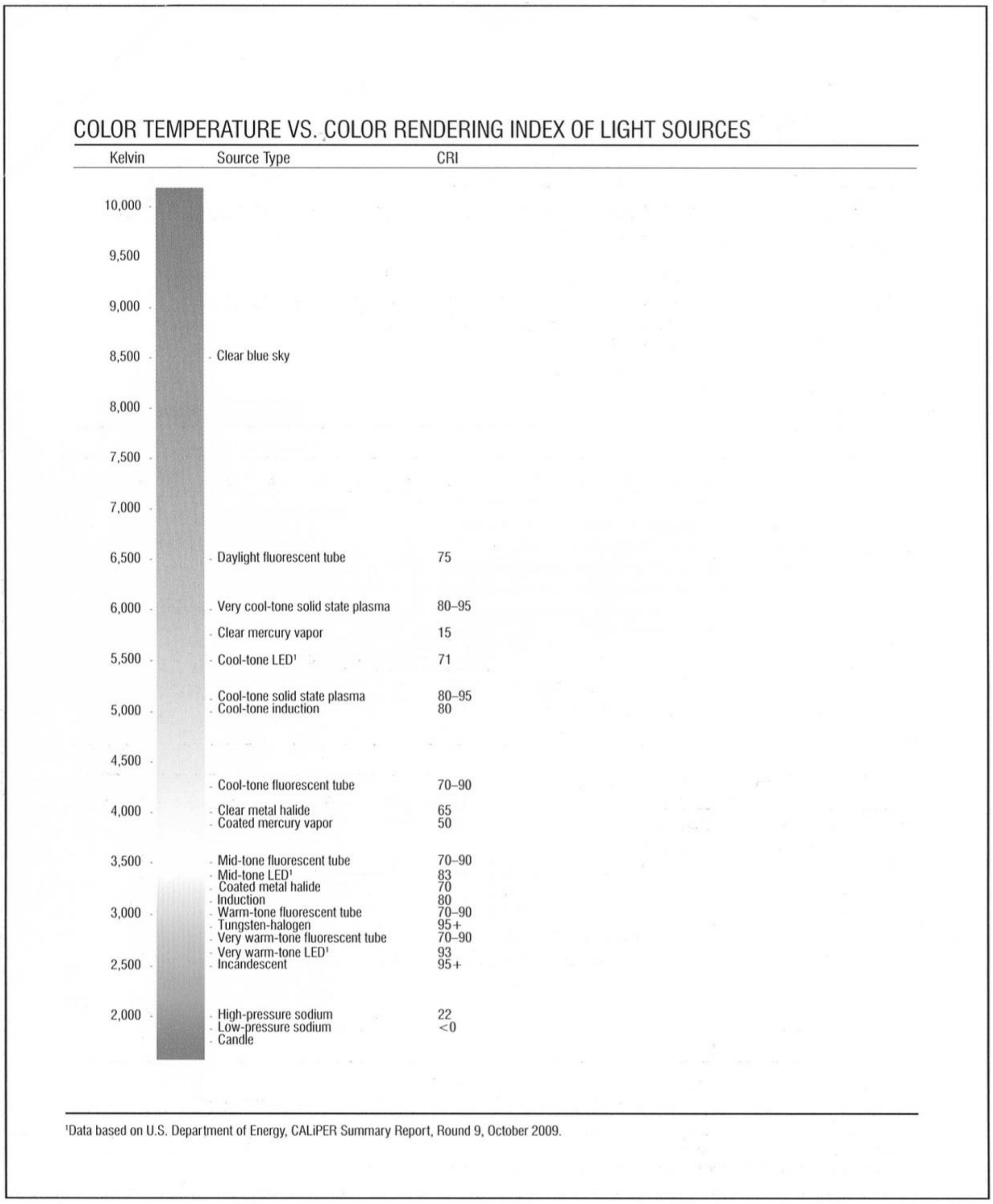


Figure 5.0.9: Colour temperature vs colour rendering index of light sources(Source: Descottes, 2011)

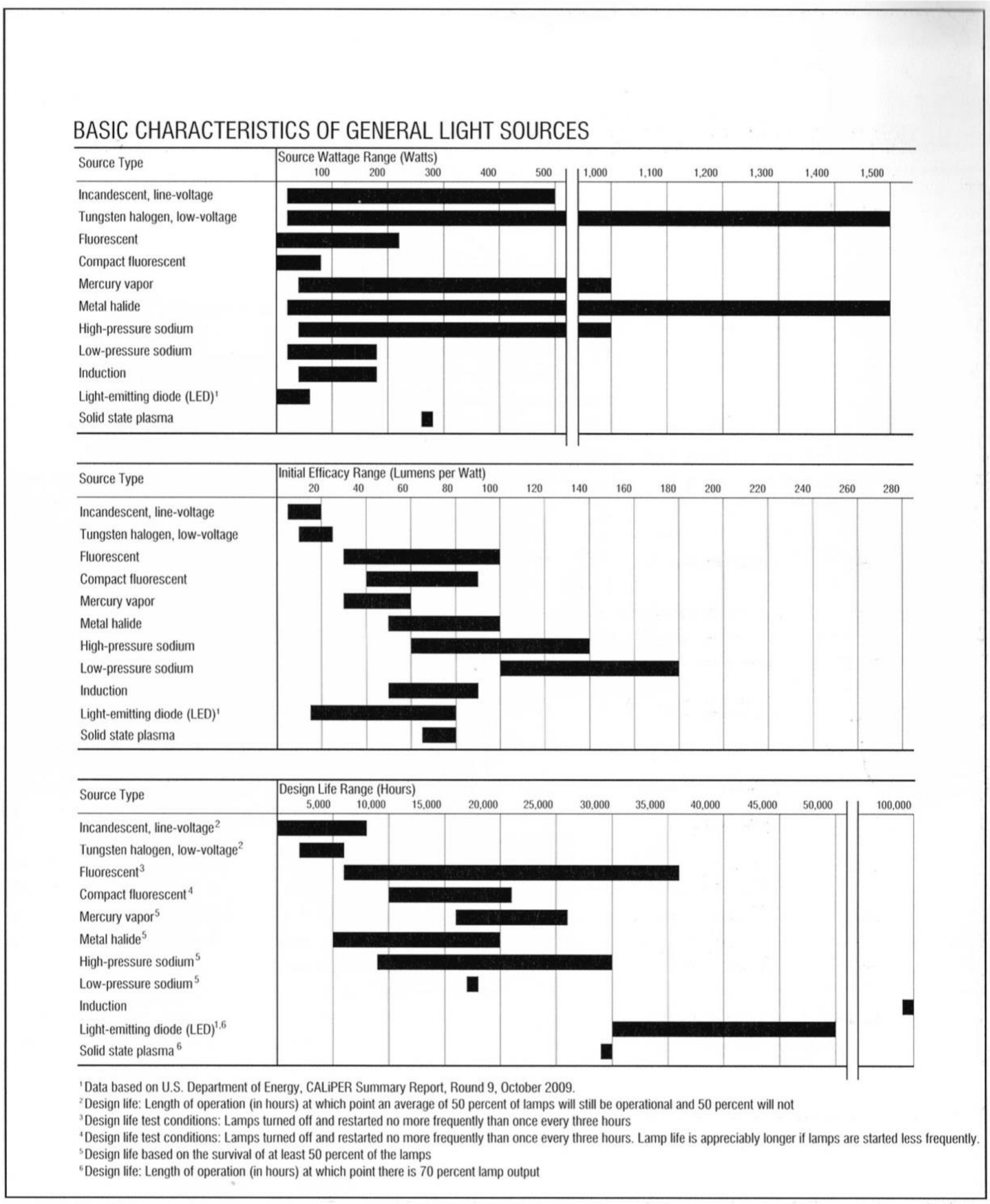


Figure 5.0.10: Basic characteristics of general light sources (Source: Descottes, 2011)

DATA SHEET D.3.1

Noise rating (NR) and speech interference level (SIL)

Room usage		*Maximum NR*
Broadcasting and recording studios		15
Concert halls		15
Theatres, intimate		20
Theatres, large		25
Music rooms		20–25
TV studios		20–25
Churches		25
Law courts		25
Lecture theatres without amplification		25
Cinemas		25
Classrooms		30
Hospital wards or operating theatres		30
Hospital day rooms or treatment rooms		35
Restaurants, intimate		35
Restaurants, large		45
Shops, sophisticated		35
Department stores		40
Supermarkets		45
Shops, general		50
Banks		50
Offices:	Executive	20
	Conference room (maximum 50 person)	25
	private offices	30
	reception rooms	30
	conference room (max.15 persons)	35
	General office	40–45
	Keyboard operators, printers	50–55
Dwellings		25–35
	Living area	30
	Bedrooms	25
Hotels	Preferable	25
	Acceptable	35

Speech interference level limits

Listening distance	*Maximum SIL (dB)*
0.2 m	69
0.4 m	63
0.6 m	59
1.0 m	54
2.0 m	48
3.0 m	45
4.0 m	42
Adjustments	
For female voice	−5 dB
For raised voice	+6 dB
For very loud voice	+12 dB
For shouting	+18 dB

Figure 5.0.11: Dada sheet for noise rating (NR) and speech interference level (SIL) (Source: Szokolay, 2008)

DATA SHEET D.3.2

Attenuation by ground cover (tree-belts) and absorption in air

Attenuation in dB per 100 m distance

Ground cover	*125 Hz*	*250 Hz*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*
Thin grass, 0.1–0.2 m	0.5	0.5	1	3	3	3
Thick grass, 0.4–0.5 m	0.5	0.5	0.5	12	14	15
Evergreen trees	7	11	14	17	19	20
Deciduous trees	2	4	6	9	12	16

Absorption in air in dB per 100 m distance

Climatic conditions		*1000 Hz*	*2000 Hz*	*4000 Hz*	*8000 Hz*
21°C	40% RH	0.3	1.3	3.3	13
	60% RH	0.3	0.6	1.6	8
	80% RH	0.3	0.6	1.6	5
2°C	40% RH	1	3.3	5	8
	60% RH	0.6	1.6	5	13
	80% RH	0	0.3	3.3	8

Figure 5.0.12: Dada sheet for attenuation by ground cover (tree-belts) and absorption in air (Source: Szokolay, 2008)

DATA SHEET D.3.3

Transmission loss (dB) of some constructions

	Average (Hz)	*Octave centre frequencies*					
		125 Hz	*250 Hz*	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*
Walls							
1 110 mm brick, plastered	45	34	36	41	51	58	62
2 150 mm concrete	47	29	39	45	52	60	67
3 220 mm brick, plastered	50	41	45	48	56	58	62
4 330 mm brick, plastered	52	44	43	49	57	63	65
5 130 mm hollow concrete blocks	46	36	37	44	51	55	62
6 75 mm studs, 12 mm plaster boards	40	26	33	39	46	50	50
7 75 mm studs, 6 mm ply both sides	24	16	18	26	28	37	33
8 Same but staggered separate studs and ply	26	14	20	28	33	40	30
Floors							
9 T&G boarding, plasterboard ceiling	34	18	25	37	39	45	45
10 Same but boards floating on glass wool	42	25	33	38	45	56	61
11 Same but 75 mm rock wool on ceiling	39	29	34	39	41	50	50
12 As 10 + 75 mm rock wool on ceiling	43	27	35	44	48	56	61
13 As 10 + 50 mm sand pugging	49	36	42	47	52	60	64
14 125 mm reinforced concrete slab	45	35	36	41	49	58	64
15 As 14 + floating screed	50	38	43	48	54	61	65
16 150 hollow pot slab + T&G boar233ds	43	36	38	39	47	54	55
Windows							
17 Single glazed, normal	22	17	21	25	26	23	26
18 Double 4 mm glass, 200 absorber reveals	39	30	35	43	46	47	37
19 Same but 10 mm glass panes	44	31	38	43	49	53	63
Partitions							
20 Two sheets 10 mm ply, 38 mm cavity		20	25	23	43	47	
21 Same + 10 kg/m^2 lead on inside faces		25	31	38	57	62	
22 Same but also fibreglass absorber in cavity		29	42	49	59	63	
23 Studs, 10 mm plasterboard both sides		16	35	38	48	52	37
24 Same + 13 mm fibreglass under plasterboard		22	39	46	56	61	50
25 Same but staggered independent frames		34	40	53	59	57	58
26 75 mm studs, 2 × (5 mm hardboard)		12	21	25	40	46	48
27 Same but 2 × (13 mm softboard)		15	25	37	51	51	51
28 100 mm studs, 2 × (5 mm hardboard)		9	19	28	39	51	60
29 Same but 2 × (6 mm hardboard)		13	30	32	38	41	44
30 200 mm hollow concrete blocks		35	35	40	47	54	60
31 100 mm precast concrete panel		36	39	45	51	57	65
32 110 mm brick, 2 × (12 render, 50 × 12 battens, 12 softboard with bonded 6 mm hardboard)		35	43	54	65	73	80
Doors							
33 50 mm solid timber, normally hung	18	12	15	20	22	176	24
34 Same but airtight gaskets	22	15	18	21	26	25	28
35 50 mm hollow core, normally hung	15						
36 Same but airtight gaskets	20						
37 Double 50 mm solid timber, airtight gaskets, absorbent space (lobby)	45						
Sheets							
38 50 mm glass wool slab (26 kg/m^2)	30	27	23	27	34	39	41
39 Corrugated fibrous cement (34 kg/m^2)	34	33	31	33	33	42	39
40 25 mm plasterboard (2 × 12.5 laminated)	30	24	29	31	32	30	34
41 50 mm plasterboard (4 × 12.5 laminated)	37	28	32	34	40	38	49

Figure 5.0.13: Dada sheet for transmission loss (dB) of some constructions (Source: Szokolay, 2008)

DATA SHEET D.3.4

Absorption coefficients (a) of materials and components

	Octave centre frequency		
	125 Hz	*500 Hz*	*2000 Hz*
Building materials			
Boarded underside of pitched roof	0.15	0.1	0.1
Boarding on 20 mm battens on solid wall	0.3	0.1	0.1
Exposed brickwork	0.05	0.02	0.05
Clinker concrete exposed	0.2	0.6	0.5
Concrete or tooled stone	0.02	0.02	0.05
Floor: cork, lino, vinyl tiles, wood blocks (parquetry)	0.02	0.05	0.1
25 mm cork tiles on solid backing	0.05	0.2	0.6
13 mm softboard on solid backing	0.05	0.15	0.3
Same but painted	0.05	0.1	0.1
13 mm softboard on 25 mm battens on solid wall	0.3	0.3	0.3
Same but painted	0.3	0.15	0.1
Floor: hard tiles or cement screed	0.03	0.03	0.05
Glass in windows, 4 mm	0.3	0.1	0.05
Same but 6 mm in large panes	0.1	0.04	0.02
Glass or glazed ceramic wall tiles, marble	0.01	0.01	0.02
Plastering on solid backing (gypsum or lime)	0.03	0.02	0.04
Plaster on lath, air space, solid backing	0.3	0.1	0.04
Plaster or plasterboard ceiling, large air space	0.2	0.1	0.04
Plywood or hardboard on battens, solid backing	0.3	0.15	0.1
Same but porous absorbent in air space	0.4	0.15	0.1
Exposed water surface (pools)	0.01	0.01	0.02
Timber boarding on joists or battens	0.15	0.1	0.1
Common absorbers			
25 mm sprayed fibres on solid backing	0.15	0.5	0.7
Carpet, e.g. Axminster, thin pile	0.05	0.1	0.45
Same, medium pile	0.05	0.15	0.45
Same, thick pile	0.1	0.25	0.65
Carpet, heavy, on thick underlay	0.1	0.65	0.65
Curtain, medium fabric, against solid backing	0.05	0.15	0.25
Same but in loose folds	0.05	0.35	0.5
25 mm glass wool on solid backing, open mesh cover	0.15	0.7	0.9
Same with 5% perforated hardboard cover	0.1	0.85	0.35
Same with 10% perforated or 20% slotted cover	0.15	0.75	0.75
50 mm glass wool on solid backing, open mesh cover	0.35	0.9	0.95
Same with 10% perforated or 20% slotted hardboard cover	0.4	0.9	0.75
3 mm hardboard, bit felt backing on 50 mm air space on solid wall	0.9	0.25	0.1
Two layers bituminous felt on 250 mm air space, solid backing	0.5	0.2	0.1
25 mm polystyrene slab on 50 mm air space	0.1	0.55	0.1
50 mm polyurethane foam on solid backing	0.25	0.85	0.9
25 mm wood wool slabs on solid backing	0.1	0.4	0.6
Same but on 25 mm battens	0.15	0.6	0.6
Same but plastered, mineral wool in cavity	0.5	0.2	0.1
Proprietary absorbers			
6 mm fibrous cement sheet on battens	0.23	0.5	0.2
Burgess perforated metal tiles, 38 mm glass wool	0.15	0.7	0.8
Caneite, 20 mm softboard tiles on solid wall	0.15	0.45	0.8
Celotex 13 mm perforated tiles on solid wall	0.1	0.4	0.45
Same but on 25 mm battens	0.1	0.45	0.4

Figure 5.0.14: Dada sheet for absorption coefficient (a of materials and components (Source: Szokolay, 2008)

DATA SHEET D.3.5

Absorption coefficients (a) continued and Abs of room contents

	Octave centre frequency		
	125 Hz	*500 Hz*	*2000 Hz*
Proprietary absorbers (continued)			
Same but 32 mm thick, on 25 mm battens	0.25	0.85	0.55
Echostop perforated plaster tiles, 22 mm mineral wool	0.45	0.8	0.65
Euphone glass wool quilt, 25 mm on 25 mm battens	0.3	0.85	0.85
Same but 38 mm in wire netting	0.5	0.9	0.9
Fibreglass 25 mm, resin bonded mat on 25 mm battens	0.1	0.55	0.75
Same but 50 mm tick on 50 mm battens	0.2	0.7	0.75
Fibreglass, 25 mm tiles on solid wall	0.1	0.6	0.6
Frenger perforated metal panel 20 mm glass wool	0.2	0.65	0.35
Gypklith 25 mm wood wool tiles on 25 mm battens	0.1	0.6	0.6
Gyproc 10 mm perforated plasterboard on 50 mm battens	0.1	0.4	0.15
Gyproc slotted plaster tiles on 50 mm battens	0.05	0.25	0.15
Same with 25 mm fibreglass backing	0.15	0.8	0.25
Paxfelt fibrous cement, 25 mm on 25 mm battens	**0**	0.55	0.7
Paxtile, perforated fc sheet, 13 mm on 50 mm battens	0.2	0.5	0.75
Perfonit perforated wood fibre tile, 25 mm air space	0.2	0.7	0.75
Semtex 25 mm resin board on 25 mm battens	0.2	0.5	0.3
Stramit 50 mm strawboard on 50 mm battens	0.25	0.35	0.45
Thermacoust wood wool slab, 50 mm on solid wall	0.2	0.8	0.75
Tyrolean Callumix plaster, 13 mm on solid wall	0.05	0.15	0.35
Same but 20 mm	0.1	0.2	0.45
Unitex, perforated wood fibre tile, 13 mm	0.2	0.6	0.65
Same but 20 mm thick	0.25	0.65	0.8
W Callum muslin covered felt on solid wall	**0**	0.75	0.7
W Callum perforated metal + 75 mm rock wool in calico	0.4	0.2	0.15
Room contents absorption (Abs) in m^2 open window units			
Air (per m^3)	0	0	0.007
Audience in upholstered seats (per person)	0.186	0.4765	0.51
Audience in wooden or padded seats (per person)	0.158	0.4	9.436
Seat, unoccupied, upholstered	0.121	0.279	0.316
Seat, unoccupied, wooden, padded or canvas	0.075	0.149	0.177
Orchestral player with instrument (average)	0.37	1.07	1.21
Note			
The floor absorption should be reduced, if 'shaded' by seats (its effectiveness is reduced) by	20%	40%	60%

Figure 5.0.15: Dada sheet for absorption coefficient 9A) continued and Abs of room contents (Source: Szokolay, 2008)

DATA SHEET D.3.6

Sound insulation of floors

Insulation for airborne sound is given in terms of TL (transmission loss), same as for walls (e.g. as in data sheet D.3.3). Impact noise insulation is measured as the sound level transmitted when impact is generated by a standard tapping machine. Only two grades are distinguished (in the UK) as indicated by the graph below (ISO standard is shown for comparison).

	TL (dB)	
Concrete slab⁺, floating screed	>48	Grade I
Concrete slab, floating wood raft	>48	Grade I
Heavy* concrete slab, soft finish	>48	Grade I
Concrete slab, suspended ceiling	>48	Grade I
Concrete, lightweight screed, soft finish	>48	Grade I
Concrete trough beam, floating screed, plasterboard ceiling	>48	Grade I or II
Wood joists, floating raft, sand pugging	>48	Grade I
Concrete, hard finish	45	Grade II
Same, plus suspended ceiling	48	Worse than grade II
Concrete, soft finish	45	Grade I
Concrete, hard finish, lightweight screed	48	Worse than grade II
Heavy* concrete, hard finish	48	Worse than grade II
Concrete, hard finish	42	Worse than grade II
Concrete, hard finish, suspended ceiling	45	Worse than grade II
Concrete, timber finish	48	Worse than grade II
Steel beam, timber floor, soft finish with suspended ceiling	48	Grade I
Wood joists, wood floor, plasterboard ceiling	35	Worse than grade II
Wood joists, wood floor, lath and plaster ceiling	40–45	Worse than grade II
Same with sand pugging	45–48	Grade II
Steel joists, precast concrete units, lightweight screed, soft finish, suspended ceiling	49	Grade I

*Heavy: $>365\ kg/m^2$.
⁺Normal: $>220\ kg/m^2$.

Figure 5.0.16: Dada sheet for Sound insulation of floors (Source: Szokolay, 2008)