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Delphi method to ranking the early design parameters impact on the cooling load of High-Rise Residential Buildings in Malaysia

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Abstract: *Buildings have consumed 36% of the world's total energy. High-rise Residential Buildings have become a trend in Malaysia. Data from National Property Information Centre Q2 2022 (NAPIC) show that the High-rise residential building is the trend for the incoming supply. The energy consumption by the Residential building in Malaysia is vital as it has contributed to 5% of final energy consumption and 21% of total electricity energy generated in the year 2019. Green Building Certifications such as LEED, BREEAM, Green Star, Green Mark have been adopted in various countries to encourage the implementation of green building. In Malaysia, GBI and GreenRE are commonly used for Green Building certification. In this study, three rounds of Delphi survey are conducted to obtain experts' opinion on significance level of each parameter. This study attempts to explore the significance level of passive design parameters on the cooling load of High-Rise Residential Buildings in Malaysia by using Delphi survey on. Experienced experts from architectural, green building consultant, and structural field in Malaysia were invited for the survey. From the survey, building orientation ranked the highest and followed by glazing (SHGC) ventilation and window to wall ratio. The findings from this study can act as a supporting tool for energy efficient (EE) criteria of GBI and GreenRe and help designers to prioritize more significant parameters during early dedsign stage.*

Keywords: *Delphi, High rise Residential, Cooling load, Sustainability*

1. Introduction

Buildings consume a significant amount of energy throughout its lifecycle [1]. In 2020, 36% of world energy is consumed by buildings [2]. Residential buildings have consumed 22% of total world energy and contributed to 17% of carbon dioxide emission while non-residential buildings and construction industries only consumed 8% and 6% of total world energy in 2020 [2].

In Malaysia, residential buildings have contributed to 5% of final energy consumption and 21% of total electricity energy generated in the year 2019 [3]. A study [4] showed that cooling load from air conditioner and refrigerator has the highest energy demand on typical Malaysian household consumption, Due to urbanization, High-rise Residential Buildings have become a trend in Malaysia. Currently, the High-rise Residential buildings have yet to become dominant in Malaysia, but the incoming supply of High-rise Residential Buildings is higher than Low-rise Residential buildings especially Apartments and Condominiums which is shown on **Figure 1** and **Figure 2** [5]. Condominiums and Apartments are trending for incoming supply of residential buildings. More focus should be asserted on the

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sustainability aspect of high-rise building for a better future development of Malaysia.

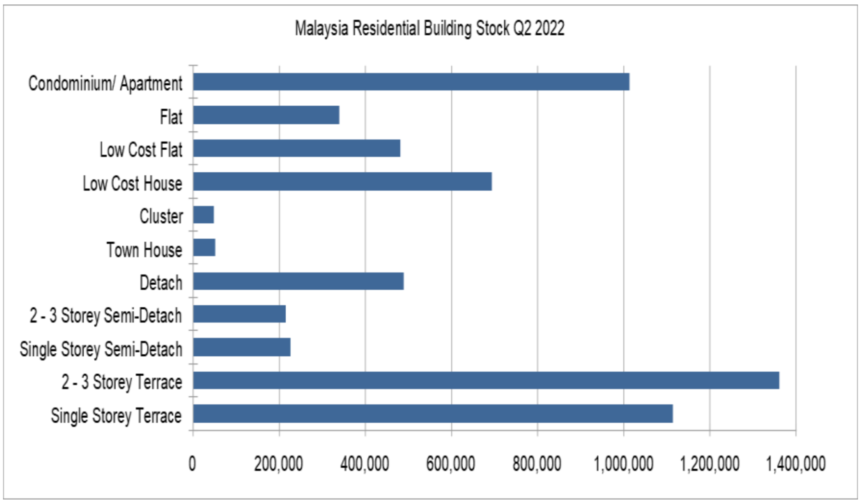

Figure 1. Malaysia Residential Building Stock Q2 2022 [5]

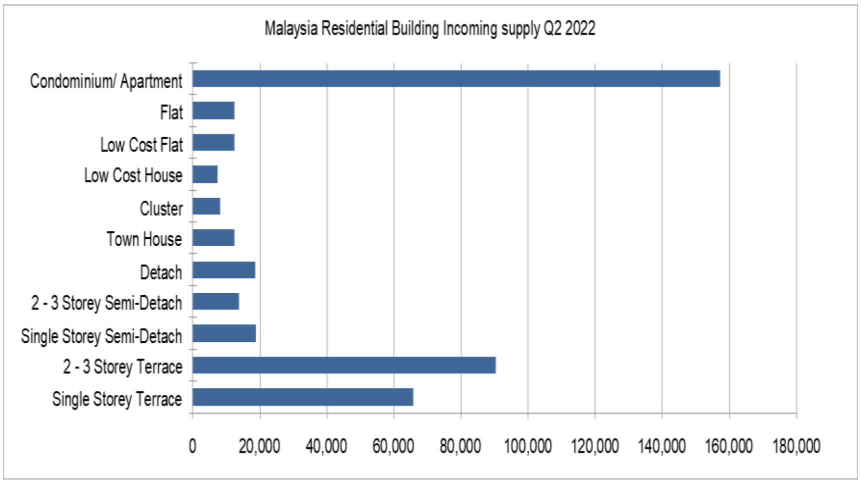

Figure 2. Malaysia Residential Building Incoming supply Q2 2022[5]

2. Delphi Method

The Delphi method was developed in the 1950s by RAND Corporation while involved in the U.S. Air Force sponsored project in the 1950s [6]. The Delphi method is a structured communication among a group of experts to obtain their opinion and build up consensus on a complex problem [7].

2.1. Delphi process summary

The Delphi method is a research technique that obtains the consensus opinion from a group of certified experts in relevant fields on a specific topic by conducting several rounds of intensive questionnaires. It is a structured communication among a group of experts to obtain their opinion and build up consensus on a complex problem [7]. The typical Delphi procedures usually consist of three rounds [8]. In the first round, opinions on a certain issue are collected open-endedly from the expert panelists. In the second round, panelists' rating on the statements in a questionnaire based on their opinions on the subject is collected. In the third round, the ratings in the previous round are reassessed by the panelists. The third round of the survey is repeated until a predetermined level of consensus among panelists is reached. The first round of the survey can be skipped sometimes and the questionnaire for the survey can be developed through literature review and interviews[9,10].

2.2 Previous studies on delphi method

Delphi survey is widely used for identifying and exploring the indicators and criteria for unknown and uncertain consensuses [11] in many fields including buildings and sustainability. For example, previous studies used Delphi method to develop sustainability indicators for campuses[12], explore consensus among expert sustainable architects for trends in sustainable architectural design [13], Identifying and Prioritizing the Benefits of Integrating BIM and Sustainability Practices in Construction Projects [14].

2.3 Number of participant and choosing the participant

There are no specific guidelines for the number of panelists used for the Delphi method[15]. Delphi panel size can vary depending on the scope of the problem under investigation, the number of available experts, and available resources in terms of time and money[15,16]. The sample size of Delphi is depending on the expertise and the quality of the participants where the collective consensus reached between expert participants rather than the number and statistical power[8,17]. Hallowell[21] suggested to use minimum of 8 participants.

Study[15] suggest that the combinations of individuals with multiple specialties and heterogeneous groups are recommended for the Delphi survey. By having the experts from the different fields in the survey, it can reduce the experts' bias against the group consensus on the subject investigated[17-19].

To select and qualify the experts for Delphi survey, a Flexible Point System for the Qualification of Expert recommended by Hallowell[20] is adopted. It recommends the panelists to score at least one point in four different achievement or experience categories with a minimum of 11 points total to qualify for the survey participation[20].The Flexible Point System for the Qualification of Expert is shown on **Table 2**.

Table 2. Flexible point system[20]

Achievement or experience	Points(each)
Professional experience	3
Years of professional experience	1
Conference presentation	0.5
Member of a committee	1
Chair of a committee	3
Peer-reviewed journal article	2
Faculty member at an accredited University	3
Writer/editor of a book	4
Writer of a book chapter	2
Advanced degrees:	
BS	4
MS	2
PhD	4

2.4. Consensus measurement

Schmidt[21] had suggested two criteria for deciding to continue or stop the Delphi rounds. The first criteria suggested is high consensus among the participants, which is measured by Kendall's W. The second criteria he suggested is constant W or, the difference of W in two successive rounds are negligible[15,21]. Kendall's W ranged from 0 to 1 where higher value means higher consensus level among participants. Kendall's W of "1" means 100% consensus among the participants and "0" means no consensus among the participants. Review of previous studies shows that Kendall's W within the identified Delphi papers ranged from 0.234 to 0.600[16].

3. Methodology

In the survey, the parameters obtained from literature are shown to participants. They are required to rate the parameters with a likert scale of 5. Three rounds of survey is done in this study. In each iterative rounds, a summary from previous round is shown to the participants and the participants are required to reconsider their rating on the parameters.

3.1. Recruiting the participants

The experts for the Delphi are recruited through profile screening through LinkedIn. The survey is done online by using Google Form. A total of 15 participants accepted the invitation for the survey. Subsequently, they were further filtered by using flexible point system[20]. The experience and expertise of chosen participants are shown on **Table 3** below.

Table 3. Participant profile summary

Participant	Year of experience	Expertise	Academic qualification level
2	5	Green building consultant	Master
7	24	Structural	PhD
8	8	Structural	Bachelor
9	7	Structural	Master
11	12	Architectural	Master
12	5	Architectural, Green building consultant	Master
13	6	Green building Consultant	Master
14	3	Green building consultant	Master
15	15	Green building consultant	Master

The parameters used in the survey is obtained through literature review. They are listed on **Table 4** below.

Table 4. Parameter list

Parameters	References
Glazing (U-value)	[22]
Glazing (SHGC)	[23]
Floor (U-value)	[24]
Roof (U-value)	[25]
External wall(U-value)	[26,27]
Internal wall (U-value)	[28,29]
External shading	[30,31]
Internal shading	[30]
wall insulation thickness	[32]
wall insulation material (R-value)	[32]
Building surface properties	[33]
Window to wall ratio (WWR)	[34]
Window to floor ratio (WFR)	[35]
Building aspect ratio	[36]
Building Height	[37]
Building Orientation	[38,39]
Natural ventilation	[40]
Building structural core placement	[41]

The targeted consensus in this study is set to $W>0.5$ which indicates acceptable consensus among participants[21]. The Delphi stops at the third round as the targeted consensus is reached. Likert scale of 5 is use in this study. The statistical data for each round is obtained by using SPSS software. There is open ended question for experts to suggest extra parameters that are not listed in the questionnaire in the first round.

4. Result and Discussion

4.1. First round result

For the first round, the W value is 0.30. It is statistically significant with $p<0.05$. From the open-ended question, the participant suggested to add landscape and heat resistance of wall insulation material into the list, thus, landscape and wall insulation material (R-value) is added to subsequent rounds. The mean score of each parameter in the first round is shown on **Figure 3**.

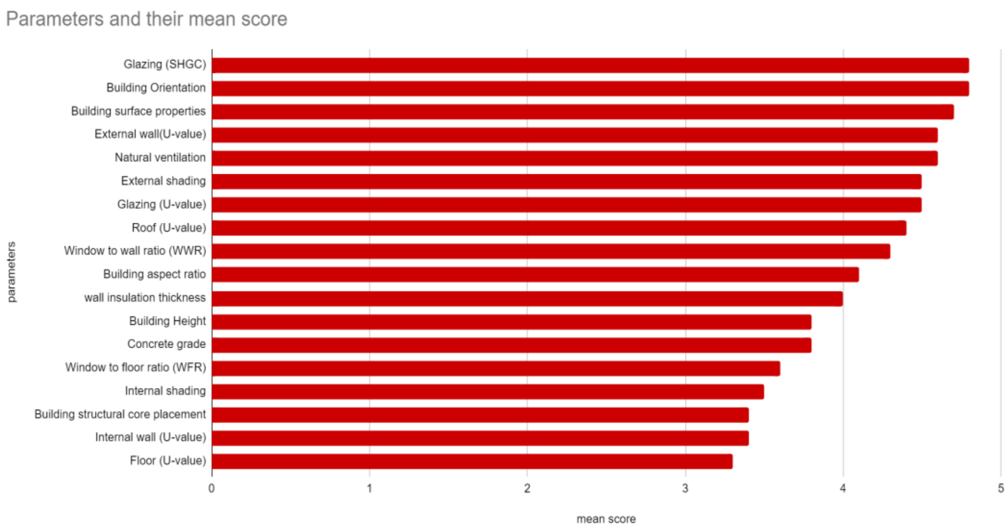

Figure 3. Round 1 score and Parameter Ranking

4.2. Second round result

In the second round, the mean score for each parameter from the previous round is shown to the participants. The participants are asked to reassess the rating of design parameters after reviewing the summary data from the first round. Compared to the first round, Kendall's W has been increased from 0.30 to 0.4. It is statistically significant with $p<0.05$. The mean score of each parameter in the second round is shown on **Figure 4.**

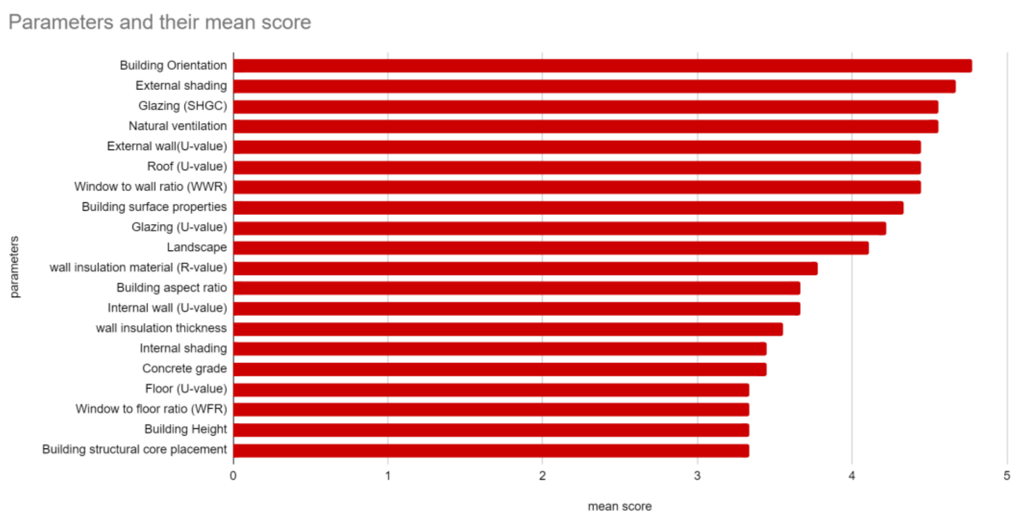

Figure 4. Round 2 Score and Parameter Ranking

4.3. Third round result

In the third round, the mean score for each parameter from the previous round is shown to the participants. The participants are asked to reassess the rating of design parameters after reviewing the summary data from the second round. Participant 14 is removed from this round as we could not contact the participant. W obtained from round 2 has been improved from 0.41 to 0.53. It is statistically significant with $p<0.05$. Since the set value of W is reached, the repeating rounds stop here. The mean score of each parameter in the third round is shown on **Figure 5,** which are the final score for each parameter.

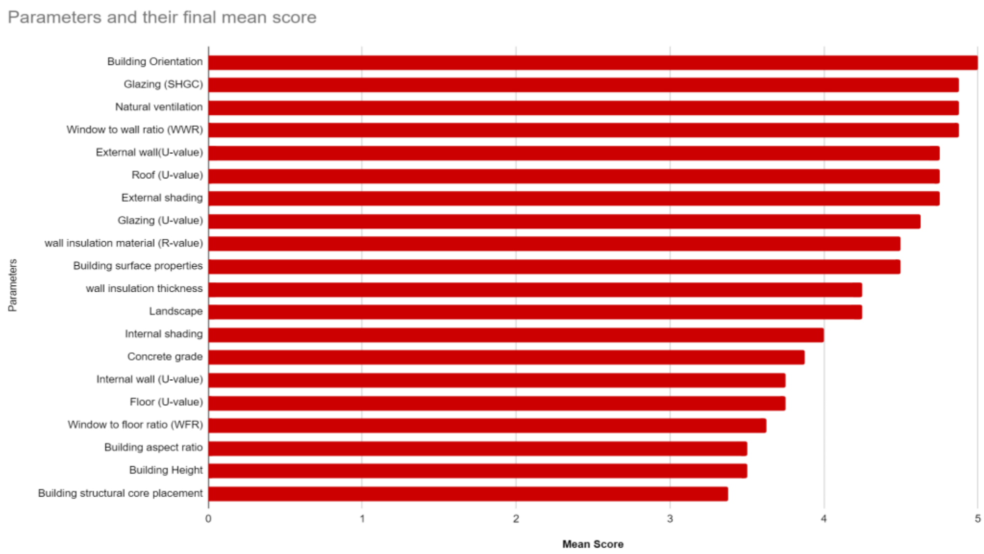

Figure 5. Round 3 Score and Parameter Ranking

4.4. Discussion on the parameters ranking

It can be observed that Building orientation ranked first for all 3 rounds of survey. Which means, the participants strongly agree that building orientation is the most significant parameter for reducing the cooling load of High-rise Residential buildings in Malaysia. Building orientation affects the amount of direct sun radiation on the building. Previous studies[38][42] recommends the buildings in tropics to have shorter sides facing east-west and reduce the number of openings facing east-west to reduce the direct radiation from sunlight.

The glazing (SHGC) also consistently achieves top 3 ranking for all 3 rounds of survey. SHGC determines how much heat passes through the windows through radiation. Higher SHGC will result in more direct sunlight entering the building.

WWR ranked 2nd in the final round, with the same ranking as SHGC and natural ventilation. It is expected to rank high as WWR is used for calculation of OTTV and RETV. Natural ventilation ranked top 5 for all 3 rounds of survey.

Natural ventilation can improve thermal comfort and reduce heat built up during daytime[23]. The external facade of buildings such as roof, external wall, and glazing is ranked high as expected. They are the main components of reducing the heat and direct sunlight from outside.

The internal partitions such as floors and internal walls are ranked low as expected. Their main function for reducing cooling load is by separating the internal space with different desired working temperature, or separating the air conditioned and non-air-conditioned rooms[28,43,44]. They do not reduce the amount of heat entering the building.

The ranking also shows that the external facade and parameters related to direct sunlight are more significant than internal components of the building. From result of round 2 and round 3, it is shown that the participants think that the wall insulation material is more important than insulation thickness, where some of the experts also comment on it during the survey. The summary for the Delphi survey is shown on **Table 5**. It shows the mean and the rank of each parameter for each round.

4.5. Comments from participants

Although the Delphi survey is mostly done online, we have an opportunity to meet up with 4 of the participants face to face, which are 1 project architect and 3 green building consultants for the survey. During the face-to-face meeting with participants, there are a few comments and justifications regarding the parameters scores from the participants. This section will provide the comments from the participants we have met.

4.5.1. Internal wall and floor

The most significant factor that affects the cooling load of high-rise residential buildings is the heat coming in from outside. The floors, internal wall and partitions are significant only when there is a special need or requirement for a specific room to have a working temperature different from adjacent rooms, for example a server room that needs to be air-conditioned 24-hours. Heat transfer between adjacent rooms is not significant if the adjacent rooms have similar working temperatures.

4.5.2. Internal shading

Internal shading has limited effectiveness compared to external shading. Importantly, the building facade reduces the amount of heat penetrating into the building. Internal shading such as curtains can effectively block the direct sunlight that passes through the window, but the heat has already entered the building.

4.5.3. Landscape

Landscapes such as trees and bushes provide good shading from sunlight but it is less effective for high-rise buildings.

4.5.4. Wall insulation thickness and wall insulation material

In Malaysia, wall insulation material is a more popular choice compared to wall insulation thickness. Thicker wall insulation is more suitable for countries with four seasons.

4.5.5. WWR

It is hard to control WWR based on the current high-rise residential building design. Reducing the window can reduce the direct sunlight penetrating the building, but reducing the window is nearly impossible. Just look at the high-rise buildings around, windows everywhere from top to bottom.

4.5.6 Natural ventilation

Natural ventilation is only significant for residential buildings or buildings that do not operate air conditioning systems 24-7. Most commercial high-rise buildings such as shopping malls and office buildings operate air-conditioning systems throughout the day.

4.5.7. Current situation of green building in Malaysia

The participants we met also shared some information regarding the current situation of green building in Malaysia.

From the participants, for all of the government's current projects, the buildings must at least obtain the lowest certification from any green building scheme used in Malaysia, which is a good start. From the architect we have interviewed, he commented that the concept of green building is still lacking in Malaysia. From his experience, the clients think that a green building is a building with green walls and roofs, but from his point of view, the green building is not only buildings that have plantations on its walls, concrete buildings can be green buildings too. He often needs to explain the concept of green buildings to his client and give advice on changes that can be made to make the building more ‘green’.

Table 5: Summary for Means and Ranking for all 3 Rounds

	Round 1		Round 2		Round 3	
Parameters	Mean	Rank	Mean	Rank	Mean	Rank
External wall(U-value)	4.6	4	4.4	5	4.8	5
Internal wall (U-value)	3.4	16	3.7	12	3.8	15
Floor (U-value)	3.3	18	3.3	17	3.8	15
Roof (U-value)	4.4	8	4.4	5	4.8	5
Glazing (U-value)	4.5	6	4.2	9	4.6	8
Glazing (SHGC)	4.8	1	4.6	3	4.9	2
wall insulation thickness	4	11	3.6	14	4.3	11
wall insulation material (R-value)	-	-	3.8	11	4.5	9
External shading	4.5	6	4.7	2	4.8	5
Landscape	-	-	4.1	10	4.3	11
Internal shading	3.5	15	3.4	15	4.0	13
Natural ventilation	4.6	4	4.6	3	4.9	2
Window to wall ratio (WWR)	4.3	9	4.4	5	4.9	2
Window to floor ratio (WFR)	3.6	14	3.3	17	3.6	17

Building aspect ratio	4.1	10	3.7	12	3.5	18
Building surface properties	4.7	3	4.3	8	4.5	9
Building Height	3.8	12	3.3	17	3.5	18
Building Orientation	4.8	1	4.8	1	5.0	1
Building structural core placement	3.4	16	3.3	17	3.4	20
Concrete grade	3.8	12	3.4	15	3.9	14

5. Conclusion

From the Delphi survey, the experts strongly agree that building orientation and glazing (SHGC) are very significant as they consistently ranked top 3 for all 3 rounds of the survey. All of the exterior building components that block direct sunlight from entering the building are ranked high from the survey. All of the parameters that influence the amount of direct sunlight entering the building such as WWR, building orientation, SHGC, are ranked high with the exception of WFR. The participants also expressed that the insulation material is more significant than insulation thickness in tropical countries.

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REFERENCES

[1] Y. Zhang, C.-Q. He, B.-J. Tang, and Y.-M. Wei, “China’s energy consumption in the building sector: A life cycle approach,” Energy Build., vol. 94, pp. 240–251, 2015, doi: 10.1016/j.enbuild.2015.03.011.

[2] UNEP, “Global Status Report for Buildings and Construction: Towards a Zero-emissions, Efficient and Resilient Buildings and Construction Sector,” 2021. [Online]. Available: https://www.unep.org/resources/report/2021-global-status-report-buildings-and-construction

[3] SuruhanjayaTenaga, “National Energy Balance 2019,” 2022. [Online]. Available: https://www.st.gov.my/en/web/download/listing/111

[4] N. Mohammed, K. A. Danapalasingam, and A. Majed, “Design, control and monitoring of an offline mobile battery energy storage system for a typical Malaysian household load using PLC,” Int. J. Power Electron. Drive Syst. (IJPEDS), vol. 9, no. 1, p. 180, 2018, doi: 10.11591/ijpeds.v9.i1.pp180-188.

[5] NAPIC, “Residential Property Stock Table Q2,” 2022.

[6] G. Rowe and G. Wright, “The Delphi technique as a forecasting tool: issues and analysis,” Int. J. Forecast., vol. 15, no. 4, pp. 353–375, 1999, doi: 10.1016/s0169-2070(99)00018-7.

[7] A. P. C. Chan, E. H. K. Yung, P. T. I. Lam, C. M. Tam, and S. O. Cheung, “Application of Delphi method in selection of procurement systems for construction projects,” Constr. Manage. Econ., vol. 19, no. 7, pp. 699–718, 2001, doi: 10.1080/01446190110066128.

[8] S. Keeney, H. McKenna, and F. Hasson, The Delphi technique in nursing and health research: Keeney/the Delphi technique in nursing and health research. Chichester, England: Wiley-Blackwell, 2011.

[9] Y. Ke, S. Wang, A. P. C. Chan, and E. Cheung, “Understanding the risks in China’s PPP projects: ranking of their probability and consequence,” Eng. Constr. Archit. Manage., vol. 18, no. 5, pp. 481–496, 2011, doi: 10.1108/09699981111165176.

[10] [10] C. K. H. Hon, A. P. C. Chan, and M. C. H. Yam, “Empirical study to investigate the difficulties of implementing safety practices in the repair and maintenance sector in Hong Kong,” J. Constr. Eng. Manag., vol. 138, no. 7, pp. 877–884, 2012, doi: 10.1061/(asce)co.1943-7862.0000497.

[11] Z. Chen and M. Pak, “A Delphi analysis on green performance evaluation indices for ports in China,” Marit. Policy Manage., vol. 44, no. 5, pp. 537–550, 2017, doi: 10.1080/03088839.2017.1327726.

[12] C.-W. Chen, J.-H. Wang, J. C. Wang, and Z.-H. Shen, “Developing indicators for sustainable campuses in Taiwan using fuzzy Delphi method and analytic hierarchy process,” J. Clean. Prod., vol. 193, pp. 661–671, 2018, doi: 10.1016/j.jclepro.2018.05.082.

[13] R. Grover, S. Emmitt, and A. Copping, “Trends in sustainable architectural design in the United Kingdom: A Delphi study,” Sustain. Dev., vol. 28, no. 4, pp. 880–896, 2020, doi: 10.1002/sd.2043.

[14] T. O. Olawumi and D. W. M. Chan, “Identifying and prioritizing the benefits of integrating BIM and sustainability practices in construction projects: A Delphi survey of international experts,” Sustain. Cities Soc., vol. 40, pp. 16–27, 2018, doi: 10.1016/j.scs.2018.03.033.

[15] [15] A. Habibi, A. Sarafrazi, and S. Izadyar, Delphi Technique Theoretical Framework in Qualitative Research The International Jo. 2014.

[16] E. E. Ameyaw, Y. Hu, M. Shan, A. P. C. Chan, and Y. Le, “Application of Delphi method in Construction Engineering and Management research: A quantitative perspective,” J. Civ. Eng. Manag., vol. 22, no. 8, pp. 991–1000, 2016, doi: 10.3846/13923730.2014.945953.

[17] C. Ibrahim, C. K. I. Belayutham, S. Mohammad, and M. Z. Ismail, “Development of a conceptual designer’s knowledge, skills, and experience index for prevention through design practice in construction,” Journal of Construction En, 2022.

[18] A. A. Karakhan, J. Gambatese, and D. R. Simmons, “Development of assessment tool for workforce sustainability,” J. Constr. Eng. Manag., vol. 146, no. 4, p. 04020017, 2020, doi: 10.1061/(asce)co.1943-7862.0001794.

[19] B. H. W. Guo et al., “A regulatory perspective on safety in design practices in New Zealand,” Saf. Sci., vol. 141, no. 105352, p. 105352, 2021, doi: 10.1016/j.ssci.2021.105352.
[20] M. R. Hallowell and J. A. Gambatese, “Qualitative research: Application of the Delphi method to CEM research,” J. Constr. Eng. Manag., vol. 136, no. 1, pp. 99–107, 2010, doi: 10.1061/(asce)co.1943-7862.0000137.
[21] R. C. Schmidt, “Managing Delphi surveys using nonparametric statistical techniques,” Decis. Sci., vol. 28, no. 3, pp. 763–774, 1997, doi: 10.1111/j.1540-5915.1997.tb01330.x.
[22] N. Al-Tamimi and A. Qahtan, “Influence of glazing types on the indoor thermal performance of tropical high-rise residential buildings,” Key Engineering Materials, pp. 23–37, 2016.
[23] S. Tong, J. Wen, N. H. Wong, and E. Tan, “Impact of façade design on indoor air temperatures and cooling loads in residential buildings in the tropical climate,” Energy Build., vol. 243, no. 110972, p. 110972, 2021, doi: 10.1016/j.enbuild.2021.110972.
[24] A. Misni, “The effect of building construction and human factors in cooling energy use,” Procedia Soc. Behav. Sci., vol. 202, pp. 373–381, 2015, doi: 10.1016/j.sbspro.2015.08.241.
[25] A. Ganguly, D. Chowdhury, and S. Neogi, “Performance of building roofs on energy efficiency – A review,” Energy Procedia, vol. 90, pp. 200–208, 2016, doi: 10.1016/j.egypro.2016.11.186.
[26] L. Bellamy, “Towards the development of new energy performance indicators for the external walls of residential buildings,” Energy Build., vol. 68, pp. 696–702, 2014, doi: 10.1016/j.enbuild.2013.08.057.
[27] M. E. Kohansal, H. R. Akaf, J. Gholami, and S. Moshari, “Investigating the simultaneous effects of building orientation and thermal insulation on heating and cooling loads in different climate zones,” Arch. Eng. Des. Manag., vol. 18, no. 4, pp. 410–433, 2022, doi: 10.1080/17452007.2021.1901220.
[28] A. Pradip and L. Thananchai, “CFD analysis on thermal comfort and energy consumption effected by partitions in air-conditioned building,” Energy Procedia, vol. 79, pp. 183–188, 2015, doi: 10.1016/j.egypro.2015.11.459.
[29] H. Amai and A. Novoselac, “Experimental study on air change effectiveness in mixing ventilation,” Build. Environ., vol. 109, pp. 101–111, 2016, doi: 10.1016/j.buildenv.2016.09.015.
[30] A. Kirimtat, B. K. Koyunbaba, I. Chatzikonstantinou, and S. Sariyildiz, “Review of simulation modeling for shading devices in buildings,” Renew. Sustain. Energy Rev., vol. 53, pp. 23–49, 2016, doi: 10.1016/j.rser.2015.08.020.
[31] A. K. K. Lau, E. Salleh, C. H. Lim, and M. Y. Sulaiman, “Potential of shading devices and glazing configurations on cooling energy savings for high-rise office buildings in hot-humid climates: The case of Malaysia,” Int. J. Sustain. Built Environ., vol. 5, no. 2, pp. 387–399, 2016, doi: 10.1016/j.ijsbe.2016.04.004.
[32] S. Mirrahimi, M. F. Mohamed, L. C. Haw, N. L. N. Ibrahim, W. F. M. Yusoff, and A. Aflaki, “The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot–humid climate,” Renew. Sustain. Energy Rev., vol. 53, pp. 1508–1519, 2016, doi: 10.1016/j.rser.2015.09.055.
[33] H. Radhi, E. Assem, and S. Sharples, “On the colours and properties of building surface materials to mitigate urban heat islands in highly productive solar regions,” Build. Environ., vol. 72, pp. 162–172, 2014, doi: 10.1016/j.buildenv.2013.11.005.
[34] S. Tong, N. H. Wong, E. Tan, and S. K. Jusuf, “Experimental study on the impact of facade design on indoor thermal environment in tropical residential buildings,” Build. Environ., vol. 166, no. 106418, p. 106418, 2019, doi: 10.1016/j.buildenv.2019.106418.
[35] Al-Tamimi, “Evaluation on Cooling Energy Load with varied Envelope Design for High-Rise Residential Buildings in Malaysia,” in Proceedings of the Tenth International Conference Enhanced Building Operations, 2010.
[36] T. Ferdous and M. Gorgolewski, “Determining the effect of building geometry on energy use patterns of office buildings in Toronto,” J. Green Build., vol. 9, no. 2, pp. 124–144, 2014, doi: 10.3992/1943-4618-9.2.124.
[37] E. Resch, R. A. Bohne, T. Kvamsdal, and J. Lohne, “Impact of urban density and building height on energy use in cities,” Energy Procedia, vol. 96, pp. 800–814, 2016, doi: 10.1016/j.egypro.2016.09.142.
[38] M. L. Ghassan, L. H. Sari, and A. Munir, “An evaluation of the tropical architectural concept on the building design for achieving thermal comfort (Case study: engineering faculty of Syiah Kuala university),” IOP Conf. Ser. Mater. Sci. Eng., vol. 1087, no. 1, p. 012013, 2021, doi: 10.1088/1757-899x/1087/1/012013.
[39] A. Dutta, A. Samanta, and S. Neogi, “Influence of orientation and the impact of external window shading on building thermal performance in tropical climate,” Energy Build., vol. 139, pp. 680–689, 2017, doi: 10.1016/j.enbuild.2017.01.018.
[40] P. Nejat, F. Jomehzadeh, M. Z. B. Abd. Majid, M. B. Mohd Yusof, and I. Zeynali, “Windcatcher as sustainable passive cooling solution for natural ventilation in hot humid climate of Malaysia,” IOP Conf. Ser. Mater. Sci. Eng., vol. 620, no. 1, p. 012087, 2019, doi: 10.1088/1757-899x/620/1/012087.
[41] M. Krem, S. T. Hoque, S. R. Arwade, and S. F. Breña, “Structural configuration and building energy performance,” J. Archit. Eng., vol. 19, no. 1, pp. 29–40, 2013, doi: 10.1061/(asce)ae.1943-5568.0000103.
[42] M. Haase and A. Amato, “An investigation of the potential for natural ventilation and building orientation to achieve thermal comfort in warm and humid climates,” Sol. Energy, vol. 83, no. 3, pp. 389–399, 2009, doi: 10.1016/j.solener.2008.08.015.
[43] A. Woodcock and A. Custovic, “ABC of allergies. Avoiding exposure to indoor allergens,” BMJ, vol. 316, no. 7137, pp. 1075–1078, 1998, doi: 10.1136/bmj.316.7137.1075.
[44] M. Bojic, F. Yik, K. Wan, and J. Burnett, “Influence of envelope and partition characteristics on the space cooling of high-rise residential buildings in Hong Kong,” Build. Environ., vol. 37, no. 4, pp. 347–355, 2002, doi: 10.1016/s0360-1323(01)00045-2