International Journal of Innovation, Creativity and Change. www.ijicc.net
Volume 13, Issue 12, 2020

Development of a Construction Instrument of Post Occupancy Evaluation for High–Rise Residential by Using Industrialised Building System

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Post Occupancy Evaluation (POE) is an activity of the building evaluation process with a focus on quality, operational performance and satisfaction of the occupants. The POE is essential to evaluate completed and occupied buildings to identify weaknesses and potential for future improvement. To date, there have been various variations of POE instruments and tools for assessing occupied buildings, particularly POE for residential buildings such as POE for public housing, POE for low-cost housing and POE for student residential colleges. However, the POE instrument for assessing high-rise housing constructed using the industrialised building system (IBS) method has not explicitly developed. In this regard, this study aims to discuss the construction of an effective POE instrument to measure the quality and performance of high-rise housing built using the IBS method. For this purpose, the three-round of Delphi method adapted by involving 15 experts selected based on their background and experience related to IBS. The results of the third round of Delphi found that 33 out of all sub-constructs are dropped because of low mean scores (<4.2 in two rounds) while 75 sub-constructs identified as final items. The results of the Delphi study also found that all ten constructs are 1) Spatial; 2) Design and aesthetics; 3) Physical; 4) Building materials; 5) Quality of work; 6) Comfort and well-being; 7) Environment and health; 8) Maintenance; 9) Value and 10) Cost are the most significant construct for developing POE instruments. Therefore, an effective Post-Occupancy Evaluation instrument for measuring the quality, performance and value of a home built using the IBS method should include all of these ten component constructs.

Key words: *Delphi technique, High-rise Residential, Industrialised Building System (IBS), Instrument, Post Occupancy Evaluation (POE.*

Introduction

The Industrial Revolution 4.0 (IR 4.0) has significantly affected the landscape of the construction industry. The average construction industry in the world as well as in Malaysia has applied automation, digitisation and simulation on a larger scale than before, accommodate with more space and opportunities spent on to upgrade the equipment and facilities that are more economical in cost, time and qualities. One of the fastest-growing technologies in the IR 4.0 era is the Industrialised Building Systems (IBS) technology that includes ready-made components and modular.

According to the Construction Industry Development Board (CIDB), IBS referred to a construction method whereby its components are either pre-fabricated at the factory and subsequently installed on the structure with minimal additional work (Fateh et al., 2020). Nawi et al. (2014) stated that IBS provides a technology incentive development method whereby every component produced in a controlled environment is integrated directly into the construction work (Mangalagowri, 2018).

IBS has provided with many advantages and benefits directly compared to the conventional methods, particularly in optimising the work processes and minimise labour costs (Hung et al., 2015). Besides, Rahim & Qureishi (2018) suggested that through the IBS method, the construction period is also shorter and can reduce the construction material on-site as well as able to control the waste of construction materials. According to Jabar and Ismail, 2015), the application of the IBS method in the construction can also make the construction site more organised and clean and indirectly guarantee the security on-site (Elliot, 2017; Mydin et al., 2014).

In general, IBS is not a brand new concept in the country's construction industry. However, since the introduction of the Ministry of Housing and Local Government (KPKT) in 1964, IBS has undergone an advance industrial revolution (Majid et al., 2011). According to Mydin et al. (2014), the progress of technology has significantly developed the IBS method to be more productive and systematic as well as improving the quality of the IBS components produced. Until now, after four decades, the IBS method has extensively used over the country, including the infrastructure and building construction. The continuous incentives and initiatives from the government also contributed to the application of the IBS method to the construction industry players.

According to Yunus et al. (2016), through the IBS method, the construction industry is targeted to produce and deliver more quality and valuable products to the consumers (Musa et al., 2014). However, there are still issues of quality and value to consumers that require comprehensive solutions. It includes issues regarding occupancy acceptance due to the poor quality of completion. Rahman et al. (2014), Haron et al., (2009), Nawi et al. (2012), and Noraini (2014) stated that the quality of IBS must not only control during site manufacture and delivery. Still, they must also include the quality of construction and performance of the building after it is ready to be occupied.

Various methods have used to control the quality and ensure excellent building performance regardless of domestic or overseas such as Quality Assessment System In Construction (QLASSIC), Construction Quality Assessment System (CONQUAS), GreenRE, Total Building Performance (TBP), Building Research Establishment's Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED). However, according to Khalil et al. (2016), the best methods for assessing the quality and performance of completed buildings after occupied are Building Performance Evaluation (BPE) and Post Occupancy Assessment (POE). In this research, the POE method chosen it is more concerned on the quality, performance and value to consumers because POE has a very significant relationship with the occupants' population compared to BPE (Li et al., 2018).

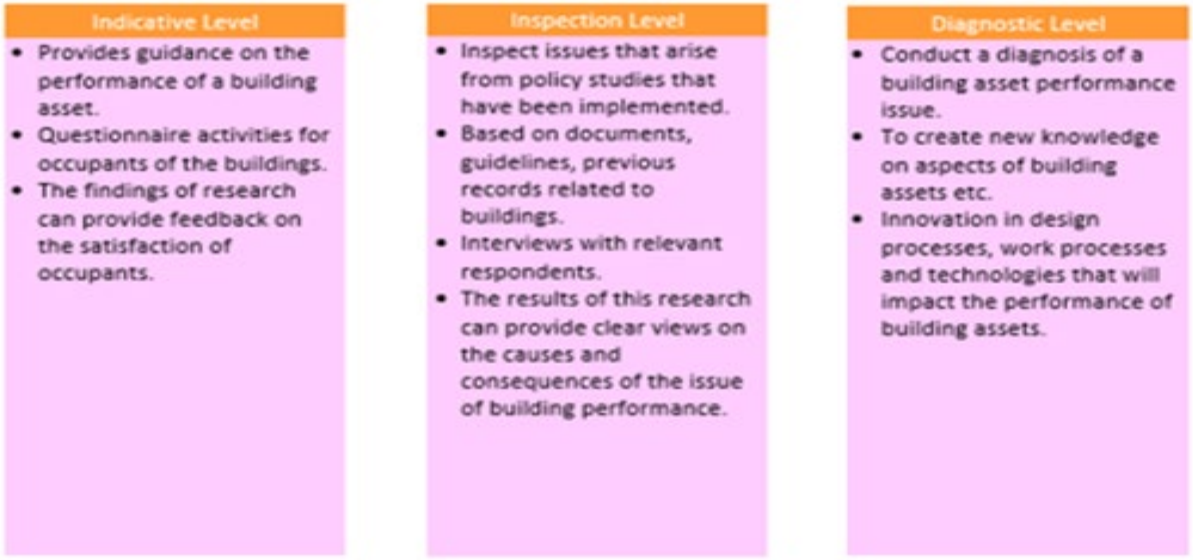
According to Baird (2001), POE is a generic term for a variety of general programs, procedures, or specific techniques to evaluate the existing buildings and facilities. Hay et al. (2018) stated that POE involves a systematic assessment of building-related opinions from the perspective of occupants who used it. It assesses to the extent which building meets the needs of its residents and identifies the ways to improve it from various aspects, especially the design, performance and quality of the building (Sanni-Anibire et al., 2016; Boarin et al., 2018).

Turpin-Brooks and Viccars (2006) stated that there are three levels in the POE process. The levels are implemented based on the time, labour, financial availability and results needed. The general approach to each level will involve planning process, research process and discovery process (Agyekum et al., 2016). The three levels are indicative level, inspection level and diagnostic level. Figure 1 shows the detail of differences between the three levels in the POE process.

POE is an essential instrument for assessing the level of comfort and satisfaction of residents as it reflects the productivity, health and well-being of the occupants (Akashah et al., 2015). Therefore, every resident must participate in POE regardless of their background. However, some residents claim that they do not enjoy the benefits of POE. This issue is due to differences in the aspects of consumer groups, socio-culture, and multiple knowledge in the

architectural discipline. In this regard, Akman (2002), proposes that POE instruments designed or developed specifically and detailed studies need to carried out for specific buildings.

Figure 1. The levels of Post Occupancy Evaluation (Turpin-Brooks & Viccars, 2006).



Currently, there have been numerous studies on related POE development as an instrument of measurement and seen as the most relevant instrument in obtaining direct feedback from residents (Noraini, 2014; Khalil et al., 2016). Current studies show that POE instruments can be more comprehensive by integrating new parameters or constructs to the measurements without changing their goals. It is because the construction industry is undergoing rapid development with the involvement of new technologies such as IBS, green buildings and smart buildings, and there will always be new measurement constructs to consider. Hassin and Azlani (2018) stated that right POE instruments should take into account valid measurement constructs, which can construct the components of what should be measured while adhering to psychometric properties (Boone, 2016). In the analysis of documents conducted from then previous studies, three constructs which are commonly associated with POE for housing, which are a quality construct, performance construct, and economic construct.

Quality Construct is an assessment of the quality of design against architecture, spatial and science building. Besides, the quality construct also takes into account the extent to which the building constructed that involved the quality of the structure, fabric, finish and fittings, engineering systems and integration of all of them. There are five dimensions underlying quality construction which include spatial analysis (SA), design and aesthetics (DE), physical (PS), building materials (BM) and construction work quality (WK).

Performance Construct is an assessment of the building's performance in terms of its ability to create a peaceful, comfortable and harmonious effect in the interior and space environment of the building. The performance construct also explains how the performance of the building can meet the needs and requests of occupants in it as well as take into account the operational and maintenance aspects. Three dimensions are underpinning these comfortable performance construct and well-being (CW), environment and health (EH) and sustainability (ST).

Economic Construct is an assessment of the building's economy in particular to the building's life cycle budget as well as the cost of renovation and adaptation costs (AC) in improving the quality and performance of buildings. In addition, economic constructs also take into account the value (VL) of the budget, whether the costs incurred provide a good return or otherwise, the overall economy of the building.

In short, Table 1 shows the highlight of previous studies on POE instruments and constructs used in measuring building quality and performance after occupation based on the analysis of the documents.

Table 1: Previous research related to POE

Construct	Sub-construct	Researcher
SA	The whole of dimensions of space, space proportions, space for occupancy, layout and use of space, size of living room, size of the master bedroom, size of bedroom 1, size of bed 2, size of kitchen space, size of living/dining area, the height of floor-ceiling, exterior perimeter, interior, utility, and service spaces	(Noraini, 2014; Khalil et al., 2016; Hay et al., 2018; Haron et al., 2015; Abdullah et al., 2010; Mustafa & Maznah, 2012; Candido et al., 2016; Preiser et al., 2015; Choi et al., 2012; Sanni-Anibire & Hassanain, 2016; Khair et al., 2015).
DE	Building facade, according to the original design, number of bedrooms, number of bathrooms/toilets, family zone interactions, personal zone interactions, horizontal circulation, vertical circulation, building orientation, micro-climate positioning, building shape, design flexibility 1, design flexibility 2.	(Noraini, 2014; Khalil et al., 2016; Hay et al., 2018; Haron et al., 2015; Abdullah & Egbu, 2010; Khamidun & Abdul Rahman, 2017; Riley et al., 2010; Li et al., 2018; Brioso et al., 2018; Orihuela & Orihuela, 2014; Jiboye, 2012).
PS	Structural strength, structural stability, fire protection, weather protection (occupants), weather protection (buildings), earthquake protection, safety protection, flood protection, damage protection	Noraini, 2014; Khalil et al., 2016; Hay et al., 2018; Haron et al., 2015; Abdullah & Egbu, 2010; Mustafa & Maznah, 2012; Ilesanmi, 2010; Cleveland & Fisher, 2014; Woo, 2017).

BM	Material for frames, wall material, window materials, door materials, wall finishes, floor finishes, ceiling finishes, toilet facilities, bathroom/sanitation facilities, water supply facilities, sewage and wastewater facilities, electrical facilities, utilities/fittings, service channels and corridors.	Haron et al., 2015; Abdullah & Egbu 2010; Mustafa & Maznah, 2012; Scott-Webber et al., 2013; Hashim et al., 2012; Lawrence & Keime, 2016; Thaddi & Admane, 2015).
WK	Meet the specifications/standards, defect (inactivity), defect (crack), defect (leakage), installation quality, fast damaged/repeated damage, harmless, emergency.	Haron et al., 2015; Abdullah & Egbu, 2010; Mustafa & Maznah, 2012; Aliyu et al., 2016; Shannon & Sinnott, 2015; Husin et al., 2015).
CW	Meet the needs of the residents, Meet the living and social life, Free and independent, Improve the quality of life, Safe and peaceful, Positive impact, Functional level, Organised and easy to operate, Advanced technology applications, Technology change, Green technology and sustainability	Khalil et al., 2016; Haron et al., 2015; Hassanain et al., 2016; Rahman et al., 2014; Husin et al., 2018; Wheeler & Malekzadeh, 2015; Bae et al., 2017).
EH	Artificial ventilation, Overall ventilation, Indoor living room, Bedroom indoor air, Indoor living room, Kitchen indoor air, Overall indoor air, Natural lighting, Artificial lighting, Glare, Overall lighting, Town noise, Noise from next door, Noise/Outward disturbance, Noise/Disturbance, overall, Inner odour, Inner odour, Overall odour, Solid waste disposal	(Noraini, 2014; Khalil et al., 2016; Hay et al., 2018; Haron et al., 2015; Abdullah & Egbu, 2010; Mustafa & Maznah, 2012; Bae et al., 2017; Rahman et al., 2019; Sari et al., 2018; Awang et al., Mustafa et al., 2019).
ST	Building/component life expectancy, Building/component damage, Available spare parts, Affordable spare parts, Easy to maintain, External expertise, Accessibility maintenance.	Khalil et al., 2016; Pereira et al., 2016; Akasah et al., 2011; Tookaloo & Smith, 2015; Alborz & Berardi, 2015).
AC	Value for money, Investment value, Evaluation and assessment.	Göçer et al., 2018; Ibem et al., 2015; Romero, 2015).
VL	Startup costs, Adjustment costs, Repair/maintenance costs.	Orihuela & Orihuela, 2014; Brioso et al., 2018; Roberts et al., 2019; Hassanain & Iftikhar, 2015).

Although POE instruments and measurement instruments established to evaluate the quality and performance of various buildings, however, until this day, there is no existence of POE instruments to measure the quality and performance of IBS. Therefore, this research aims to

build an effective Post Occupancy Evaluation instrument useful in the quality and performance of houses built using constructed industrial systems recommended by experts.

Metodhology

This research used a qualitative approach by adapting Delphi technique in structured interview protocols conducted with experts to identify the constructs that are the most important in the construction of Post Occupational Assessment Instruments (POE). The structured interview protocols are an essential process in determining final items of construction. At the same time, Delphi's techniques adapted to provide insights into critical data that involved the perception and expectation of panellists related to development that is important in line with the Linear Numerical Scale (Table 2) and used in developing POE instruments with the panel approval.

Table 2: Linear Numerical Scale

Linear Numerical Scale	Level of importance
1 < Mean < 1.8	Very not importance
1.8 < Mean < 2.6	Not importance
2.6 < Mean < 3.4	Moderate
3.4 < Mean < 4.2	Importance
Mean > 4.2	Very Importance

The Delphi technique in this research consists of three rounds of structured interviews with 15 panellists who have experienced and expert practitioners in the field of IBS and held positions at the management level for at least ten years in the construction industry. Table 3 below shows the background of the subject in the interview.

Table 3: List of research experts for interview protocols

No	Position	Category	Experience
1	Chief Asst. Director	Technical Dept	13 years
2	Director of Engineering Dept	Technical Dept	18 years
3	Director of Engineering Dept	Technical Dept	21 years
4	Operation Manager	IBS Manufacturer	12 years
5	Project Manager	Developer	16 years
6	Project Manager	Developer	14 years
7	Project Manager	Developer	14 years
8	General Manager	Contractor	16 years
9	General Manager	Contractor	10 years
10	Chairman	Research Inst	12 years
11	Professor VK7	Academic	22 years
12	Assoc. Professor DS54	Academic	14 years
13	Assoc. Professor DS54	Academic	14 years
14	Assoc. Professor DS54	Academic	12 years
15	Senior Lecturer	Academic	11 years

The structured interview instruments include the identified constructs and sub-constructs through document analysis in the literature review. There are ten constructs and 108 sub-constructs in total. The Cohen Kappa Index is used to analyse the validity and reliability of the interview instrument. The results of the analysis (Table 4) found that all constructs exceeded the specified value of K_f = > 0.61 (Good).

Table 4: The results of the analysis

Construct	ID Item	K_f	Level of Agreement
SA	SA1 – SA14	0.667	Good
DE	DE1 – DE13	0.744	Good
PS	PS1 – PS9	0.852	Very Good
BM	BM1 – BM14	0.857	Very Good
WK	WK1 – WK8	0.833	Very Good
CW	CW1 –CW26	0.758	Good
EH	EH1 – EH11	0.846	Very Good
ST	ST1 – ST7	0.810	Very Good
AC	AC1 – AC3	0.778	Good
VL	VL1 – VL3	1.000	Very Good
Average **K_f**		0.807	Very Good

Data analysis performed at every interview round. The mean score used to identify constructs because the mean is easy to use to present information about the expert panel's collective judgment. The constructs evaluated is fundamental (Mean> 4.2) in any of two interview rounds will be selected as final items for the construction of the POE instrument.

Findings and Discussions

A total of three rounds of structured interviews are conducted by applying the Delphi technique to 15 expert panels as research respondents. In the first round, all the constructs and sub-constructs presented to respondents to give a rating based on the level of importance, which are 1= Very not importance; 2= Not importance; 3=Moderate; 4=Importance; and 5=Very importance. The results of the first round of Delphi presented, as shown in Table 5.

Table 5: First round result of Delphi

Construct	Sub-construct	Mean <4.2	Mean > 4.2
SA	14 item	3	11
DE	13 item	6	7
PS	9 item	3	6
BM	14 item	1	13
WK	8 item	1	7
CW	11 item	4	7
EH	26 item	1	25
ST	7 item	4	3
AC	3 item	0	3
VL	3 item	0	3

The first round of Delphi shows that 85 sub-constructs had a mean score of 4.2, and 23 sub-constructs had a mean score of less than 4.2. As the mean score for every sub-construct is 4.2 and above in any two rounds, then the overall sub-constructs of the first round remain the same for the second round of Delphi.

In the second round of Delphi, 22 sub-constructs dropped out due to a mean score of less than 4.2 for the second time, while 74 sub-constructs selected as the final item after having a mean score of more than 4.2 twice in two rounds. Twelve sub-constructs are retained for the next round because they have a mean score value of less than 4.2 and a mean score greater than 4.2. Table 6 shows the results of the second round of Delphi.

Table 6: Second round result of Delphi

Construct	Sub-construct	Mean <4.2	Mean > 4.2
SA	14 item	3	11
DE	13 item	6	7
PS	9 item	2	7
BM	14 item	1	13
WK	8 item	1	7
CW	11 item	4	7
EH	26 item	12	14
ST	7 item	4	3
AC	3 item	0	3
VL	3 item	0	3

From 12 sub-constructs taken to round three of Delphi, 11 were dropped out for a mean score of less than 4.2 while only one sub-construct was approved as the final item making the number of sub-constructs finalised items of POE instruments is 75. Table 7 below shows the results of the third round of Delphi, and Table 8 shows the number of sub-constructs that remained as the final item.

Table 7: Third-round result of Delphi

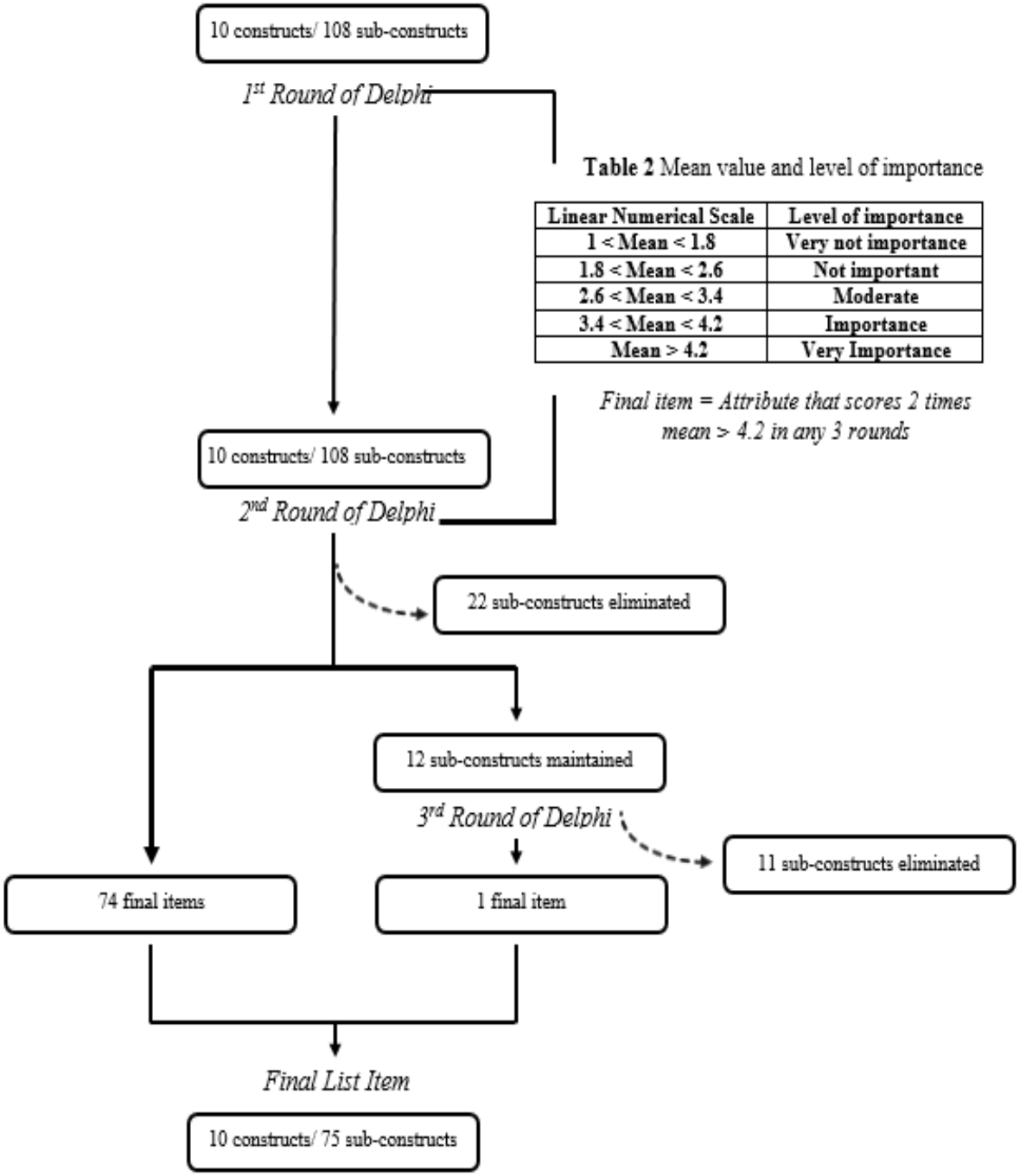
Construct	Sub-construct	Mean <4.2	Mean > 4.2
PS	1 item	0	1
CW	11 item	11	0

Table 8: The number of final items per construct

Construct	Sub-construct	Dropped out	Last Item
SA	14 item	3	11
DE	13 item	6	7
PS	9 item	2	7
BM	14 item	1	13
WK	8 item	1	7
CW	11 item	4	7
EH	26 item	12	14
ST	7 item	4	3
AC	3 item	0	3
VL	3 item	0	3

Figure 2 shows a summary of the Delphi process results for all rounds conducted along with final item resolutions agreed by the panel of experts (see Table 8).

Figure 2. Summary of the Delphi process and final item selection



All respondents agreed to use a total of 10 construct items and 75 sub-construct items as POE instruments for high-rise residential use using the IBS method.

Table 8: Final items agreed by expert panels

Construct		Sub-construct
Quality	**SA**	Overall dimensions of space, proportions of space, layout and use of space, size of living room, size of the master bedroom, size of bedroom 1, size of bed 2, size of kitchen space, size of living/dining area, floor-to-ceiling height, space utilities and services
	DE	Refer to the original design, the number of bedrooms, number of bathrooms/toilets, building orientation, building shape, the flexibility of design 1, and flexibility of design 2.
	PS	Structural durability, structural stability, weather protection (occupants), weather protection (buildings), damage protection, safety protection, and fire protection
	BM	Material for frames, wall material, window materials, door materials, wall finishes, floor finishes, ceiling finishes, toilet facilities, bathroom/sanitation facilities, water supply facilities, sewage and wastewater facilities, electrical facilities, and utilities/pairing.
	WK	Meet the specifications /standards, defect (inactivity), defect (fracture), defect (leak), installation quality, harmless, emergency.
Performance	**CW**	Meet the needs of the people, meet the living and social life, improve the quality of life, safe and peaceful, working at acceptable levels, advanced technology applications, green technology, and sustainability.
	EH	Overall thermal comfort, temperature, natural air conditioning, indoor living room, indoor bedroom, indoor kitchen, indoor kitchen, overall indoor air, natural lighting, glare, town noise, noise from the side, noise/disturbance, the smell inside is out.
	ST	Replacement parts are easy to find, affordable, and easy to maintain
Economy	**AC**	Value for money, investment value, evaluation and assessment.
	VL	Startup costs, adjustment costs, repair/maintenance costs

Conclusion

In conclusion, this research concluded that the view of occupants satisfaction of their home is essential and influenced by quality, performance, and value. Therefore, it is necessary to evaluate the occupants' level of satisfaction based on Post-Occupancy Evaluation (POE). Practical evaluation requires instruments that able to measure what should be measured and

fulfil the psychometric criteria. Thus, the POE instrument for assessing the level of satisfaction of occupants in high-rise residential by using the IBS method manages to be developed. Based on the document analysis, a total of 10 constructs and 108 sub-constructs identified. All of these constructs and sub-constructs underwent a structured expert interview to determine which items were most significant (mean> 4.2) finalised as final items in the POE instrument. Three structured interviews carried by adopting the Delphi method to gain consensus among the experts. The third round of interview found that the final items consisted of 10 constructs and 75 sub-constructs. It concluded that all constructs and sub-constructs that have identified and agreed by experts for Post-Occupancy Evaluation (POE) instruments in high-rise residential use by using the industrialised building system (IBS) method.

Acknowledgements

The researchers would like to express grateful appreciation to the University of Tun Hussein Onn Malaysia (UTHM) for funding this research under the Tier 1 grant (H252). Researchers also would like to thank all the research partners from UTHM, Sultan Idris University of Education (UPSI), and Nottingham Trent University, who contributed valuable their knowledge and expertise in assisting this research.

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