EPI International Journal of Engineering
Volume 4, Number 1, February 2021, pp. 65-74
DOI: 10.25042/epi-ije.022021.10

*p*ISSN 2615-5109
*e*ISSN 2621-0541

# Integration of Natural and Artificial Light on Energy Efficiency of Mega Bank Makassar Tower Building

Isty Cahyani[a,*], Ramli Rahim[b], Baharuddin Hamzah[c]

[a]Department of Architecture, Faculty of Engineering, Hasanuddin University, Makassar. Indonesia. Email: istythecat@mail.com
[b]Department of Architecture, Faculty of Engineering, Hasanuddin University, Makassar. Indonesia. Email: yb8bri@yahoo.com
[c]Department of Architecture, Faculty of Engineering, Hasanuddin University, Makassar. Indonesia. Email: baharsyah@unhas.ac.id

**Abstract**

One of the largest energy consumers in the world is buildings. The energy consumed generally comes from the air conditioning and lighting systems. Lighting systems account for 25% of the total energy consumption in buildings. The strategy used in building design is to reduce energy consumption while maintaining the best comfort in a building. The application of energy-saving concepts from the building sector is optimizing the lighting system by integrating natural and artificial lighting systems. This study aims to determine the light intensity in the integrated lighting system of natural and artificial manually and also to find out how much energy can be saved with the integrated lighting system manually. The research location is at the Mega Bank Makassar Tower Building. The research sample was selected by purposive sampling and the sixth floor was chosen as the research location. In this study, simulations were carried out using the DIAlux 4.13 program to integrate natural and artificial light and to calculate the amount of energy efficiency in the workspace. To obtain optimal light intensity and energy savings, a simulation was carried out by turning off half the light points in the workspace, especially the light points around the building openings. The simulation results show that the average integrated lighting quality meets the minimum lighting requirements and can save energy usage by up to 50%.

*Keywords: Energy efficiency; integration lighting; workspace*

## 1. Introduction

Buildings are one of the largest energy consumers, the World Green Building Council states that the construction sector absorbs 30-40% of the world's total energy. The average energy use of office buildings in Indonesia is 250 KWh/m$^2$/year. This figure exceeds the standard for energy use in office buildings, which is 180 KWh/m$^2$/year. It can be concluded that many office buildings in Indonesia are still energy-wasteful [1]. In a typical high-rise office building, the proportion of energy use generally includes 55% for air conditioning systems, 25% for lighting systems and the remaining 20% for other equipment (elevators, pumps, electronic equipment, etc.) [2]. Although the use of energy for artificial lighting is smaller than air conditioning, but by minimizing the use of energy for lighting, it means that energy consumption in the building can be reduced so that the lighting system must be a special concern at the early stages of planning to create energy-efficient buildings that meet the requirements of visual comfort of the space [3].

*Corresponding author. Tel.: +6281241741002
*Perumahan Bukit Garaganti Graha Blok D/3*
*Gowa, South Sulawesi*
*Indonesia 92118*

The office as a work area requires a comfortable level of natural lighting so that users in it can carry out activities smoothly and have good work productivity. Good lighting levels can be achieved by utilizing natural and artificial lighting. In some buildings, artificial lighting is needed in space zones that are far from natural light sources. By integrating natural and artificial lighting systems, it is easy to achieve the required light intensity in each space zone. For efficient use of energy, it is necessary to have a system that is used to control the lighting requirements so that lighting can be optimized and the demands of visual comfort can be achieved.

The Mega Bank Tower Building is one of the multi-story office buildings in Makassar City. Based on the initial survey in this building through direct observation, measurement of light intensity in the workspace and interviews with building users, it can be concluded that the distribution of lighting into the workspace is uneven. There are several workspaces that only use natural lighting because the intensity of natural light entering the space is high enough that it does not require artificial lighting. However, there are also workspaces that must use artificial lighting because the work zone is far from natural light sources.

Based on some of the things mentioned above, the authors thought to analyze the lighting system, as well as effective design in energy use efficiency by properly integrating natural and artificial lighting in the workspace at the Menara Bank Mega Makassar Building to optimize the lighting system and increase work productivity his employee.

## 2. Literature Review

### *2.1. Lighting*

Light is a form of energy that is radiated or emitted from a source in the form of waves and is part of the whole group of electromagnetic waves, which are converted into visible light [4]. Light is an important element in illumination and vision. The presence of light in the environment aims to illuminate the various forms of elements that exist in the building so that the space becomes clearly observed as if you feel the visual atmosphere (visual sense).

There are two types of light sources that can be used for lighting in the room, namely natural light from the sky dome and artificial light from electric lighting. Natural lighting plays an important role in sustainable development because it can be utilized without the need for energy and does not cause pollution, thereby reducing pollutants [5].

Based on Darmasetiawan and Puspakesuma [6], 5 (five) criteria to consider to get good lighting, are:

a. Lighting level
b. Luminance distribution
c. Luminance of glare
d. Light directionally and shadows
e. Light colours dan colours rendering

### *2.2. Natural lighting*

Natural lighting is lighting produced by a natural light source, namely the sun with its strong light but varies according to hours, seasons, and places. Natural lighting in a building will reduce the use of artificial light, thus saving energy consumption and reducing pollution levels. According to Kroelinger in Thojib [7] that natural light is distributed into the room through openings on the side (side lighting), openings above (top lighting), or a combination of both.

### *2.3. Artificial lighting*

Artificial lighting is lighting produced by light sources other than natural light. Artificial lighting is very necessary when the position of the room is difficult to achieve by natural lighting or when natural lighting is insufficient [8]. According to the National Standardization Agency No.03-6575-2001, artificial lighting systems can be grouped into three, namely: evenly distributed lighting systems, local lighting systems and uniform and local combined lighting system [9].

Table 1. Recommended average lighting level

| Space Function | Lighting Level (lux) |
|---|---|
| Office complex | |
| Director's room | 350 |
| Workspace | 350 |
| Computer room | 350 |
| Meeting room | 300 |
| Drawing space | 750 |
| Archives | 150 |
| Educational institutions | |
| Class room | 250 |
| Library | 300 |
| Laboratory | 500 |
| Drawing room | 750 |
| Canteen | 200 |

### *2.4. Visual comfort*

Visual comfort is the need for a good level of lighting in a room. Good lighting is lighting that can meet the needs of its users, related to the types of activities carried out in the space [10].

Visual comfort has a very strong relationship with lighting. Visual comfort in a building is influenced by the lighting design in the building. Visual comfort is fulfilled if space users can form a comfortable spatial impression. Lighting design does not only function to show visual objects that can be seen, but also serves to generate visual comfort which psychologically affects its performance so that work productivity can increase [11]. For eye comfort, the recommended lighting level by SNI 03-6575-2001 is shown in Table 1.

### *2.5. Energy efficiency*

Energy saving (energy efficiency) in architecture is to minimize energy use without limiting or changing the function of the building, the comfort, or productivity of its occupants. Energy saving is done by optimizing energy use according to the level of need. One way is through building design that can save electricity usage, both for cooling/cooling the air in the room and for lighting [12].

The problem of lighting both natural and artificial cannot be separated from the use of energy in a building, because lighting is one of the things that has a big influence on energy consumption besides the air conditioning system [13].

Energy Consumption Index (Energy Use Intensity) or IKE (EUI) based on the calculation formula in DKI Jakarta Governor Regulation No. 38 of 2012 is the amount of energy used by a building to expand its conditioned area in one month or one year. IKE is used as a reference to see how much energy conservation the building is doing. This Energy Consumption Intensity is the ratio between the total energy consumption during a certain period (1 year) and the building area. The IKE unit is $kWh/m^2$ per year [14].

According to the results of research conducted by ASEAN-USAID in 1987 whose report was only issued in 1992, the target size of the Energy Consumption Intensity (IKE) of electricity for Indonesia is as follows: IKE for offices (commercial) is 240 kWh/m$^2$ per year, shopping centers 330 kWh/m$^2$ per year, hotel/apartment: 300 kWh/m$^2$ per year and for hospitals: 380 kWh/m$^2$ per year. If the IKE value is lower than the lower limit, then the building is said to be energy efficient. If the IKE value is between the lower limit and the reference, then the building is said to be rather frugal. If it is between the reference and the upper limit, then the building is said to be a bit extravagant so it needs to make some changes. If it is above the upper limit, it is necessary to do retrofitting or replacement.

### *2.6. Energy efficiency*

The office is a hall (building, house, room) where one takes care of a job (company and so on) or a place to work [15]. The office itself has several functions which include receiving information, recording information, managing information, providing information and protecting assets and assets.

## 3. Research Methods

This type of research is research with descriptive and correlational quantitative methods. This method was chosen in connection with the idea of research that seeks to combine the results of observations (observations made in the form of illumination measurements with a luxmeter) with simulations of natural and artificial integration lighting contours using the DIAlux 4.13 software simulation. In this study, calculations and optimization of electrical power consumption were also carried out in order to energy efficiency.

### *3.1. Research location*

The research location is in the capital city of South Sulawesi Province, namely the city of Makassar. The Mega Bank Makassar Tower Building is located in Tamalate District, Maccini Sombala Village, which is precisely on Jl. H.M. Patompo in the Trans Studio area. The Bank Mega Makassar Tower has a land area of 9,600 m² and a building area of 6,000 m² consisting of 12 floors and 1 basement.

### *3.2. Population and sample*

In this study, the subject population is all employees who are active in the workspace in the Mega Bank Makassar tower building who will be the respondents in this study. The sampling technique used was the purposive sampling method. The sample selection of the workspace was taken one floor from the total number of 12-story buildings. The workspace selected is the workspace on the 6th floor.

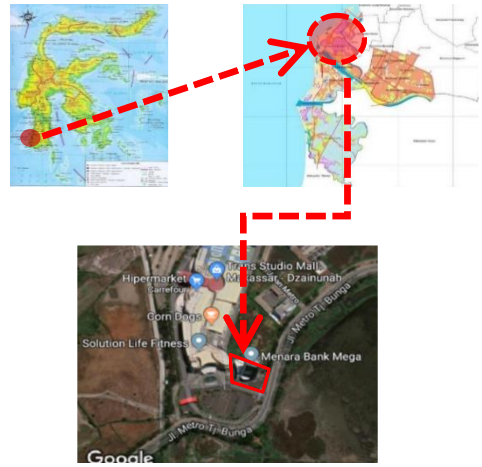


Figure 1. (a) Map of South Sulawesi; (b) Map of Tamalate district; (c) Map of Mega Bank Makassar Tower Building location

Figure 2. Mega Bank Makassar Tower Building

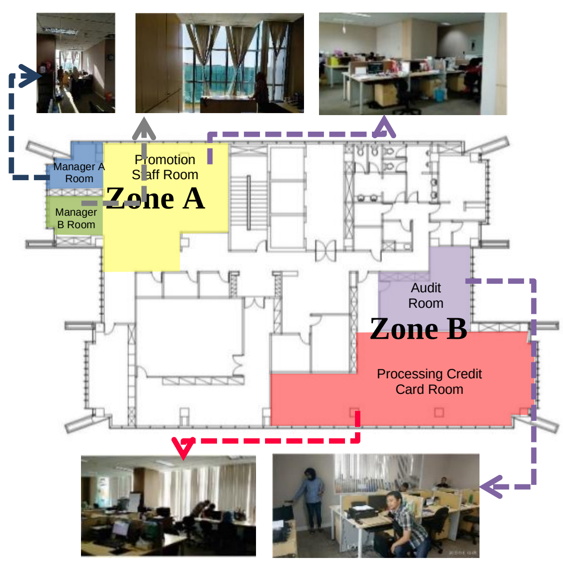


Figure 3. Division zone light intensity measurement

### *3.3. Data collection*

The data obtained are sourced from primary data and secondary data. Primary data was obtained during observations and measurements in the workspace in the form of data from space measurements, the number of occupants in the room, dimensions and positions of openings, light intensity, and activities. While secondary data were obtained from relevant works of literature and through searching on the internet regarding the data related to this study.

Data collection techniques used in this research are literature study, observation, interviews and questionnaires, measurement of light intensity, simulation and calculation of electrical power in lighting.

### *3.4. Data analysis*

The analysis of this research is quantitative with descriptive statistics. The descriptive statistic analysis technique used in this study is the presentation of data in a visual form such as histograms, polygons, and diagrams. Analysis of simulation with DIAlux program to integrate natural and artificial light and to calculate the amount of energy efficiency in the workspace.

## 4. Discussion

### *4.1. Lighting quality integration of natural and artificial (Manual)*

In the existing condition, the research object still utilizes natural lighting from openings in the walls (windows) and also the use of lamps as lighting (combined lighting systems). The average natural lighting on the research object has met the standardization of lighting in the workspace, but there are still some areas where the lighting level is still below the standard so that artificial lighting is used to increase the level of illumination of the area which is still below standard. This causes the area that has been fulfilled by natural lighting to still receive artificial lighting so that the area's illumination level is far above the standard of 350 lux. This results in ineffective use of lamps and a waste of energy. For this reason, a simulation was carried out using the DIALux 4.13 program to obtain an even level of lighting according to standardization.

The simulation is done by turning off several light points in areas that have received sufficient natural lighting. This simulation is carried out with the sky conditions that are already in the simulation program, namely clear sky. Simulation time is morning, afternoon and evening at 09.00, 12.00 and 15.00. Location data that is input into the DIAlux program is Makassar City with a position of Longitude 119.40° and Latitude -5.10°. The workplane is placed at a height of 0.75 cm from the floor level.

a. Promotional Room Combination Lighting Quality (Manager A Room, Manager B Room and Promotion Staff Room)

The results of the manual combination lighting simulation shown in Fig. 4 consist of 16 light points with the type of lamp used is PHILIPS TCS260 2xTL5-28W HFP M6_827 with a distance between lamps of 2.4 meters. In this simulation, there are 8 light points that are extinguished close to the opening (window).

In Fig. 4 it can be seen that in the morning the promotional staff room gets more natural light from the opening on the Northeast side. So that the work area on that side is very bright. Likewise with Manager Room A because there is an opening on the Northeast side. Meanwhile, Manager B Room only gets a little natural light from outside because the opening is only on the Northwest side. At Daytime, the light intensity is almost evenly distributed in Manager Room A, Manager Room B and Promotion Staff Room. In the afternoon, a lot of natural light enters through the opening on the Northwest side. So Manager Room A and B are very bright in the afternoon.

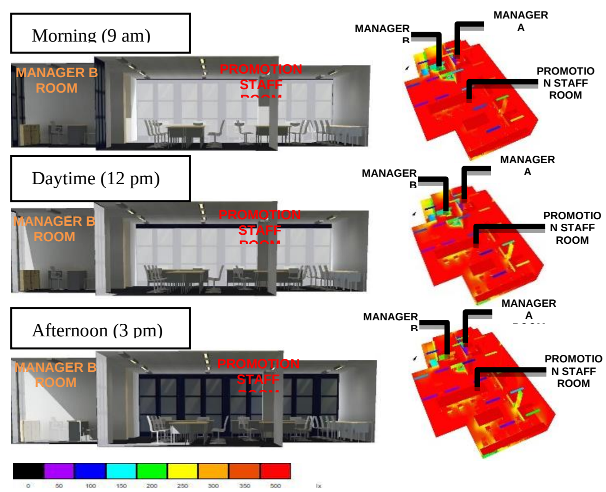


Figure 4. Zone A manual combination lighting (Manager Room A, Manager Room B and promotion staff room)

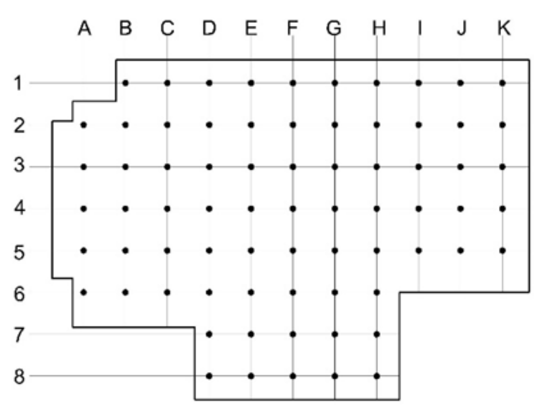


Figure 5. Measuring point of Zone A

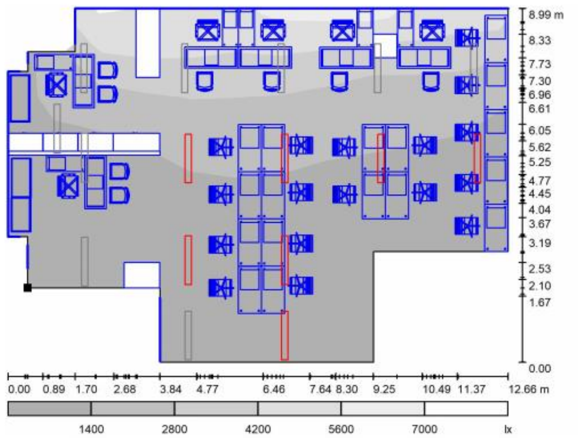

Figure 6. Simulation results of combination lighting Zone A in the morning

From Table 2, the simulation results show that the level of manual combination lighting in Zone A with clear sky conditions in the morning far exceeds the standard. This is because the average illumination is 1258 lux, which means it exceeds the standard workspace illumination of 350 lux.

In the Fig. 7, it can be seen at points B1, C1, D1, E1, F1, G1, H1, I1, J1 and K1 that the light intensity is above 3000 lux, far exceeding the standard. This is because this measuring point is at an opening facing the Northeast so that in the morning the light intensity in this area is very high.

From Table 3, the simulation results show that the level of manual combination lighting in Zone A with clear sky conditions during the day far exceeds the standard. This is because the average illumination is 1001 lux, which means it has exceeded the standard workspace illumination of 350 lux. However, the intensity of the light has decreased from the morning.

Table 2. Simulation results of combination lighting Zone A in the morning

| | A | B | C | D | E | F | G | H | I | J | K | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 5862 | 5228 | 5679 | 5133 | 4871 | 5124 | 4797 | 4798 | 4527 | 3968 | 4999 |
| 2 | 1184 | 2550 | 2503 | 3266 | 3276 | 3165 | 3124 | 2522 | 1905 | 2573 | 1895 | 2542 |
| 3 | 1380 | 1685 | 2055 | 2082 | 2038 | 1965 | 1880 | 1604 | 1598 | 1528 | 1269 | 1735 |
| 4 | 903 | 448 | 392 | 1336 | 1486 | 1476 | 1374 | 1274 | 1301 | 1130 | 1048 | 1106 |
| 5 | 1066 | 529 | 492 | 1065 | 1125 | 1193 | 1092 | 905 | 938 | 724 | 760 | 899 |
| 6 | 724 | 544 | 596 | 947 | 994 | 1041 | 1009 | 747 | | | | 825 |
| 7 | | | | 959 | 829 | 963 | 919 | 619 | | | | 858 |
| 8 | | | | 1106 | 790 | 883 | 865 | 559 | | | | 841 |
| | | | | | | **Average** | | | | | | **1258** |

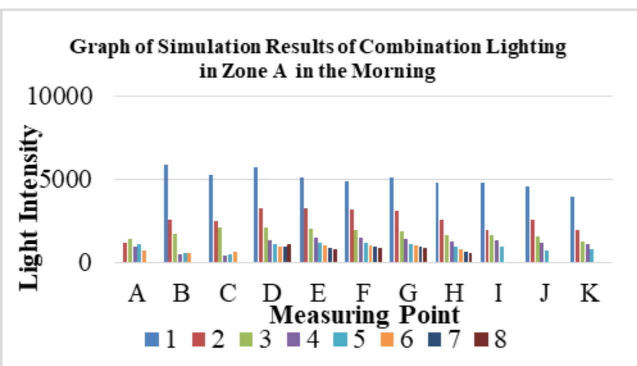


Figure 7. Simulation results of combination lighting in Zone B in the morning

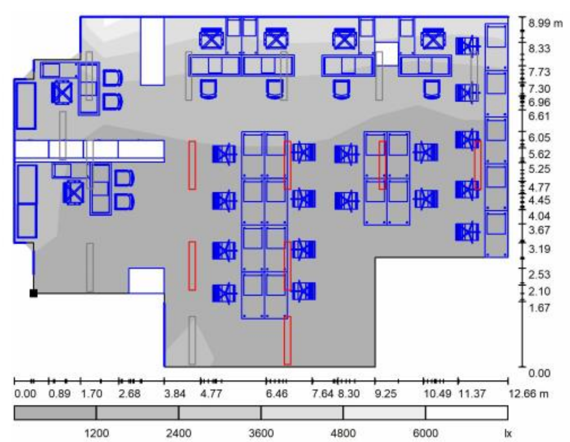

Figure 8. Simulation results of combination lighting Zone A in the daytime

Table 3. Simulation results of combination lighting Zone A in the daytime

| | A | B | C | D | E | F | G | H | I | J | K | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 5363 | 4264 | 3443 | 3440 | 3384 | 3485 | 3371 | 3215 | 3168 | 3160 | 3629 |
| 2 | 1716 | 1473 | 1741 | 1611 | 1785 | 1782 | 1779 | 1584 | 1069 | 1413 | 1427 | 1580 |
| 3 | 1752 | 1007 | 1331 | 1239 | 1228 | 1232 | 1216 | 1134 | 1059 | 1006 | 997 | 1200 |
| 4 | 1561 | 590 | 434 | 912 | 1043 | 1067 | 1030 | 944 | 975 | 881 | 888 | 939 |
| 5 | 1816 | 717 | 518 | 783 | 817 | 890 | 845 | 667 | 693 | 542 | 623 | 810 |
| 6 | 1162 | 703 | 541 | 775 | 794 | 865 | 833 | 567 | | | | 780 |
| 7 | | | | 964 | 738 | 844 | 800 | 498 | | | | 769 |
| | | | | 1802 | 839 | 793 | 752 | 473 | | | | 932 |
| | | | | | | **Average** | | | | | | **1001** |

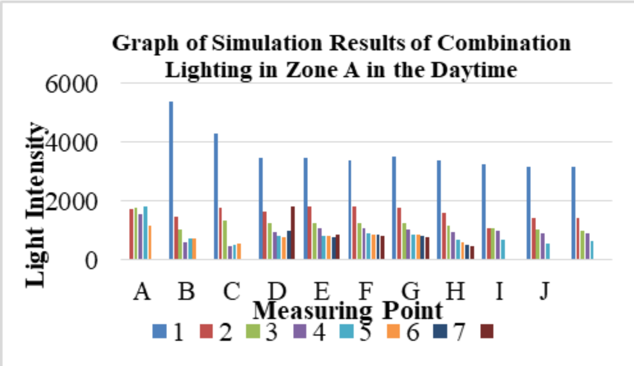


Figure 9. Simulation results of combination lighting in Zone A in the daytime

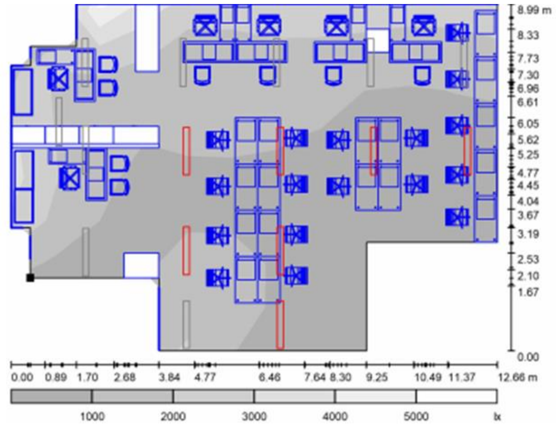

Figure 10. Simulation results of combination lighting Zone A in the afternoon

Table 4. Simulation results of combination lighting Zone A in the afternoon

| | A | B | C | D | E | F | G | H | I | J | K | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 4039 | 3528 | 2022 | 2074 | 2023 | 2130 | 2065 | 1904 | 1900 | 2004 | 2369 |
| 2 | 2718 | 1785 | 1538 | 1241 | 1318 | 1310 | 1305 | 1162 | 884 | 988 | 1070 | 1393 |
| 3 | 2164 | 1079 | 1222 | 199 | 1066 | 1050 | 1039 | 965 | 918 | 856 | 854 | 1037 |
| 4 | 2801 | 1389 | 791 | 966 | 1026 | 1011 | 971 | 874 | 903 | 809 | 812 | 1123 |
| 5 | 2703 | 1372 | 837 | 867 | 824 | 898 | 843 | 637 | 643 | 510 | 579 | 974 |
| 6 | 1909 | 1085 | 720 | 860 | 872 | 970 | 906 | 580 | | | | 988 |
| 7 | | | | 1487 | 1056 | 1037 | 914 | 537 | | | | 1006 |
| 8 | | | | 2553 | 1236 | 923 | 821 | 508 | | | | 1208 |
| | | | | | | **Average** | | | | | | **1104** |

In Fig. 9, it can be seen that points B1, C1, D1, E1, F1, G1, H1, I1, J1 and K1 which are near the opening have high light intensity, which is above 3000 lux. However, it has decreased slightly compared to the morning.

From Table 4, the simulation results show that the level of manual combination lighting in Zone A with clear sky conditions in the afternoon exceeds the standard. This is because the average illumination is 1104 lux, which means it exceeds the standard workspace illumination of 350 lux.

In Fig. 11, it can be seen that at points B1, C1, D1, E1, F1, G1, H1, I1, J1 and K1 decreased from morning to evening. This is because in the afternoon the light entering through the opening in the Northeast direction has decreased. On the other hand, the points in the opening leading to the Southwest have increased, namely at points D8, E8, F8, G8 and H8.

b. Lighting Quality Combination of Credit Card Processing Promotion Room and Audit Room

The results of the manual combination lighting simulation in Zone B can be seen in Fig.10 consisting of 22 light points with the type of lamp used is PHILIPS TCS260 2xTL5-28W HFP M6_827 with a distance between lamps of 2.4 meters. In this simulation, 11 light points that were extinguished near the opening (window), can be seen in Fig. 12.

In Fig. 12, it can be seen that in the morning natural light enters the building from the opening on the southeast side so that the light intensity in this area is quite high. While the area on the Northwest side is a bit dark. During the day, the light entering the building is almost evenly distributed because light enters the building through openings to the Southeast and Southwest. In the afternoon, the area on the northwest side of the Credit Card Processing Room is very bright. While in the Audit Room it is not bright, because in this room there is only an opening on the southeast side.

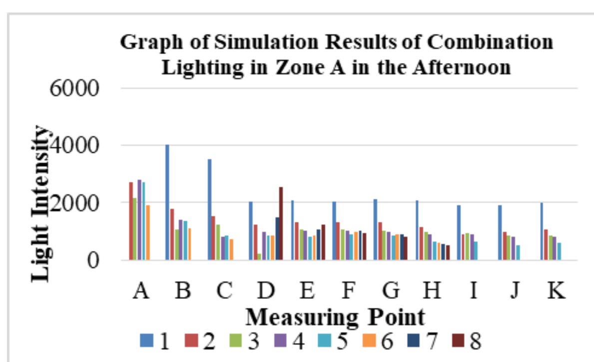


Figure 11. Simulation results of combination lighting in Zone A in the afternoon

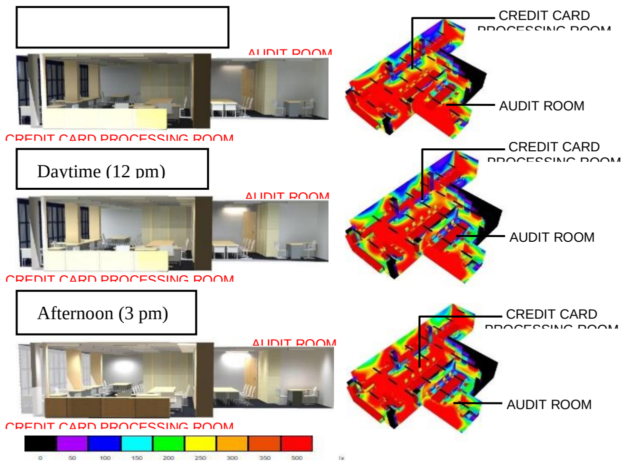


Figure 12. Simulation results of combination lighting Zone B in the morning, daytime and afternoon

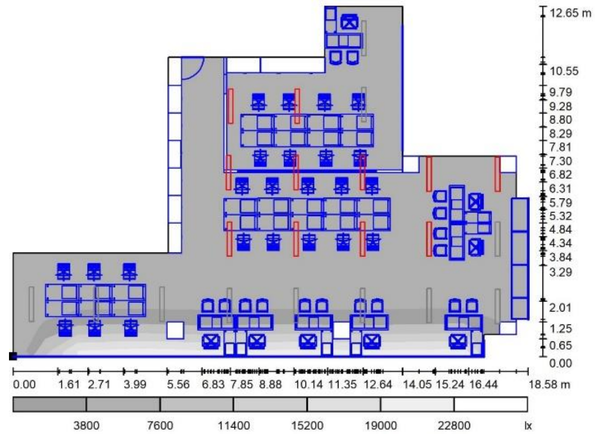


Figure 14. Simulation results of combination lighting B Zone in the morning

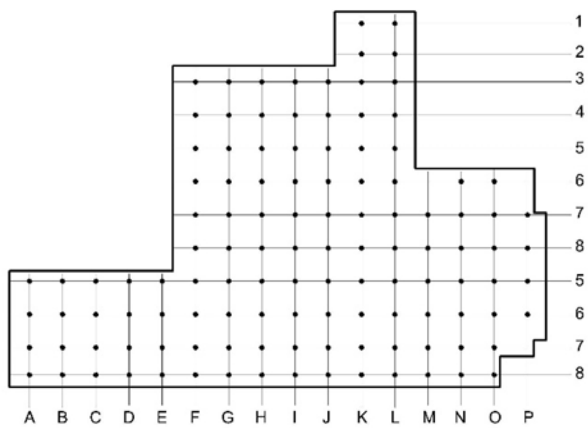


Figure 13. Measuring point of Zone B

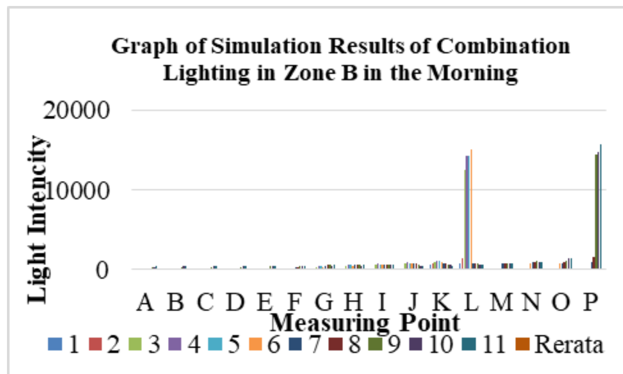


Figure 15. Simulation results of combination lighting in Zone B in the afternoon

Table 5. Simulation results of combination lighting Zone B in the morning

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | 568 | 718 | | | | | 643 |
| 2 | | | | | | | | | | | 812 | 1430 | | | | | 1121 |
| 3 | | | | | | 61 | 340 | 494 | 583 | 776 | 954 | 12447 | | | | | 535 |
| 4 | | | | | | 56 | 497 | 671 | 765 | 886 | 1074 | 14193 | | | | | 658 |
| 5 | | | | | | 92 | 445 | 581 | 664 | 805 | 1072 | 14227 | | | | | 610 |
| 6 | | | | | | 184 | 337 | 431 | 576 | 801 | 1028 | 14972 | | 819 | 815 | | 560 |
| 7 | | | | | | 311 | 529 | 597 | 680 | 741 | 831 | 719 | 837 | 900 | 859 | 1028 | 730 |
| 8 | | | | | | 376 | 610 | 657 | 710 | 760 | 774 | 773 | 857 | 987 | 1024 | 1590 | 829 |
| 9 | 375 | 351 | 361 | 367 | 465 | 435 | 607 | 623 | 693 | 676 | 710 | 751 | 857 | 1060 | 1092 | 14442 | 1492 |
| 10 | 381 | 414 | 423 | 422 | 432 | 456 | 510 | 551 | 573 | 554 | 580 | 640 | 788 | 1024 | 1397 | 14757 | 1494 |
| 11 | 479 | 521 | 533 | 516 | 421 | 482 | 565 | 580 | 612 | 553 | 495 | 663 | 820 | 1027 | 1392 | 15639 | 1581 |
| 12 | 877 | 911 | 918 | 937 | 1042 | 917 | 952 | 828 | 947 | 818 | 1012 | 905 | 1158 | 1273 | 1397 | | 993 |
| **Average** | | | | | | | | | | | | | | | | | **932** |

Table 5 shows that the level of manual combination lighting in Zone B with clear sky conditions in the morning exceeds the standard. This is because the average illumination is 932 lux, which means it exceeds the standard workspace illumination of 350 lux.

Figure 15 shows the light intensity in the L and M measuring point areas is very high, this is because these points are close to the opening facing the Northeast. So in the morning, the light intensity is very high. While in the area of measuring points A12 to O12 even though they are also close to the opening, the light intensity is low compared to the area of measuring points L and M. This is because the area of measuring points A12 to B12 is in the southwest so that in the morning the incoming natural light is quite low compared to the measuring point area in the Northeast.

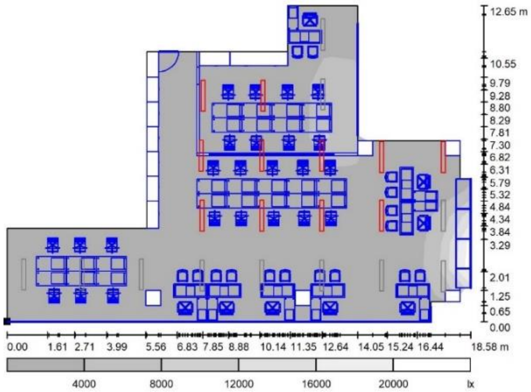

Figure 16. Simulation results of combination lighting Zone B in the daytime

From Table 6, it can be seen that the level of manual combination lighting in Zone B with clear sky conditions during the day exceeds the standard. This is because the average illumination is 662 lux, which means it exceeds the standard workspace illumination of 350 lux. The intensity of the light has decreased from the morning.

Figure 17 shows the measuring point area A12 to O12 has a very high light intensity because this area is close to building openings. So that during the day a lot of natural light enters the room. Table 7 shows that the level of manual combination lighting in Zone B with clear sky conditions in the afternoon exceeds the standard. This is because the average illumination is 718 lux, which means it exceeds the standard workspace illumination of 350 lux. The intensity of the light has increased from noon.

Table 6. Simulation results of combination lighting Zone B in the daytime

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | 320 | 486 | | | | | 403 |
| 2 | | | | | | | | | | | 419 | 801 | | | | | 610 |
| 3 | | | | | | 48 | 282 | 388 | 403 | 456 | 494 | 869 | | | | | 682 |
| 4 | | | | | | 50 | 347 | 556 | 588 | 581 | 533 | 876 | | | | | 705 |
| 5 | | | | | | 85 | 293 | 490 | 527 | 543 | 551 | 787 | | | | | 669 |
| 6 | | | | | | 191 | 245 | 392 | 493 | 594 | 641 | 614 | | 660 | 660 | | 644 |
| 7 | | | | | | 284 | 465 | 533 | 564 | 578 | 605 | 602 | 703 | 712 | 637 | 811 | 678 |
| 8 | | | | | | 340 | 560 | 589 | 617 | 633 | 640 | 656 | 716 | 752 | 686 | 1037 | 748 |
| 9 | 374 | 342 | 369 | 379 | 460 | 419 | 580 | 599 | 628 | 614 | 634 | 652 | 690 | 730 | 588 | 1116 | 735 |
| 10 | 400 | 426 | 449 | 442 | 432 | 454 | 514 | 552 | 554 | 532 | 519 | 557 | 624 | 669 | 703 | 1100 | 695 |
| 11 | 529 | 580 | 605 | 579 | 455 | 518 | 619 | 638 | 650 | 583 | 454 | 613 | 710 | 753 | 761 | 993 | 714 |
| 12 | 1129 | 1221 | 1233 | 1249 | 1328 | 1202 | 1251 | 1119 | 1249 | 1102 | 1305 | 1123 | 1329 | 1370 | 1395 | | 1304 |
| | | | | | | | | | **Average** | | | | | | | | **662** |

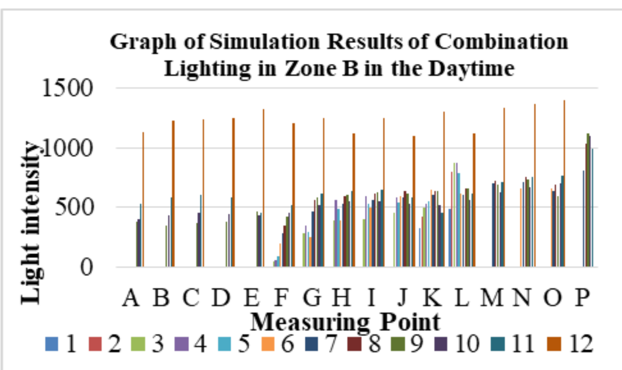


Figure 17. Simulation results of combination lighting in Zone B in the afternoon

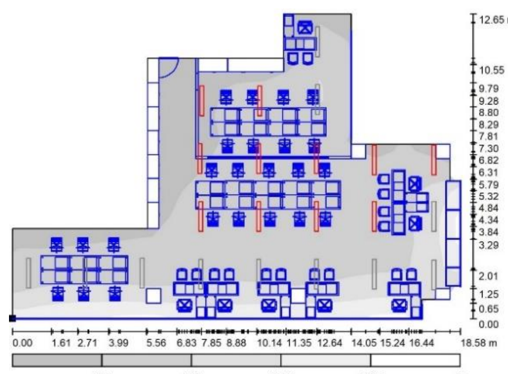

Figure 18. Simulation results of combination lighting Zone B in the afternoon

Table 7. Simulation results of combination lighting Zone B in the afternoon

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | 281 | 407 | | | | | 344 |
| 2 | | | | | | | | | | | 353 | 597 | | | | | 475 |
| 3 | | | | | | 64 | 299 | 413 | 397 | 463 | 425 | 621 | | | | | 523 |
| 4 | | | | | | 63 | 410 | 581 | 610 | 591 | 473 | 625 | | | | | 549 |
| 5 | | | | | | 113 | 367 | 523 | 561 | 569 | 530 | 627 | | | | | 579 |
| 6 | | | | | | 206 | 326 | 434 | 540 | 627 | 651 | 575 | | 785 | 789 | | 700 |
| 7 | | | | | | 368 | 582 | 646 | 691 | 699 | 720 | 742 | 854 | 837 | 749 | 881 | 797 |
| 8 | | | | | | 447 | 713 | 759 | 774 | 795 | 805 | 826 | 854 | 887 | 783 | 989 | 857 |
| 9 | 590 | 566 | 637 | 640 | 856 | 686 | 857 | 864 | 903 | 901 | 893 | 906 | 916 | 971 | 760 | 1066 | 919 |
| 10 | 606 | 743 | 848 | 915 | 905 | 827 | 902 | 990 | 1003 | 969 | 899 | 894 | 990 | 1057 | 999 | 1116 | 993 |
| 11 | 787 | 1039 | 1177 | 1224 | 1162 | 942 | 1228 | 1310 | 1339 | 1291 | 899 | 1058 | 1296 | 1363 | 1278 | 1082 | 1163 |
| 12 | 1749 | 15080 | 15167 | 15421 | 16141 | 15354 | 15281 | 15023 | 15298 | 15129 | 17185 | 14989 | 15316 | 15359 | 15805 | | 15731 |
| | | | | | | | | | **Average** | | | | | | | | **718** |

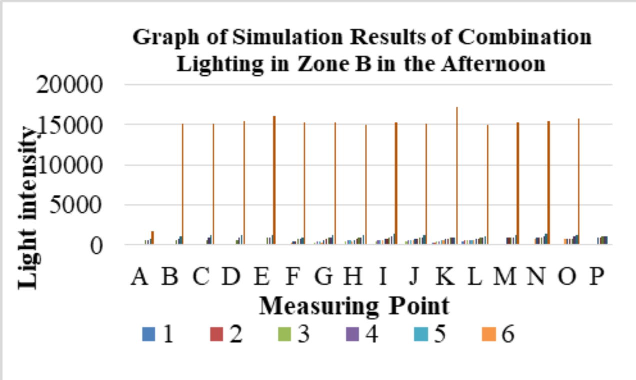


Figure 19. Simulation results of combination lighting in Zone B in the afternoon

Figure 19 shows that the light intensity in the measuring point area B12 to O12 experienced a very high increase, namely above 10,000 lux on average. This is because the area is close to the opening facing the Southwest so that in the afternoon there is a lot of natural light that enters the room. Meanwhile, the area of measuring points L and M which are also near the opening has decreased because the area is in the Northeast. So that in the afternoon the natural light that enters the area is quite a bit compared to the area in the Southwest.

### *4.2. Analysis of Natural and Artificial Lighting Energy Calculation*

To determine the amount of energy consumption in the existing artificial lighting system on the research object, the researchers conducted a lighting simulation using the DIAlux 4.13 program on the artificial lighting system on objects with the same conditions as conditions in the field.

Table 8. Result of calculation of energy consumption of existing artificial lighting research object

| No | Lighting Zone | Energy Lighting Evaluation (kWh/a) | Area | Total Energyper m² (kWh/(a.m²) |
|---|---|---|---|---|
| 1 | Zone A | 1405.44 | 94.12 | 14.93 |
| 2 | Zone B | 1855.62 | 148.17 | 12.52 |
| | Total | 3261.06 | 242.29 | 13.46 |

Table 9. Result of calculation of energy consumption of existing artificial lighting research object

| No | Lighting Zone | Energy Lighting Evaluation (kWh/a) | Energy Lighting Combination (kWh/a) | Area m² | Total Energy per m² (kWh/(a.m²)) |
|---|---|---|---|---|---|
| 1 | Zone A | 1405.44 | 702.72 | 94.12 | 7.47 |
| 2 | Zone B | 1855.62 | 927.81 | 148.17 | 6.26 |
| | Total | 3261.06 | 1630.53 | 242.29 | 6.73 |

From Table 8, it can be seen that the total amount of lighting energy in the research object is 3261.06 kWh/a. This amount is a calculation of lighting energy consumption per year, which is obtained from simulations of lighting energy consumption. To find out the amount of energy used in the manual combination lighting system, namely a lighting system that utilizes natural light that enters the building and also uses artificial lighting by turning on light points in areas that are less exposed to natural light and turning off light points in areas that have sufficient light intensity. so that energy use can be more efficient, can be seen in the following table.

From Table 9, the combined lighting energy is obtained from the amount of lighting energy used for a year multiplied by 50% (the number of light points that are lit half of the total number of light points). While the total energy per m² is obtained from the total lighting energy divided by the total area. From this description, it can be concluded that the amount of lighting energy per year used on the research object when all lights are on is 3261.06 (kWh/a). While the amount of manual combined lighting energy per year used is 1630.53 (kWh/a). So that the use of electricity with a combination lighting system can reduce half of the lighting energy consumption on the object.

## 5. Conclusion

An effective lighting system can be obtained from a lighting system that utilizes natural and artificial lighting optimally so that it can save energy and users feel comfortable occupying the space. The quality of lighting in the Menara Bank Mega building using a combination of natural and artificial lighting systems manually results in exceeding standardization. This system is carried out by turning off several light points in areas that have received sufficient natural lighting and continuing to turn on the lights in areas that still lack the level of illumination so that the lighting level can be evenly distributed but the result, the light intensity exceeds the minimum standardization for the workspace. But with this system can save energy use.

From the simulation results of the combination of natural and artificial lighting systems that have been done manually, this lighting system can save energy use by up to 50%, which is 1630.53 kWh/a. So, it can be concluded that the combination of natural and artificial lighting systems manually is a lighting system that can save energy use. Based on the results of the research discussed in the previous chapter regarding the Quality of Natural and Artificial Lighting and Manual Combination Lighting. So, it is recommended to the users of the Menara Bank Mega Building not to turn on the lights if the natural light illumination meets the minimum standardization for the workspace so that energy is not wasted. The building manager should also review the control grouping of the light points, the light points that are close to the openings should be grouped in one control so that the light points that are far from the opening can be turned on without turning on the light points that are close to the opening.

## Acknowledgements

Thanks to the employees of Mega Bank Tower Building for their cooperation during this research.

## References

[1] P. F. Erahman, A. M. Nugroho, and N. Sujudwijono, "Rent Office with Natural Lighting Approach in Malang City," *J. Mhs. Jur. Arsit. Univ. Brawijaya*, vol. 3, no. 4, 2015. [in Bahasa]

[2] O. R. Gw and B. S. Kusumo, "Evaluation Study of Natural Lighting in Joint Lecture Building III, University of Muhammadiyah Malang," *J. Media Tek. Sipil*, vol. 9, no. 1, pp. 50–60, 2011. [in Bahasa]

[3] N. Jamala, "Lighting Analysis of Energy Efficient Buildings (Case Study: Wisma Kalla Building in Makassar)," *J. Penelit. dan Karya Ilm. Arsit. Usakti*, 2018. [in Bahasa]

[4] R. R. Janis, W. K. Y. Tao, and P. E. Affiliate, *Mechanical and Electrical Systems in Buildings Sixth Edition*, Sixth Ed. New York: Pearson Education, Inc., 2005.

[5] B. Evans, *Daylight in Architecture*. New York: Architectural Record Book McGraw-Hill Book Company, 1981.

[6] L. Darmasetiawan, Christian, and Puspakesuma, *Lighting Techniques and Lamp Layout, Vol. 1*. Jakarta: Gramedia, 1991. [in Bahasa]

[7] J. M. S. A. Thojib, "Visual Comfort Through Natural Lighting In The Office," *J. RUAS*, vol. 11, no. 2, 2013. [in Bahasa]

[8] N. Amin, "Optimization of the Lighting System by Utilizing Natural Light (Case Study of the Lab. Electronics and Microprocessor Untad)," *J. Ilm. Foristek*, vol. 1, no. 1, pp. 43–50, 2011. [in Bahasa]

[9] I. Badan Standarisasi Nasional, "Procedures for Designing Natural Lighting Systems in Buildings," 2001. [in Bahasa]

[10] Soegijanto, *Buildings in Indonesia with a Humid Tropical Climate in Terms of Building Physics*. Jakarta: Direktorat Jenderal Pendidikan Tinggi, 1999. [in Bahasa]

[11] N. Jamala and R. Rahim, *Visual Comfort Theory and Applications*. Makassar: Badan Penerbit Universitas Negeri Makassar, 2017. [in Bahasa]

[12] T. Handayani, "Energy Efficiency in Building Design," *Spektrum Sipil*, vol. 1, no. 2, pp. 102–108, 2010. [in Bahasa]

[13] A. R. Riandito, "Energy Efficiency in the Library Room of the Faculty of Civil Engineering and Planning, Islamic University of Indonesia through Optimization of Natural and Artificial Lighting," Universitas Atma Jaya Yogyakarta, 2012. [in Bahasa]

[14] Pemerintah DKI Jakarta, "DKI Jakarta Government Regulation No. 38 of 2012 concerning Green Buildings." Jakarta, 2012. [in Bahasa]

[15] Pusat Bahasa Indonesia, *Indonesia Dictionary*, 3rd ed. Jakarta: Pusat Bahasa, Departemen Pendidikan Nasional, 2001. [in Bahasa]