Jurnal Kejuruteraan 35(2) 2023: 511-521
https://doi.org/10.17576/jkukm-2023-35(2)-23

Application of Building Information Modelling (BIM) Six Dimension (6D) in Green Buildings: A Case Study of Sunshine and Daylight Analysis

Guomin Wei[a,b], Asmawan Mohd Sarman[a*], Lillian Gungat[a], Minghe Li[b], Ling Shen[a] & Goh Siew Fang[a]

[a]*Civil Engineering, Faculty of Engineering, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia*
[b]*Baise University, Baise 533000, China*

**Corresponding author: asmawan@ums.edu.my*

Received 5 August 2022, Received in revised form 30 September 2022
Accepted 30 October 2022, Available online 30 March 2023

ABSTRACT

Although a considerable amount of research has been focused on how building information modeling (BIM) helps improve sustainable construction, BIM(6D) model validation and efficient data analysis methods are still lacking. This study aims to provide the more effective research method and analytical method. The Greenjiansville Sunshine analysis software Sun2020 and daylight analysis software Dali2020 were used for 6D modeling and simulation and real simulation of a building outside the daylight range and time. The daylight coefficients, outdoor visual field observation rate, and daylight quality were calculated for the rooms inside the building. The results show that single the daylight statistics and analysis color map can not accurately analyze whether the actual daylighting meets the demand, but combined with Power BI comprehensive analysis can get fast and accurate results. This paper provides important guidance for building researchers and practitioners to better align BIM development with green building development in the future.

Keywords: BIM 6D; Daylight Analysis; Green Building; Sunlight Analysis

INTRODUCTION

The concept of sustainable development is rapidly evolving to embrace the ongoing relationship among social, economic, and natural systems. In 2018, Wang Tiehong (2018) president of the China Building Association, stated that the transformation and upgrading of the construction industry should focus on green development and should comprehensively and deeply promote the development of green buildings, prefabricated buildings, and ultralow-energy-consumption passive buildings (L. Yujie. et al. 2017; Mazzoli, C. et al. 2021).

From 2015 to the end of June 2021, Hamed. and Hamidreza et al. focused on the studies published in the domains of BIM and sustainability, which have been published in the seminal databases as Scopus and Web of Science (WoS), and they found that green buildings and rating system are two themes considered in BIM and sustainability (Ferdosi H. et al. 2022; Carvalho JP. et al. 2021; Fokaides PA. et al. 2020). BIM provides essential data and information for projects and encompasses several valuable functions for building performance analysis method (Liu S. et al. 2015), materials and resources, energy and atmosphere, sustainable sites, indoor environmental quality, and innovation (Mirpanahi MV. et al. 2021; Huang, B. et al. 2021).

The BIM 6D concept is associated with aspects related to energy efficiency and simulation, which themselves are associated with environmental pollution and the sustainability of the building. Aspects associated with efficient and sustainable maintenance, as well as the life cycle of materials, must be considered (Charef, R. et al. 2018). By means of 6D model, the real behaviour of the building can be simulated, helping to make decisions about the design and operation of the building (Yule, S. et al. 2006; Montiel-Santiago, F. J. et al. 2020). This is because it makes it possible to improve energy efficiency, which, in turn, provides greater quality and comfort in the use of the building. It is in the design phase of new buildings when the greatest emphasis can be placed on the future building being built for sustainability and energy efficiency, i.e., when the building geometry is decided, as well the orientation, compactness, envelope, etc (Zhan, S. et al. 2020; Mésároš, P. et al. 2021).

Autodesk Revit, the most popular BIM authoring tool among researchers, has been referred to in 42 research articles and used in modelling works. Other software, such as ArchiCAD, is discussed in review papers in refs. (L. Sanhudo. et al. 2018; Z. Alwan. et al. 2016; W.-T. Hong. et al. 2019; F. Mellado. et al. 2020; S.B.M. Ali. et al. 2020). Although a considerable amount of research has been focused on how Building Information Modeling (BIM) helps improve sustainable construction (Ferdosi H. et al. 2022). BIM tools such as the ERGON module of IES-VE can model real operational data and by utilizing its integrated processes, the requirements of the LEED standard can

be analyzed and evaluated from various aspects such as daylight, reduced consumption of water, and other utilities (Ansah MK. et al. 2019; Wen, Q. et al. 2020). While much research has focused on how BIM can help improve sustainable construction, there are still a limited number of studies that have investigated the BIM process in sustainability fields.

In this work, the possibilities of improving the energy efficiency of a building that the BIM methodology offers are studied. The reasonable use of natural light, this considers the great energy-saving potential that the role of daylight can play on a daily basis and the quality of the internal space quality. In terms of lighting buildings, by simulating the energy model, the possibility of improving efficiency can be studied from various perspectives, such as daylight, building orientation. Power BI was used for visual analysis of sunlight analysis data and daylight analysis data. In addition to analyzing the energy model, the most important work of this study is to provide readers with convenient guidance for the integrated application of BIM and Power BI.

METHODOLOGY

INTRODUCTION TO SUN 2020 AND DALI2020

Sun2020 is a professional sunshine analysis software released by Thsware company. This sunshine analysis tool is popular in many architectural design industries. The software can provide sunshine simulation, sunshine analysis, export analysis report and other functions to provide more sunshine data for architectural design.

Dali2020 is a professional daylight analysis software by Thsware. The biggest difference between this software and sunshine analysis software is that the research object of daylight analysis is the interior of the building, and it can calculate the daylight coefficient, daylight level. Generally, designers like to use sunshine analysis in combine with daylight analysis.

Current energy analysis software can export various kinds of file format for analysis, but there are still some detailed data in BIM that cannot be exported. However, Power BI can be used as a universal tool of data management to address the issue that operability is not treated the same in analysis research as in BIM. Figure 1 illustrates the research procedure of this study.

METHODS

Considering that Revit can interact with more BIM softwares, so it is selected for modeling. Although Revit contains additional item of light analysis, Sun2020 and Dali202 software can achieve more analysis of sunlight. Therefore, they are used in this study to simulate sunshine and daylight respectively. The specific operation process is shown in Figure 1.

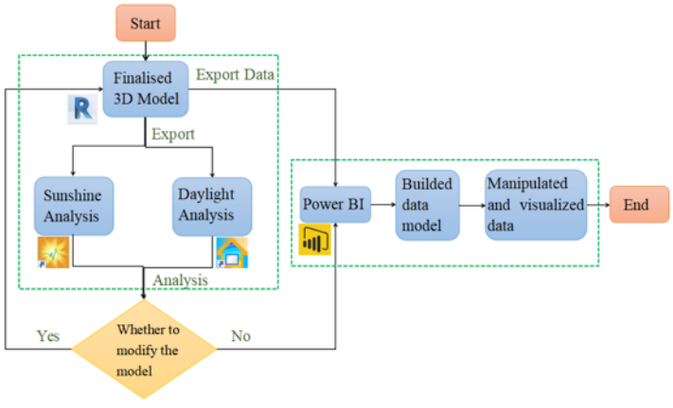


FIGURE 1. Flow chart of research methods and procedure of this study

RESULTS AND DISCUSSION

The overall sunshine situation of the building will be discussed in section 3.1, including the analysis of the shielding relationship between the 2# school building and other buildings, and the analysis of the sunshine duration in a day in the area around the 2# school building. Section 3.2 will discuss how to quickly and accurately analyze the indoor daylight results of 2# school building by combining Power BI.

SUNSHINE ANALYSIS RESULTS

In this project, it was necessary to calculate the sunshine conditions of the 2# school building, library, dining hall, and other buildings in the campus. The relationship between the shielding and the being shielded between buildings is shown in Table 1. According to the data in the table, the 2# school building is only blocked by the original school building, but It also blocks the library and dining hall.

TABLE 1. The basic situation of object buildings in the shielding area of the base

Sheltered buildings		Shelter buildings
Name	Height (m)	Name
2# School building	10.7	Original school building
Office building	3.3	Gate guard, Library, Dining hall
Gate guard	3.3	Library
Library	9.7	2# School building, Original school building, Dining hall
Original school building	12.3	
Dining hall	6.6	2# School building, Library, Original school building

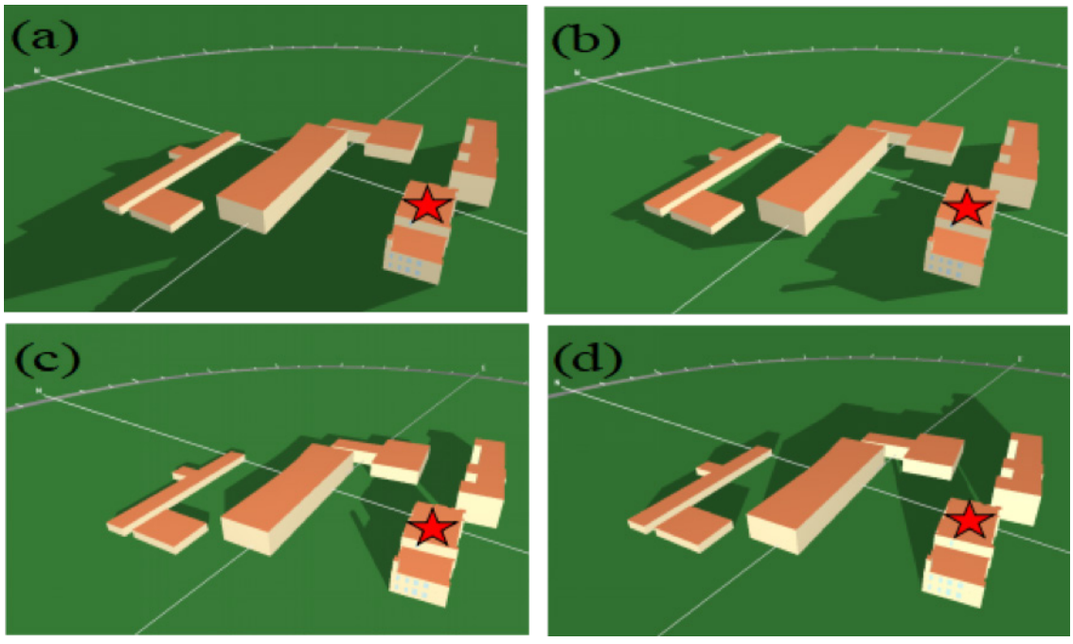


FIGURE 2. The shadow range of 2# school building obtained from Sun2020 from 8:00 to 16:00
(a)At 8 o 'clock, (b) At 9 o 'clock, (c)At 15 o 'clock, (d)At 16 o 'clock

Figure 2 shows the shadow changes of buildings from 8:00 a.m. to 4:00 p.m., among which the building marked with five stars is the 2# school building. The shadow changes in the figure reveal that the 2# school building is only covered by a small range of the original school building before 9:00 a.m. The rest of the time it's not covered by other buildings. The sunshine low after 16:00 is very weak, so this paper did not analyze.

The most commonly used parameter in several empirical models that have been used to calculate solar radiation is sunshine duration, because it can be easily and reliably measured, and data are widely available (Al-mostafa ZA. et al. 2014; Almorox J. et al. 2005).

Figure 3 presents the sunshine duration of each point in the analysis area of 2# school building. The sunshine duration in this study refers to the continuous sunshine obtained by analysis during the effective period of the winter solstice (the day with the fewest hours of sunshine) for the main window facing the object building. The numbers in different colors indicate the length of daylight at that point. After analyzing the sunshine duration of the area around the 2# school building, it was found that the sunshine duration of the southern area was basically 8 h, while the northern area was backlit, and the sunshine duration of some areas was zero. The variation of sunshine duration on the east and west sides was more obvious, reaching more than 3 h. Therefore, all window lighting time of the 2# school building was more than 3 h, so sunshine conditions were met.

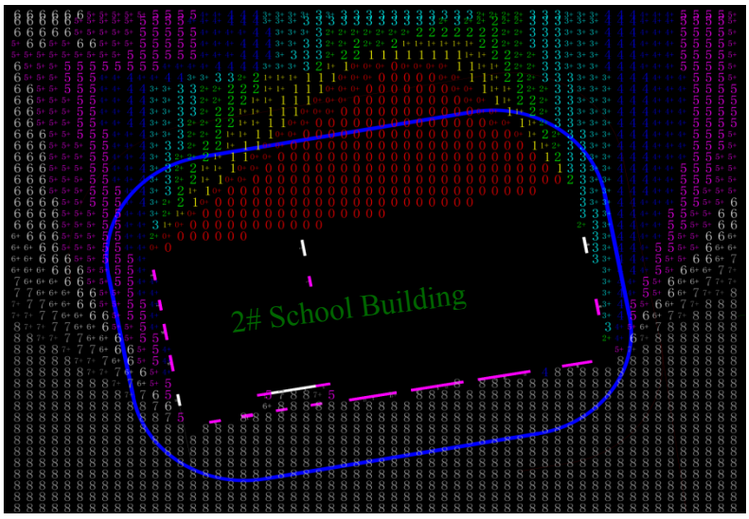


FIGURE 3. The sunshine duration of each point in the analysis area of 2# school building from Sun2020

DAYLIGHT ANALYSIS RESULTS

Detailed analysis on this finding is performed using statistical analysis to determine the association between each parameter. Daylight analysis is quite different from sunshine analysis, mainly as follows: (1) The research object of daylight analysis is indoors, while that of the sunshine analysis is outdoors. (2) The statistical object of daylight analysis is the calculation point in the room, and the calculation objects of sunshine analysis are the sunshine window and the plane area of the building. (3) The light climate condition in daylight analysis is all cloudy, while the light climate condition in sunshine analysis is sunny.

According to the requirements of the "Building Lighting Design Standard," the lighting coefficient of office, toilet, corridor, restaurant, and classroom in the building should be calculated. The calculation results are shown in the following charts.

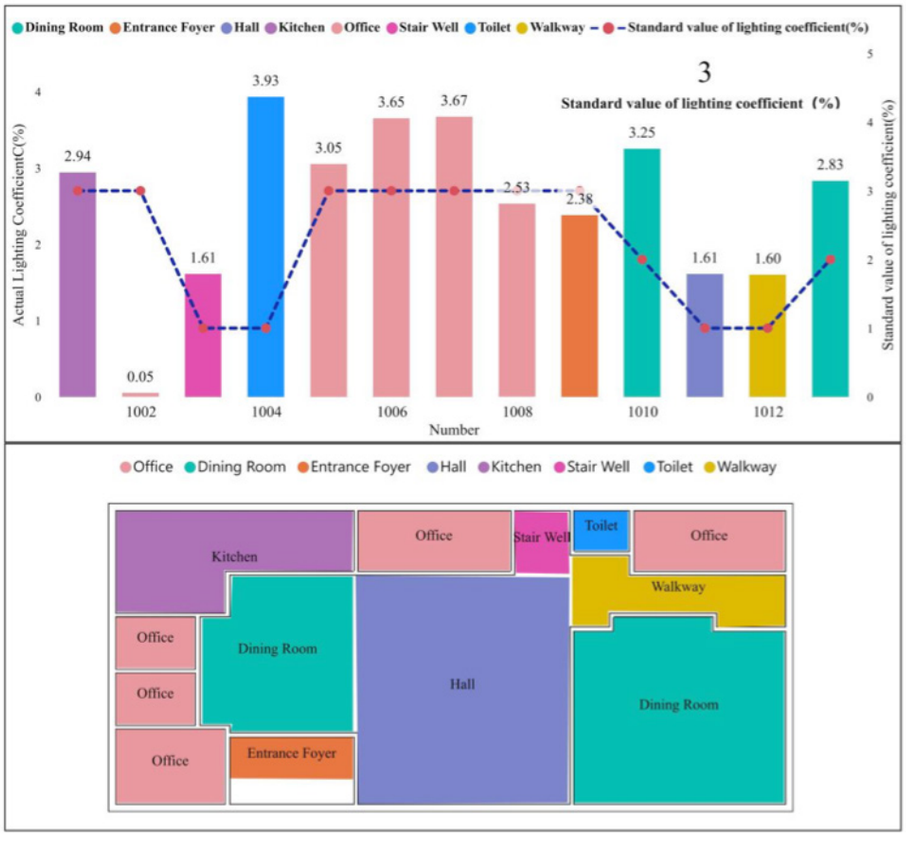


FIGURE 4. Daylight analysis statistical graph on the first floor from Power BI

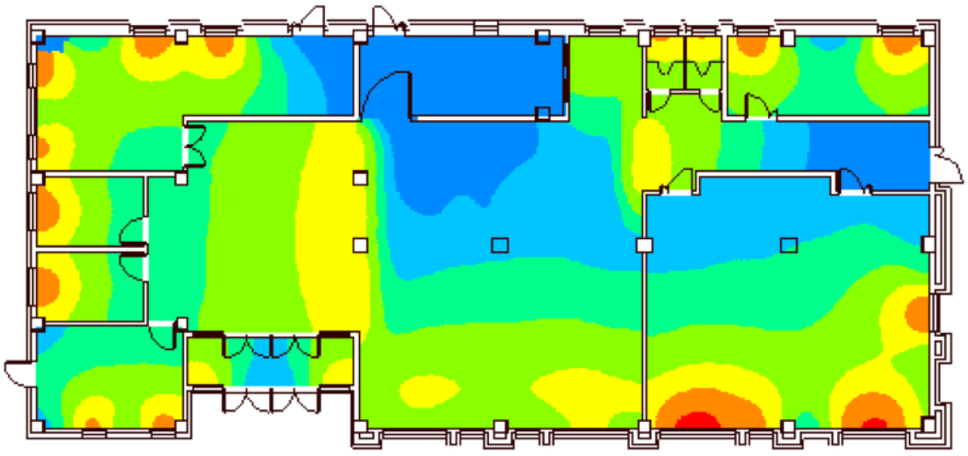
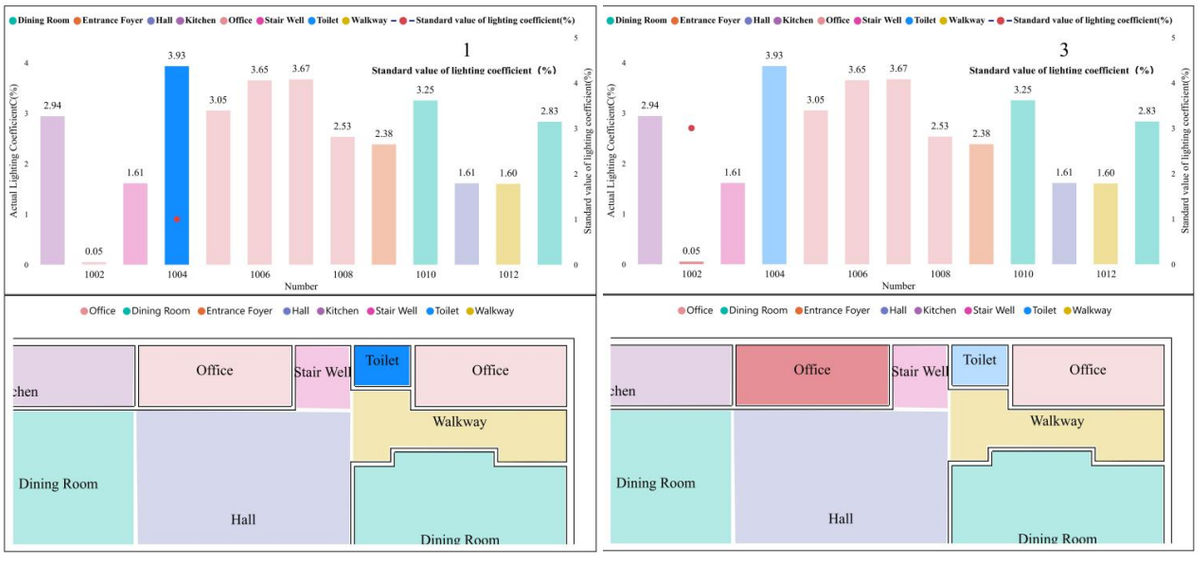


FIGURE 5. Daylight analysis color map on the first floor from Dali2020



(a)daylight analysis of the toilet on the first floor

(b)daylight analysis of the office on the first floor

FIGURE 6. Daylight analysis and color map in diffierent rooms on the first floor from Power BI

Figure 4 shows the actual and standard daylight rates for all rooms on the first floor. This analysis data can be visually interacted with the colored map of the room. If any data is viewed in Power BI, it can visually interact with related data, and this analysis process can greatly improve productivity.

Figure 5 is a daylight analysis map on the first floor. The color map of daylight coefficient analysis directly reflects the daylight effect of each room in the building. The figure legend shows the fill colors within the standard values (e.g. When the lighting coefficient is in the range of 11.0%-12.6%, the analysis map is shown in red.) This map was exported by the analysis software Dali2020, which vividly shows the daylight dynamics in the plane of the first floor, but it is not analyzed by Power BI. Because there is still no perfect way to analyze it in Power BI, which is also a problem that needs to be solved urgently.

Figure 6 (a) shows the daylight situation of toilets on the first floor. As can be seen from the figure, the actual daylight coefficient of the toilet is 3.93%, which is the highest among all the rooms on the first floor. According to Figure 5, there is no abnormality in the lighting of this room, but according to "Green Building Evaluation Standard", the standard value of lighting coefficient of toilets is only 1%. So the daylight of this room cannot satisfy the daylight requirement.

Figure 6 (b) shows the daylight of the office on the left side of the stairwell on the first floor. The actual daylight value of this room is very low, only 0.05%, which is consistent with the lighting situation of the office shown in Figure 5. Therefore, this room must increase the daylight by expanding the window area or adding some facilities that can improve the natural lighting.

Figure 7 shows the actual and standard daylight rates for all rooms on the second floor. Figure 8 is the daylight

analysis map on the second floor. According to figure 8, the daylight situation of the walkway and storeroom room on the second floor are not very good. Combined with the daylight data of the walkway in Figure 9 (a) to analysis, the actual daylight rate is 0.8%, and the standard daylight rate is 1%, so it basically meets the daylight requirement. However, combined with the daylight data of the storeroom room in figure 9 (b), it is found that the daylight requirement of the room is far from meeting the daylight requirement.

Figure 10 shows the actual and standard daylight rates for all rooms on the third floor. Figure 11 is the daylight analysis map on the third floor. According to these two pictures, it can be seen that the daylight situation of the third floor is basically the same as that on the second floor. The daylight value of the area near the window of the classroom is relatively high in a wide range, which leads to the high daylight value of the classroom, which is verified in figure 12 (a). Figure 12 (b) shows the daylight factor of the office to the right of the toilet, which is perfect and it can be verified from Figure 11.

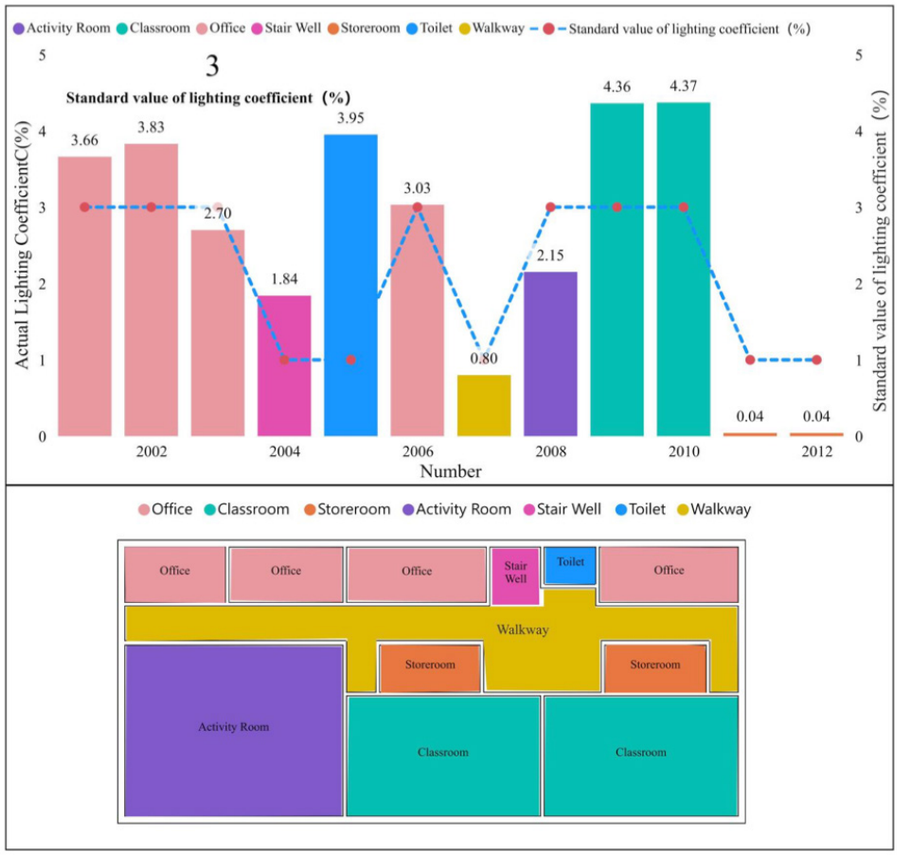


FIGURE 7. Daylight analysis statistical graph on the second floor from Power BI

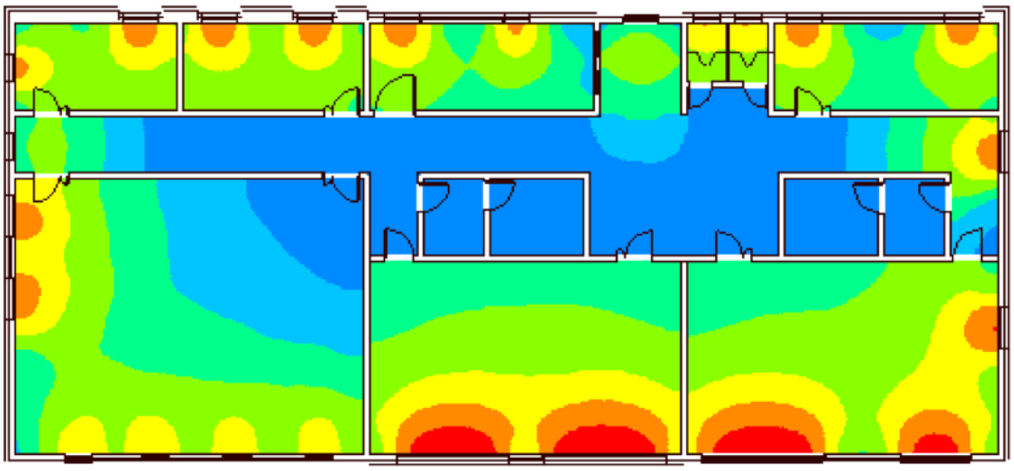
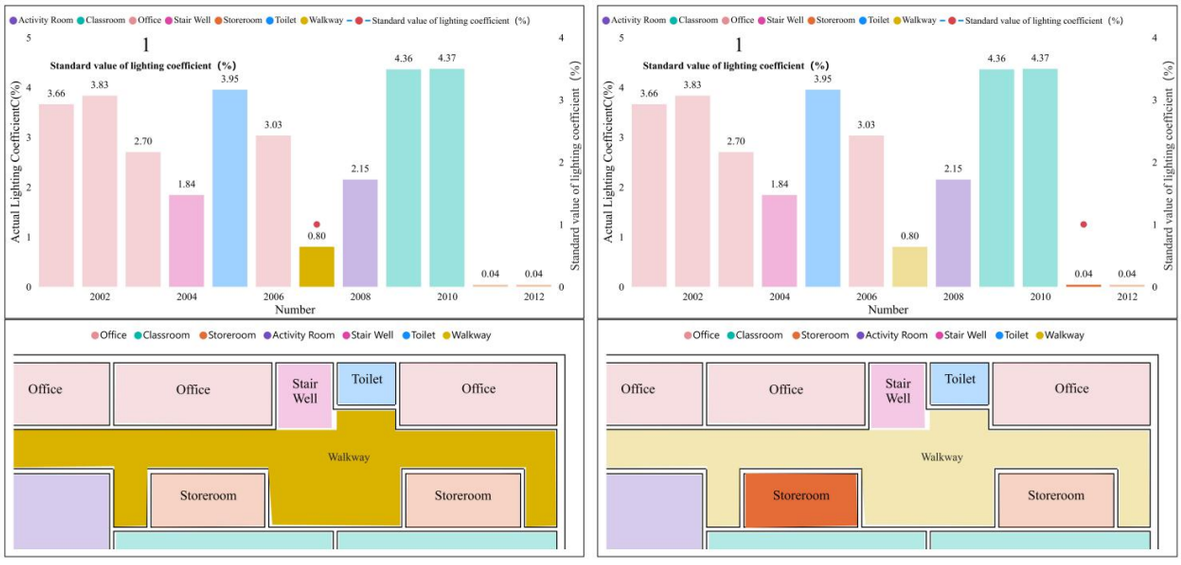


FIGURE 8. Daylight statistics and analysis color map on the second floor from Dali2020



(a) daylight analysis of the walkway on the second floor

(b) daylight analysis of the storeroom on the second floor

FIGURE 9. Daylight analysis and color map in different rooms on the second floor from Power BI

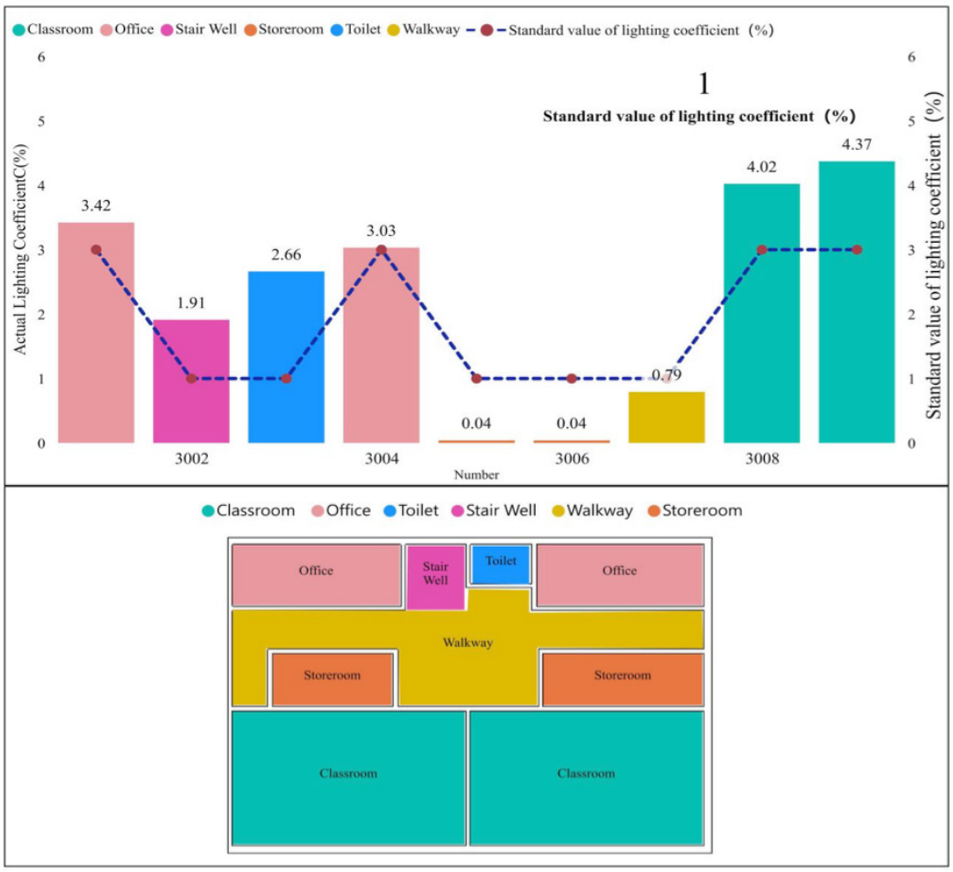


FIGURE 10. Daylight analysis statistical graph on the third floor from Power BI

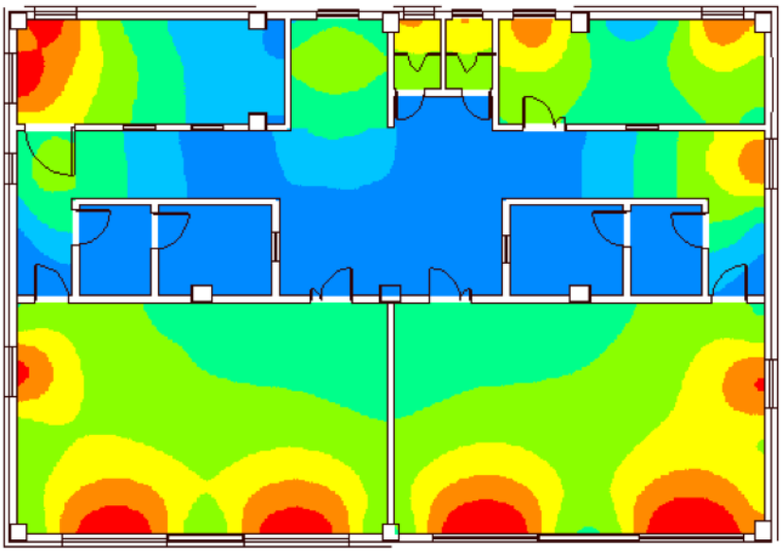
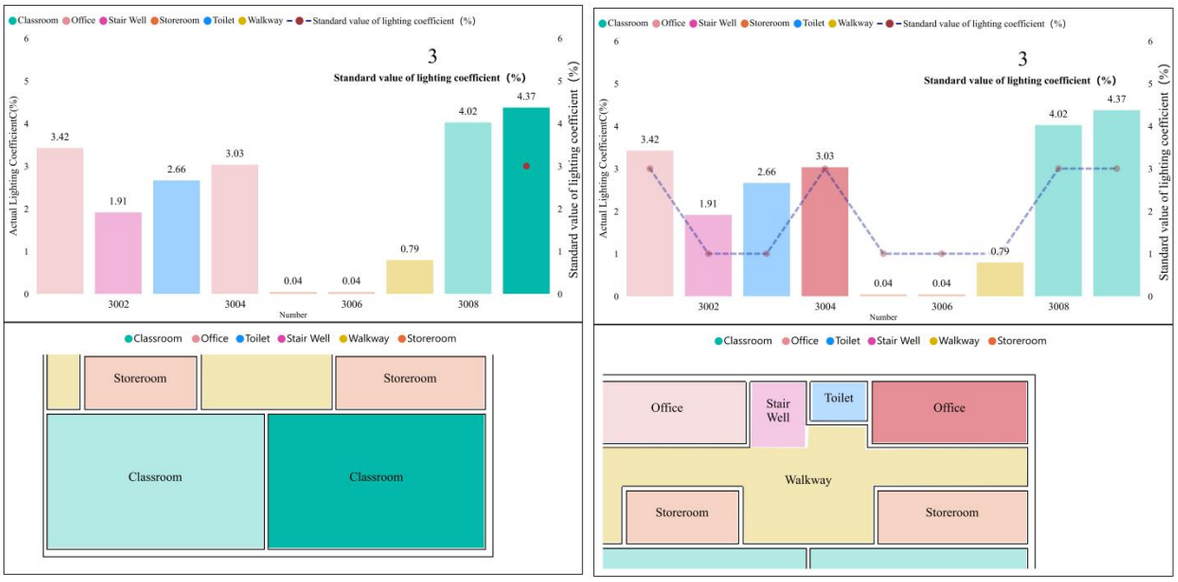


FIGURE 11. Daylight statistics and analysis color map on the third floor from Dali2020



(a) daylight analysis of the stair well on the third floor (b) daylight analysis of the office on the third floor

FIGURE 12. Daylight analysis and color map in different rooms on the third floor from Power BI

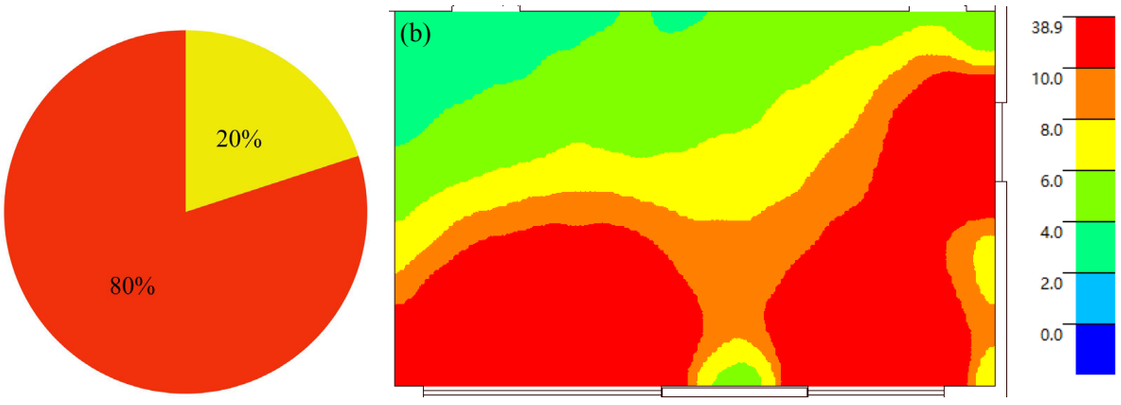


FIGURE 13. The visual field rate was evaluated by the proportion of visual field quality in the room and the color distribution of field rate in the whole area

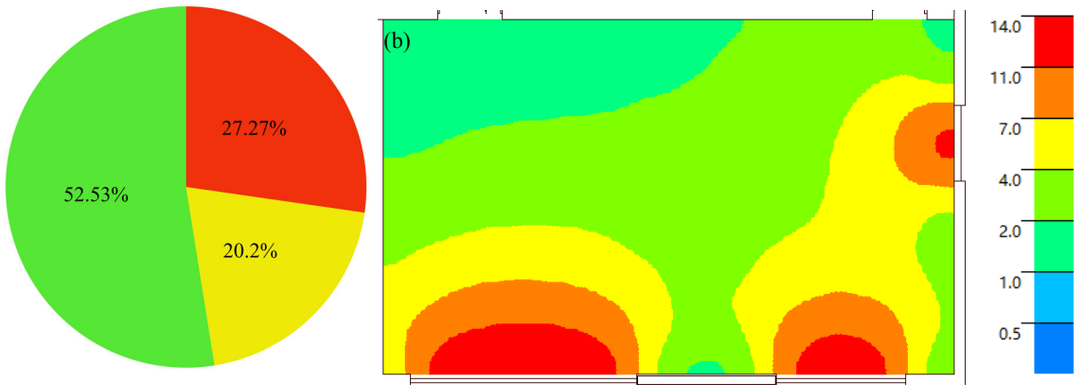


FIGURE 14. Daylight was evaluated by the percentage of indoor daylight mass and the daylight distribution map of the whole area

In addition to the usual daylight calculation for a school building, the analysis of vision (which refers to the ratio of people indoors who can see the outdoor landscape area), the glare index (which is an important index to evaluate the quality of the lighting), and taking the classroom 2010 on the second floor as an example to conduct the comprehensive evaluation.

Figure 13 shows that the room had a good outdoor view rate, and Figure 14 shows that the room also had a good lighting effect. In the field of vision, the uncomfortable situation was caused by the improper distribution of brightness or the extreme brightness contrast in space and time. Therefore, a simulation calculation of the dazzle light index of the room was performed, and the daylight glare index (DGI) value of the room was 16.7 (less than the DGI limit of 25). In each index analysis, the daylight effect of this room was basically consistent with the requirement.

The case study introduced in this contribution showed how data can be further interactively visualized beyond BIM tools. Through the integrated application of Power BI and BIM, more convenient and accurate data analysis can be achieved. The following problems were found in this case analysis:

1. No abnormality was found in the daylight statistics and analysis color map on the first floor, but the actual daylight coefficient was 3.93%, much higher than the standard value of 1%. Combined with the data analysis table, the abnormality of this data could be obviously found.
2. According to the daylight statistics and analysis color map on the second floor, it is found that the daylight coefficient of the walkway and the storeroom are low. Combined with the data analysis chart, it is found that the actual daylight of the walkway is 0.8%, basically meeting the daylight requirement, while the daylight coefficient of the storeroom is only 0.04%, far from meeting the requirement.
3. Data interaction between graphs and colored maps in Power BI enables fast and accurate positioning of analytical data.

CONCLUSION

The combination of Sun2020 and Dali2020 can comprehensively simulate the sunshine situation outside the building and the daylight situation of each room inside the building, so as to make more effective use of natural light.

Finally, it is important to study the use of BIM light environment analysis software. It can output a report, but it cannot be more output file format. This is still not convenient for later data analysis. If Power BI can import different file formats, or the daylight statistics and analysis color map can export more detailed data and be analyzed with Power BI, then data analysis of the green energy savings is more effective. This is an area that green software researchers must focus on immediately.

DATA AVAILABILITY STATEMENT

Not Applicable, because all data, models, and code generated or used during the study appear in the submitted article.

ACKNOWLEDGEMENT

The authors would like to thank to Universiti Malaysia Sabah, Malaysia and Baise University, China for supporting this study.

DECLARATION OF COMPETING INTEREST

None

REFERENCES

Almorox, J., Benito, M. & Hontoria, C. 2005. Estimation of monthly Angström–Prescott equation coefficients from measured daily data in Toledo, Spain. *Renew Energy* 30(6): 931–6.

Al-mostafa, Z.A., Maghrabi, A.H. & Al-shehri, S.M. 2014. Sunshine-based global radiation models: a review and case study. *Energy Convers Manag* 84: 209–16.

Ansah, M.K., Chen, X., Yang, H., Lu, L. & Lam ,P.T.I. 2019. A review and outlook for integrated BIM application in green building assessment. *Sustainable Cities and Society* 48: 101576.

Carvalho, J.P., Almeida, M., Braganca, L. & Mateus, R. 2021. Bim-based energy analysis and sustainability assessment—application to Portuguese buildings. *Buildings* 11(6):246.

Charef, R., Alaka, H. & Emmitt, S. 2018. Beyond the third dimension of BIM: A systematic review of literature and assessment of professional views. J. *Build. Eng* 19: 242–257.

F. Mellado & E.C. Lou. 2020. Building information modelling, lean and sustainability: an integration framework to promote performance improvements in the construction industry. Sustain. *Cities Soc* 61: 102355.

Ferdosi, H., Abbasianjahromi, H. & Banihashemi, S. et al. 2022. BIM applications in sustainable construction: scientometric and state-of-the-art review. *International Journal of Construction Management* 1-13.

Fokaides, P.A., Apanaviciene, R., Cerneckiene, J., Jurelionis A, Klumbyte E, Kriauciunaite-Neklejonoviene, V., Pupeikis, D., Rekus, D., Sadauskiene, J. & Seduikyte, L. et al. 2020. Research challenges and advancements in the field of sustainable energy technologies in the built environment. *Sustainability (Switzerland)* 12(20):8417–8420.

Huang, B., Lei, J., Ren, F., Chen, Y., Zhao, Q., Li, S., & Lin, Y. 2021. Contribution and obstacle analysis of applying BIM in promoting green buildings. *Journal of Cleaner Production* 278: 123946.

L. Sanhudo, et al. 2018. Building information modeling for energy retrofitting - a review, Renew. Sustain. *Energy Rev* 89: 249-260.

L. Yujie, W. Zhilei, Chang Ruidong & Li Yongkui. 2017. Building Information Modeling (BIM) for green buildings: A critical review and future directions. *Automation in Construction* 83:134-148.

Liu, S., Meng, X. & Tam, C. 2015. Building information modeling based building design optimization for sustainability. *Energy Build* 105:139–153.

Mazzoli, C., Iannantuono, M., Giannakopoulos, V., Fotopoulou, A., Ferrante, A. & Garagnani, S. 2021. Building information modeling as an effective process for the sustainable re-shaping of the built environment. *Sustainability* 13(9): 4658.

Mésároš, P., Spišáková, M., Mandičák, T., Čabala, J., & Oravec, M. M. 2021. Adaptive design of formworks for building renovation considering the sustainability of construction in BIM environment—Case study. *Sustainability* 13(2): 799.

Mirpanahi, M.V. & Noorzai, E. 2021. Modeling the relationship between critical BIM attributes and environmental sustainability criteria using PLS-SEM technique. *J Archit Eng* 27(4): 04021037.

Montiel-Santiago, F. J., Hermoso-Orzáez, M. J. & Terrados-Cepeda, J. 2020. Sustainability and energy efficiency: BIM 6D. Study of the BIM methodology applied to hospital buildings. Value of interior lighting and daylight in energy simulation. *Sustainability* 12(14): 5731.

S.B.M. Ali, et al. 2020. Application of building information modelling (BIM) in analysing the building energy performances of an office building. *Int. J. Adv. Sci. Technol* 262–282.

W. Tiehong. 2018. The Future of Construction Industry Transformation and Upgrading is Coming, China Construction News, 11-16.

W. Tiehong, K. Ibrahim & S.-C. Loo. 2019. Urging green retrofits of building façades in the tropics-A review and research agenda. *Int. J. Technol* 10 (6): 1140-1149.

Wen, Q., Li, Z., Peng, Y. & Guo, B. 2020. Assessing the effectiveness of building information modeling in developing green buildings from a lifecycle perspective. *Sustainability* 12(23): 9988.

Yule, S., Flin, R., Paterson-Brown, S., Maran, N. & Rowley, D. 2006. Development of a rating system for surgeons' non-technical skills. *Med. Educ* 40: 1098–1104.

Z. Alwan. 2016. BIM performance framework for the maintenance and refurbishment of housing stock. *Struct. Surv* 34 (3): 242-255.

Zhan, S., Chong, A. & Lasternas, B. 2020. Automated recognition and mapping of building management system (BMS) data points for building energy modeling (BEM). Build. Simul, 1–10.