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Conditions for Implementing Windowless Offices in High-Density Urban Centers of Malaysia: A Bibliometric and Systematic Review

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ABSTRACT

The dearth of land in high-density urban centres necessitates constructing structures with deep interiors, with little or no connection to the external environment. Additionally, the negative relationships between high-rise structures in the city centres in recent times are increasingly making contact with the outdoor environments undesirable. Whether in the built environment, decision sciences, healthcare, or technological disciplines, there is a need to understand the factors necessary for windowless office implementation, its prominent researchers, and geographical contexts, among other conditions for practical application. These background variables could assist in arriving at emerging themes, problems and gaps for concrete windowless office development in Malaysia. In this systematic review, the bibliographic information of title, abstract and keywords was mined from 255 documents on the Scopus database to generate scientometric maps and links showing relationships on co-authorship, co-citation, co-occurrences, and bibliometric coupling. The top trending variables in windowless office research are COVID-19, energy efficiency, indoor air quality, heart rate variability, performance assessment, visual reality, and workplace environment. Like other advanced economies in Asia, Malaysia is seen to attain a satisfactory level of development to implement the windowless office design module, with stable electricity power, technological advancement, and psychological stability of the people. The emerging variables in this review will give novel directions in exploring the developmental, psychological and health conditions for effective windowless office implementation in the country and similar economies in Asia, Africa and South America, where metropolises are fast becoming compacted due to ever-growing city centres.

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1. Introduction

From the earliest times, human beings have always sought protection from natural conditions. Paradoxically, since people began to live in buildings, conscious efforts have been made to reunite with the outdoor environment through fenestrations (Martin, Maris, & Simberloff, 2016; Sato & Inui, 1994). However, in urban centres today, air pollution, incessant noise, and other negative spatial relationships make contact with the outdoor environments increasingly undesirable.

Moreover, excessive construction of buildings in built-up sections of metropolitan areas has created an urgent need for ever more efficient use of space. As a result, buildings are becoming more prominent and compacted together, leading to complete windowless offices or virtual windowless spaces with considerable distance from windows. In many instances, efforts are increasingly being made to create more effective use of windowless underground spaces and basements as office spaces (Boubekri et al., 2020; Mahyuddin et al., 2022; Yap et al., 2021). Other times, fenestration is controlled in large building spaces for security considerations, disaster prevention, or production of precision equipment, such as factories and power plants, by creating windowless environments due to functional requirements. A windowless environment could therefore be seen as a spatial configuration without any windows or a space where workstations are far from windows, without any exposure to direct natural daylight (Boubekri, Cheung, Reid, Wang, & Zee, 2014).

Psychologically, Ko et al. (Ko et al., 2020) find a passive relationship between views from a window on thermal comfort, human emotion, and the cognitive performance of occupants. Nevertheless, these associations are modified in windowless offices. On their part, Sato and Inui (1994) found that windowless office spaces have adverse effects on human behaviour. Research indicates that people who feel tense and entrapped sometimes perceive claustrophobic symptoms when staying in windowless spaces for a prolonged period.

Additionally, findings indicate that windowless environments affect occupants' attention to work and sleep quality, with attendant effects on individuals and society in general, leading to workplace accidents, mistakes, and errors, thereby decreasing productivity (Boubekri et al., 2014; Canazei, Pohl, Bliem, Martini, & Weiss, 2017). Besides interior decorations to mitigate the psychological impact, workers in windowless offices also bring to their workplace items such as natural plants, pictures of plants and landscapes, among other personal items, to improve indoor air quality and control their stress levels (Bringslimark, Hartig, & Patil, 2011; Dolan, Foy, & Smith, 2016; Mahyuddin et al., 2022). Understanding the potential adverse effects of staying in windowless environments, according to Canazei et al. (2017), is, therefore, of necessity.

In practice, Goharian and Mahdavinejad (2020) note that deep-plan buildings, or windowless offices, require advanced light transmission systems to compensate for lighting demands for effective performance. Interestingly, technological advancements in lighting, ventilation, and air conditioning are also rapidly providing supportive solutions to physical openings in institutional buildings, resulting in the planning and design of windowless offices. Furthermore, research is being carried out to optimize daylight performance and obtain energy efficiency in the windowless indoor environment through digital windows, Circadian System Entrainment, Fiber Optics Daylighting System, and virtual reality, among other scientific monitoring procedures, theoretical calculations, and computational simulations (Chen, Zhang, & Du, 2020; Sithravel & Ibrahim, 2021).

Besides the psychological consequences, Bringslimark et al. (2011) see massive benefits of windowless office modules in compacted city centres, shielding buildings from pollution and noise, among other negative impacts between structures. Consequently, as buildings are increasingly becoming larger, deeper and more compact due to the windowless design style, more research is necessary to mitigate the attendant challenges associated with the design and developmental model. Whether in the built environment, decision sciences, healthcare, or technological discipline, there is a need to understand the current research direction in windowless offices, conditions for its practical application, environmental contexts, and prominent researchers of the system before arriving at the emerging problems and gaps for more productive studies. This study, therefore, reviews the physical, psychological, technological and economic conditions for effectively implementing windowless office design modules in Malaysia, among other fast-developing economies.

In brief, this article's introduction mentions the historical human quest for shelter and relates it to the current trend of windowless office spaces due to urban challenges. It also explores their psychological and practical impacts on occupants, emphasizing the need for research to optimize such designs in rapidly developing economies like Malaysia, addressing physical, psychological, technological, and economic aspects.

2. Methodology

The methodology for this study involves a systematic description of decisions made in selecting document sources, data screening, excluded materials, analysis tools, and data presentation choices, as shown in Figure 1. The data identification, screening, inclusion and exclusion in this study utilized the Systematic Review approach based on the principles of PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Page et al., 2021). Accordingly, the PRISMA principles include "identifying" articles through keywords, "screening" the sources to exclude extraneous materials and deciding on the materials to be "included" for further evaluation (p.5). In addition, this study was limited to the Scopus database in the materials identification to avoid complications accompanying data analysis from varying sources using the VOSviewer software in its current edition.

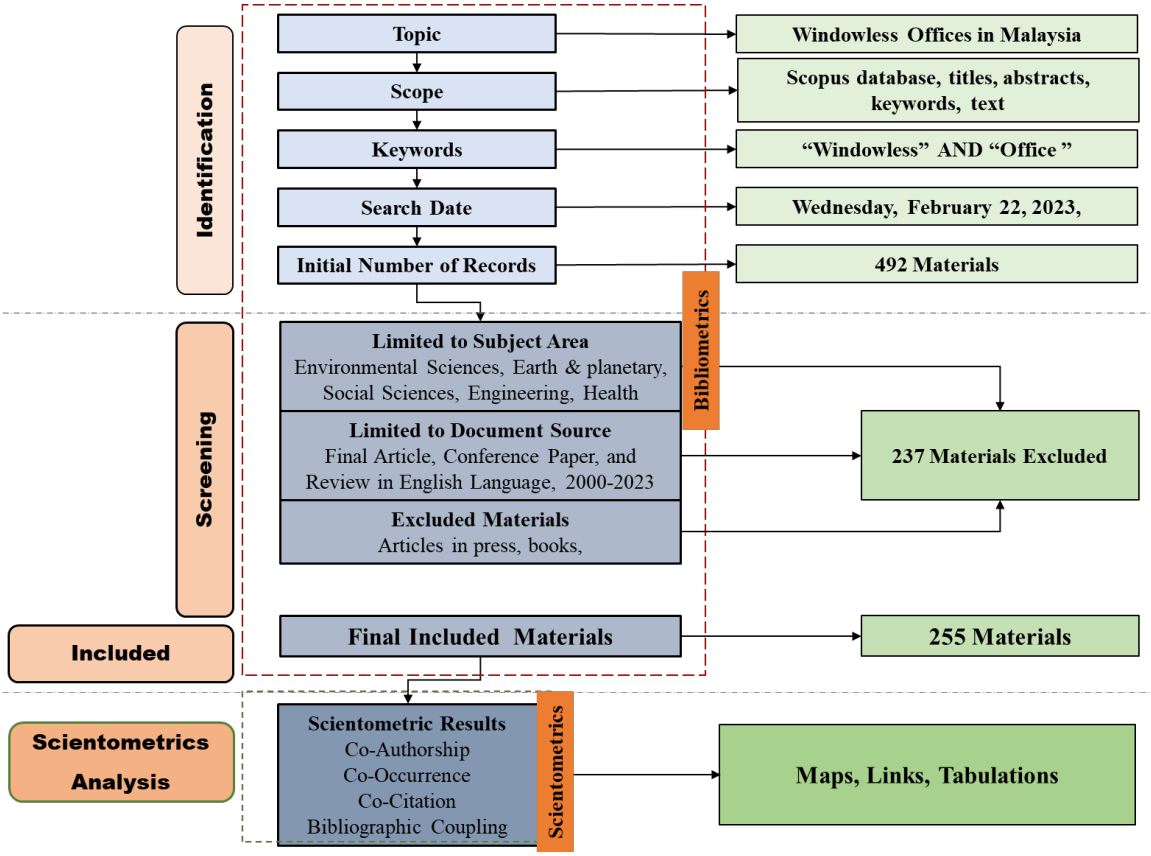

Figure 1 Systematic Data Source Identification, Screening, and Inclusion in Windowless Office Research

2.1 Database

In this study, a database could be seen as an organized collection of structured information, or data, typically stored electronically in a computer system. Therefore, the Scopus database was utilized as this study's source of materials owing to its broader pool of indexed publications. In addition, researchers recognize the Scopus database as a superlative archive regarding the number of satisfactory-quality materials (Peter, Majid, & Tukiman, 2023; Tanko & Mbugua, 2021). Therefore, the broader coverage of the Scopus database avails more materials in this study's search query. Furthermore, since its inception in 2004, the Scopus database has increasingly become a top choice for publication due to its comprehensive nature, including research from a wide variety of subjects (Abbas, Jusoh, Mas'od, Alsharif, & Ali, 2022; Ghaleb, Alhajlah, Abdullah, Kassem, & Al-Sharaf, 2022; Sahi et al., 2022). Another justification for choosing the Scopus database for this analysis is its provision for mining up to 2,000 documents simultaneously for scientometric data evaluation using the VOSviewer software (Zakka, Abdul Shukor Lim, & Chau Khun, 2021).

Therefore, the study relies on the comprehensive Scopus database, acknowledged for its vast, high-quality materials across diverse subjects, chosen for its broad coverage and suitability for mining up to 2,000 documents simultaneously for scientific data analysis using VOSviewer software. Furthermore, utilizing the Scopus database for this analysis is justified based on its broader coverage and provision to mine a more comprehensive range of materials into the VOSviewer analysis tool.

2.2 Data Identification

Data identification may be seen as a set of activities to systematically define the set of information processes of a study and establish clear prioritizing criteria (Ali & Faruquie, 2015). For example, identifying published materials in the "windowless office in Malaysia" subject area returned negligible results. However, expanding the query onto "windowless AND office" yields 492 initial documents. The resulting documents encompass all materials that mentioned the searched terms individually or collectively in their title, abstract, keywords, and paper body. The limited results of the search query carried out on February 22, 2023, confirm the novelty of the research area. Therefore, this study explores data identification as a systematic process to define information priorities, noting that a specific search for "windowless office in Malaysia" yielded minimal results while broadening the query to "windowless AND office" produced 492 initial documents, confirming the novelty of the research area by encompassing materials mentioning the terms in various contexts.

2.3 Data Screening

Data screening in systematic review involves an examination of data properties to eliminate variables that do not match the research questions but may affect the interpretation of results

from statistical models (Cheshmehzangi, 2015; Wang, McKee, Torbica, & Stuckler, 2019).

Data screening was necessary for this study to streamline the materials and attain the standards for utilizing the VOSviewer analysis tool. The search query was further examined to define the data and eliminate materials that are not directly related to the subject area. First, the document sources were restricted to journal articles, conference proceedings and review papers written in English, excluding articles in the press, book chapters, and editorial notes. A limitation was also placed on the subject area covering papers in engineering, built environment, social sciences, medicine and health disciplines.
Consequently, materials in mathematics, chemistry, biology, and veterinary medicine were excluded. Also screened were materials in the press, book chapters, and editorial notes, among other documents published earlier than 2000. With the screened materials identifying excluded and included documents, the final query search was executed as follows:

> ALL (windowless AND office) AND (EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "ECON") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "NEUR") OR EXCLUDE (SUBJAREA , "VETE") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "PHAR")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2000 - 2023)) AND (LIMIT-TO (SRCTYPE , "j") OR LIMIT-TO (SRCTYPE , "d")) AND (LIMIT-TO (LANGUAGE , "English"))

The final results of 255 materials were included and utilized in the ultimate analysis from the data screening: As the Scopus database supports the export of up to 2,000 materials at a time to the VOSviewer software (van Eck & Waltman, 2022), the final query results were deemed sufficient to conduct further analysis.

In brief, data screening, a critical part of systematic review, involves refining materials to meet analysis standards; in this study, the process involved excluding irrelevant data sources and narrowing the subject area to disciplines like engineering, social sciences, and medicine, ultimately using 255 materials for analysis in VOSviewer, meeting the software's capability of handling up to 2,000 items from Scopus.

2.4 Data Inclusion

With the satisfactory results of including materials, the 255 materials were exported as CSV (comma-separated values) files into Microsoft Excel, along with their bibliographical and reference contents. Other important bibliometric information includes author names and affiliations, journal type, and rankings, most of which are available in the Scopus database. The included materials were finally exported and downloaded as a single Microsoft Excel file to the computer system and loaded into the VOSviewer software for the scientometric analysis (Krauskopf, 2018). Eleven documents that were found to incorporate "windowless office" directly in their title, abstract, or keywords were utilized for an in-depth systematic review, analyzing the variables, methods and tools to reveal gaps and trends for further studies.

In brief, after exporting the 255 materials from Scopus into Excel, important bibliometric data like author details, affiliations, and journal rankings were gathered, allowing comprehensive analysis using VOSviewer software. Out of these, 11 documents specifically addressing "windowless office" were further scrutinized for an in-depth systematic review, examining variables, methods, and trends to identify gaps for future studies.

2.5 Data Analysis Tool

The VOSviewer computer program version 1.6.18.0 was utilized for the bibliometric and scientometric evaluations. VOSviewer is a free computer software for scientific data analysis and producing graphical outputs (van Eck & Waltman, 2022). Scientometrics involves an objective and reliable review of defined material source(s), converting qualitative information into quantitative data by creating graphical relationships (Oladinrin, Gomis, Jayantha, Obi, & Rana, 2021). According to the software producers (van Eck & Waltman, 2022), VOSviewer is a software application for building maps based on network data, and displaying and investigating these maps. It is used for creating maps based on network data, graphical visualizations, and pragmatic explorations to create meaningful relationships. In reality, the computer software creates distance-based network maps where the distance among nodes indicates closeness and connections (Oraee, Hosseini, Papadonikolaki, Palliyaguru, & Arashpour, 2017).

Data previously exported from the Scopus database were inputted into the VOSviewer software, units of analysis were selected, and results were generated as map-based co-authorship, co-occurrence, and co-citation, among others. The results established relevant information concerning critical linkages to authors, journals, and research topics, highlighting novel areas for further productive research directions.
As an analysis tools summary, the study used VOSviewer, a software for scientometric analysis, to process data exported from Scopus, creating graphical representations like co-authorship, co-occurrence, and co-citation maps. These maps reveal meaningful connections among authors, journals, and research topics, identifying areas for further research directions.

3. Results and Discussion

The findings from this scientometric review were analyzed based on the bibliometric information obtained in the Scopus database and the network maps generated from the VOSviewer program. Subsequently, the results were examined regarding document type, prominent authors, top journal source, co-authorship, co-citation, co-occurrence and bibliometric coupling to reveal trending keywords in windowless office research.

3.1 Analysis of Documents

The analysis entails distributing mined materials into different disciplines concerning the application of windowless office design. A limitation was also placed on the Source Type of the mined materials from journal articles, reviews, and indexed conferences. By these search preferences, more than 83% of mined materials were journal publications, 15% were conferences, and the remaining two per cent were review articles. The higher percentage of indexed journals and sources affirms the data as authoritative and reliable (Oguntona, Aigbavboa, & Dywili, 2022; Zakka et al., 2021). Distribution of the Subject Area shows that about 24% of the material mined falls into Engineering, 20% Environmental Sciences, 16% Social Sciences, and 10% Medical and Health Sciences, among other traces of Agriculture, Psychology, Energy, Computer and Material Sciences, Art and Humanities. The document analyses were done using the bibliographic information in the Scopus database. The Modal frequency of publications on windowless offices in Engineering and Environmental Sciences confirms its importance and applications in the disciplines. As presented in Figure 2, the document analysis categorizes materials by discipline in the context of windowless office design, primarily sourced from journals, conferences, and review articles, highlighting the authoritative and reliable nature of the data. Over various fields, such as Engineering and Environmental Sciences, the modal frequency of publications emphasizes the significance and application of windowless offices in these disciplines.

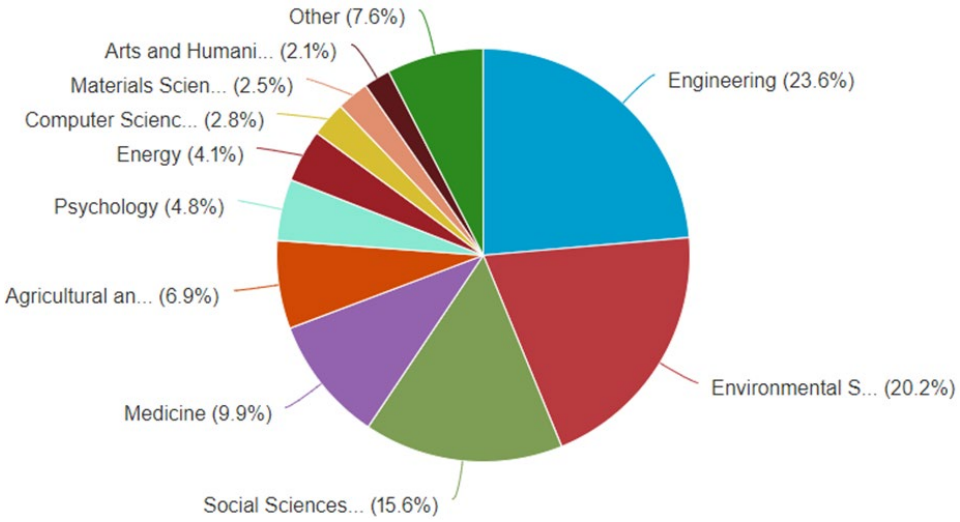

Figure 2 Distribution Documents Based on Subject Area

Furthermore, with the restriction in Year of Publication between 2000 and February 2023, the results show active research on windowless offices in 2000, as shown in Figure 3. However, it was not until 2010 that more than ten materials on the subject matter were published. The sudden rise of publications on windowless offices, reaching an all-time peak of 31 documents in 2020, indicates its potential and applications in the post-COVID-19 era. The surge of publications in 2020 may be better appreciated with the "two-period moving average" on the graph. The phenomenon confirms the increasing attention paid to windowless office buildings, especially in Europe, North America, and, most recently, Asia's more advanced countries (Chen et al., 2020).

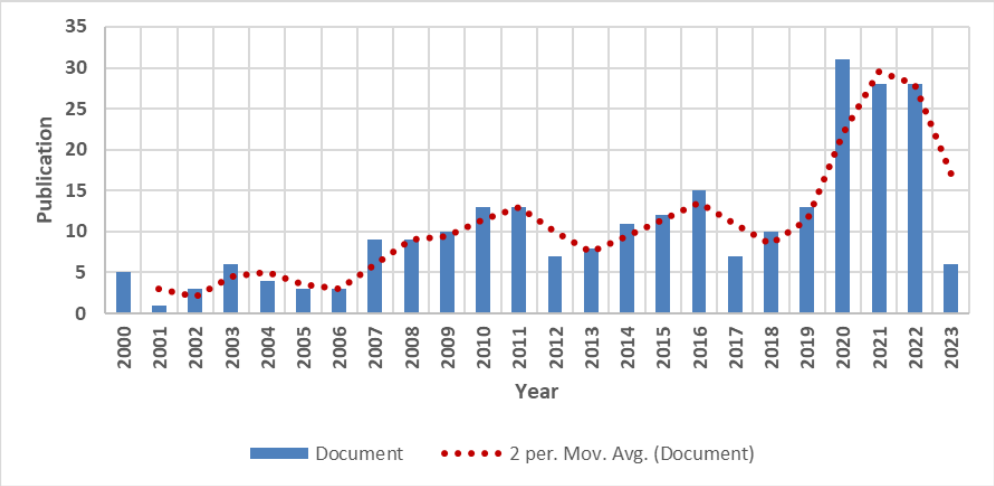

Figure 3 The Sudden Rise of Publication on Windowless Office in the Post-Covid 19 era.

In brief, the study restricts publication from 2000 to February 2023, revealing a significant increase in materials on windowless offices from 2010, peaking at 31 documents in 2020, signalling growing interest and potential applications post-COVID-19. The "two-period moving average" illustrates this surge, highlighting the increasing focus on windowless office buildings by different authours, notably in Europe, North America and emerging in Asia's more advanced nations.

3.2 Top Authors in Windowless Office Research

This section presents the prolific and most cited authors in Windowless Office Research (WOR), their respective disciplines, impact and links to other authors. In this study, the top authors include those with at least four documents from the query outcome. Knowledge of the top authors in the study area is necessary to spur research interest, encourage collaboration, and enhance interdisciplinary networking for interdisciplinary productivity (Khudzari, Kurian, Tartakovsky, & Raghavan, 2018; Yu, Wang, Zhang, & Zhang, 2018). Additionally, new scholars in the subject area will have direction concerning the authors to follow, their articles, and their impact. Besides the authors' names, their respective number of articles, citation metrics, and disciplines were also captured alongside their most cited publications and scientometric links, respectively, as shown in Table 1. Though the authors were ranked according to the resulting documents in the query string, their h-index impact, representing the citation ratio per document, was also computed.

Table 1: Bibliometric Analysis Showing Top Researchers on Windowless Office

S/N	Author	Discipline	Doc. in Query	Total Pub.	Total Cita.	h-index	Co-Auth. Link	Co-Cita. Link	Most Cited Article in Subject Area
1	Hong, T.	Architecture	5	238	5,610	40 (5)	16	31.00	(Yeom, et al, (2020)
s2	Patil, G.G.	Healthcare	5	44	1,859	21 (7)	11	31.97	(Grinde & Patil, 2009)
3	Soh, C.K.	Engineering	5	247	7,263	45 (4)	30	18.83	(Roberts, et al. 2016)
4	Andersen, M.	Architecture	4	145	2,495	29 (6)	13	53.76	(Andersen, Mardaljevic, & Lockley, 2012)
5	Boubekri, M.	Architecture	4	38	742	13 (9)	9	64.57	(Boubekri et al., 2020)
6	Car, J.	Healthcare	4	417	23,823	71 (1)	26	11.84	(Roberts et al., 2016)
7	Christopoulos, G.I.	Business	4	66	1,307	17 (8)	21	16.59	(Roberts et al., 2016)
8	Han, K.T.	Architecture	4	25	676	11 (12)	3	28.28	(Han, 2009)
9	Hartig, T.	Planning	4	129	15,454	56 (3)	7	268.22	(Bringslimark, Hartig, & Patil, 2009)
10	Lockley, S.W.	Healthcare	4	285	16,624	62 (2)	8	56.47	(Andersen et al., 2012)
11	Lohr, V.I.	Architecture	4	32	1,099	14 (10)	4	15.82	(Relf & Lohr, 2003)
12	Roberts, A.C.	Engineering	4	47	554	14 (11)	26	12.81	(Roberts et al., 2016)
13	Yeom, S.	Architecture	4	14	284	8 (13)	14	14.62	(Yeom et al., 2020)

Note: Doc. (Documents); Pub. (Publications); Cita. (Citations); Auth. (Author)

Bibliometric analysis of the search results shows that Hong, T., Patil, G. G., and Andersen, M., are the most prolific publishers on WOR, with five documents each. Other ten authors complete the prominent researchers in the subject area, with at least four publications each. Outside the query search, the bibliometric information of the top authors, as captured on the Scopus database, indicates that most of them published more than ten articles, with Car, J. (417); Soh C. K. (247), and Hong, T, (238) standing out brilliantly. In terms of research impact, representing the number of citations per document, Car, J. (71), Lockley, S. W (62), and Hartig, T. (56) are worth mentioning. More than 53% of the top authors in the study area are in Architecture and Planning, with the remaining shared in the 3:2:1 ratio among Healthcare, Engineering, and Business. The distribution also confirms the central position of Architecture as a discipline in the planning and designing of office spaces for optimum human comfort (Chantzaras, 2019; Jutraz & Zupancic, 2014).

Furthermore, the mined materials from the Scopus database, saved as CSV MS Excel documents, were loaded into the VOSviewer software as Bibliographic Data from Reference Manager File, producing co-authorship, co-citation, co-occurrence and bibliometric coupling. The Scientometric analysis generated co-authorship links among the authors with at least one document from the resulting query search. By definition, co-authorship entails establishing academic collaboration and teamwork among authors by publishing research materials to address some interdisciplinary concerns (Oladinrin et al., 2021; Peter et al., 2023). Emphasizing the need for co-authorship analysis, Adegoriola, Lai, Chan, and Amos (2021) view the lack of scientific collaboration as a signal of lower research output, evident in inadequate productivity. From the co-authorship analysis in VOSviewer, the top collaborators in windowless research include Soh, C.K., Car, J., and Roberts, A.C., each with more than 25 links with other scholars across disciplines.

In today's world, interdisciplinary research is encouraged as many problems are immune to treatment from a single discipline perspective. That is why co-citation analysis is necessary to establish relationships among published documents for concrete solutions to novel problems. According to Wang, McKee, Torbica, and Stuckler (2019), co-citations are carried out to gain insights into the disciplines contributing to an area of research. Co-citation analysis is a technique for scientometric mapping which assumes that some publications frequently cited together have some similarities in theme or structure (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021; van Nunen, Li, Reniers, & Ponnet, 2018). Generally, researchers agree that article co-citation is a commonly deployed methodology for defining the relationships within a specific scientific domain (Estevão, Garcia, Filipe, & Fernandes, 2017; Hosseini et al., 2018). Additionally, Donthu et al. (2021) stressed the benefits of co-citation analysis, including finding the most influential authors or publications and discovering thematic clusters by scholars.

In this review, the author's co-citation links were extracted in the VOSviewer analysis of the published materials on WOR. The co-citation analysis was performed on authors with at least twelve publications from the data mined from the Scops database, a point with clearly defined themes. As van Eck and Waltman (2014, 2022) recommended, the fractional counting result identified five main themes or disciplines involved in WOR publications. In brief, the Top Authors section highlights influential authors and their impact on Windowless Office Research (WOR), emphasizing the importance of understanding these key figures to foster collaboration and interdisciplinary connections. The study showcases top authors, their publication metrics, and disciplinary impact, indicating Architecture's central role in designing office spaces for optimal comfort. Additionally, the analysis explores co-authorship and co-citation links among researchers, underscoring the need for interdisciplinary collaboration and thematic clustering for effective problem-solving in this field.

As presented in Figure 4, the five major disciplinary themes generated from the co-citation analysis, with their respective central authors included Ulrich, R. S. in Healthcare (deep yellow); Hartig, T. in Planning (green); Lohr, V. I in Architecture (blue); Veitch, J. A. in Psychology (red); and Lockey, S. W in Sciences (light yellow).

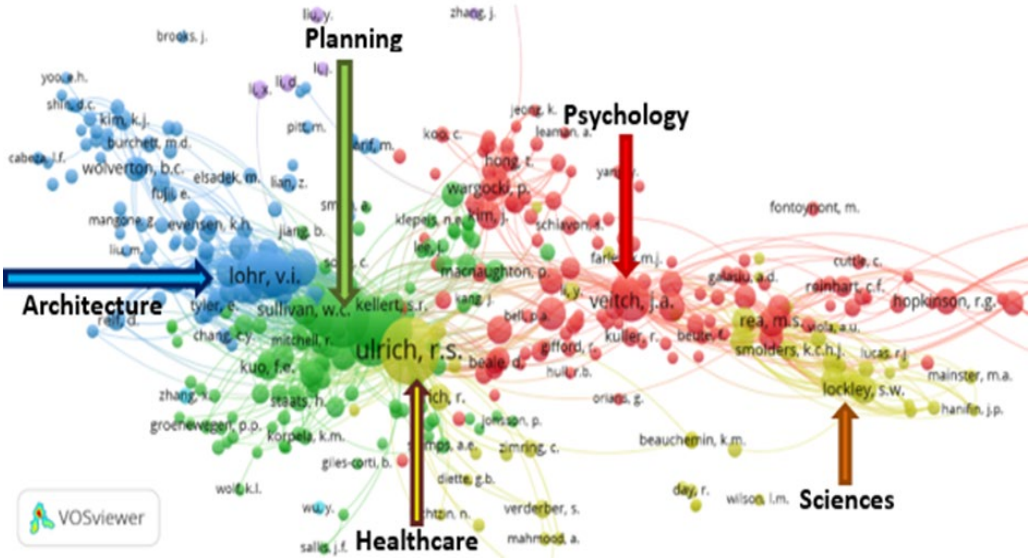

Figure 4 Five main disciplines emerged from the Co-Citation analysis of Windowless Office Research. (Available at https://tinyurl.com/2f88ppc5)

Interestingly, the co-citation analysis also reveals the passive contributions of Ulrich, R. S, Kaplan, R. S., and Veitch, J. A., whose works are extensively cited by many researchers in the subject area. From the analysis of top authors, co-authorship, and co-citations in WOR, the three most prominent authors are seen to be Hartig, T., Lohr, V. I., and Lockey, S. W., representing Planning, Architecture and Sciences, respectively.

In brief, the co-citation analysis identifies five major disciplinary themes in Windowless Office Research (WOR) linked to crucial authors like Ulrich, Hartig, Lohr, Veitch, and Lockey, showcasing their passive but substantial contributions, with Hartig, Lohr, and Lockey emerging as the prominent figures in Planning, Architecture, and Sciences within WOR research.

3.3 Journals Publishing Windowless Office Research

This section presents the top journals in which WOR outputs are published. Scholars setting out to contribute to the development of the subject area need to follow the top journals to identify current trends and topical issues, concrete research problems and substantial gaps for conducting practical research outcomes, as presented in Table 2. The journals were also first ranked according to the number of documents resulting from the query search in the Scopus database.

Table 2: Top Journal Sources with Publications on Windowless Office Research

S/N	Journal Name	Doc. in Query	Total Pub.	Total Cita.	Cite-Score 2022	Co-Cita. Link	Biblio. Coupl. Link	Most Cited Article in Subject Area	Publisher
1	Building and Environment	34	3,327	36,930	11.1	137.0	653.9	(Ko et al., 2020)	Elsevier
2	Journal of Environmental Psychology	12	488	5,042	10.3	284.2	428.5	(Aries, Veitch, & Newsham, 2010)	Elsevier
3	Horttechnology	11	837	883	2.3	137.5	157.8	(Lohr & Pearson-Mims, 2000)	American Society for Horticultural Science
4	International Journal of Environmental Research and Public Health	10	44,778	234,677	5.2	33.4	261.7	(Grinde & Patil, 2009)	Multidisciplinary Digital Publishing Institute (MDPI)
5	Lighting Research and Technology	9	234	1,360	5.8	55.9	203.8	(Jakubiec & Reinhart, 2012)	SAGE
6	Environment and Behavior	8	156	2,104	13.5	274.9	220.6	(Kaplan, 2001)	SAGE
7	Indoor and Built Environment	8	472	2,639	5.6	44.9	202.5	{Formatting Citation}	SAGE

8	Buildings	6	3,251	10,049	3.1	166.5	127.1	(Dolan et al., 2016)	Multidisciplinary Digital Publishing Institute (MDPI)
9	Hortscience	6	1,092	3,473	3,2	140.4	137.4	(Bringslimark, Hartig, & Patil, 2007)	American Society for Horticultural Science
10	Facilities	4	223	1,022	4.6	32.9	72.9	(Smith, Tucker, & Pitt, 2011)	Emerald Publishing
11	Health Environments Research and Design Journal	4	296	990	3.3	27.2	115.2	(Nejati, Shepley, Rodiek, Lee, & Varni, 2016)	SAGE
12	LEUKOS-Journal of Illuminating Engineering Society of North America	4	90	749	8.3	42.8	79.6	(Pechacek, Andersen, & Lockley, 2008)	Taylor & Francis

Doc. (Documents); Pub. (Publications); Cita. (Citations); Biblio. (Bibliometric); Coupl. (Coupling)

The bibliometric analysis of sources, ranked according to the number of articles in the query search, indicates that the Journal of Building and Environment is the top choice source for researchers on Windowless Office, with 34 documents, followed by the Journal of Environmental Psychology (12), Horttechnology (11), and International Journal of Environmental Research and Public Health (10), with more than ten documents respectively. Besides the top-four journal sources, the others produced less than ten materials in the query search, indicating the relatively novel disposition of research on windowless offices. In addition to the frequency of search results, the total publications, citations, impact, publishers, and most cited articles for each journal were extracted from the Scopus database. Most of the indices for the journal analyses were extracted from the bibliographic information extracted from the Scopus database.

However, the scientometric links were extracted in the VOSviewer analysis of the document sources, using fractional counting as recommended by van Eck and Waltman (2014, 2022) for more precise results. From the option to create a map based on bibliometric data, the documents extracted from the Scopus database were selected and loaded, and journal co-citations and bibliometric coupling analysis were performed to produce maps and links.

In this review, the journal co-citation links were extracted in the VOSviewer analysis of the published materials on WOR. According to Sahi et al. (2022), co-citation analysis creates themes and subthemes among extracted materials, defining the relationships between two or more cited sources. From the data mined, a co-citation analysis was performed on Cited Sources with at least 33 publications, a point at which the themes were clearly defined. Then, with fractional counting as recommended by van Eck and Waltman (2014, 2022), five main themes were identified, built around the primary journal sources. The five top journals co-cited in most publications on WOR include the Journal of Environmental Psychology, Environment and Behaviour, Buildings, Hortscience, and Horttechnology, all with fractional links of 137 and above co-citation links.

In brief, this Journal section focuses on top journals in Windowless Office Research (WOR), guiding scholars toward current trends, research gaps, and critical issues within the field. The analysis ranks the Journal of Building and Environment, Journal of Environmental Psychology, Horttechnology, and International Journal of Environmental Research and Public Health as primary sources, highlighting their significance in a relatively nascent area of research on windowless offices.

Furthermore, a bibliometric coupling was performed on the mined material sources to identify the influential journals referenced in most publications on WOR. This analysis also follows the same method as the option to Create a Map Based on Bibliometric Data; the document extracted from the Scopus database was selected and loaded. Bibliometric coupling analysis was performed based on sources with a minimum number of two referenced documents. As a result, the five top journals appearing in most WOR references include Building and Environment, Journal of Environmental Psychology, International Journal of Environmental Research and Public Health, Environment and Behaviour, and Lighting Research and Technology, as highlighted in Figure 5.

In brief, the bibliometric coupling identified the most referenced journals in Windowless Office Research (WOR), spotlighting Building and Environment, Journal of Environmental Psychology, International Journal of Environmental Research and Public Health, Environment and Behaviour, and Lighting Research and Technology as the top journals frequently referenced in WOR publications.

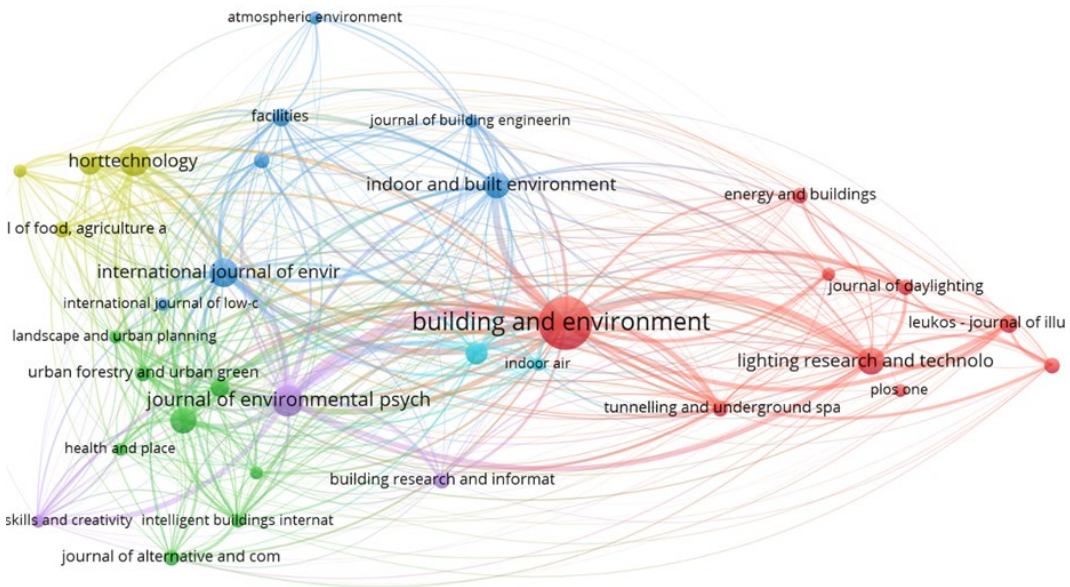

Figure 5: Bibliometric Coupling of Most Referenced Journals in Windowless Office Research (Available at https://tinyurl.com/2fpwkbwr)

3.4 Distribution of Windowless Office Research

In addition to information on articles, citations, and disciplines of the top authors on WOR, authors' geographical spreads were also extracted from the bibliographic information in the Scopus database. Khudzari et al. (2018) and Krauskopf, (2018) establish the need to be conversant with authors in various countries and continents working on similar research projects for possible collaboration and networking. Here, the contextual spread was also ranked according to the number of documents that emerged in the final query search.

The top countries with WOR shown in Table 3 indicate that the United States, United Kingdom, Netherlands and China lead in the number of documents and citations on the subject matter. Furthermore, the same countries head the co-citation, where at least two documents are cited together several times. Additionally, the bibliographic coupling, representing similarity in the reference list of the WOR, confirms the above countries and Australia as the top countries in the subject area. It could also be deduced from the table of the top ten countries with the most WOR publications that 47% are in Europe, 33% are in Asia, and the remaining 20% are in North America and Australia. While there is relative spread in the geographical spread among continents, as presented in Figure 6, it could be seen that the top countries in the research area all fall in the category of "developed" economies, with a stable government, advanced technology and, very notably, stable electricity power (World Economic Forum, 2019). Though Malaysia, as the country of interest in this study with three documents, does not make it to the top researching nations in WOR, the country is seen to possess the attributing qualities of a stable government with advanced technology, stable electricity energy, among other potentials to support the trending module in urban planning and design. Therefore, the Asian countries on the top researching nations in the subject area, especially Singapore, with a similar climate, form a reliable case study for experimentation and simulation of WOR in Malaysia.

Table 3: Windowless Office Research Publications Based on Countries

S/N	Name of Country	Document in Query	Citation Links	Country Co-Authorship	Country Biblio. Coupling	Continent
1	United States	94	435	24	2,560.4	North America
2	United Kingdom	32	180	18	2,295.2	Europe
3	Netherlands	20	196	10	961.7	Europe
4	China	19	104	12	823.7	Asia
5	South Korea	15	92	4	368.7	Asia
6	Canada	13	119	3	419.5	North America
7	Hong	11	68	7	518.2	Asia

	Kong					
8	Australia	10	62	6	903.3	Australia
9	Germany	10	51	7	766.1	Europe
10	Denmark	8	64	4	351.6	Europe
11	Italy	8	55	6	630	Europe
12	Japan	8	74	5	267.2	Asia
13	Norway	8	229	6	420.9	Europe
14	Singapore	8	72	6	673.1	Asia
15	Sweden	8	140	6	339.9	Europe

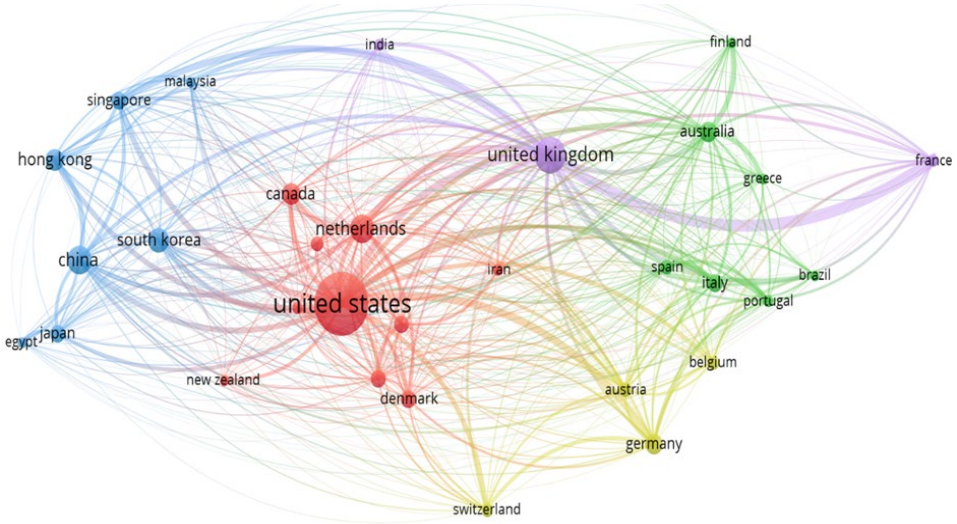

Figure 6 Bibliometric Coupling of Most Referenced Countries on Windowless Office Research (Available at https://tinyurl.com/2z7tnu6h)

In brief, this review not only details the top authors in Windowless Office Research (WOR), including their articles, citations, and disciplines but also examines the geographical distribution of these authors, emphasizing the importance of understanding and collaborating with researchers globally. The top countries involved in WOR, such as the United States, United Kingdom, Netherlands, China, and Australia, show a concentration of research in "developed" economies, with potential for collaboration and the study of similar climatic conditions in countries like Singapore for application in Malaysia.

3.5 Main Themes in Windowless Office Research

The five broad groupings of phenomena from which researchable topics arise are recognized as people, records, things, dynamics/energy, and ideas/thoughts (Ilesanmi, 2016; Leedy & Ormrod, 2010). Nevertheless, the multidisciplinary solution to research problems hardly fits into the packed categories, especially with the mundane issues of Sustainable Development Goals (SDGs) broadly classified into economic, environmental and social domains. The literature shows that WOR, as a blend of environmental design and sociological perception of people, involves the mundane dynamics of psycho-social actualization and energy optimization of the physical sciences.

Consequently, at the VOSviewer keyword analysis of three mentions, five themes emerged from the main disciplines involved in WOR, namely Humanity from Planning with 868 links, Psychological Perceptions from Psychology with 413 links, Workplace from Architecture with 382 links, optimal productivity from physical sciences, and healthcare from the Healthcare discipline with 221 links. Moreover, besides the main themes of Humanity, Psychology, Workplace, Productivity, and Healthcare, other new themes on WOR have been trending in the last two years, as presented in Figure 7.

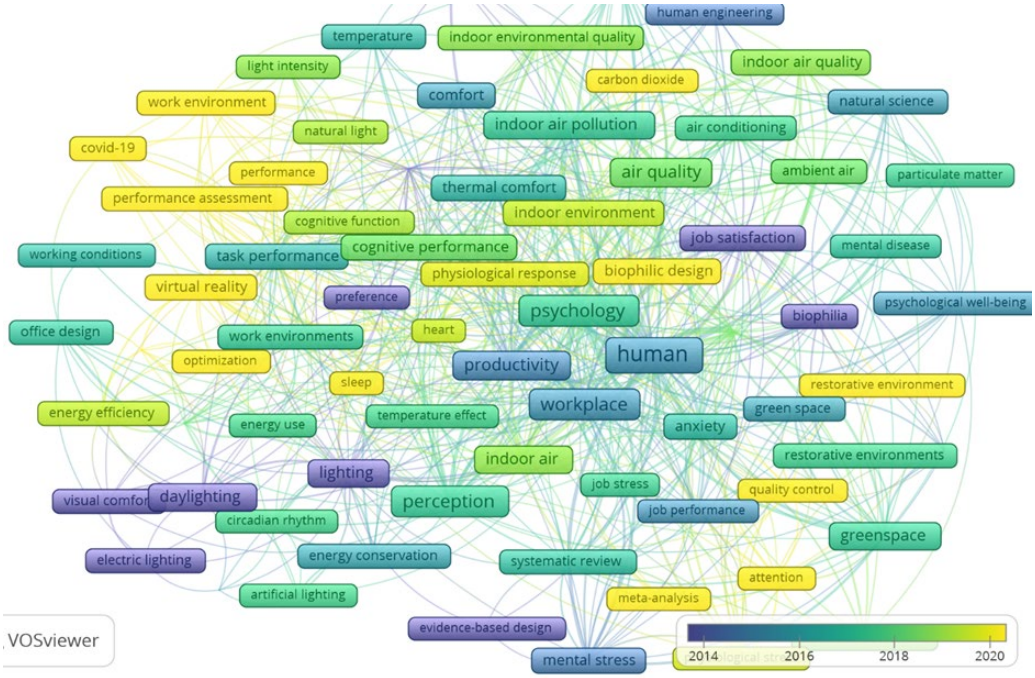

Figure 7: Keyword Co-Occurrence Showing Trending Themes in WOR investigation.
(Available at https://tinyurl.com/2q22hyf3)

With a frequency of three mentions, trending keywords in the WOR from 2020 include visual reality with 11 mentions, biophilic design (10), indoor environment (9), restorative environment (3), work environment (6), and spatial quality control (3). Trending keywords relating to healthcare performance assessment (6), physiological response (5), attention to work (4), cognitive function (3), and sleepiness (3). Furthermore, the healthcare discipline is trending with keywords such as COVID-19 (7), air quality (18), and heart rate variability of windowless office occupants (7). On the other hand, concrete studies on WOR in the physical sciences are trending with keywords of indoor air (14), ambience air (5), energy efficiency (5), natural lighting (4), energy optimization (3), and carbon dioxide control (3).

These themes agree with the finding by scholars that Covid-19, air quality, visual reality, and digital windows are essential concerns in the 2020s (Ibukun & Adebayo, 2021; Mahyuddin et al., 2022; Mouratidis & Hassan, 2020; Wohn, Kum-Biocca, Sharma, & Khandakar, 2020; Yap et al., 2021). Since Trisos et al. (2022) view emerging trends as themes that seek to address specific research gaps by leveraging new approaches to data and technology (p. 1330), young scholars in WOR should identify and explore one or more emerging themes for impactful contributions to the subject area.

In brief, the study identifies rending research themes within Windowless Office Research (WOR), emphasizing the multidisciplinary nature of WOR problems and the emerging trends in keywords, including concerns like COVID-19, air quality, visual reality, and digital windows. These findings highlight the evolving landscape of WOR, suggesting that young scholars should explore and contribute to these emerging themes for impactful advancements in the field.

3.6 Windowless Office Research Variables and Methods

To further zoom into the details of WOR, ten of the accessible documents on the Scopus database that directly mentioned "windowless office" in their title, abstract, or keywords were critically reviewed to reveal the variables, methodological instruments and tools utilized for the studies, as tabulated in Table 4. A systematic analysis is necessary to identify problems and gaps for tangible and impactful research into the subject area, especially by young scholars.

Table 4: Windowless Office Research Variables and Methodologies, Identifying Emerging Keywords.

Area/ Background	Attributes/ Variables	Methodology	
		Instrument	Analysis Tool
Windowless Office, Design and Spatial Psychology	**Design** Ambient room qualities, Digital windows, Illuminance performance, Light exposure, Productivity, Skylight, Workflow	Human experiment, Survey Questionnaire	**Soft Wares** Binary Logistic, Bonferroni, Correction factors, Mood scale,

(Bringslimark et al., 2011; Canazei et al., 2017; Ko et al., 2020; Weng et al., 2020; Wohn et al., 2020)	**Perception** Cognitive performance, Connectedness to nature, Control at work, Decision-making behaviour, Environmental perceptions, Job demands, Metacognitive status, Office type, Perceived restorativeness, Personal decoration, Personal pictures, Personal pictures of nature, Personal plants, Preferences, Satisfaction, Subjective evaluation, Thermal perceptions, **Emerging Keywords** Work environment, Biophilia design, Workplace performance, Performance assessment, Indoor environment, Restorative environment.	, interview	Oxford Happiness, Regression Analysis, Zero-Order Correlations **Tests** Analyses of Variance (ANOVA), General Symmetry Test, Attention test of PVT, Independent-sample T-Tests, Cognition Test of STROOP, Independence Test, Pearson's Chi-Square Test, Permutation Tests, Two-Way Mixed Repeated measures
Area/ Background	**Attributes/ Variables**	**Methodology**	
		Instrument	**Tool**
Windowless office, Health and Well-being (Boubekri et al., 2014, 2020)	Cognitive function, Emotional states, Eye-tracking, Eye symptoms, Genes, Human electroencephalogram (EEG), Medications, Melatonin production, Mental fatigue, Mental health, Perceived threat, Perceived stress level, Personal lifestyle, Physical health, Sleep quality, Stress levels, Visual comfort **Emerging Keywords** Covid-19, Physiological response, Attentiveness, Sleep Assessment, Heart rate reliability	Experiment on human Participants, Survey	Short Form-36, Pittsburgh Sleep Quality Index, Chi-Square Test of homogeneity
Area/ Background	**Attributes/ Variables**	**Methodology**	
		Instrument	**Tool**
Windowless office, Science and Engineering (Chen et al., 2020; Goharian & Mahdavinejad, 2020; Roberts et al., 2016)	Amount of illuminance, Circadian lighting, performances, Computerized tasks, Daylighting performance, Designed lighting layouts, distribution of Light, Electrodermal activity, Functional Magnetic, Lighting intensity, Light pipes efficiency, Noise level, Sun azimuth angle, Task control, Thermal comfort, Ray tracing simulation, Resonance Imaging, Visual environment, Visual indoor lighting performances. **Emerging Keywords** Carbon dioxide levels, Energy efficiency, Indoor air, Quality control, Optimization	Observation, Lighting simulations, Review	DIALux, Fibre Optics Daylighting System (FODS), Grasshopper plug-ins, Rhinoceros 3D Modelling software, Spectrum testing equipment,

Consequently, publications in the five themes from the co-citation analysis, namely architecture, planning, psychology, health, and sciences, were analyzed and grouped into three study background aspects of design and spatial perception, health and well-being, and science and engineering. Each document's research variables, instruments and tools were scrutinized to reveal current research directions and gaps. While the variables were identified as attributes, perceptions and emerging keywords, the analysis tools were classified as soft wares and statistical tests.

The systematic table presents three different studies that focus on the effects of windowless offices on different aspects of human well-being and productivity. The first study, which falls under Design and Spatial Psychology, investigates how different design features, such as digital windows and skylights, impact ambient room qualities, illuminance performance, workflow, and productivity. The study also explores the role of personal decoration and plants in influencing cognitive performance, job demands, and thermal perceptions. The researchers utilized a survey questionnaire and interview to gather data from human participants and employed different analysis tools such as regression analysis, binary logistic, and zero-order correlations to analyze the data.

The second study, which falls under the area of Health and Well-being, focuses on the impact of windowless offices on human cognitive function, emotional states, and sleep quality. The researchers used tools such as eye-tracking, human electroencephalogram (EEG), and survey to gather data on eye symptoms, perceived stress levels, and visual comfort. The study also explored the impact of external factors such as COVID-19 on human physiological responses, attentiveness, and heart rate reliability. Finally, the researchers analyzed the data using the Chi-Square Test of homogeneity, Short Form-36, and Pittsburgh Sleep Quality Index.

The third study, which falls under Science and Engineering, investigated the impact of windowless offices on lighting performance, thermal comfort, noise levels, and task control, among others. The researchers utilized tools such as Grasshopper plug-ins, Rhinoceros 3D Modelling software, and Spectrum testing equipment to simulate lighting scenarios and measure lighting intensity, distribution, and efficiency. The study also explored the impact of environmental factors such as carbon dioxide levels and indoor air quality on optimizing lighting and energy efficiency. The researchers utilized different analysis tools, such as Ray tracing simulation and Functional Magnetic Resonance Imaging, to analyze the data.

The table presents various studies highlighting the importance of windowless office design in human well-being and productivity. For example, studies show that design features such as digital windows, skylights, and personal decoration can influence ambient room qualities, cognitive performance, and job demands. The studies also highlight the importance of external factors such as COVID-19, carbon dioxide levels, and indoor air quality on human physiological responses, lighting optimization, and energy efficiency. The researchers utilized different tools and analysis methods to gather and analyze data, providing a comprehensive understanding of the factors influencing the windowless office design.

In brief, this section critically reviewed ten specific documents from the Scopus database on "windowless office" topics, examining variables, methodology, and tools used, revealing critical research gaps, especially for young scholars in this field. These documents highlighted the impact of windowless office design on human well-being and productivity, exploring variables like lighting, cognitive function, and external factors such as Covid-19, utilizing various tools like EEG, surveys, and simulation software to analyze their impact comprehensively.

4 Study Constraints and Limitation

This study holds the potential to inform policy development not only in Malaysia but also in analogous economies across Asia, Africa, and South America, especially in rapidly urbanizing areas. However, limitation lies in its exclusive reliance on the Scopus database, potentially excluding significant contributions from other reputable databases like Web of Science and PubMed. To ensure a comprehensive understanding, a more inclusive review incorporating diverse sources could enrich the variables established in this research. Additionally, further investigations should explore the interconnections between windowless office design and various emerging factors within space planning, healthcare, psychological perceptions, and technological innovations, all explored in this thorough bibliometric and systematic review. Expanding the scope to explore these connections can lead to more comprehensive insights and guide more effective policies and practices.

5 Conclusion

The scarcity of land in urban centers has spurred the rise of windowless office designs, particularly in densely developed city cores. Extracted from the Scopus database, this review aimed to identify critical authors' emerging themes across diverse geographical contexts and propose new research directions for effectively implementing windowless office systems, particularly in Malaysia.

The review emphasizes the pivotal role of creating work environments that prioritize employees' health and productivity, considering the substantial impact of office design on their well-being. Studies referenced in this review shed light on the effects of windowless office environments and propose strategies to enhance workplace design, offering a valuable empirical reference for researchers and practitioners in this field.

While several Asian countries are exploring windowless office designs, they notably reflect higher levels of development with stable economies, advanced technology, and reliable energy sources, crucial for powering the digital infrastructure integral to such systems. Conversely, Malaysia demonstrates a level of development capable of effectively implementing windowless office designs, supported by stable power sources, technological advancements, and the psychological stability of its populace. This review underlines the potential and suitability of Malaysia in adopting such design modules.

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