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An overview of motivators and challenges of passive design strategies

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An overview of motivators and challenges of passive design strategies

Nor Aqilah Haji Juffle[1,a] , Md Motiar Rahman[2,b]

[1]Ph.D Candidate, Civil Engineering Programme Area, Faculty of Engineering, Universiti Teknologi Brunei, Brunei Darussalam.
[2]Associate Professor, Civil Engineering Programme Area, Faculty of Engineering, Universiti Teknologi Brunei, Brunei Darussalam.

Corresponding author: [a)] p20210002@student.utb.edu.bn
[b)] motiar.rahman@utb.edu.bn

Abstract. Growing concerns over high energy consumption and CO_2 emissions from residential buildings have boosted the adoption of passive design strategies (PDS) globally, for their promising solution to address these issues, and also positively influencing occupant productivity. As such, many governments and organizations have developed relevant codes and procedures to encourage and enforce the adoption of PDS. Despite the increased focus, the adoption of PDS is still trailing behind in developing countries, particularly in a hot, dry and humid climate zone. This paper examines the current state of PDS adoption in such climates, and extracts relevant motivators, and challenges. The data was gathered through a structured review of literature. Initial results show the extraction of thirty-five motivators and forty-six challenges to PDS adoption. The key motivators include reduction in energy consumption and energy bills, while key challenges include high initial investment and lack of awareness. These are expected to generate a general awareness among stakeholders and allow a better understanding of the underlying issues for non-adoption of PDS. Future research will examine the extracted sets of motivators and challenges through a questionnaire survey in a hot, dry and humid climate zone.

Keywords: carbon emission, challenges, energy consumption, motivators, PDS adoption

1. Introduction

Rapid increase in development led to a boom in construction activities, hence increased the negative impact of the sector on the environment [1]. Reportedly, the construction industry is responsible for a considerable amount of energy consumption and CO_2 emissions, specifically from residential buildings [2]. Additionally, buildings are responsible for about 40% of total energy consumption and nearly one-third of total global CO_2 emissions, which is a clear evidence of the devastating impact on the environment [3]. This energy consumption and CO_2 emissions might double or even triple in the next centuries, particularly in countries with either a hot-dry (e.g. Middle Eastern countries) or hot-humid climate (e.g. countries like Brunei, Malaysia and Indonesia), which further affects climate change [4].

Consequently, it is important to find a way to reduce energy consumption and CO_2 emissions. In order to alleviate the issues, it is widely accepted that the adoption of passive design strategies (PDS) will greatly reduce energy consumption and CO_2 emissions while maintaining indoor thermal comfort [5, 6]. PDS are features intrinsic to the form and design of a building that works on the basis of two natural phenomena, i.e. sun/sunlight and wind, and is used in combination with factors like orientation and aspect ratio (i.e. length to breadth ratio of building), shading and many others as underlying situations for architectural and/or structural designs. [7]. Due to its considerable positive impact on energy consumption and CO_2 emissions, many governments and organizations have developed relevant codes and procedures to encourage and enforce the adoption of PDS [7]. The benefits of adopting PDS have also been reported, e.g., in terms of reduction in energy use and CO_2 emissions; savings in maintenance and repair costs; and improved comfort and productivity of occupants [8, 9]. In recent years, research on PDS concepts has increased globally, particularly in hot-dry and hot-humid countries [10-12].

Despite all these benefits and increased focus on the adoption of PDS into practices, such countries' actions and practices are not being widely adopted. So, to address these gaps, this study aims to investigate what exactly motivates or discourages the industry and occupants from incorporating PDS. The findings will form the basis for further analysis and subsequent inclusion in a questionnaire survey designed to investigate the perceptions on motivators and challenges to PDS adoption. The outcomes are also expected to update existing literature, raise awareness among construction industry practitioners, and document necessary feeding materials for future research. The following sections of the paper discuss the methodology adopted for this paper, the findings of the research done so far, and finally, the conclusions.

2. Methodology

The structured literature review was conducted from academic listings of Science Direct, Taylor and Francis, and Emerald Insight, published within the last two decades, i.e. from 2001 to 2020. The following five keywords were first used individually: "residential building," "energy efficiency," "low carbon building," "passive design," and "optimization."; and then together, to identify 1,713 papers. This was further reduced to 261 papers after removing publications with the same title and repetition caused by the keywords during the first stage. Next, the abstracts and the remaining contents of papers were scanned to ensure that the papers primarily deal with reduction of energy consumption and low carbon emissions, and to ensure that they are related to PDS, which further reduced to 195 papers, with 156 papers from hot, dry and humid climates. These 156 papers were considered for review, which includes papers that are published in countries with a hot-dry climate (i.e., Saudi Arabia and Nigeria) and a hot-humid climate (i.e., Malaysia, Singapore, Indonesia, and India).

3. PDS adoption

The first movement of PDS (Passive Design Strategies) adoption struck the construction industry in developed countries, such as the USA, which held its first passive design conference in May 1976 as a means to overcome huge energy consumption and other obstacles that were encumbering innovation [13]. Numerous studies indicate that the PDS market would be huge, but its adoption is slow in many countries, such as Malaysia, Indonesia, and Pakistan [14-16]. According to the report in 2020, China is in the early stage of PDS adoption. Many people are not familiar with the concept of PDS [17]. China currently attaches great importance to energy conservation and CO_2 emission reduction, and targets to reduce energy consumption and CO_2 emissions by 25% over the next decade [18]. Accordingly, there are numerous publications and research results for PDS adoption in China [19]. China's first publication on guidelines for adopting PDS appeared in 2015 [20]. However, there was no clear vision or definition of when the adoption of PDS should be achieved. Also, some provinces and cities in China have just put policies in place that make it easier to adopt PDS, but have not done much to promote it [21].

Then, adoption of PDS concept in Malaysia's construction industry can be traced back to a decade or earlier [22]. However, in the past five years or so, the interest in PDS adoption has intensified among numerous stakeholders in the construction sector [23]. As part of improving PDS adoption, Malaysia has introduced the guidelines for PDS adoption for their residential buildings [24]. Nonetheless, the guidelines for PDS adoption have been initiated in the country since 2017 by the government but are only limited to their internal projects [25]. It was then known that the progress of PDS was then dominated by the non-residential sector from 2017 onwards [26]. Since then, Malaysia has taken a number of steps to make it easier for people to use PDS [27]. However, only 5% of the residential sector uses PDS every year [28]. While, adoption of PDS in Indonesia's construction industry can be traced back to a decade or earlier [29], in the last five years or so, there has been a surge in interest in PDS adoption among a wide range of construction stakeholders [30]. It was found that Indonesia was highly aware of PDS in the construction industry, however, the usage of the technology in the country was low [31]. Studies found very high awareness of PDS among the surveyed population of construction stakeholders, compared to the low adoption rate of only 4% [32, 33]. This might be due to the absence of any general standard and regulation for PDS adoption in Indonesia, where only large projects have started using PDS, mostly in commercial buildings, in the last few years [32, 34].

In addition, the PDS adoption in India is still at an early stage, with growth of 5.0% each year [35]. Furthermore, PDS is not mandated across all the states yet, although energy efficiency was prioritized over all other concerns, and it is expected to grow significantly [36]. In India, the support for the adoption of PDS from governmental bodies is still poor [37]. There are no uniform PDS standards and guidelines regarding the implementation of PDS [34, 36]. Also, the present studies indicate that there is a potential for adopting PDS in India [37]. Moreover, private sectors have just started to evaluate the value and cost of adopting PDS [38]. As compared to other countries, Pakistan's adoption of PDS is very slow, with only private individuals and a few fragmented public initiatives fully embracing it [39]. However, unfortunately, PDS adoption in Pakistan has neither been made mandatory by the Pakistan government nor been widely adopted by construction organizations [40]. The construction activities in Pakistan are still using old and outdated construction equipment. The government has issued several policies, yet most of the policies are not clearly defined on PDS standard [41]. Furthermore, the industry is facing numerous problems, like a lack of both skilled and unskilled workers, expensive building materials, and low standards of health performance [42].

4. Motivators

The literature search extracted 35 motivators in six groups that drive the adoption of PDS, which are tabulated in table 1 and briefly discussed below.

4.1. Financial benefits

The ability to reduce energy consumption and energy bills have been identified as the key motivator for PDS adoption. The reduction of energy comes from the incorporation of natural phenomena, which reduces the need for mechanical cooling or heating [43]. Energy reduction can bring financial benefits to users or owners, as users can save money on energy bills, which in the long run can actually pay off the initial installation costs and save even more [44, 45]. A study reported that the financial benefits from reduced energy consumption are 10 times higher than the additional construction costs required to practice PDS [46], and energy consumption can be reduced by 25% – 60% [47].

4.2. Social benefits

The adoption of PDS enhances the quality of life of occupants, which then improves occupant health and comfort [46, 47]. These come from user-friendly design that leads to better indoor air quality (i.e., lower concentration of CO_2 emissions). Besides, PDS components implemented in the building, such as insulation, solar shading, and green walls, contribute to an improved quality of life for individuals [48, 49]. These were observed in Singapore, Hong Kong, and Malaysia [50, 51]. Furthermore, the occupants of the PDS building used about 45%–62% less electricity [49, 52]. This results in the improved satisfaction and well-being of building occupants.

4.3. Environmental benefits

According to studies in Hong Kong and Singapore, one of the primary motivators for adopting PDS is environmental benefit [49, 53]. Due to the enforcement of environmental policies and regulations, clients' demand to adopt PDS also increased, as the adoption resulted in a healthier work and living environment [54]. Also, adoption of PDS could protect biodiversity and ecosystems. This is supported by studies in India, China, and Malaysia stating that the environmental benefits are driving the adoption of PDS, resulting in an increase in the PDS adoption rate [50, 55]. Clearly, these factors make a positive contribution to the adoption of PDS [56].

4.4. Reliance on climate
The adoption of PDS conserves natural resources, which is one of the main motivators for adopting PDS [57]. Studies in Singapore and Hong Kong reported that the reliance on climate on PDS adoption helps to reduce a building's environmental impact by decreasing its contribution to CO_2 emissions [58]. The use of natural phenomena for PDS adoption also anticipates the stakeholders' adoption of PDS, which decreases the reliance on mechanical systems to provide heating and cooling energy demands [59]. This led to less of an effect on climate change, which further drive the stakeholders to adopt PDS.

Table 1. Motivators to PDS.

Group 1: Financial Benefits	–	Energy conservation in structural design, energy conservation in architectural design, high return on investment from rental and property values, reduces energy consumption and costs/bills, reduces maintenance and repair costs of buildings, attract premium clients/increased building value
Group 2: Social Benefits	–	User friendly design, provide better health for occupants due to improved indoor air quality, improve comfort, satisfaction and well-being of building occupants, improve the quality of life for individuals; improve occupant's productivity
Group 3: Environmental benefits	–	Reduce material use and use low impact PDS materials, healthier work and living environment, improved air and water quality, enforcement of environmental policies and regulations, protecting biodiversity and ecosystems
Group 4: Reliance on climate	–	Reduced impact on the climate change, decrease use of natural resources, reduced in the environmental pollution, improved visual amenity, reduced impact on the environment for CO_2 emission
Group 5: Cliental demand	–	Market competition, high awareness and knowledge of client, better image through PDS, recognition from the industry, promotion of successful PDS project as case examples, personal commitment due to awareness of environmental concerns, availability of PDS suppliers, government incentives schemes for PDS adoption
Group 6: Consultant influence	–	Clients have better public image, public awareness to PDS initiatives, client collaboration towards PDS initiatives; business commitment to adopt PDS, lack of client knowledge, professional accreditation for PDS adoption, consultants have good reputation of using PDS

4.5. Cliental demand
Clients or owners, who play a major role in the construction process, are motivated to meet PDS standards since they are aware of the benefits of adopting PDS [58]. Also, since clients are the key decision makers for PDS adoption, it is easier for a project team to adopt PDS practices once a client

expresses interest [59]. This shows that clients are aware of the potential benefits and knowledge of PDS, which leads them to show interest and consequently demand for PDS adoption. Also, market competition is one of the main reasons Australia and Singapore adopted PDS in their construction sector [60].

4.6. Consultant influence
Consultant influence as a motivator was reported in Australia, Singapore, and India [57, 61]. Due to clients' uncertain knowledge and awareness of PDS, consultant service providers play the key role in explaining, suggesting, and persuading them to adopt PDS [46]. Furthermore, consultants' professional accreditation and knowledge of PDS allow them to maintain their reputation and create a superior image, which further motivates the client to adopt PDS [55]. This is supported by studies in Malaysia, Hong Kong, and Australia stating that consultant influence drives their adoption of PDS [53, 61].

5. Challenges
In addition to the aforementioned motivators, the literature search extracted 46 challenges in six groups, which are shown in table 2 and briefly discussed below.

5.1. Financial issues
The most common challenge mentioned in the literature is 'high initial cost' [62-64] across many countries, like Malaysia, Singapore, Indonesia, Nigeria, and Saudi Arabia. This is attributed to the actual and perceived high investment costs for PDS, which are 25% higher than the costs/fees for traditional design, and the risk of unanticipated costs related to the use and practice of PDS [65]. Most of the extra cost comes from the detailed analysis done by consultants based on the underlying climate, the choice of appropriate building materials that costs 3% - 4% more than traditional materials, lack of experts' experience with PDS and relevant materials, and their skill levels [66]. The high cost of investment also affects the rate of adoption, particularly where the PDS technology is not available in the local market, so requiring their import [67]. Indeed, high costs drive potential stakeholders away from adopting PDS, irrespective of the need to address high energy consumption in buildings [68].

5.2. Government issues
The government issues are key challenges that prevent the adoption of PDS [69]. They refer to the absence of rules, regulations, and guidance documentation and the limited policy framework provided by the government for the adoption of PDS [51, 70]. Due to the lack of these rules and regulations, PDS are not widely used in such countries [71]. Previous studies have found that the lack of rules and regulations is the biggest problem with PDS adoption in Thailand, Indonesia, Pakistan, and India [42, 72].

5.3. Management issues
The process of adopting PDS in buildings itself can create some challenges [55]. The complexity of PDS adoption entails practical difficulties in defining specific design requirements [57]. Since PDS is diverse, it necessitates not only full collaboration and effective communication among project team members but also close collaboration with suppliers, experts, and owners [60]. PDS design is prone to failure in the absence of close interaction and effective communication among project team members. This is also backed up by studies from Vietnam, Malaysia, Nigeria, and Saudi Arabia that stated gaps between all stakeholders' collaboration and decisions could make it hard for PDS to be adopted [71].

5.4. Technical issues
The lack of training has resulted in inadequate knowledge and information on PDS [72]. Therefore, the number of qualified people to adopt PDS is still insufficient. In addition, the enforcement by the government to adopt PDS is still low, which causes hesitation among clients and developers to adopt PDS due to insufficient awareness about PDS technology and its potential [65, 73]. Hence, a lack of

technical abilities of PDS, including overestimates of the initial cost premium, hinders the adoption of PDS.

Table 2. Challenges to PDS.

Group 1: Financial issues	–	High initial costs of PDS adoption, lack of government incentives and grants, technical difficulty in design due to unfamiliar with PDS concepts, cost of passive technologies and materials are expensive, increased cost pressure without the benefits of scale economies, long pay back periods from PDS practices, lack of financial resources/capital to support PDS, risk of unforeseen costs in adopting PDS
Group 2: Government issues	–	Absence of guiding policy to improve technical capability of consultants, lack of enforcement from government for the construction of PDS, lack of relevant laws and regulations to drive PDS adoption, ineffective government programs focused on PDS, lack of environmental enforcement for PDS, absence of an official sustainable design body, lack of government support concerning PDS, lack of training provided by the government focused on PDS
Group 3: Management issues	–	Unwillingness to change the conventional way, lack of communication and collaboration across all stakeholders, lack of expertise within the organizations, conflict of interest, lack of empowerment to support PDS, weak organizational structure to support PDS, lack of support from the senior management on PDS adoption
Group 4: Technical issues	–	Lack of easily accessible resource and documentation, lack of access to external PDS technical support, lack of technical ability within the project team, limited availability of PDS suppliers locally, poor supplier commitment towards PDS, lack of skilled personnel, lack of exemplar “demonstration project”
Group 5: Socio-cultural issues	–	Lack of client demand to adopt PDS, lack of marketization of PDS specifications, existence of attitude and perception issues regarding PDS, weak public pressure towards PDS technology, lack of environmental concerns, lack of culture on PDS concepts, cultural change resistance by stakeholders, tendency to maintain current practices by the owners
Group 6: Knowledge issues	–	Lack of awareness of expertise, lack of awareness of benefits on PDS adoption, lack of professional knowledge, uncertainty with PDS technology and materials, lack of awareness of clients, lack of education and knowledge in PDS technology, society’s inadequate awareness regarding passive building, perception about PDS technology (e.g. distrust)

5.5. Socio-cultural issues

Socio-cultural factors largely prevent PDS adoption in hot-dry and hot-humid countries [35, 44]. According to a study covering Malaysia and Indonesia, occupant/client behaviours and culture are the main factors that prevent the adoption of PDS [53, 62]. Such behaviours are related to cultural attitudes, such as not believing the positive benefits of PDS adoption and the resistance to change from traditional design. In addition, there is a lack of awareness of the positive benefits of PDS adoption within the construction sector in hot-dry and hot-humid countries where market demand does little to motivate clients or owners to adopt PDS [68, 72]. Hence, society is not fully aware of successful PDS adoption in such countries, hence the low demand for PDS adoption.

5.6. Knowledge issues

The lack of awareness of PDS is another key challenge that prevents the adoption of PDS [72–74]. Due to the uncertain knowledge and awareness, clients reject or avoid adopting PDS, as the adoption of PDS may result in extra costs [75]. Also, a lack of awareness among stakeholders appears to be the key challenge of PDS adoption in Vietnam [73]. This is supported by studies in Indonesia, India, Pakistan, Iraq, and Malaysia stating that the low level of awareness among people working in client organizations and stakeholders' organizations is obstructing the adoption of PDS [32,74]. Therefore, it may affect adoption behavior due to the minimal principal knowledge and understanding.

6. Conclusion

With rapid development, the building sector is, and will continue to be, a major energy user. The adoption of PDS is one way to reduce such energy consumption and consequent CO_2 emissions. Despite many diverse benefits, PDS adoption is still relatively low in hot-dry and hot-humid countries. As such, this paper attempted to explore the current state of PDS adoption in such countries and extracted various motivators and challenges to PDS adoption, through a structured literature review. A list of 35 motivators and 46 challenges were identified. These motivators and challenges will be examined in the next phase of this research through a questionnaire survey of contractors, consultants, and developers/clients in the Brunei construction industry, before devising a set of strategies and/or framework for wider adoption of PDS. The overall results are expected to help and improve the use of PDS in construction industries in general, and in hot-dry and humid countries in particular. The outcomes are also expected to benefit a number of parties, such as financial institutions, investors, developers, and policymakers.

References

[1] World Green Building Council (WGBC). *New report: the building and construction sector can reach net zero carbon emissions by 2050*. 2019.
[2] International Energy Agency (IEA). *Tracking Buildings 2020*. 2020. Available from: https://www.iea.org/reports/tracking-buildings-2020
[3] International Energy Agency (IEA). *The Critical Role of Buildings*. 2019. Available from: https://www.iea.org/reports/the-critical-role-of-buildings
[4] Alagbe OA, Caiafas MA, Olayemi BO and Joel OO 2019 Enhancing energy efficiency through passive design: a case study of halls of residence in Covenant University, Ogun State. *IOP Conf Ser Mater Sci Eng*. **640**(1) 012017
[5] Mirrahimi S, Mohamed MF, Haw LC, Ibrahim NLN, Yusoff WFM and Aflaki A 2016 The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot–humid climate. *Renew Sustain Energy Rev*. **53** 1508–19
[6] Zhou C, Wang Z, Chen Q, Jiang Y and Pei J 2014 Design optimization and field demonstration of natural ventilation for high-rise residential buildings. *Energy Build*. **82** 457–65
[7] Al-Tamimi NA and Fadzil SFS 2011 The Potential of Shading Devices for Temperature Reduction in High-Rise Residential Buildings in the Tropics. *Procedia Eng*. **21** 273–82
[8] Chen X and Yang H 2017 A multi-stage optimization of passively designed high-rise residential buildings in multiple building operation scenarios. *Appl Energy*. **206** 541–57
[9] Omrani S, Garcia-Hansen V, Capra BR and Drogemuller R 2017 On the effect of provision of

balconies on natural ventilation and thermal comfort in high-rise residential buildings. *Build Environ*. **123** 504–16

[10] Yang W, Wong NH and Lin Y 2015 Thermal Comfort in High-rise Urban Environments in Singapore. *Procedia Eng*. **121** 2125–31

[11] Friess WA and Rakhshan K 2017 A review of passive envelope measures for improved building energy efficiency in the UAE. *Renew Sustain Energy Rev*. **72** 485–96

[12] Hu F and Zheng X 2015 Carbon Emission of Energy Efficient Residential Building. *Procedia Eng*. **121** 1096–102

[13] Karimpour M, Belusko M, Xing K, Boland J and Bruno F 2015 Impact of climate change on the design of energy efficient residential building envelopes. *Energy Build*. **87** 142–54

[14] Roslan Q, Ibrahim SH, Affandi R, Mohd Nawi MN and Baharun A 2016 A literature review on the improvement strategies of passive design for the roofing system of the modern house in a hot and humid climate region. *Front Archit Res*. **5**(1) 126–33

[15] Song G Chen W and Xu M 2020 Case Study on Prefabricated Sunspace-Addition Renovation for Existing High-Rise Residential Buildings and Its Energy Consumption Simulations. *IOP Conf Ser: Earth Environ Sci*. 012021

[16] Tong S, Wen J, Wong NH and Tan E 2021 Impact of façade design on indoor air temperatures and cooling loads in residential buildings in the tropical climate. *Energy Build*. **243** 110972

[17] Yaşar Y and Kalfa SM 2012 The effects of window alternatives on energy efficiency and building economy in high-rise residential buildings in moderate to humid climates. *Energy Convers Manag*. **64** 170–81

[18] Hassan SA 2020 The effect of residential building façade design on energy consumption for hot desert climate. *IOP Conf Ser Mater Sci Eng*. **928** 022029

[19] Zhang N and Bi Y 2020 The development and application of passive architecture in China. *E3S Web of Conferences*. 04019

[20] Sorgato MJ, Melo AP and Lamberts R 2016 The effect of window opening ventilation control on residential building energy consumption. *Energy Build*. **133** 1–13

[21] Qingyuan Z and Yu L 2014 Potentials of Passive Cooling for Passive Design of Residential Buildings in China. *Energy Procedia*. **57** 1726–32

[22] Sang X, Pan W and Kumaraswamy MM 2014 Informing Energy-efficient Building Envelope Design Decisions for Hong Kong. *Energy Procedia*. **62** 123–31

[23] Gou S, Nik VM, Scartezzini J-L, Zhao Q and Li Z 2018 Passive design optimization of newly-built residential buildings in Shanghai for improving indoor thermal comfort while reducing building energy demand. *Energy Build*. **169** 484–506

[24] Leng PC, Hoh Teck Ling G, Ahmad MH, Ossen DR, Aminudin E and Chan WH 2020 Thermal Performance of Single-Story Air-Welled Terraced House in Malaysia: A Field Measurement Approach. *Sustainability*. **13**(1) 201

[25] Tatarestaghi F, Ismail MA and Ishak NH 2018 A Comparative Study of Passive Design Features/Elements in Malaysia and Passive House Criteria in the Tropics. *J Des Built Environ*. **18**(2) 15–25

[26] Al-Tamimi N and Fadzil SFS 2012 Energy-efficient envelope design for high-rise residential buildings in Malaysia. *Archit Sci Rev*. **55**(2) 119–27

[27] Ramli NH 2012 Re-adaptation of Malay House Thermal Comfort Design Elements into Modern Building Elements – Case Study of Selangor Traditional Malay House & Low Energy Building in Malaysia. *Iran J Energy Environ*.

[28] Zaki WRM, Nawawi AH and Sh.Ahmad S 2012 Environmental Prospective of Passive Architecture Design Strategies in Terrace Houses. *Procedia - Soc Behav Sci*. **42** 300–10

[29] Berawi MA, Kim AA, Naomi F, Basten V, Miraj P, Medal LA and Sari M 2021 Designing a smart integrated workspace to improve building energy efficiency: an Indonesian case study. *Int J Constr Manag*. 1–24

[30] Khalid A 2020. Passive Design, Urban-Rural Architectural Morphology for Subtropics. *Eur J*

Sustain Dev. **9** 376
[31] Chen Y, Mae M, Taniguchi K, Kojima T, Mori H, Trihamdani AR, Morita K and Sasajima Y 2021 Performance of passive design strategies in hot and humid regions. Case study: Tangerang, Indonesia. *J Asian Archit Build Eng*. **20**(4) 458–76
[32] Nugroho AM, Citraningrum A, Iyati W and Ahmad MH 2020 Courtyard as Tropical Hot Humid Passive Design Strategy: Case Study of Indonesian Contemporary Houses in Surabaya Indonesia. *J Des Built Environ*. **20**(2) 1–12
[33] Alfata MNF, Hirata N, Kubota T, Nugroho AM, Uno T, Ekasiwi SNN and Antaryama N 2015 Field Investigation of Indoor Thermal Environments in Apartments of Surabaya, Indonesia: Potential Passive Cooling Strategies for Middle-class Apartments. *Energy Procedia*. **78** 2947–52.
[34] Mahar WA, Verbeeck G, Reiter S and Attia S 2020 Sensitivity Analysis of Passive Design Strategies for Residential Buildings in Cold Semi-Arid Climates. *Sustainability*. **12**(3) 1091
[35] Hemchandra P and Hangargekar P 2016 Integrated approach in building design for passive cooling in hot and dry climates of India. *Int Res J Eng Technol*. **3**(6) 2664–9
[36] Dhakate T and Khan MS 2018 Concepts of Passive Design in Composite Climate. *Int J Res Eng Sci Manag.* **1**(10) 126–7
[37] Santy, Matsumoto H, Tsuzuki K and Susanti L 2017 Bioclimatic Analysis in Pre-Design Stage of Passive House in Indonesia. *Buildings*.**7**(4) 24
[38] Vartholomaios A 2015 The residential solar block envelope: A method for enabling the development of compact urban blocks with high passive solar potential. *Energy Build*. **99** 303–12
[39] Izadyar N, Miller W, Rismanchi B and Garcia-Hansen V 2020 Impacts of façade openings' geometry on natural ventilation and occupants' perception: A review. *Build Environ*. **170** 106613
[40] Ahmed T, Kumar P and Mottet L 2021 Natural ventilation in warm climates: The challenges of thermal comfort, heatwave resilience and indoor air quality. *Renew Sustain Energy Rev* **138** 110669
[41] Edeisy M and Cecere C 2017 Envelope Retrofit in Hot Arid Climates. *Procedia Environ Sci*. **38** 264–73
[42] Kuzhakova A, Kolgashkina V and Shilkin N 2019 Architectural and engineering solutions for high-rise residential buildings with nearly zero energy balance. *IOP Conf Ser: Earth Environ Sci*. 012003
[43] Gondal IA, Syed Athar M and Khurram M 2021 Role of passive design and alternative energy in building energy optimization. *Indoor Built Environ*. **30**(2) 278–89
[44] Nutkiewicz A, Jain RK and Bardhan R 2018 Energy modeling of urban informal settlement redevelopment: Exploring design parameters for optimal thermal comfort in Dharavi, Mumbai, India. *Appl Energy*. **231** 433–45
[45] Rana J, Hasan R, Sobuz HR and Tam VWY 2020 Impact assessment of window to wall ratio on energy consumption of an office building of subtropical monsoon climatic country Bangladesh. *Int J Constr Manag*. 1–2
[46] Bakhtiar F and Khan F 2014 Potential of Passive Cooling Strategies in Pakistan: A Case Study of Peshawar Region. *Sci Technol Dev.* **33**(4) 159–64
[47] Bughio M, Khan MS, Mahar WA and Schuetze T 2021 Impact of Passive Energy Efficiency Measures on Cooling Energy Demand in an Architectural Campus Building in Karachi, Pakistan. *Sustainability.* **13**(13) 7251
[48] Sohail M 2017 An Attempt to Design a Naturally Ventilated Tower in Subtropical Climate of the Developing Country; Pakistan. *Environ Clim Technol*. **21**(1) 47–67
[49] Srivastav S and Jones PJ 2009 Use of traditional passive strategies to reduce the energy use and carbon emissions in modern dwellings. *Int J Low-Carbon Technol*. **4**(3) 141–9
[50] Gangwar G, Kaur P and Singh I 2020 A Study of Passive and Active Strategies through Case

Studies for the Composite Climate Zone of India. *Civ Eng Archit.* **8**(6) 1370–89
[51] Othman AR and Sahidin N 2016 Vertical Greening Façade as Passive Approach in Sustainable Design. *Procedia - Soc Behav Sci.* **222** 845–54
[52] Y. Azmy N and E. Ashmawy R 2018 Effect of the Window Position in the Building Envelope on Energy Consumption. *Int J Eng Technol*. **7**(3) 1861
[53] Laurini E, De Vita M, De Berardinis P and Friedman A 2018 Passive Ventilation for Indoor Comfort: A Comparison of Results from Monitoring and Simulation for a Historical Building in a Temperate Climate. *Sustainability*. **10**(5) 1565
[54] Lotfabadi and Hançer 2019 A Comparative Study of Traditional and Contemporary Building Envelope Construction Techniques in terms of Thermal Comfort and Energy Efficiency in Hot and Humid Climates. *Sustainability.* **11**(13) 3582
[55] Khalaf M, Ashrafian T and Demirci C 2019 Energy Efficiency Evaluation of Different Glazing and Shading Systems in a School Building. *E3S Web Conferences.* **111** 03052
[56] Khalil A-A, Fikry M and Abdeaal W 2018 High technology or low technology for buildings envelopes in residential buildings in Egypt. *Alexandria Eng J*. **57**(4) 3779–92
[57] Kim S-H, Shin K-J, Kim H-J and Cho Y-H 2017 A Study on the Effectiveness of the Horizontal Shading Device Installation for Passive Control of Buildings in South Korea. *Int J Polym Sci*. **2017** 1–11
[58] Wong I and Baldwin AN 2016 Investigating the potential of applying vertical green walls to high-rise residential buildings for energy-saving in sub-tropical region. *Build Environ*. **97** 34–9
[59] Saleem AA, Bady M, Ookawara S and Abdel-Rahman AK 2016 Achieving standard natural ventilation rate of dwellings in a hot-arid climate using solar chimney. *Energy Build*. **133** 360–70
[60] Lu S, Wang R and Zheng S 2017 Passive Optimization Design Based on Particle Swarm Optimization in Rural Buildings of the Hot Summer and Warm Winter Zone of China. *Sustainability*. **9**(12) 2288
[61] Liu S, Kwok YT, Lau KK-L, Ouyang W and Ng E 2020 Effectiveness of passive design strategies in responding to future climate change for residential buildings in hot and humid Hong Kong. *Energy Build*. **228** 110469
[62] Mushtaha ES, Mori T and Masamichi E 2012 The Impact of Passive Design on Building Thermal Performance in Hot and Dry Climate. *Open House Int*. **37**(3) 81–91
[63] Toutou A, Fikry M and Mohamed W 2018 The parametric based optimization framework daylighting and energy performance in residential buildings in hot arid zone. *Alexandria Eng J*. **57**(4) 3595–608
[64] Yao R, Costanzo V, Li X, Zhang Q and Li B 2018 The effect of passive measures on thermal comfort and energy conservation. A case study of the hot summer and cold winter climate in the Yangtze River region. *J Build Eng*. **15** 298–310
[65] Sedki A, Hamza N and Zaffagnini T 2013 Effect of Orientation on Indoor Thermal Neutrality in Winter Season in Hot Arid Climates Case Study: Residential Building in Greater Cairo. *Int J Eng Technol*. **5**(6) 712–6
[66] Lei J, Yang J and Yang E-H 2016 Energy performance of building envelopes integrated with phase change materials for cooling load reduction in tropical Singapore. *Appl Energy*. **162** 207–17
[67] Aflaki A, Mahyuddin N, Al-Cheikh Mahmoud Z and Baharum MR 2015 A review on natural ventilation applications through building façade components and ventilation openings in tropical climates. *Energy Build*. **101** 153–62
[68] Nnodu V, Obiegbu M and Eneche P 2017 An Assessment of Sustainable Energy-efficient Strategies for Retrofitted Building Development in Abuja, Nigeria. *Arch Curr Res Int*. **9**(1) 1–12
[69] Octaviani DS, Susanto D and Suganda E 2020 The performance of the building envelope in high-rise residential related to occupant's comfort. *IOP Conf Ser: Earth Environ Sci.* 012028

[70] Sun X, Gou Z and Lau SS-Y 2018 Cost-effectiveness of active and passive design strategies for existing building retrofits in tropical climate: Case study of a zero energy building. *J Clean Prod.* **183** 35–45

[71] Abdul OHK 2016 Optimization of Building Energy Performance through Passive design strategies. *Br J Appl Sci Technol*. **6**(13) 1–16

[72] Baghaei Daemei A, Haghgooy Osmavandani P and Samim Nikpey M 2018 Study on Vernacular Architecture Patterns to Improve Natural Ventilation Estimating in Humid Subtropical Climate. *Civ Eng J*. **4**(9) 2097

[73] Ochedi DET and Taki DA 2019 Energy Efficient Building Design in Nigeria: An Assessment of the Effect of the Sun on Energy Consumption in Residential Buildings. *J Eng Archit*. **7**(1)

[74] Jannat N, Hussien A, Abdullah B and Cotgrave A 2020 A Comparative Simulation Study of the Thermal Performances of the Building Envelope Wall Materials in the Tropics. *Sustainability* **12**(12) 4892

[75] Prieto A, Knaack U, Klein T and Auer T 2017 25 Years of cooling research in office buildings: Review for the integration of cooling strategies into the building façade (1990–2014). *Renew Sustain Energy Rev.* **71** 89–102