TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 2245 - 2253

Weightage Evaluation Criteria for Daylight Retrofitting in Existing Campus Buildings

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Article Info
Volume 83
Page Number: 2245 - 2253
Publication Issue:
May - June 2020

Article History
***Article Received**: 11August 2019*
***Revised**: 18November 2019*
***Accepted**: 23January 2020*
***Publication**: 10 May2020*

Abstract:

Artificial lighting in buildings is one of the major sources of energy that generates a large amount of CO2. The use of light energy globally is expected to increase to more than 40% by 2020. Hence, daylight retrofitting is one of the strategies that can be implemented to improve the existing lighting conditions. However, the implementation of daylight retrofitting requires a thorough consideration to ensure that the desired outputs such as the quality and quantity of daylight, energy reduction, and low implementation costs are achieved upon completion. In this study, several criteria for the daylight retrofitting of existing buildings in higher learning institutions were developed based on visual comfort, indoor comfort, design, economic, resource availability, and environmental factors. This study aims to provide an overview of the information needed to improve energy efficiency in existing buildings, thus contribute to the growing body of knowledge in this field. A survey regarding the importance of each criteria was conducted by distributing questionnaires to architects with experience in daylight retrofitting. The survey data was analysed using the factor analysis, factor score, and weightage factor to rank the sub-criteria according to its importance for daylight retrofitting based on the weightage values obtained. The established criteria provide an overview and act as a source of reference for decision-makers regarding the most influential criteria for optimal retrofit solutions.

Keywords: *Daylighting, lighting, retrofitting, Campus Buildings*

I. INTRODUCTION

Existing buildings worldwide contribute more than 40% of the total global energy used. The majority of existing buildings was built prior to the energy crisis, particularly when energy efficiency was not a serious issue. Nowadays, existing buildings contribute to the excessive use of energy as well as poor indoor air quality and thermal comfort [1]. Existing educational buildings, for instance, represent one of the building types that consume excessive energy [2]. Campus buildings are a commercial building type, in which the lighting appliances consume the highest amount of electricity [3]. Thus, retrofitting has become a relevant solution that has to be implemented to improve the energy performance, especially in lighting systems [2]. In a recent study by [4], one of the notable issues relating to sustainability in existing campus buildings was high energy consumption. The authors indicated that retrofitting was necessary to improve energy consumption and comfort level.

With regards to comfort level, retrofitting with daylighting is one of the initiatives implemented to improve visual comfort levels and enhance the educational environments during the teaching and learning activities. Although artificial lighting can provide visual comfort, daylighting is preferred as it offers various physiological, psychological, and economic benefits [4]. According to [5], daylighting was the primary source of light in a building prior to the advancement of technology, whilst artificial lights acted as a supplementary to natural light. Nowadays, daylighting is an important element in building design, and it has become an architectural statement for lighting due to environmental concerns and energy usage. [6] indicated that lighting constitutes the major energy consumption in a building and represents 20%

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of the global electricity consumption. Thus, the implementation of daylighting has become an integral strategy to save energy. Lighting energy consumption is expected to increase further by 2030 due to the growing population, thereby leading to an increasing demand for energy [7].

Nevertheless, the implementation of retrofitting is challenging, and a wide range of factors need to be evaluated by the decision-makers in various fields. Specifically, various factors such as economic, environmental, and design need to be considered to deliver an end-product that is satisfactory to the users [1]. Thus, this study aims to develop specific criteria for the decision-making process when implementing daylight retrofitting in existing buildings.

II. LITERATURE REVIEW

A. Daylighting

The use of artificial lighting in existing buildings is one of the major sources of energy consumption, representing 15-60% of the total energy usage. Hence, retrofitting can help to significantly reduce the lighting energy demand by 50%. The implementation of daylighting is a crucial aspect of retrofitting as the building component is replaced to achieve maximum daylight performance [9].

Daylighting is the utilisation of natural light inside the building space, also known as passive solar energy [10]. When a building has the potential to receive adequate natural light, the implementation of daylighting is considered to be beneficial [11]. The source of light produced from daylighting is a gentle form that originates from several sources such as the blue skies, clouds, and reflected or diffused sunlight. As compared to direct sunlight, daylight offers uniformity and distribution of illuminance [12].

At present, designers have started to design buildings with daylight features as artificial lighting has been shown to consume high energy levels. Daylighting, on the other hand, provides beautiful architectural effects and improves the air-conditioning heat load [13]. [14] indicated that the benefits of natural light utilisation include the added comfort levels, maximised views of the external building environment, and calming indoor environments that ultimately lead to improved productivity of the occupants.

B. Daylighting Retrofitting Implementation in Higher Learning Institutions

It has been recently mentioned that universities should be at the forefront of the discovery and dissemination of knowledge, tools, and technology related to sustainability [15]. Thus, the improvement of energy efficiency in buildings has become an important strategy in educational and institutional buildings through the implementation of several resources such as the use of natural lighting [9]. Table 1 highlights several case studies that were conducted regarding the use of daylighting as part of the retrofitting initiatives in existing buildings. A case study in University in Rome exploited the use of daylight retrofitting in their campus building and reported the pleasant effects it had on the users. Besides, two educational buildings in Italy were selected for a cost-optimal assessment to identify the best retrofit method for the lighting system in these buildings. Hence, daylighting is considered as one of the options to improve energy consumption apart from the replacement to energy-efficient lighting. Case studies were also performed in the University of Applied Science, Stuttgart, Germany and a university in Turkey/ Konya to improve the energy performance in lighting. The potential of daylight retrofitting was investigated through the monitoring of visual comfort and measurement of light energy savings based on the daylight availability. Additionally, a simulation exercise for daylighting was conducted at the University of Science and Technology (JUST), in which several daylight retrofitting techniques were proposed for the classroom. The evaluation was performed by assessing the illuminance levels required to achieve visual comfort using the retrofit solution for lighting. Moreover, another simulation study was also performed in an educational building in Antofagasta, Chile, whereby several parameters for daylight retrofitting such as light distribution, intensity, and profundity of sun penetration, and the possibility of glare were considered. In Modibbo Adama University of Technology, Yola, an experimental design was performed for the implementation of daylighting by deploying lux meters to assess the lighting levels. Simulation studies were also conducted to assess the daylight levels and to estimate the daylight factors under different light conditions.

Based on the review from previous studies, it was observed that many of these studies focused on daylight retrofitting that involved design simulations, energy, and cost analyses. Thus, this paper will focus on developing the assessment criteria for the implementation of daylight retrofitting.

Table 1: Case studies on daylight retrofit in existing campus

Universities	Method	Objective(s)
1. Building in Rome Italy University [17]	Case study	Propose several methods of retrofitting, user's evaluation and renovation cost estimation
2. Boston University [18]	Case study – energy and cost analysis	Investigate the opportunities for achieving significant energy reduction
3. Educational buildings in Italy [2]	Case study – cost analysis	Optimal cost analysis
4. University of Applied Science, Stuttgart [15]	Case study – simulation	Investigate efficient lighting solutions -luminance and illuminance distribution, use of electrical lighting and thermal
5. University in Turkey/ Konya and Germany, Stuttgart [16]	Case study – simulation	Performance analysis for lighting retrofit and measurements and observations of pre-retrofit lighting performance
6. University of Science and Technology [4]	Case study - simulation	Investigate the illumination levels for daylight implementation
7. Building in Antofagasta midtown, Chile [19]	Case study - simulation	Identification of parameters of light intensity and distribution, and profundity of sun and glare
8. Modibbo Adama University of Technology, Yola [9]	Case study - simulation	Evaluation of lighting levels and estimation of daylight factor

C. Criteria for Retrofitting with Daylighting

When an existing building is selected for daylight retrofitting, an imperative decision-making process is required to ensure it achieves maximum energy efficiency upon completion. In this process, several factors such as the amount and quality of daylight, reduction of environmental impact and many more are considered [20]. [21] also noted that light optimisation using the retrofit strategy is a complex process that needs to be investigated critically.

In total, 39 sub-criteria were established for daylighting and classified according to 6 major criteria consisting of the following: 1) visual comfort, 2) indoor comfort, 3) design, 4) environmental, 5) economic, and 6) resource availability. The establishment of the main criteria and corresponding sub-criteria is shown in Table 2 and Table 2(a).

Table 2: Retrofitting criteria for daylighting

Main Criteria	Sub-criteria	References
Visual Comfort	a. Analyse placement and configuration	[22], [23]
	b. Glare and control contrast	[11], [22], [24], [25]
	c. Provide a good and pleasant view	[7], [12], [27]
	d. Uniformity of daylight distribution	[28]
	e. Integrate with artificial lighting control systems	[14], [24], [29]
	f. Reduce the veiling reflection	[27]
	g. Avoid direct beam	[22], [23], [27]
	h. Locate windows high in a wall	[24], [30]
	i. Determine the daylight factor (DF)	[14], [31], [32], [33], [6], [2],
	j. Commissioned of lighting control system	[35]
	k. Painting	[12], [22]
	l. Cleaning (National Institute of Building Science, 2016)	[35]
	m. Pruning and replacing landscape	[35]
Indoor Comfort	a. Thermal comfort	[11], [29]
	b. Impact on	[11], [29]

	cooling	
Design	a. Building massing and orientation	[23], [36], [37], [29]
	b. Floor to ceiling height	[36] , [38]
	c. Interior design and space planning layout	[22], [23], [27]
	d. Integration with artificial lighting control	[11], [14], [24], [27], [37]
	e. Placement of furniture	[37]
	f. Window orientation	[34] ,[39], [40]

Table 2(a): Retrofitting criteria for daylighting

Main Criteria	Sub-criteria	References
Design (cont'd)	g. Window sizing: window to wall ratio	[11], [34], [37], [41]
	h. Window type	[11], [22], [42]
	i. Window shape	[27], [43], [44]
	j. Glazing material	[45], [46], [47]
	k. Glazing area	[12], [27]
	l. Glazing orientation	[48]
	m. Colour and texture of reflective surface	[10], [36], [37]
	n. Incorporate interior and exterior	[22], [37], [49], [29]
	o. Consider the daylight redirecting system	[42], [50]
	p. Looking for adjacent condition or obstruction	[11], [36], [42], [51]
Economic	a. Energy and cost savings	[22], [27], [52]
	b. Return on investment	[27]
	c. Simple payback	[27] , [52]
	d. Construction cost	[42], [52]
	e. Maintenance cost	[22]
Resource Availability	a. Solar geometry and sky angle	[27], [42]
	b. Sky pattern and condition	[14], [53], [40], [54], [55]
Environmental	a. Greenhouse gas emission	[56]

III. METHODOLOGY

The 39 sub-criteria established in this study for daylight retrofitting were subjected to factor analysis, factor score, and weightage factor data analyses available in the Statistical Package for the Social Science (SPSS) statistical software programme. Factor analysis is a method of analysis that reduces a large number of items in the questionnaire [57]. Factor analysis was conducted using the following procedures:

A. Kaiser Meyer Olkin (KMO) and Barlett's Test of Sphericity

KMO is used to evaluate the sampling adequacy of the data collected. The values range from 0 to 1, in which the minimum acceptable value is 0.50 [58]. On the other hand, Barlett's test of sphericity is used to determine the statistical significance of the data at $P < 0.05$ [59]. According to [57], the results achieved from KMO and Barlett's Test of Sphericity are used to indicate the suitability of the data for factor analysis (Piaw, 2014).

B. Factor of Extraction

The factor of extraction method produces or extracts the smallest number of factors that are needed to explain each variable [59]. Although there are several choices of extraction methods, Principal Component Analysis (PCA) was selected in this study as it describes the data in the empirical summary by placing the number of variables into the smallest set of factors [60].

C. Factor to be Retained

This method is used to decide which factor should be retained based on the eigenvalue, whereby an eigenvalue of 1.0 or more is considered reliable for extraction and further analysis [57], [59]

D. Rotational Method

The function of the rotational method is to simplify the variables in each group of factors [58]. All the variables in each factor are represented by a value

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known as factor loading. In this process, the factors are labelled and the variables are arranged accordingly to easily understand the data interpretation [59]. The rotational method used in this paper is known as orthogonal with varimax rotation. This method was selected as it minimises the variables with high loadings for each factor, in which each factor varies from low to high loadings [59]The rotational method generates the output of the data that can be obtained from the *Rotated Component Matrix* in SPSS [61].

E. Factor Loading

Factor loading indicates the significance of the criteria. According to [62], the minimum value suggested for factor loading is 0.50, while 0.7 – 0.8 is acceptable and 0.90 is excellent. [59] also indicated that a value of 0.40 and above is a strong factor loading value. In this study, a factor loading value of 0.50 was considered as the minimum requirement.

Once the data reduction from the factor analysis has been performed, the data is subjected to a factor score and weightage factor analysis. According to [63], the purpose of the factor score is to further analyse the data by assigning a numerical score value for the further justification of each variable. This method is performed by multiplying the factor loading (FL) from each variable with the average mean value to produce the score of sub-criteria, FSsc. The equation (1) used is shown below:

$$FS = FL \times Y \quad (1)$$

where,
FS = Factor score; FL = Factor loading; Y = Mean value

The weightage factor is performed to depict the influence of the criteria based on the weight value. It allows a comparison to be made for each criterion by ranking the criteria based on the weight [64]. The result of the weightage factor is expressed as the total weightage value following normalisation to 1 or 100. To calculate the weightage factor, equation (2) is used as follows:

$$\pi \text{ sub-criteria} = \frac{\text{\% Stratum in Variables (sub-criteria)}, FSsc}{\text{\% Stratum in Criteria}, FSc} \quad (1) \quad (2)$$

where,
FS_{sc} = Factor score for each item in the sub-criteria
ΣFSc = Cumulative of factor score in the criteria

IV. RESULTS AND DISCUSSION

Table 3 shows the results of the KMO and Barlett's Test of Sphericity for daylight retrofitting. The KMO achieved in this study was 0.872 and the Barlett's Test of Sphericity obtained was significant at *P* = 0.000. Both test results exceeded the recommended value, thereby indicating that all the 39 variables achieved the sampling adequacy and were statistically significant.

Table 3: Kaiser-Meyer-Olkin and Barlett's Test of Sphericity for Daylight Retrofitting

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.872
Bartlett's Test of Sphericity	Approx. Chi-Square	2791.614
	df	741
	Sig.	.000

Table 4 and Table 4(a) shows the results obtained for the factor analysis, factor score, and weightage factor analyses. The results from the factor analysis were subjected to principal component analysis with varimax rotation, in which 39 variables were loaded into the analysis. However, 5 variables were eliminated as their factor loading values were less than the recommended value of 0.50. Thus, the criteria presented in the table achieved factor loading values of 0.50 and above. For factor score and weightage factor analyses, the sub-criteria were classified into the main criteria and arranging according to its significance based on the weightage value.

For the visual comfort criteria, cleaning and painting were placed at the first and second-highest rank with weightage values of 9.352% and 9.035%, respectively. These observations indicate that cleaning services are an important requirement for retrofitting to maintain comfort levels and maximise the required daylight penetration. As for painting, the choice of paint colour and the maintenance of the paint were important features for effective and consistent daylight. For the second main criteria (indoor comfort), thermal comfort and the impact of cooling requirements achieved a weightage of 51.179% and 48.821%, respectively. It is important to evaluate the potential heat loss or heat gain in the interior building space as the incoming daylight is based on the sunlight that produces direct heat. For the design criteria, the shape of the window, room size, and daylight redirecting system achieved the

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highest weightage with values of 10.369%, 9.356%, and 8.856%, respectively. The shape of the window has a large influence on the uniformity of light received together with the potential glare contrast. For the daylight redirecting system, the use of features such as light pipes and light shelves was suggested to maximise the daylight admission due to differences in the uniformity of daylight received at different places.

For the environmental criteria, greenhouse gas emission was an important factor in retrofitting, in which the potential reduction of carbon emission based on energy reduction was estimated. For the economic criteria, important costs such as maintenance costs, return on investment, construction costs, and payback period were taken into consideration. Lastly, for the resource availability criteria, sky pattern and solar geometry were the two most significant criteria with weightage values of 58.223% and 41.777%, respectively. Sky pattern and solar geometry indicate the amount and quality of daylight received in the building interior space. These features also show the variation of the sun's ray intensity that occur daily, annually, and seasonally.

Table 4: Weightage for Daylight Retrofit Criteria

Main Criteria	*Sub-Criteria*	*Weightage Factor (%)*
Visual Comfort	Cleaning	9.352
	Painting	9.035
	Analyze placement and configuration	8.801
	Locate high windows high in a wall	7.756
	Good and pleasant view	7.721
	Avoid direct beam	7.698
	Total daylight factor	7.369
	Uniformity daylight distribution	7.416
	Pruning and planting	7.322
	Reduce reflection of light	7.299
	Glare and control contrast	7.275
	Integrate with artificial light	6.970
	Commissioned properly the lighting control	5.985
		100
Indoor Comfort	Thermal comfort	51.179
	Impact on cooling requirement	48.821
		100
Design	Window shape	10.369
	Size of room	9.356
	Daylight redirecting system	8.856
	Incorporated interior and exterior shading	8.230
	Adjacent condition obstruction	7.367
	Window sizing	6.954
	Placement of furniture	6.879
	Colour and texture of wall ceiling	6.829
	Glazing orientation	6.729
	Window orientation	6.717
	Glazing type and material	6.592
	Glazing area	6.529
		100
Environmental	Greenhouse gas emission	100
		100
Economic	Maintenance cost	28.474
	Return on investment	25.054
	Construction Costs	24.082
	Simple payback	22.390
		100
Resource Availability	Sun patterns and condition	58.223
	Solar geometry and effective sky angle	41.777
		100

CONCLUSION

The criteria developed in this study can be utilised for the decision-making processes regarding the daylight retrofitting of existing buildings. The results obtained in this study for various criteria such as economic, environmental, design, resource availability, and comfort criteria offer several important aspects for consideration. It is envisaged that potential decision-makers comprising stakeholders from higher learning institutions (HLI), property owners, and other organisations who are interested in retrofitting will be able to use this information to achieve their long-term investment goals, energy reduction and enhancement of energy performance. The economic criteria established in this study can be used as a method to assess the long-term profitability of investment and investment potential in terms of the payback period, return on investment, construction costs, and maintenance costs. On the other hand, the environmental aspects covered in this study provide the optimal design criteria with minimal environmental impact. Likewise, comfortability ensures that the design does not only provide energy savings but also offer users a convenient environment to live or work in, thereby resulting in improved health and productivity of occupants. The design criteria outlined in this study for daylight retrofitting such as the window shape, room size, and space planning ensures that natural light is maximised in the building design. Besides, resource availability is essential to harness the natural resources available without causing any heating or cooling issues. Hence, the criteria developed in this study serve as a guideline for optimisation and transparency that ultimately lead to effective and mutual decisions in daylight retrofitting.

ACKNOWLEDGEMENT

This research was funded by the Research University Grant (UTMER, Grant no:18J10) provided by Universiti Teknologi Malaysia.

REFERENCES

[1] A. Kumar, P. S. Chani, & R. Deoliya, R, "Green Retrofit Potential in Existing Research Laboratories and Demonstration of Energy Efficient and Sustainable Technologies : Case Study". International Journal of Science, Engineering and Technology Research (IJSETR), vol. 3, no.3, pp. 400–405, 2014.

[2] M. Bonomolo, C. Baglivo, G.Bianco,G., P.M. Congedo, M. Beccali, "Cost optimal analysis of lighting retrofit scenarios in educational buildings in Italy buildings in Italy", Energy Procedia. vol. 126, pp. 171–178, 2014.

[3] K. Konis, K. "Evaluating daylighting effectiveness and occupant visual comfort in a side-lit open-plan office building in San Francisco, California". Building and Environment.vol. 59, pp. 662–677, 2013.

[4] S. Ma'bdeh , & B. Al-Khatatbeh. " Daylighting retrofit methods as a tool for enhancing daylight provision in existing educational spaces-A case study", Buildings. vol 9, no.7, pp. 1-18, 2019.

[5] L. Edwards, and P. Torcellini, "A Literature Review of the Effects of Natural Light on Building Occupants" National Renewable Energy Laboratory. Colorado, July 2002.

[6] S.N. Kamaruzzaman, R. Edwards, E. Marinie, A. Zawawi, and A.I. Che-ani, Achieving energy and cost savings through simple daylighting control in tropical historic buildings, Energy and Buildings, vol. 90, pp. 85–93, 2015.

[7] N. Gentile, M.C. Dubois, W. Osterhaus, S. Stoffer, C.N.D. Amorim, D. Geisler-Moroder, and R. Jakobiak. "A toolbox to evaluate non-residential lighting and daylighting retrofit in practice", Energy and Buildings. vol. *123*, pp. 151–161, 2016.

[8] R. Albatici, A. Gadotti, C. Baldessari, & M. Chiogna. "A decision-making tool for a comprehensive evaluation of building retrofitting actions at the regional scale", Sustainability. vol. 8, no. 10, 2016.

[9] O.M. Idowu, A.U. Attah, "Retrofitting for Daylight Enhancement of Institutional Buildings", FUTY Journal of the Environment. Vol. 13, no. 1, pp. 93–103, 2019.

[10] S,F. Syarifah Fairuz, H. Byrd, Energy and Building Control Systems in the Tropics, 1st edition. Pulau Pinang: Universiti Sains Malaysia. 2012

[11] M.A.U. Haq, M.Y, Hassan, H, Abdullah, H.A. Rahman, M.P. Abdullah, F. Hussin, and D.M. Said, "A Review on Lighting Control Technologies in Commercial Buildings, Their Performance and Affecting Factors", *Renewable and Sustainable Energy Reviews*. Vol. 33, pp. 268–279, 2014.

[12] Debra, "Daylighting and Fenestration Design", Journal of Environmental Psychology, pp. 209–256, 2002.

[13] A. Zain-Ahmed, K. Sopian, M.Y.H. Othman, A.A.M. Sayigh, and P.N. Surendran, "Daylighting as a passive solar design strategy in tropical buildings: A case study of Malaysia", Energy Conversion and Management, vol. 43, pp. 1725–1736, 2002.

[14] D.H.W. Li, "A Review of Daylight Illuminance Determinations and Energy Implications", Applied Energy, vol. 87. No 7, pp. 2109–2118. 2010.

[15] Erhart

[16] D.K. Erhart, A. Tereci, K. Univeristy, I.Future. and E. Districts, "Daylight enhancement and lighting retrofits in educational buildings"2016.

[17] M. Citterio, C. Romeo, "Retrofit of a University Building in Rome Italy. Energy Conservation in Buildings and Community System Case Study Overview". Rome Italy: International Energy Agency. 2003

[18] M. Gevelber, R. Choate, K. Sheehan, T. Vitolo, E. Ercolino, L. Ricci, M. Mchale, M,O, "Opportunities for Achieving Significant Energy Reduction in Existing University Buildings : Developing efficient HVAC operations", 2007.

[19] M. Palme, M.K. Saldías Moreno, and R.C. Segovia, "Natural light monitoring and sustainable retrofit of

classrooms in Antofagasta, Chile", *Integrated building design*. pp 579–582, 2013.
[20] M. Sedor, C.T, Griffin, and K. Konis, "The role of structures in daylighting retrofits for existing buildings. Structures and Architecture: Concepts, Applications and Challenges", Proceedings of the 2nd International Conference on Structures and Architecture. ICSA 2013. Pp. 1784–1790. 2013
[21] M, Rabani, H.B. Madessa. and N. Nord, "A state-of-art- review of retrofit interventions in buildings towards nearly zero energy level", Energy Procedia. vol. 134, pp. 317-326. 2017
[22] R.Allen, "Daylighting guide for canadian commercial buildings. canada: public works and government services canada", 2002.
[23] Debra. "Daylighting and Fenestration Design", Journal of Environmental Psychology. pp. 209–256. 2002
[24] E. Ne'eman, E. "A comprehensive approach to the integration of daylight and electric light in buildings", Energy and Buildings. no. 6, pp. 97–108, 1984
[25] A. Galatioto, and M. Beccali, "Aspects and issues of daylighting assessment : a review study", renewable and sustainable energy reviews, vol. 66, pp.852–860. 2016.
[26] M. Beccali, M. Cellura, M. Fontana, S. Longo, and M. Mistretta, "*Energy retro fi t of a single-family house : Life cycle net energy saving and environmental benefits*", vol. *27*, pp. 283–293. 2013.
[27] A.Robinson, S. Selkowitz, D.Curcija, M. Donn, S.Greenberg, E. Lee, A. McNeil, C. Regnier, and F. Rubinstein, "Tips for Daylighting with Window" (1st edi). United States: Lawrence Berkeley National Laboratory. 2013.
[28] A.A.Y. Freewan, "Impact Of External Shading Devices On Thermal and Daylighting Performance of Offices In Hot Climate Regions", Solar Energy, vol. 102, pp. 14–30.
[29] P.K. Soori, and M.Vishwas, "Lighting Control Strategy for Energy Efficient Office Lighting System Design", Energy and Buildings, vol. 66, pp. 329–337. 2013.
[30] Branz "Passive solar design guidelines for inclusion in New Zealand Homes. Sustainability Fact Sheet" pp. 1–8, 2014.
[31] K. Carrier, and M.S. Ubbelohde, "The Role of Daylighting in Leed Certification: a Comparative Evaluation of Documentation Methods" Retrieved from: http://www.coolshadow.com/images/research/LEED_and_Daylight.pdf, 2005.
[32] J. Melorose, R. Perroy, and S. Careas, "The Daylight Factor and Actual Illuminance Ratios. Statewide Agricultural Land Use Baseline 2015". Lighting research and technology, pp. 64–68, 2015.
[33] L. Brotas, L, and M. Wilson, The average total daylight factor. Light and Engineering, vol. 16, no 2, pp. 52–57. 2008.
[34] R.A. Mangkuto, M. Rohmah, and A.D. Asri, "Design optimization for window size, orientation, and wall reflectance with regard to various daylight metrics and lighting energy demand: A case study of buildings in the tropics" Applied Energy, vol. 164, pp. 211–219. 2016.
[35] National Institute Building Science
[36] E. Rice, Daylight in facade renewal : using new metrics to inform the retrofitting of aging modern-era facade types. *master thesis*: massachusetts institute of technology. 2006.
[37] K. Robertson, "Daylighting Guide for Buildings", 2013.
[38] S. Daryanani, "Design consideration for the daylighting of new commercial buildings". *Energy and Buildings*, no. 6, pp. 109–118. 1984
[39] M. Bodart, and A. De Herde, "Global energy savings in offices buildings by the use of daylighting", Energy and Buildings, vol. *34*, no. 5, pp. 421–429, 2002.
[40] J. Lu, D. Birru, and K.Whitehouse, "Using Simple Light Sensors to Achieve Smart Daylight Harvesting", Proceedings of the 2nd ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Building - BuildSys ', vol. 10, no. 73. 2010.
[41] A. Eltaweel, and Y.Su, "Parametric Design and Daylighting: A Literature Review", Renewable and Sustainable Energy Reviews, vol. 73, pp. 1086–1103, 2017.
[42] Wilson. "Daylighting and Window Design", The Chartered Institution of Building Services Engineers London. Friary Press: Great Britain. 1999.
[43] I. Acosta, C. Miguel Angel, M. J.F, (2016), Window design in architecture: analysis of energy savings for lighting and visual comfort in residential space, vol.168, pp.493-506, 2016.
[44] E. Fernández, B. Beckers, and G. Besuievsky, "A Fast Daylighting Method to Optimize Opening Configurations in Building Design", Energy & Buildings, vo. 125, pp. 205–218, 2016.
[45] Q. Du, J. Yang, and T.H. Zhou, "Decision Making on Glass Selection in Building Façade", Advanced Materials Research, vol. 250-253. pp. 2792–2795. 2011
[46] P. Lyons P, and R. Hamber, "Your Home: Australia's Guide to Environmentally Sustainable

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ISSN: 0193-4120 Page No. 2245 - 2253

Homes – Skylight", (5th ed). Australia: Australian Government Department of Industry. 2013.

[47] W.J. Hee, M.A. Alghoul, B. Bakhtyar, O. Elayeb, M.A. Shameri, M.S. Alrubaih, and K. Sopian, "The Role Of Window Glazing On Daylighting And Energy Saving In Buildings. Renewable and Sustainable Energy Reviews", vol. 42, pp. 323–343, 2015.

[48] D.L. Basham, K.I. Ferguson, J.W. Wright, and G.W. Moy. "Design: Interior, Exterior Lighting and Controls", United States, America: Unified Facilities Criteria. 2013.

[49] V. Mikler, and M. Labrie, *Passive Design Toolkit*. City of Vancouver. Retrieved from: http://vancouver.ca/files/cov/passive-home-design.pdf. 2009.

[50] R.P. Leslie, R.M. Raghavan, O.MS. Howlett, and C. Eaton. "The Potential of Simplified Concepts for Daylight Harvesting", Lighting Res. Technology, vol. 37, no. 1, pp. 21-40. 2005

[51] C. DiLouie, "Designing a daylight harvesting System. Retrieved from: http://www.automatedbuildings.com/news/aug07/articles/zing/070723051101dilouie.htm, 2007.

[52] A. Bakshi, and J.A, Jakubiec, "A Simple Cost-Benefit Estimation for Daylighting Design and Analysis During the Design Process". 12th Conference of International Building Performance Simulation Association, 14-16 November. Sydney, Australia: Proceeding of Building Simulation, pp. 593–600. 2011.

[53] M.M. Al Sadek, "Shading Device Design Alternative Decision Making", Master Thesis, King Fahd University of Petroleum and Minerals, Saudi Arabia. 2001.

[54] S. Graf, J. Brown, R. White, and B. Wilcock, "Daylighting and Integrated Design Considerations", 2012.

[55] G.Y. Yun, H.Kim, and J.T. Kim, "Effects of occupancy and lighting use patterns on lighting energy consumption", Energy and Buildings, vol. 46, pp. 152–158, 2012.

[56] P. Huovila, P, M. Ala-Juusela, L. Melchert, S. Pouffary, C. C. Cheng, D. Urge-Vorsatz, S. Koeppel, N. Svenningsen, and P. Graham, "Buildings and Climate Change: Summary for Decision Makers". France:United Nations Environment Programme. 2009.

[57] C.Y.Piaw, "Kaedah dan Statistik Penyelidikan", 3rd edition, Shah Alam: McGraw-Hill, 2014.

[58] B. Williams, T. Brown, A. Onsman, "Exploratory Factor Analysis: A five-step guide for novices", Australasian Journal of Paramedicine, vol. 8, no. 3, 2012.

[59] J. Pallant,J, Spss Survival Manual. A step by Step Guide to Data Analysis Using SPSS for Windows (Version 12), 1st edi, New South Wales: Allen and Unwin, 2014.

[60] B. Tabachnick, and S.Fidell, "Using Mutivariate Statistics", (6th edition.), United States of America: Pearson Education, Inc, 2013.

[61] A. Costello, J. Osborne, J, "Best Practice in Exploratory Factor Analysis: Four Recommendations for Getting the most from your Analysis Practical Assessment, Research & Evaluation". vol. 10, no. 7, pp. 1-9, 2005.

[62] H. Kaiser, "An index of factorial simplicity", *Psychometrika*, vol. 39, pp. 31–36. 1974

[63] J. Dien, and G. Frishkoff, "Introduction to Principal Components Analysis of Event-Related Potentials". pp 1–42. Retrieved from: https://www.researchgate.net/publication/228449904_Introduction_to_Principal_Components_Analysis_of_Event-Related_Potentials

[64] H. Maletta, and B. Aires, "Weighting. Spsstools" pp. 1–19. Retrieved from http://www.spsstools.net, March 2007