Lighting System Design

ELECTENG 310 - Project 2

Team 2

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Commissioned by Eco Design Ltd

2nd June 2022

The Design Team

Project team

The design team for this project consists of 4 undergraduate electrical engineering students. Their images and names are as follows:

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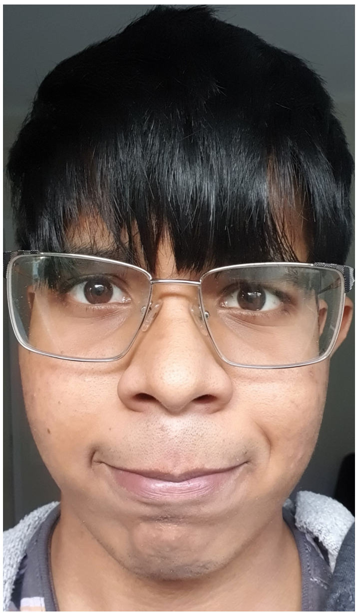

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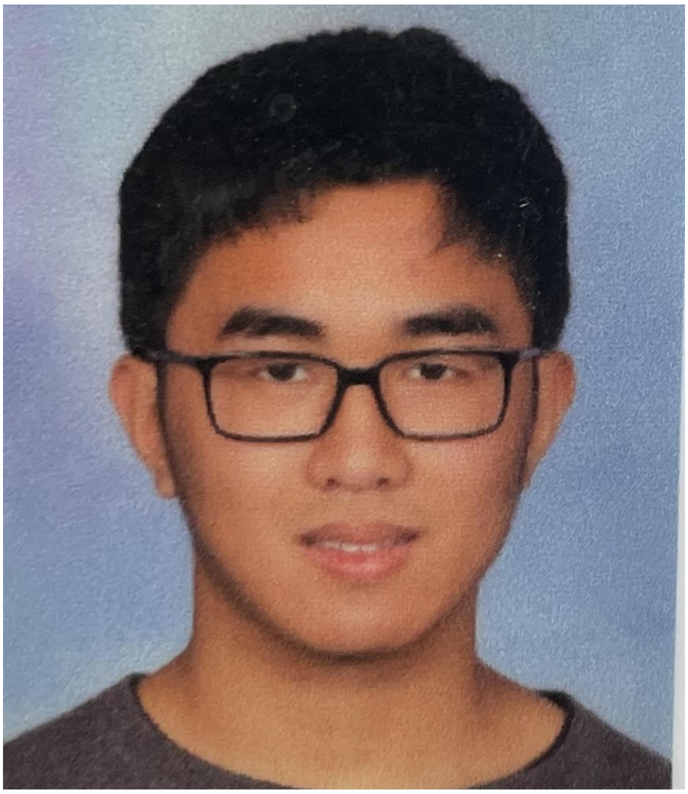

Role and responsibility

The entire building was divided into quarters and each team member was assigned and expected to populate these quarters with appropriate luminaires. All team members are expected to contribute equally to the workload consisting of evaluating and selecting luminaires, checking each other's work and report writing.

Task

The task at hand consists of replacing all of the existing luminaires due to its inefficient use of power, illuminance and uniformity not meeting the standards set by AS/NZS 1680.1 [1].

Abstract

In this report, commissioned by Eco Design Ltd, is an evaluation of the existing lighting system and proposed replacement lighting system for the building looking to be purchased. The system is based on current LED technology, and has been designed to minimise operating costs and CO2 emissions, while providing quality lighting to the building. The lighting design has been evaluated based on compliance with standards AS/NZS 1680. The proposed design also includes emergency lighting, which is essential in ensuring that the building complies with New Zealand Building Code standards. Simulation software was used to evaluate the existing lighting system and validate the proposed lighting system, and the results are presented.

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1.0 Introduction

1.1 Client Requirements

The client for this project is Tony Tavita from Eco Design Ltd. The client intends to purchase a new building with the intention of expanding global partnerships, having secured contracts for the next 10 years. The building consists of a variety of rooms, including office spaces and CAD rooms, The client is looking to evaluate and potentially replace the existing lighting system, which contains outdated fluorescent luminaires. This project will involve a condition assessment of the existing lighting system and a proposed replacement design for levels 1 and 2 of the building and the stairs. This proposed design will include modern LED technology, which is significantly more efficient. In addition, the proposed design will include an emergency evacuation lighting design which is used in the event of a fire or loss of power to the building.

The primary goal of the proposed lighting design is to minimise the cost of operation and maintenance and to minimise CO_2 emissions of the system. This means that, in this project, CO_2 emissions must be considered for the existing design and minimised for the proposed design. Also, the lamp recycling cost needs to be minimised, and a break even cost for installing the proposed design must not exceed 15 years.

The proposed design must also comply with AS/NZS 1680 lighting standards. This includes maintaining a minimum uniformity specified in Table 3.2 of AS/NZS 1680.1 [1]; maintaining a minimum average illuminance specified in Table D1 of AS/NZS 1680.2.1 [2] and Table E1 of AS/NZS 1680.2.2 [3]. Also, the emergency lighting system must comply with minimum illuminance requirements specified in section 1.3 of Clause F6 Compliance Document for New Zealand Building Code [4]. The evaluation of the proposed design is to be carried out using Light Loss factors calculated at 50,000 hours.

1.2 Tools Used

In this project, DIALux 4.13 was used to evaluate the existing lighting system and design the proposed lighting system. Github and Google Drive were used for storing and sharing project files among the team.

1.3 Design Methodology

The design process began with looking at the existing lighting system and evaluating the illuminance and uniformity against AS/NZS standards. From there, a proposed lighting system design was constructed, using current LED technology. DIALux was used to iteratively evaluate and refine the design, in terms of illuminance, uniformity, cost and CO2 emissions, among other key client requirements. Various iterations were tested to ensure that the design was at its full potential.

2.0 Existing Lighting System Condition Assessment

As per the client's requirements, an evaluation was carried out in order to quantify the performance of the existing luminary design. This evaluation covers the CO_2 emissions, operational and disposal costs and luminary performance according to the standards set by AS/NZS 1680 [1].

2.1 Illuminance & Uniformity

The results of the luminary performance evaluation of different sections of the building were tabulated, the results of which can be seen in Appendix A.

Overall, this report finds that there are many sections of the building that do not meet the maintained illuminance and uniformity standards set by AS/NZS 1680 [1]. It can also be seen that there are also some sections that 'overperform' where certain illuminances are much higher than the standard which causes inefficient power consumption.

2.2 Operational & Waste Management Costs & CO_2 Emissions

An evaluation of the operational costs and power efficiency of the existing lighting system was conducted, the results of which can be seen in Table 1.

Table 1: Tabulated evaluation of Costs & Emissions.

	Level 1	Level 2	Stairs	Total:
Total power [W]:	9144	7296	228	16668
Annual energy usage [kWh]:	30,175	24,077	752.4	55004.4
Annual CO2 emission [kg]:	2926.98	2335.47	72.98	5335.43
Number of T8 lamps:	246	192	6	444
Lamp recycling cost [$]:	327.49	248.89	10.37	586.75

From the data shown in Table 1, it can be seen that the existing lighting system has a power consumption of 55,000 kWh resulting in over 5 tons of CO_2 emissions to be produced each year according to the figures derived at Table 9 by the Ministry for the environment (2020) [6].

2.3 Emergency Lighting

This report also finds that the current lighting system does not include emergency lighting. This is a significant safety risk to all occupants of the building in the event of an evacuation and does not meet New Zealand Building code standards [4] which, according to the New Zealand Government, could potentially incur legal consequences to the client.

3.0 Proposed Lighting System Design

The proposed design consists of LED luminaire arrangements and is presented in the following sections.

3.1 Floor 1 Base Lighting Design

Fig. 1 shows the luminaire layout for Floor 1 base lighting. The orange grid shows the modulated ceiling on Floor 1. All luminaire arrangements were designed to be compatible with modulated ceilings measuring 1200*600mm as seen in Fig.1. Refer to Appendix B for the luminaires used.

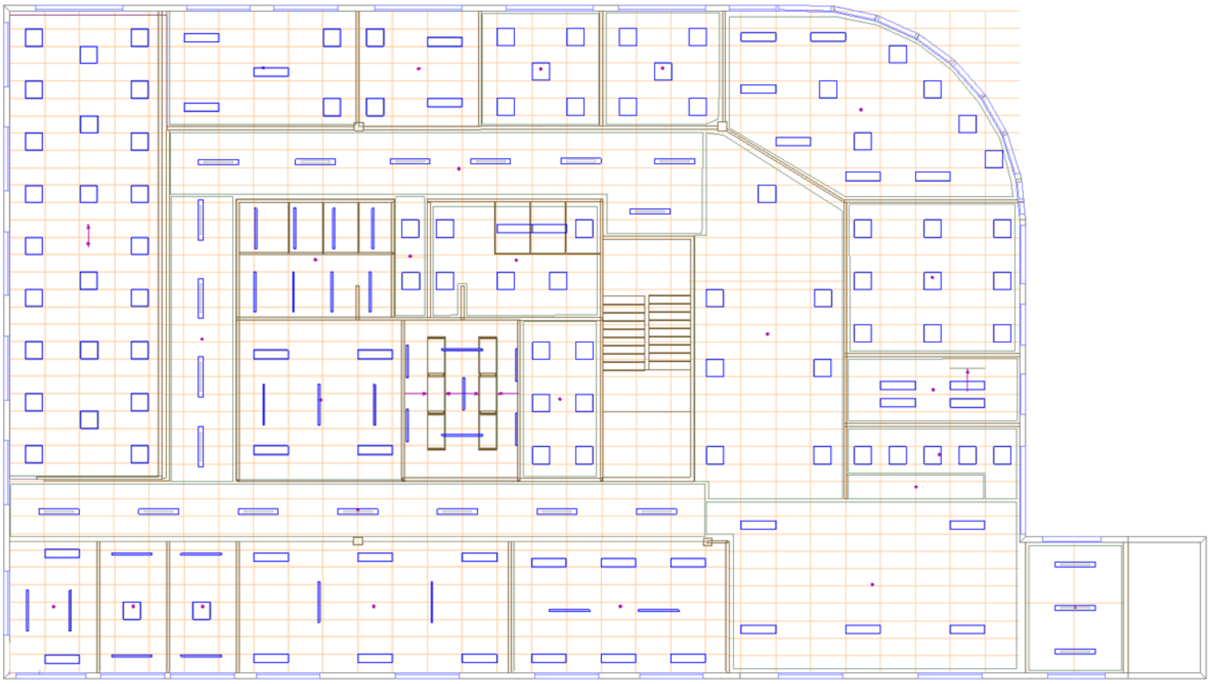

Fig. 1: Luminaire layout for Floor 1 base lighting

3.2 Floor 2 Lighting Design

Fig. 2 shows the luminaire layout for Floor 2 base lighting. Note that this level does not include a modulated ceiling, however the ceiling is higher on Floor 2 compared to Floor 1. As such, suspended luminaires were primarily used on this floor. Refer to Appendix C for the luminaires used.

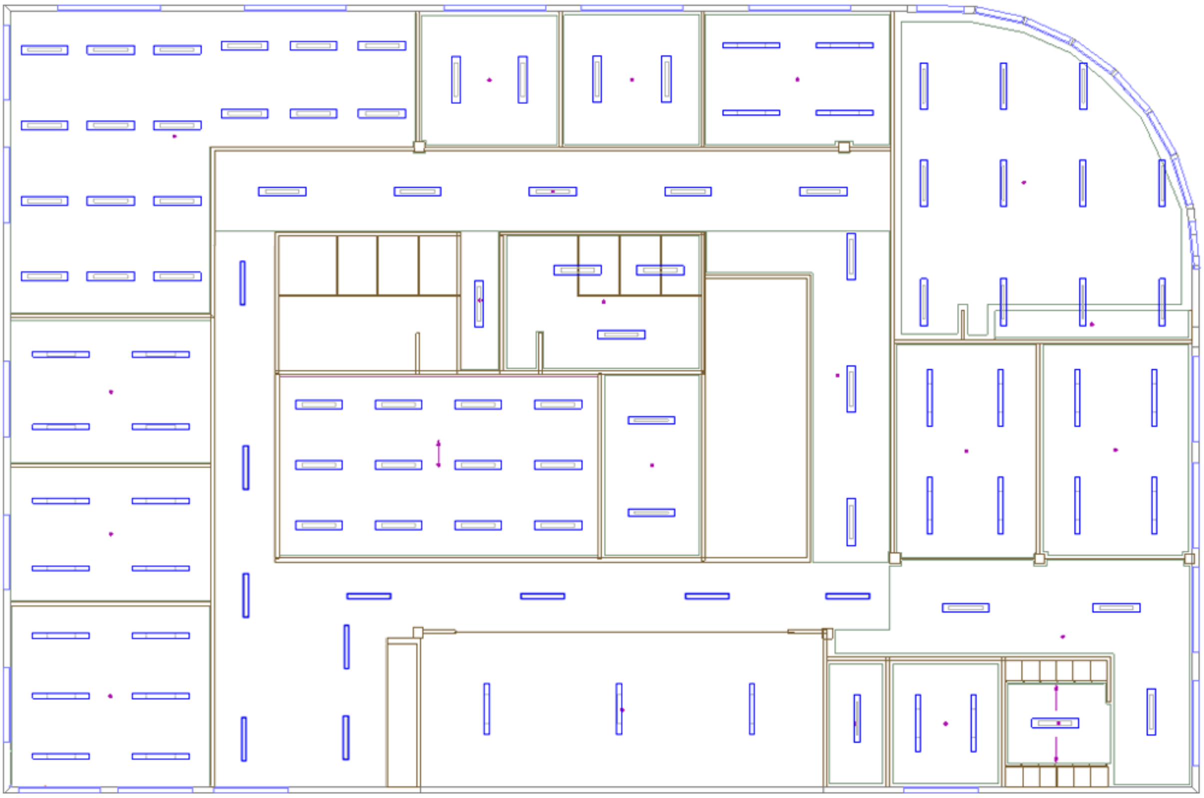

Fig. 2: Luminaire layout for Floor 2 base lighting

3.3 Stairs Lighting Design

Fig. 3 shows the luminaire layout for the stairs base lighting. To maximise uniformity wall mounted luminaires are used. Refer to Appendix D for the luminaires used.

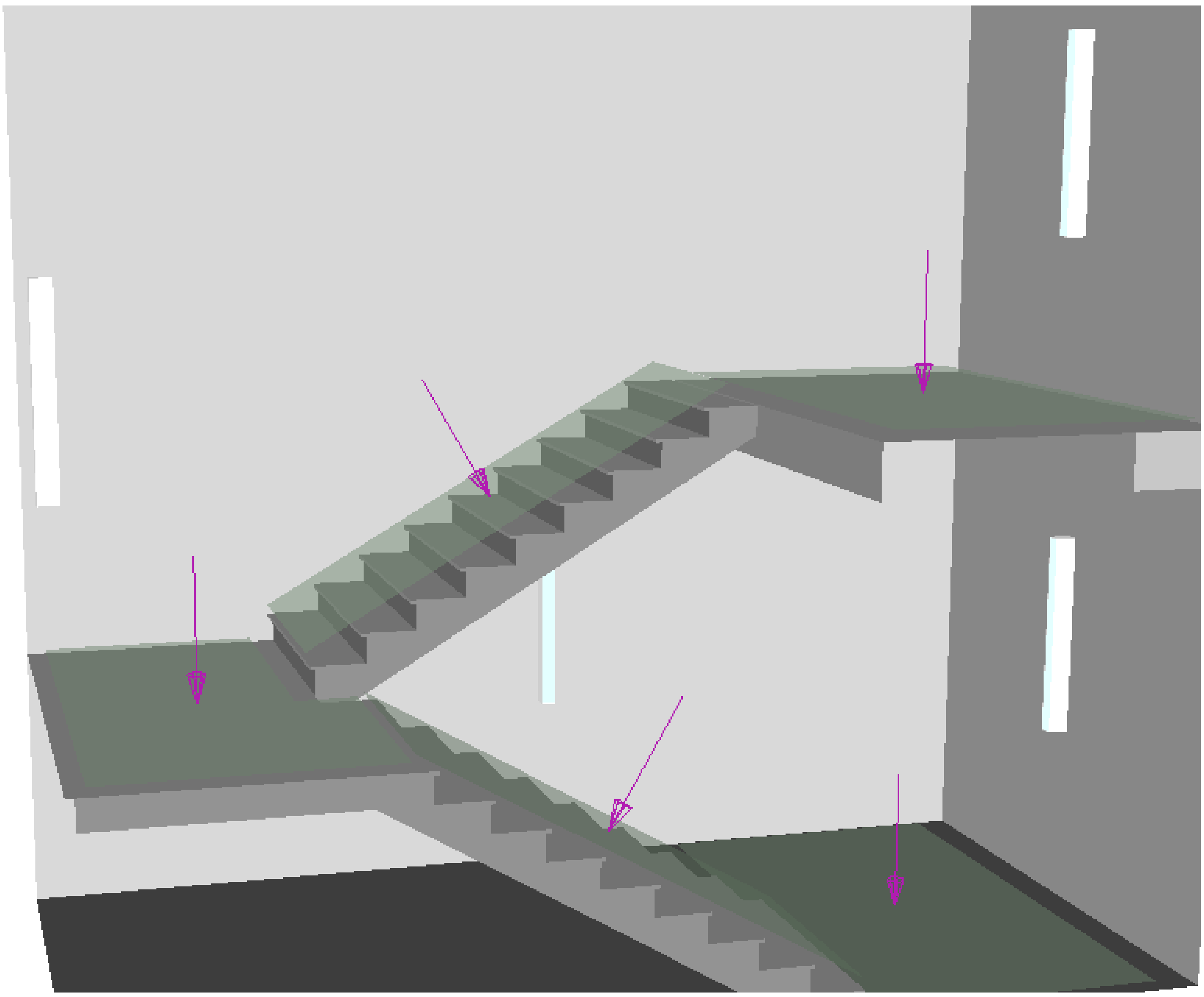

Fig. 3: Luminaire layout for stairs base lighting

3.4 Emergency Lighting Design (Floor 1 & 2)

Fig. 4 shows the luminaire layout for Floor 1 emergency lighting and Fig. 5 shows the luminaire layout for Floor 2 emergency lighting. Refer to Appendix B for the luminaires used on Floor 1 and Appendix C for the luminaires used on Floor 2.

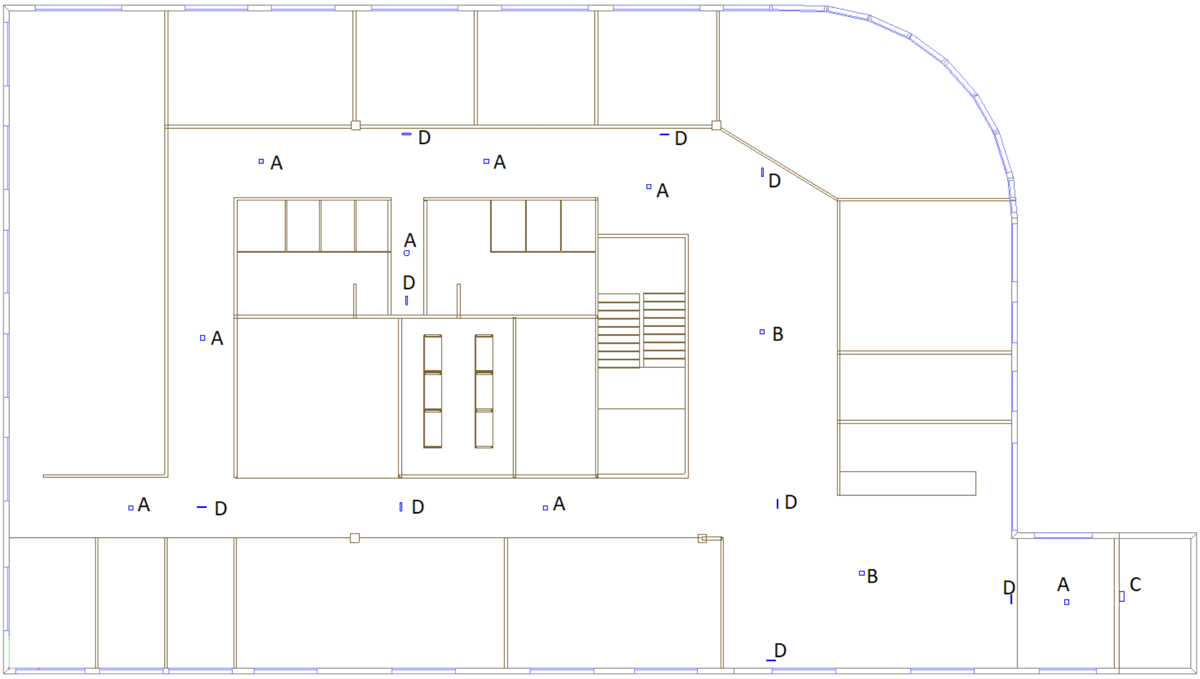

Fig. 4: Luminaire layout for Floor 1 emergency lighting

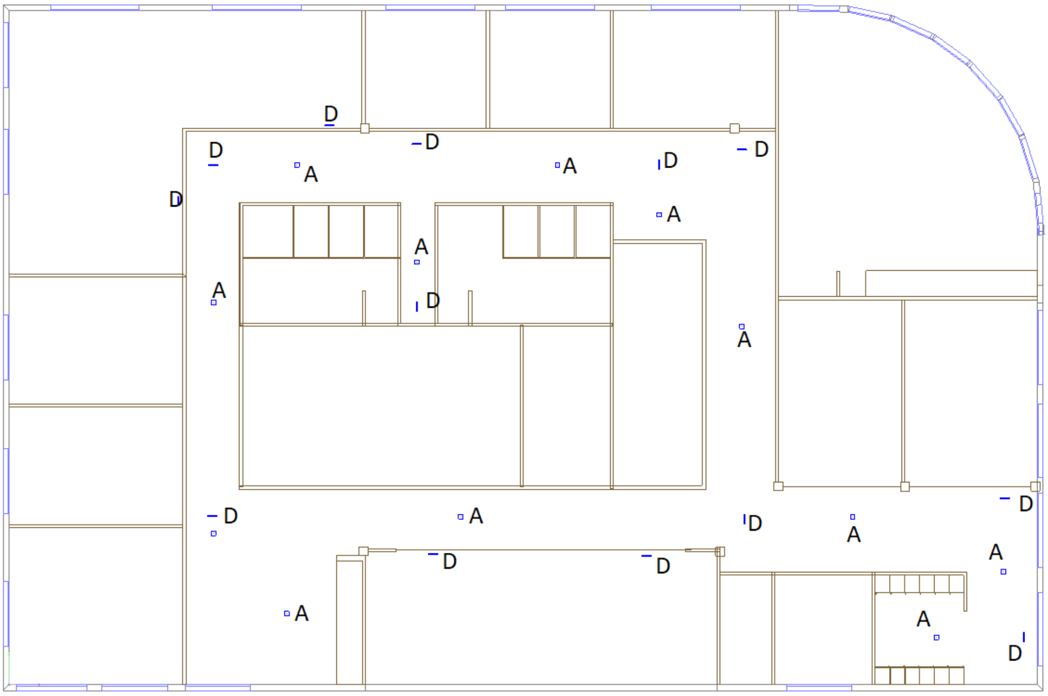

Fig. 5: Luminaire layout for Floor 2 emergency lighting

4.0 System Performance

4.1 Power Consumption & CO_2 emissions

An evaluation of the proposed design finds that the total power consumption and therefore CO_2 emissions have been reduced by more than half. The previous evaluation of the existing design finds that the existing design had an annual energy usage of 55000kWh, therefore, generating 5400 kgs of equivalent CO_2 emissions according to the rates in table 9 derived by the Ministry for the Environment[6]. In comparison, the proposed design was evaluated to have an annual energy usage of 21320 kWh and therefore generate 2068 kgs of equivalent CO_2 emissions. For the complete evaluation please refer to Table E1 of Appendix E.

4.2 Base Luminaire & Emergency Lighting Costs

Level 1 has 169 luminaries, Level 2 has 106 luminaries and the stairs have 4 luminaries for a total of 279 luminaries installed in the whole building. The client has provided a fixed installation cost of $300 for the cost calculations, therefore the total cost of LED installation is $83,700.

Similarly, Level 1 has 11 emergency satellites and 9 exit signs, Level 2 has 12 emergency satellites and 13 exit signs, and the stairs have 3 emergency satellites and 1 exit sign for a total of 49 emergency luminaires. Therefore the total cost of emergency lighting installation is $14,700.

4.3 Power Reducing Features

All lights on the first and second floor are equipped with DALI dimmable drivers, workers who feel the lights are too bright or wish for a small bit of extra lighting on top of daylight are able to adjust the lights to their liking while decreasing the overall power usage.

Some luminaries on the second floor also have daylight sensor ELS combined with their DALI dimmable driver to further intensive saving power however because meeting illuminance standards with minimum power consumption was prioritised the rooms with this feature and rooms without will seem arbitrary.

5.0 Meeting Client Requirements

5.1 Achieving Required Minimum Illuminance

The recommended minimum illuminance according to AS/NZS standard 1680 (reference) is summarised in Table 2 below.

Table 2: Recommended minimum illuminance according to AS/NZS standard 1680

Room Type	**Recommended Minimum Illuminance (lx)**
CAD room	600
Office	320
Meeting room	320
Files (vertical)	320
Kitchen	160
Lobby	160
Toilet	40
Corridor	40

The illuminance values achieved in the proposed design are summarised in Appendix E. Comparing the achieved illuminance values against the standards, it is clear that the proposed design achieves the recommended minimum illuminance.

5.2 Achieving Required Minimum Uniformity

The recommended minimum uniformity according to AS/NZS standard 1680 (reference) is summarised in Table 3 below.

Table 3: Recommended minimum uniformity according to AS/NZS standard 1680-1

Room Type	**Recommended Minimum Uniformity**
Circulation Spaces	0.3
General Lighting Systems	0.5
Task	0.7

The uniformity values achieved in the proposed design are summarised in Appendix E. Comparing the achieved uniformity values against the standards, it is clear that the proposed design achieves the recommended minimum uniformity.

5.3 Visual Comfort - Glare & Contrast

As per the client's requirements, a design decision has been made to arrange and choose luminaires that achieve comfortable viewing in areas where there is expected to be prolonged staff occupancy. It was determined that there are two factors that affect the visual comfort of staff: lighting contrast and glare (UGR). UGR is a measure of the psychological effects [10] of the illuminance of luminaires upon direct viewing. The higher this rating on a luminary is, the higher the effects of the visual discomfort on the occupants. As such a design decision was made to select and use luminaires that have classifications of UGR<=16 to UGR<=19 in accordance with the standards set by AS/NZS-1680-2-2[3] for visual comfort due to glare. Additionally, good contrast was also achieved by using luminaires that have very wide dispersion of light that ensures interiors are uniformly lit where dark areas on walls and ceilings are eliminated in order to achieve visual comfort.

As for areas of circulation, mainly corridors, where the occupancy is expected to be short, a design decision has been made to use suspended luminaires suspended at heights of 0.3 to 0.7m with backlights in order to minimise the effects of glare, maximise individual height accessibility and achieve uniformly lit walls and ceilings for visual comfort. The luminaries chosen for these spaces have a UGR of <=16 in accordance with the standards set by TABLE 8.2 of AS/NZS-1680-1[1] and have backlights in order to ensure the contrast between the ceiling and floor is even.

A design decision was made to choose luminaires with dimmable drivers, so that the occupants can adjust the brightness to their comfortable level of illuminance.

5.4 Break Even Analysis

Existing lighting system uses 55,004.40 kWh annually which, as indicated in Tony Tavita's lecture slides [8], has a rate of $0.25 per kWh resulting in an annual energy cost of $13,751. In contrast, the proposed LED lighting system uses 21320 kwH annually and costs $5330. Therefore each year the new design saves $8420. Additional expenses, according to Interwaste [7], include the lamp recycling cost of $587 and the installation cost of $83,700. It will take 10 years for the renewed LED lighting system to break even.

5.5 Minimising CO2 Emissions

As per the client's requirements a design decision of maintaining illuminance within a 20% margin above the required Lx values as specified by the standards was made in order to decrease the amount of luminaires used per section which in turn reduces power consumption and therefore minimising CO2 emissions.

Another design decision that was made was the utilisation of high Lumen efficacy luminaires, by selecting luminaires with relatively high Lumen output per Watt, the total power that needs to be consumed in order to achieve a certain illuminance was lowered. Generally, almost all of the luminaires that populate the proposed design have 140+ Lumen/Watt.

5.6 Emergency Lighting

In order to meet the client's and legal requirements as indicated by Clause F6 of the New Zealand building code, several emergency luminaires were installed ranging from general escape route lighting to illuminated safety signs pointing to the direction(s) of designated emergency exits. Clause F6 of the New Zealand building code states, that the emergency luminary arrangements must meet the following objectives:

- Escape routes will, at minimum, have a maintained illuminance of 1 lux from wall to wall.
- Anti-panic areas will, at minimum, have a maintained illuminance of 0.2 lux. Wall zone 0.5m allowed

- Exit signs should be recognizable from, at most, 24 metres away.
- An exit sign must be visible from any point of the escape route.
- Exit signs should be installed in rooms with more than one exit.

The client has stated the design of Anti-panic area emergency illumination is not required. It was found that only the south corridor of Level 1 exceeded 24m. All emergency luminaires chosen have self-test monitoring to ensure that workers can replace luminaries and maintain a functioning emergency lighting system. The only exit to this building is the main entrance on Level 1 and therefore all exit signs on the second floor point towards the stairs.

To visualise this arrangement the following ceiling reflection plan was labelled with arrows to show how the illuminated safety signs were arranged. Fig.6 shows the ceiling reflection plan for Floor 1; Fig.7 shows the ceiling reflection plan for Floor 2, and Fig.8 shows the ceiling reflection plan for the stairs.

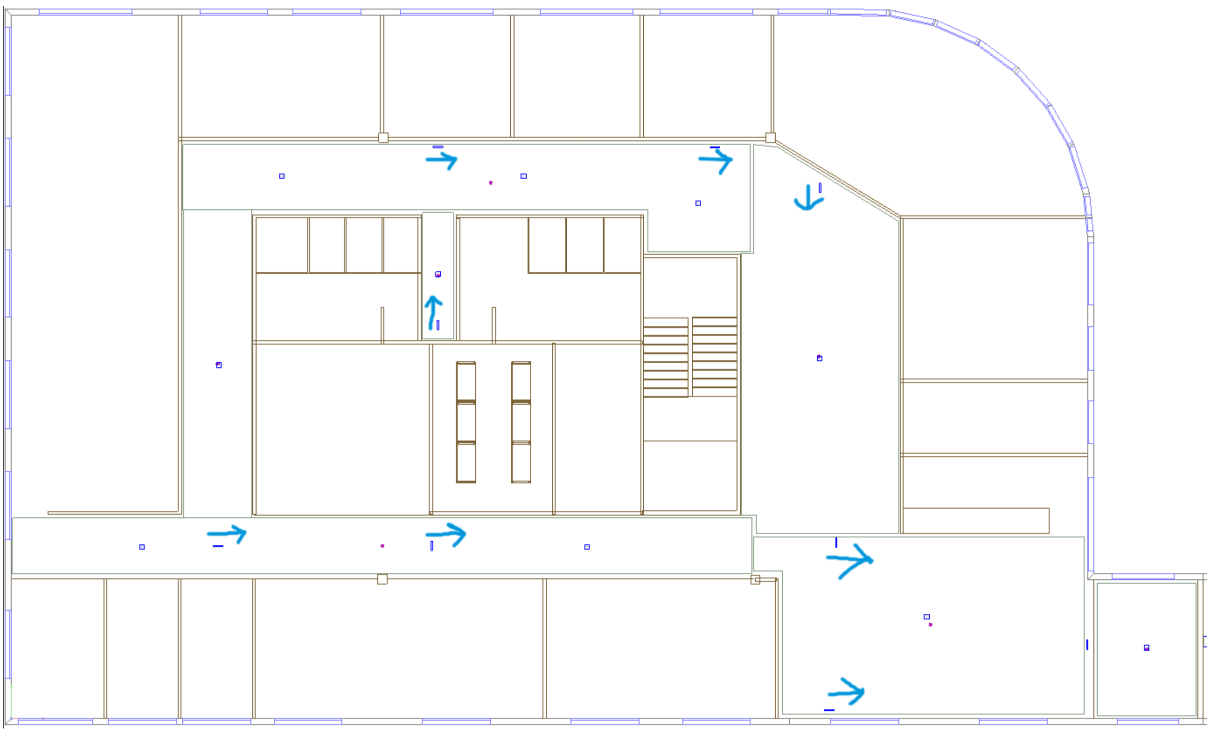

Fig.6: Ceiling reflection plan for Floor 1

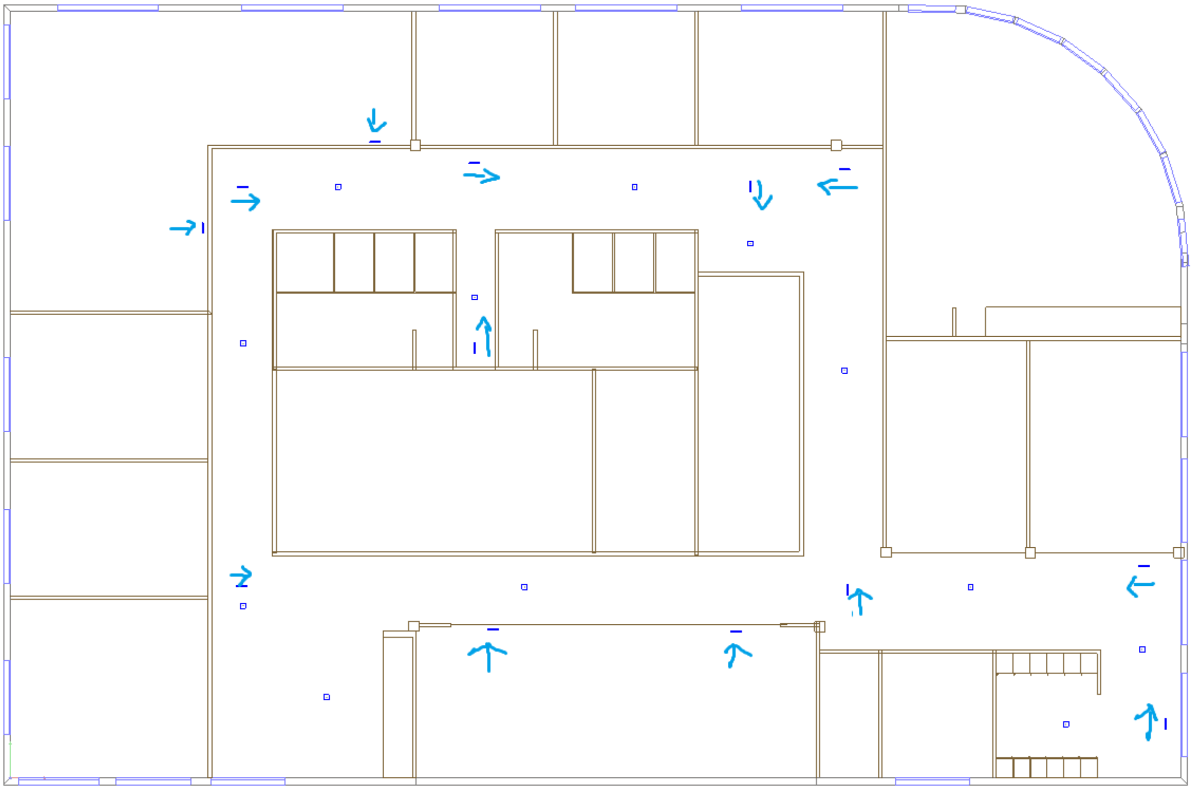

Fig.7: Ceiling reflection plan for Floor 2

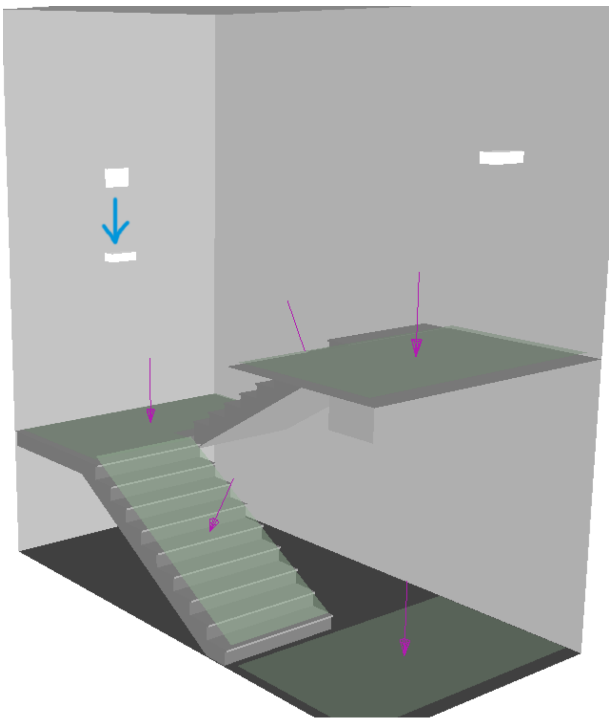

Fig.8: 3d rendering of the stairs for clarity

5.7 Colour rendering

As per the client’s requested design consideration of good colour rendering, a design decision of using luminaires with CRI(Ra) >80 ratings were made in order to achieve this. The colour rendering index is a measurement of a luminaire’s ability to show the natural colours of the object it illuminates, the higher this measure is the more natural the colours of objects are according to Westinghouse[11].

5.8 Colour temperature

As per the client's requested design considerations, a design decision of using luminaires rated with 4000K of correlated colour temperature was made as this colour temperature is generally perceived as being neutral, which makes it an ideal choice for task-oriented sections and allows for visual clarity[12].

6.0 Conclusion and Recommendations

As required by Tony, the new proposed design must accomplish the following requirements and consider the following design considerations:

- Efficient lighting - reduced power consumption
- Emergency lighting system
- Minimise installation and energy usage costs
- Comfortable viewing
- Accurate colour representation

By making a design decision to choose dimmable and low power luminaires the proposed lighting system manages to cut the existing power consumption and therefore CO2 emissions by more than half and potentially more if the client chooses to install a dynamic lighting system.

In order to minimise the investment needed to install new luminaires a design decision was made to restrict the average illuminance values of each room to a maximum of 20% higher than that of the standard where possible. This resulted in the installation cost of the system to be $83,700 and is calculated to take 10 years for the proposed lighting system to break even, 5 years shorter than the client requirements deadline. The proposed system also meets New Zealand Government interior and workplace lighting standards[1,2,3].

This design adds the missing emergency luminaires that are necessary to meet all outlined legal requirements found at clause F6 and will safely guide the workers out of the building in an emergency.

Lastly, in order to ensure that the design consideration of comfortable viewing and accurate colour representation of luminaries have been met, a design decision was made to select luminaires with corresponding attributes relating to visual comfort and clarity such as CRI and colour temperature.

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Appendices

Appendix A - Evaluation of Existing Lighting System

Table A.1 and Table A.2 shows an evaluation of the existing lighting system of Level 1 of the building and Table A.3 and Table A.4 shows an evaluation of the existing lighting system of Level 2. Table A.5 shows an evaluation of the existing lighting system on the stairs.

As can be seen by the average illuminance, uniformity and glare ratings, there are a number of issues with the existing lighting system.

Table A.1: Tabulated evaluation of Level 1.

No:	Room / Area	Eav [lx] (AS/NZS1680)	Eav [lx] Calculated	u0 Calculated	Compliance with AS/NZS1680 [yes / no]
1	101 Entrance	160	114	0.688	N
2	102 Lobby 1	160	282	0.258	N
3	103 Lobby 2	160	223	0.316	Y
4	104 Enquiry Desk	320	412	0.338	N
5	104 Reception	320	256	0.267	N
6	105 Mail (E Vertical)	320	247	0.452	N
7	106 Manager	320	517	0.255	N
8	107 Director	320	430	0.196	N
9	108 Office	320	538	0.392	N
10	109 Office	320	565	0.497	Y
11	110 Office	320	530	0.344	N
12	111 Office	320	653	0.416	N
13	112 CAD	600	629	0.364	N
14	113 Office	320	341	0.404	N
15	114 Office	320	391	0.452	N
16	115 Office	320	377	0.435	N
17	116 Conference	240	435	0.339	N
18	117 Meeting	320	528	0.344	N
19	118 Office	320	608	0.646	Y
20	119 Files (E Vertical) 1	320	306	0.315	N

21	119 Files (E Vertical) 2	320	425	0.555	Y
22	119 Files (E Vertical) 3	320	385	0.335	N
23	119 Files (E Vertical) 4	320	305	0.273	N
24	120 Server	320	460	0.563	Y
25	121 Female	40	102	0.118	N
26	122 Male	40	110	0.24	N
27	Corridor North	40	118	0.534	Y
28	Corridor West	40	178	0.54	Y
29	Corridor South	40	262	0.484	Y
30	Corridor Toilets	40	163	0.691	Y

Table A.2: Glare rating of CAD rooms on Level 1

No:	Room / Area	Max UGR allowed (AS/NZS1680)	Max UGR in X-direction (Calculated)	Max UGR in Y-direction (Calculated)	Compliance with AS/NZS1680 [yes / no]
1	112 CAD	19	19	22	N

Table A.3: Tabulated evaluation of Level 2.

No:	Room / Area	Eav [lx] (AS/NZS1680)	Eav [lx] Calculated	u0 Calculated	Compliance with AS/NZS1680 [yes / no]
1	201 Kitchen	160	324	0.534	Y
2	201 Bench	240	238	0.78	N
3	202 Meeting	320	294	0.692	N
4	203 Meeting	320	266	0.607	N
5	204 Lockers (E vertical) 1	200	102	0.66	N
6	204 Lockers (E vertical) 2	200	114	0.612	N
7	205 Meeting	320	122	0.705	N
8	206 Cleaner	80	150	0.756	Y
9	207 Office	320	318	0.701	N
10	208 Office	320	275	0.739	N
11	209 Office	320	262	0.723	N
12	210 CAD	600	316	0.625	N
13	211 Office	320	329	0.731	Y
14	212 Office	320	366	0.781	Y

15	213 Office	320	301	0.743	N
16	214 Female	40	104	0.135	N
17	215 Male	40	106	0.144	N
18	216 CAD	600	327	0.655	N
19	217 Power	160	192	0.739	Y
20	Balcony	80	91	0.449	Y
21	Hot Desk	320	179	0.711	N
22	Corridor Lockers	80	138	0.607	Y
23	Corridor South East	40	163	0.635	Y
24	Corridor South	40	167	0.692	Y
25	Corridor Hot Desk	40	260	0.621	Y
26	Corridor West	40	166	0.682	Y
27	Corridor North	40	142	0.662	Y
28	Corridor East	40	148	0.596	Y
29	Corridor Toilets	40	140	0.705	Y

Table A.4: Glare ratings of CAD rooms on Level 1

No:	Room / Area	Max UGR allowed (AS/NZS1680)	Max UGR in X-direction (Calculated)	Max UGR in Y-direction (Calculated)	Compliance with AS/NZS1680 [yes / no]
1	210 CAD	19	28	22	N
2	216 CAD	19	27	21	N

Table A.5: Tabulated evaluation of the stairs.

No:	Room / Area	Eav [lx] (AS/NZS1680)	Eav [lx] Calculated	u0 Calculated	Compliance with AS/NZS1680 [yes / no]
1	First floor	80	150	0.787	Y
2	Second floor	80	165	0.87	Y
3	Landing	80	97	0.911	Y
4	Stairs lower part	80	157	0.722	Y
5	Stairs upper part	80	116	0.81	Y

Appendix B - Floor 1 Luminaires

This appendix contains tabulated details of the luminaires used at the first level of the building.

Table B.1: Luminair schedule of Level 1

Product	Dimension(LxWxH)	Mounting Type	Flux	Power	LLMF@50kh
ETAP US21I0/LEDN25D	1195 mm x 295 mm x 100 mm	Recessed	2500lm	17W	0.98
ETAP US3141/LEDN20D	596 mm x 596 mm x 100 mm	Recessed	2200lm	21W	0.98
V3RDK0M/N5L0D0X1	1417 mm x 76 mm x 71 mm	Surface	1750lm	19W	0.99
U25M2/LEDN25D	596 mm x 596 mm x 85 mm	Recessed	2900	19W	0.98
V3WDJ0M/N4LLD0X0	1123 mm x 60 mm x 90 mm	Surface/Wall	4100lm	30.7W	0.98
R3111/LEDN220DX1	1380 mm x 180 mm x 35 mm	Surface mounted/suspended	2200lm	15.9W	0.98

Table B.2: Luminair schedule of the emergency lighting used at level 1

Label	Product	Dimension (LxWxH)	Mounting Type	Flux	Power	Battery lifetime
D	ETAP K1R142/1-A	315 mm x 33 mm x 219 mm	Surface mounted or wall mounted.	90lm	2.8W	10 years
C	ETAP K282/2-A	359 mm x 180 mm x 100 mm	Surface mounted	65lm	2W	10 years
A	ETAP K9R112/3-AX1-D800A25	152 mm x 152 mm x 32 mm	Surface mounted	280lm	0.9W	8 years
B	ETAP K9R122/3-AX1-A630A630	152 mm x 152 mm x 32 mm	Surface mounted	300lm	0.9W	8 years

Appendix C - Floor 2 Luminaires

This appendix contains tabulated details of the luminaires used at the second level of the building.

Table C.1: Luminaire schedule of level 2

Product	Dimension(LxWxH)	Mounting Type	Flux	Power	LLMF@50kh
ETAP R3311/LEDN220DX1	1380mm x 180mm x 35mm	Surface-mounted or suspended	2150 lm	15.2W	0.98
ETAP R3311/LEDN445DX1	1380 mm x 260 mm x 35 mm	Surface-mounted or suspended	4350lm	28W	0.98
ETAP R3311/LEDN455DX1	1380 mm x 260 mm x 35 mm	Surface-mounted or suspended	5500lm	36W	0.98
ETAP R735R1/LEDN2435DEX1	1680 mm x 150 mm x 50 mm	Surface-mounted or suspended	3600lm	27W	0.98

Table C.2: Luminair schedule of the emergency lighting used at level 2

Label	Product	Dimension (LxWxH)	Mounting Type	Flux	IP rating	Monitoring	Battery
A	ETAP K9R112/3-AX1-D800A25	152 mm x 152 mm x 32 mm	Surface mounted	280lm	42	EST+ self-test	8 years
D	ETAP K1R142/1-A	315 mm x 33 mm x 219 mm	Surface or wall mounted.	90lm	42	EST+ self-test	10 years

Appendix D - Stairs

This appendix contains tabulated details of the luminaires used at the stairs between the second and first levels of the building.

Table D.1 - Luminaire schedule of stairs

Product	Dimension(LxWxH)	Mounting Type	Flux	Power	LLMF@50kh
ETAP R820R1/LEDN25D	1162 mm x 80 mm x 121 mm	Surface-mounted or suspended	2550lm	20W	0.98

Table D.2 - Luminair schedule of the emergency lighting used at the stairs

Product	Dimension(LxWxH)	Mounting Type	Flux	Power	Battery lifetime
ETAP K1R142/1-A	315 mm x 33 mm x 219 mm	Surface Mounted	90lm	2.8W	10 years
ETAP K282/2-A	359 mm x 180 mm x 100 mm	Surface Mounted	65lm	2W	10 years
ETAP K9R122/3-AX1-A630A630	152 mm x 152 mm x 32 mm	Surface Mounted	300lm	0.9W	8 years

Appendix E - Evaluation of Proposed lighting plan

Table E:1 - Tabulated evaluation of Level 1 under proposed lighting system

No:	Room / Area	Eav [lx] (AS/NZS1680)	Eav [lx] Calculated	u0 Calculated
1	101 Entrance	160	186	0.7
2	102 Lobby 1	160	187	0.446
3	103 Lobby 2	160	182	0.562
4	104 Enquiry Desk	320	386	0.7
5	104 Reception	320	396	0.643
6	105 Mail (E Vertical)	320	365	0.526
7	106 Manager	320	383	0.721
8	107 Director	320	391	0.568
9	108 Office	320	371	0.741
10	109 Office	320	366	0.716
11	110 Office	320	376	0.589
12	111 Office	320	324	0.525
13	112 CAD	600	643	0.577
14	113 Office	320	336	0.516
15	114 Office	320	322	0.638
16	115 Office	320	322	0.648
17	116 Conference	240	272	0.553
18	117 Meeting	320	345	0.575
19	118 Office	320	348	0.52
20	119 Files (E Vertical) 1	320	335	0.611
21	119 Files (E Vertical) 2	320	335	0.693
22	119 Files (E Vertical) 3	320	331	0.575
23	119 Files (E Vertical) 4	320	338	0.596
24	120 Server	320	348	0.716
25	121 Female	40	205	0.575
26	122 Male	40	191	0.642
27	Corridor North	40	191	0.6
28	Corridor West	40	242	0.623

29	Corridor South	40	147	0.525
30	Corridor Toilets	40	212	0.767

Table E:2 - Glare rating of CAD room Level 1 under proposed lighting system

No:	Room / Area	Max UGR allowed (AS/NZS1680)	Max UGR in X-direction (Calculated)	Max UGR in Y-direction (Calculated)	Compliance with AS/NZS1680 [yes / no]
1	112 CAD	19	16	17	Yes

Table E:3 - Tabulated evaluation of Level 2 under proposed lighting system

No:	Room / Area	Eav [lx] (AS/NZS1680)	Eav [lx] Calculated	u0 Calculated
1	201 Kitchen	160	218	0.432
2	201 Bench	240	231	0.866
3	202 Meeting	320	348	0.64
4	203 Meeting	320	319	0.623
5	204 Lockers (E vertical) 1	NA	189	0.648
6	204 Lockers (E vertical) 2	NA	196	0.649
7	205 Meeting	320	325	0.6
8	206 Cleaner	80	109	0.797
9	207 Office	320	421	0.522
10	208 Office	320	363	0.554
11	209 Office	320	347	0.576
12	210 CAD	600	695	0.519
13	211 Office	320	330	0.399
14	212 Office	320	329	0.571
15	213 Office	320	335	0.7
16	214 Female	40	146	0.157
17	215 Male	40	165	0.291
18	216 CAD	600	694	0.538
19	217 Power	160	165	0.647
20	Balcony	80	148	0.128
21	Hot Desk	320	373	0.177

22	Corridor Lockers	80	230	0.804
23	Corridor South East	40	235	0.648
24	Corridor South	40	240	0.543
25	Corridor Hot Desk	40	332	0.253
26	Corridor West	40	313	0.558
27	Corridor North	40	204	0.738
28	Corridor East	40	195	0.653

Table E:4 - Glare rating of CAD rooms Level 2 under proposed lighting system

No:	Room / Area	Max UGR allowed (AS/NZS1680)	Max UGR in X-direction (Calculated)	Max UGR in Y-direction (Calculated)
1	210 CAD	19	18	17
2	216 CAD	19	17	16