Critical Factors that Influence Lean Premise Design Implementation: A Case of Hong Kong High-rise Buildings

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Abstract

When a building design fails to meet the end-user's needs after construction, it is considered faulty. Faulty designs often lead to renovation, demolition, and material waste. This study aims to identify critical factors that influence the implementation of the Lean Premise Design (LPD) scheme in high-rise residential (HRR) buildings to facilitate sustainability practices, ensure energy conservation, promote innovative green technologies and water efficiency, and reduce abortive works in Hong Kong's HRR buildings. A comprehensive literature review of concepts similar to LPD scheme and sustainability practices in designing and developing high-rise buildings was undertaken. In addition, interviews were conducted to validate factors influencing LPD adoption. The study focused on sustainable building design relating to users' behaviour patterns and expectations, social needs, green maintenance technologies, and government initiatives. According to the mean score ranking, 20 factors are critical to adopting LPD schemes, accounting for 47.6% of all identified factors. Government-sponsored LPD education, explicit LPD objectives in design, and construction waste reduction are among the key *drivers* of LPD. Nonetheless, developers' emphasis on return on investment, varied buyer expectations, and diverse end-user requirements stand as the most significant *barriers* to LPD. The Mann-Whitney U test also revealed that expert groups disagree on some factors. The study's findings are consistent with recent research on the critical success factors of identified sustainability concepts in the construction industry.

Keywords: End-users; High-rise; Hong Kong; Lean Premise Design; Sustainability.

1. Introduction

The construction industry is the world's second most significant emitter of greenhouse gases (Li et al., 2017). Traditionally, activities embedded in building construction are not environmentally friendly (Lu & Tam, 2013). Hong Kong is a resource-scarce city and imports most construction materials from China and other countries (Hossain et al., 2021). Also, environmental effects from construction waste have become a significant concern (Zhang et al., 2012), with existing landfill capacity predicted to be exhausted soon (Yu et al., 2021). Hong Kong's extensive construction and demolition (C&D) waste generation makes waste disposal a significant social and environmental challenge (Yu et al., 2013).

According to recent policy addresses, the Hong Kong Special Administrative Region (HKSAR) government is determined to accelerate Hong Kong's transformation into a low-carbon city, with a target of reducing carbon intensity by 2030. This study explores the potential of introducing Lean Premise Design (LPD) scheme to reduce abortive work and C&D waste in residential buildings. LPD means only basic furnishing will be provided in new residential buildings, such as water and gas supply, waste discharge, sanitary fittings, and windows. Internal finishing built-in fixtures like kitchen and bathroom cabinets, cooking ovens, and air-conditioners will not be installed (Lam et al., 2023).

2. Literature review

2.1 Sustainability in Hong Kong: An Overview

Construction activities have resulted in large-scale consumption of materials and resources, leading to environmental pollution (Ding, 2008). Population and economic growth in cities have led to global urbanization and a continuous rise in population density in urban areas (Al-Kodmany, 2011). The HKSAR government is also determined to apply commercially available green building technologies in public projects in the immediate future. Thus, there is a need to implement sustainable practices during building design stage to incorporate the needs and perceptions of the potential end-users.

2.2 Knowledge and practice gaps, challenges, and value of LPD Implementation: Hong Kong context

Adverse environmental effects of construction waste caused by the development of Hong Kong's spectacular built environment are now a serious concern (Lu, 2019), in contrast to the past, when C&D waste management was not given as much attention. The construction industry is Hong Kong's major solid waste generator (Wong & Yip, 2004). Despite challenges, the Hong Kong government has established construction waste management (CWM) regulations, codes, and programs in recent decades (Hao et al., 2011; Lu & Tam, 2013). There are several construction waste management practices in

Hong Kong (Bao et al., 2020; Chan & Aghimien, 2022; Hossain et al., 2017); nonetheless, further study on lean designing out waste is required (Lam et al., 2022).

Reducing, reusing, recycling, rethinking, refusing, and repairing are circular economy C&D waste management strategies (Bi et al., 2022). LPD strategies similarly focus on waste reduction, resource management and enhanced communication. LPD bridges the communication gap between end users and stakeholders in high-rise building (HRB) development. Thus, applying for LPD offers opportunities to minimize C&D waste.

2.3 Scope and justification for this study

Several studies in recent literature have investigated issues regarding sustainability applications in buildings – such as Dwaikat and Ali's (2018) study on the economic benefits of green buildings. Other studies have developed sustainability assessment systems for new and existing buildings (Mahmoud et al., 2019). However, little research has been conducted to address environmental issues caused by abortive work, mismatches between building design and end-user requirements, and overprovision of unnecessary fixtures and components in Hong Kong's buildings. This paper discusses factors influencing LPD adoption in developing sustainable buildings.

3. Research methodology

The study adopted a mixed-methods approach combining content analysis of literature review and existing reports (Zhang et al., 2012), experts' interviews (Bao et al., 2020) and questionnaire survey. Mixed-methods research enhances data validity, reliability, and causal inferences by allowing for data convergence or divergence in hypothesis testing (Abowitz & Toole, 2010). Readers are referred to Zou et al. (2014) regarding the mixed-methods process used in this study. Figure 1 illustrates the research strategy. Relevant findings from the desktop literature review and interviews were consolidated through a questionnaire survey to assess how stakeholders in Hong Kong's built environment perceive the LPD scheme's ability to enhance regional sustainable development.

3.1 Data collection

3.1.1 Experts' Interview

Thirteen experts were interviewed. The identified factors from the literature, expert interviews, and authors' observations aided in forming the factors of the variables. Tables 1 and 2 list the variables used.

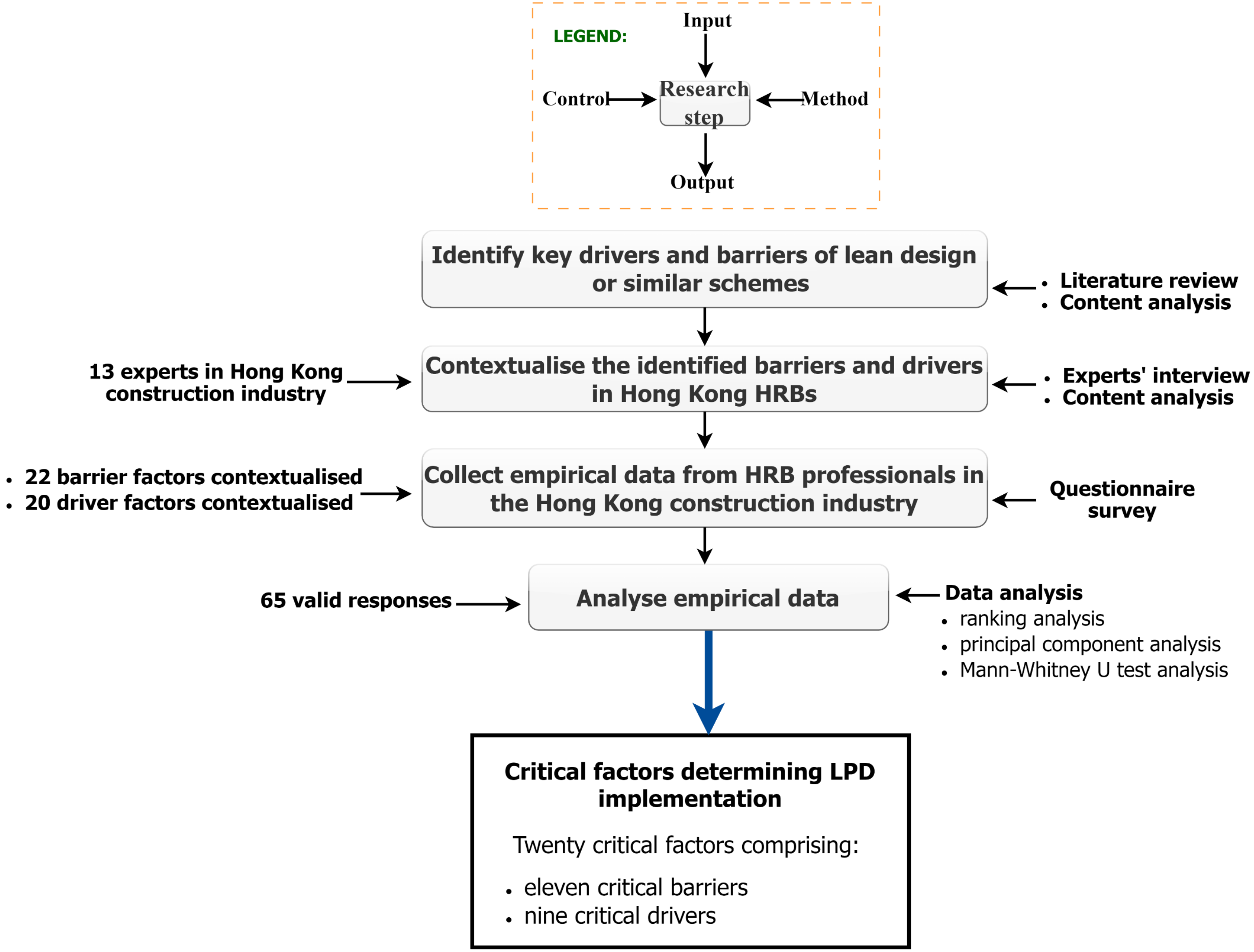

Figure 1: Overall research strategy

Table 1: **LPD drivers' factors**

Code	Driver factors	Reference
d01	Building professional training: Training for building professionals (e.g., engineers, architects)	3
d02	Stakeholder communication platform: Building a communication platform for all stakeholders	8
d03	Government bonus and credits: Government provides bonuses and credits to developers who adopt LPD design, such as extra GFA and achievement awards.	Study
d04	Government facilitates buyer acceptance: Government facilitates buyers to accept LPD design (e.g., reduction in stamp duty)	2
d05	Government promotes LPD education	2
d06	Construction waste reduction	2,6
d07	Energy consumption reduction	2,6
d08	Material usage reduction	2,6
d09	Circular economy for carbon reduction: Improved circular economy to reduce carbon emission	Study
d10	Construction cost reduction	2,6,7
d11	Efficient design process: Improved efficiency in design process	2
d12	Streamlined design and communication: Streamline design and communication process	2
d13	Workload reduction in design and management: Reducing workloads in building design and project management by reducing scope of interior design/provisions	Study
d14	Clear LPD objectives in design: Clear definition of LPD objectives in design stage	8
d15	Improve company culture	2
d16	Shift to outcomes philosophy: Shifting from outputs (products) to outcomes philosophy.	Study
d17	Inventory and spare parts reduction	2
d18	Enhanced standardization in construction: Enhance standardization in building design, construction, and management	2
d19	Enhanced MiC: Enhance Modular Integrated Construction	Study
d20	Offsite construction adoption and rework reduction: Easier to adopt offsite construction technology and reduce rework on-site	Study

2=(Marhani et al., 2013); **6**=(Pan et al., 2015); **7**=(Bajjou & Chafi, 2018); **8**=(Chbaly, 2021); **Study**=Experts' suggestions (via interview) and authors' input.

Table 2: **LPD barriers' factors**

Code	Barrier factors	Reference
b01	Lack of LPD knowledge: Building industry lacks knowledge and skills of LPD	1,3,4,7,10,11,12
b02	Designers' unfamiliarity with LPD concept: Building designers are not familiar with concept of LPD	7,11
b03	Perception of developer-centric benefits: Thought that LPD is only beneficial to developers	Study

Code	Barrier factors	Reference
b04	Developers ROI focus: Developers focus on ROI (finances, branding, social responsibility)	Study
b05	Profit compromise from GFA reduction	Study
b06	Increased design cost for LPD: Implementing LPD may require more time for market research, thus increasing design cost	7
b07	Less glamorous LPD units: LPD building units may look less glamourous as compared to traditional design, which renders them less attractive to potential buyers	Study
b08	Stringent requirements and approvals	1,13
b09	Resistance to change in design: Resistance to change from traditional design practices	1,4,7,9,10,11,12
b10	Inability to define peoples' expectations/requirements	7,8
b11	Diverse buyer expectations: Expectations of buyers in different price ranges are diverse. (Potential buyers of building pricing from lower to middle range (say 0.5-1000m) may prefer ready-to-move-in condition, while buyers for luxury buildings prefer to renovate by themselves.)	Study
b12	Government's limited sustainability focus: Government does not care for sustainability in building development	1,7,9,10,12
b13	Absence of lean construction culture: Absence of a lean culture in construction field	3,7,12
b14	Insufficient management skills: Insufficient management skills of designers and builders	1,7,9,10,12
b15	Lack of top management support	3,4
b16	Avoidance of decision-making responsibility: Avoidance of making decisions and taking up responsibility in defining scope of "lean design."	1,7,12
b17	Lack of stakeholder communication: Lack of communication and feedback among stakeholders	7,8
b18	Reluctance to embrace new approaches: Building professionals are reluctant to new design approaches if current system 'works.'	3,7
b19	Lack of early user feedback: Lack of communication and feedback from end-users on their requirements in early design stage	9,8
b20	Limited application in procurement: Limited application in design-and-build procurement models	1,12
b21	Diverse end-user requirements: End-user requirements are too diverse	7
b22	Environmental constraints from site: Environmental constraints due to differences in site conditions	5,11

1=(Sarhan & Fox, 2013); **3**=(Ogunbiyi et al., 2014); **4**=(Shang & Sui Pheng, 2014); **5**=(Olamilokun, 2015); **7**=(Bajjou & Chafi, 2018); **8**=(Chbaly, 2021); **9**=(Babalola et al., 2018); **10**=(Hussain et al., 2019); **11**=(Dehdasht et al., 2020); **12**=(Balkhy et al., 2021); **Study**=Experts' suggestions (via interview) and authors' input.

3.1.2 Questionnaire survey

Purposive sampling and snowball sampling were adopted, in which respondents were selected based on their expertise in (i) sustainable building design and construction, (ii) awareness of lean premise design, and (iii) construction industry. Professionals' email addresses in government agencies and construction firms were obtained from their organizations' websites for snowball sampling.

Table 3 and Figure 2 depict experts' backgrounds and demographics. Out of the 66 responses retrieved from the experts, only 65 were suitable for analysis. Some potential respondents needed to be more conversant with the concept of LPD and thus declined the invitation to participate.

The reliability of this study was acceptable (see Table 6) and adequate compared with similar studies where (i) over 82% of the respondents (66 responses) had been working in construction industry for over 20 years (Leung et al., 2014); (ii) sample sizes are greater than 30 (33 samples) (Darko et al., 2017), as indicated by central limit theorem in statistics; (iii) due to novelty of the topic, few (26) valid responses were considered acceptable (Chileshe et al., 2018); and (iv) sample size of 65 is considered reasonable when compared with similar studies (Osei-Kyei et al., 2017).

Table 3: Experts' profiles and opinions on LPD and sustainable practices

Expert's demographics	#Respondents, (%)	LPD awareness	#Respondents, (%)
Profession		**LPD awareness**	
Architect	13, (20)	Very low	18, (27.69)
Building Contractor	5, (8)	Low	12, (18.46)
Building developer	10, (15.38)	Average	24, (36.92)
Engineer	21, (32.31)	High	8, (12.31)
Interior designer	1, (1.54)	Very high	3, (4.62)
Researcher	6, (9.23)		
Surveyor	9, (13.85)	Very low – Low (Group 1)	30, (46.15)
		Average – Very high (Group 2)	35, (53.85)
Years of experience		**Stage to implement sustainable practices**	
< 5 years	5, (7.69)	All stages	2, (3.08)
5 – 10 years	7, (10.77)	Construction stage	1, (1.54)
11 – 15 years	7, (10.77)	Design and construction stage	1, (1.54)
16 – 20 years	5, (7.69)	Design stage	19, (29.23)
> 20 years	41, (63.08)	Facility management	1, (1.54)
		Planning and design stage	41, (63.08)

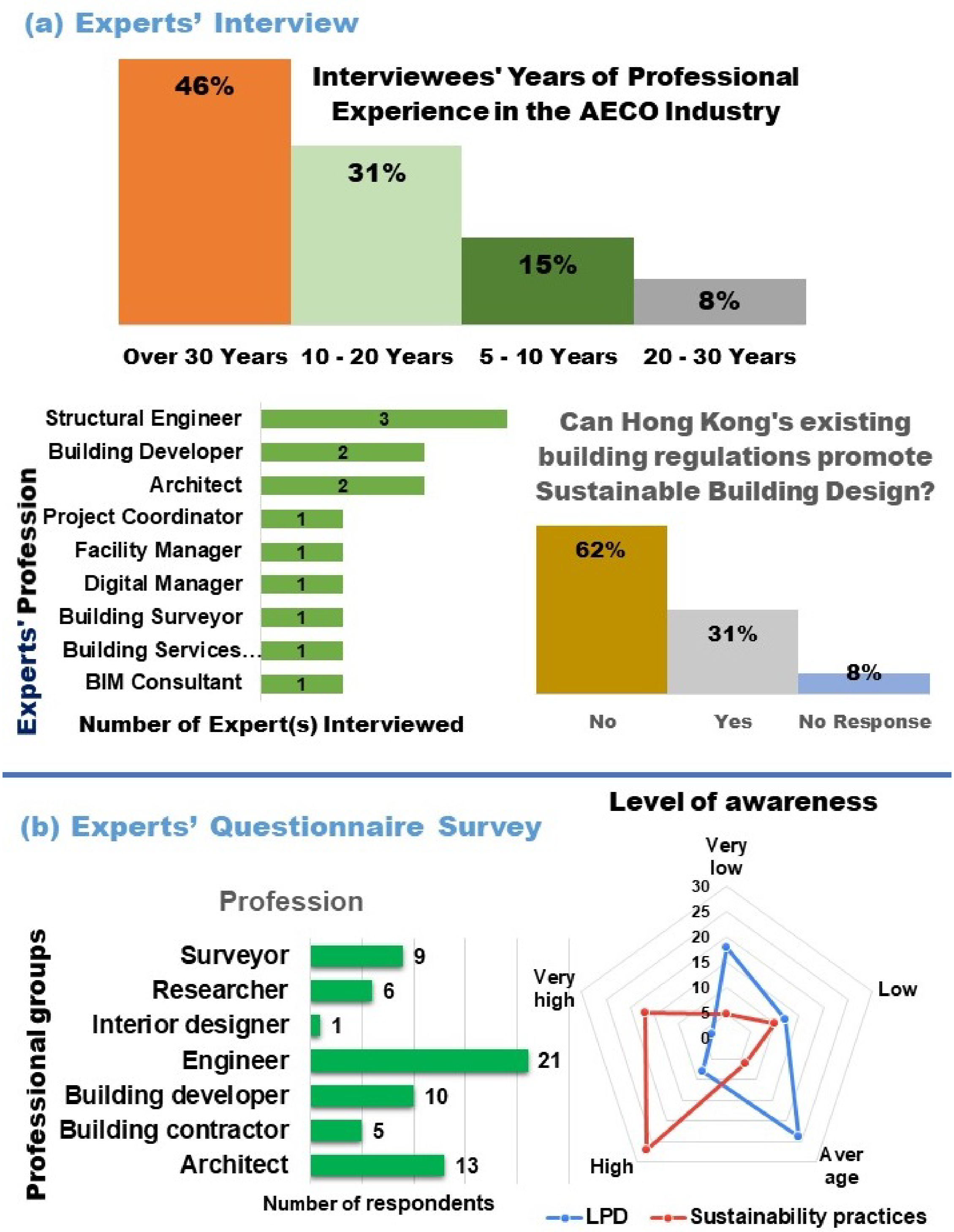

Figure 2: Experts' demographics

3.2 Data analysis techniques

3.2.1 Mean Score Ranking

Survey respondents rated their level of agreement on each factor based on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree". Mean score (MS), the average value received by a specific statement or factor, is used with the standard deviation (SD) to determine the rankings for each factor. When two factors are tied, the factor with the lowest SD value ranks higher; however, if the factors have the same mean and SD, they retain the same rank (Olawumi et al., 2018). Similar studies have used this approach (Kazeem et al., 2021). Factors with a mean value greater than the average of all factors (3.4 and 3.9 for barriers and drivers, respectively) were identified as critical factors influencing LPD scheme adoption in Hong Kong.

3.2.2 Normality test

The technique in Pallant's (2016) study was used to check for normality in this study using IBM SPSS. A Shapiro-Wilk normality test, appropriate for the sample size, revealed that non-parametric tests are required since the data are not normally distributed ($p < 0.05$).

3.2.3 Principal Components Analysis

Principal components analysis (PCA) and factor analysis (FA) are statistical techniques that produce a smaller number of linear combinations of the original variables in a way that captures majority of variability in pattern of correlations (Pallant, 2016). These two sets of techniques are similar and are frequently used interchangeably by researchers (Pallant, 2016). Ideally, PCA produces components while FA produces factors; however, this study employs the former and refers to its outcomes as factors (Tabachnick & Fidell, 2019).

3.2.4 Mann-Whitney U test

Mann-Whitney U (M-W U) test is used to evaluate if there are differences in perception of the factors between the two professional groups. When the p-value is ≤ 0.05, the null hypothesis, "*there is no significant statistical difference in median values of the same factor between two groups,*" is rejected.

4. Survey results and findings

4.1 Mean score rankings

4.1.1 Drivers of LPD scheme

The top five LPD drivers are "*d05−government promotes LPD education*" (4.2), "*d14−clear LPD objectives in design*" (4.1), "*d06−construction waste reduction*" (4.1), "*d04−government facilitates buyer acceptance*" (4.14) and "*d08−material usage reduction*" (4.11). "*d16−Shift to outcomes philosophy*" has the lowest response frequency with a mean rank of 3.4. However, all drivers have a response frequency greater than 66%, implying that experts agree on the importance of these driver factors and that they are vital components to consider for effective LPD adoption for a future potential user. The two expert groups ranked some drivers differently, reflecting contrasting opinions on these drivers. As shown in Table 4, group 2 ranked "*d14−clear LPD objectives in design*"

6th and "*d10−construction cost reduction*" 13th, while group 1 ranked them 1st and 4th, respectively. Professionals with substantial LPD knowledge agree that defined LPD design objectives and the potential for construction cost reduction will drive LPD implementation in Hong Kong.

Table 4: Experts' opinions on LPD drivers

	Overall				**Group 1**			**Group 2**		
Code	**Mean**	**SD**	**Rank**	**Critical**	**Mean**	**SD**	**Rank**	**Mean**	**SD**	**Rank**
d05	4.2	0.8	1	Yes	4.0	0.9	7	4.3	0.7	1
d14	4.1	0.7	2	Yes	4.1	0.7	1	4.2	0.7	6
d06	4.1	0.7	3	Yes	4.1	0.8	2	4.2	0.6	4
d04	4.1	0.9	4	Yes	4.0	0.9	5	4.3	0.8	2
d08	4.1	0.8	5	Yes	4.1	0.9	3	4.1	0.6	7
d07	4.1	0.7	6	Yes	4.0	0.8	6	4.2	0.6	5
d09	4.0	0.9	7	Yes	3.8	1.0	12	4.3	0.6	3
d10	4.0	1.0	8	Yes	4.0	1.0	4	3.9	1.0	13
.	.	.	.	.	.	.	.	.	.	.
.			.	.			.			.
.	.	.	.	.	.	.	.	.	.	.
.			.	.			.			.
d16	.	.	20	No	.	.	20	.	.	19

Note: SD = standard deviation; **Group 1** = professionals with 'very low' – 'low' LPD awareness; **Group 2** = professionals with 'average' –' very high' LPD awareness; **Critical drivers** = mean ≥ 3.90; Mean and SD values have been rounded to the nearest decimal.

4.1.2 Barriers to LPD Scheme

Based on MS and SD rankings, the top barriers to LPD scheme implementation are "*b04−developers ROI focus*" (MS=3.9), "*b11−diverse buyer expectations*" (3.8); "*b21−diverse end-user requirements*" (3.8); "*b19−lack of early user feedback*" (3.7); "*b13−absence of lean construction culture*" (3.6); "*b09−resistance to change in design*" (3.6); and "*b17−lack of stakeholder communication*" (3.5). However, some barriers were ranked differently by the professional groups. For instance, "*less glamorous LPD units*" (b07) ranked 7th by the professionals with 'average' to 'very high' LPD awareness levels (group 2). However, the same barrier was ranked 19th by professionals with 'very low' to 'low' LPD awareness (group 1). Similarly, "*b18−reluctance to embrace new approaches*" ranked 6th by group 2 professionals was ranked 14th by group 1 professionals. Furthermore, "*b09−resistance to change in design*", ranked 13th by professionals in group 2, was ranked 4th by professionals in group 1, as shown in Table 5. As a result of the awareness level of professionals in group 2, they believed that the LPD building units might look less attractive than the traditional building design. Also, group 2 professionals indicated that building professionals are reluctant to use a new design if existing approach works.

Table 5: Experts' opinions on LPD barriers

	Overall				Group 1			Group 2		
Code	**Mean**	**SD**	**Rank**	**Critical**	**Mean**	**SD**	**Rank**	**Mea n**	**SD**	**Rank**
b04	3.9	0.8	1	Yes	3.8	0.9	3	4.0	0.8	1
b11	3.8	0.8	2	Yes	3.8	0.9	1	3.8	0.8	2
b21	3.8	0.9	3	Yes	3.8	0.8	2	3.8	1.0	3
b19	3.7	0.8	4	Yes	3.7	0.8	5	3.6	0.7	5
b13	3.6	1.0	5	Yes	3.5	1.0	8	3.7	0.9	4
b09	3.6	1.1	6	Yes	3.7	1.0	4	3.4	1.2	13
b17	3.5	1.1	7	Yes	3.4	1.1	11	3.5	1.0	8
b16	3.5	0.8	8	Yes	3.4	0.7	12	3.5	0.9	9
b15	3.5	1.0	9	Yes	3.4	1.0	9	3.5	1.0	11
b18	3.4	1.0	10	Yes	3.3	1.0	14	3.6	1.0	6
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
b03	2.7	1.0	22	No	2.8	1.0	22	2.7	1.0	22

Note: SD = standard deviation; **Group 1** = professionals with 'very low' – 'low' LPD awareness; **Group 2** = professionals with 'average' –' very high' LPD awareness; **Critical barriers** = mean ≥ 3.36; Mean and SD values have been rounded to the nearest decimal.

4.2 Establishing critical factors' grouping via PCA

Prior to FA, Cronbach's alpha coefficient was used to assess the scale's internal consistency, with 0.7 considered an acceptable result for scale reliability (Saka et al., 2022). Table 6 shows that all factors passed the test.

Table 6: Factors' reliability test

Factor	**Number of items**	**Cronbach's Alpha**
Drivers	20	0.902
Barriers	22	0.785

FA consists of three significant steps: determining data suitability, factor extraction, and factor rotation and interpretation. Assessing data suitability addresses two significant issues: sample size and strength of the relationship between variables. While Kaiser-Meyer-Olkin (KMO) value and Bartlett's test of sphericity (BTS) check the latter issue, there is little agreement among authors on how large a sample should be for the former. MacCallum et al. (1999) developed a theoretical framework for the effects of sample size on factor recovery. Studies have shown that large samples are required for FA (Aghimien et al., 2022). However, Preacher and MacCallum (2002) demonstrated that in studies with small sample sizes, the population factor structure can be recovered adequately if communalities (which are proportion of common variances found in individual variables) are high, model error is low, and only a few factors are retained.

Table 7 shows that all items have high communalities (greater than 0.3), indicating that they fit with other items in their component (Pallant, 2016). Additionally, de Winter et al. (2009) demonstrated that when data are well conditioned, FA can produce reliable results with sample sizes as small as 50, even with minor distortions. According to Olawumi and Chan (2020b), a key consideration in FA is that data sample size and number of factors adhere to a 5:1 ratio. Two additional tests were performed to determine the factorability of the data: the KMO value and BTS. KMO values range from 0 to 1 and measure the relative compactness of correlations among factors. FA is appropriate for the study because the BTS is significant (p=0.000), and the KMO values (0.6 and 0.76) are greater than or equal to 0.6, which is recommended as the minimum value for a good factor analysis (Tabachnick & Fidell, 2019). Kaiser's criterion, also known as eigenvalue rule, was used to determine the number of factors. Thus, PCA can be applied to the data set obtained from this study since essential prerequisites have been met.

Table 7: Critical factor communalities and data factorability and adequacy tests

Barriers	**Communalities**		**Drivers**	**Communalities**	
Code	Initial	Extraction	Code	Initial	Extraction
b01	1.00	0.84	d01	1.00	0.85
b02	1.00	0.79	d02	1.00	0.70
b03	1.00	0.87	d03	1.00	0.79
b04	1.00	0.55	d04	1.00	0.88
b05	1.00	0.70	d05	1.00	0.71
b06	1.00	0.81	d06	1.00	0.84
b07	1.00	0.74	d07	1.00	0.85
b08	1.00	0.77	d08	1.00	0.89
b09	1.00	0.74	d09	1.00	0.76
b10	1.00	0.74	d10	1.00	0.82
.	.	.	.	.	.
.			.		
.	.	.	.	.	.
b20	.	.	d20	.	.
b21	1.00	0.60			
b22	1.00	0.61			
KMO = 0.60			**KMO** = 0.76		
BTS: χ^2 = 570.15; df = 231; p = 0.00			**BTS:** $\chi 2$ = 818.61; df = 190.00; p = 0.00		

χ^2 = Chi-Square; **df** = degree of freedom; p= significant value of BTS

The correlation matrix revealed the presence of many coefficients with values of 0.3 or higher. The KMO value (0.6) was within the recommended range, and BTS reached statistical significance, indicating that the correlation matrix is factorable. PCA revealed the presence of eight components with eigenvalues greater than one, each of which explained approximately 22.1%, 13.1%, 8.5%, 7.3%, 6.8%, 5.5%, 5.1%, and 5.08% of the variance.

A six-factor component solution was obtained for the twenty drivers, which explained 77.25% of the variance. All driver items have factor loadings greater than 0.5. Hence, the LPD scheme's drivers are classified into six categories, as shown in Table 8: design and management, sustainable management, offsite construction method, training and collaboration, government involvement and support, and cost efficiency.

Furthermore, out of the 22 items, only four factor-loadings "*b06−increased design cost for LPD*", "*b07−less glamorous LPD units*", "*b08−stringent requirements and approvals*", and "*b20−limited application in procurement*" are less than 0.5. These barrier factors have moderate loadings, suggesting the principal component represents them less, and they explain less data variance. Variables with high factor loadings represent underlying dimension for that factor, and the components were given a group name based on the cluster's general theme at the authors' discretion (Olawumi & Chan, 2020a). Consequently, LPD barriers are classified into eight categories: knowledge and skill; support, communication, and feedback; perceived benefit; finance and implementation time; culture; design practices; user requirements and procurement; and environment and regulatory barriers, as shown in Table 9.

Table 8: Factor analysis of LPD drivers

Drivers	Factor loadings	Eigenvalue	% Of variance explained	Cumulative % of variance explained
Design and management		7.61		38.02
d13	0.85			
d12	0.78			
d15	0.64			
d14	0.58			
Sustainable management			2.42	
d08	0.87			
d07	0.75			
d09	0.74			
d06	0.74			
Offsite construction method			1.96	
d19	0.90			
d20	0.88			
d18	0.63			
d17	0.53			
Training and collaboration			1.36	
d01	0.87			
d02	0.74			
d16	0.56			

Drivers	Factor loadings	Eigenvalue	% Of variance explained	Cumulative % of variance explained
Government's involvement and support			1.08	
d04	0.92			
d03	0.72			
d05	0.60			
Cost efficiency			1.02	
d10	0.84			
d11	0.65			

Table 9: Factor analysis of LPD barriers

Barriers	Factor loadings	Eigenvalue	% of variance explained	Cumulative % of variance explained
Knowledge and skill		4.86	22.11	22.11
b01	0.87			
b02	0.85			
b14	0.57			
Support, communication, and feedback		2.87	13.06	35.17
b15	0.76			
b16	0.73			
b12	0.60			
b17	0.56			
b19	0.51			
Perceived benefit		1.86	8.47	43.64
b07	0.31			
b03	0.92			
Finance and implementation time		1.60	7.26	50.90
b05	0.77			
b06	0.46			
b04	0.81			
Culture		1.50	6.80	57.70
b18	0.83			
b13	0.52			
Design practices		1.21	5.48	63.18
b10	0.83			
b09	0.68			
User's requirements and procurement		1.13	5.12	68.30

Barriers	Factor loadings	Eigenvalue	% of variance explained	Cumulative % of variance explained
b21	0.73			
b11	0.56			
b20	0.49			
Environment and regulation		1.12	5.08	73.38
b22	0.82			
b08	0.45			

4.3 Mann-Whitney U test analysis

Table 10 summarises the results of the Mann-Whitney U tests for the LPD barriers and drivers. "*Stakeholder communication platform*" (d02) and "*shift to outcomes philosophy*" (d16) record different expert opinions based on M-W U test p-values (0.007 and 0.014, respectively). Driver "*d02 - stakeholder communication platform*" (8^{th}) was ranked higher by experts with a higher level of LPD awareness than by experts with a lower level of LPD awareness (18^{th}). This disparity indicates that group 2 experts understand the LPD scheme, as it agrees with Göçer et al. (2015), who noted that improved communication among stakeholders increases sustainable design adoption. The Mann-Whitney U test p-value (0.035) between the expert groups indicates a statistically significant difference in their perspectives on barrier "*b07–less glamorous LPD units*" (Ogunbiyi et al., 2014). Furthermore, group 2 experts ranked this barrier (b07) higher (7^{th}) than group 1 experts (ranked 13^{th}). LPD designers and stakeholders should ensure that LPD-based apartments do not appear less appealing to buyers. To ensure general acceptance of the LPD scheme, stakeholders must consider the apartment's aesthetics. Ghomeshi and Jusan (2013) also established differences in cognitive and physical opinion bases between designers and end-users, so designers must consider users' preferences when designing their apartments.

Table 10: M-W U Tests of LPD barriers and drivers

LPD Barriers			**LPD Drivers**		
Code	Z	p-value	Code	Z	p-value
b01	-0.58	0.56	d01	-1.23	0.22
b02	-0.48	0.63	d02	-2.68	0.01*
b03	-0.11	0.92	d03	-1.07	0.28
b04	-1.03	0.30	d04	-1.36	0.17
b05	-0.06	0.95	d05	-1.71	0.09
b06	-0.67	0.50	d06	-0.43	0.66
b07	-2.11	0.04*	d07	-0.99	0.32
b08	-0.41	0.68	d08	-0.04	0.97
b09	-0.92	0.36	d09	-1.91	0.06
b10	-0.64	0.53	d10	-0.69	0.49
b11	-0.10	0.92	d11	-0.53	0.60

b12	-0.15	0.88	d12	-0.90	0.37
b13	-0.84	0.40	d13	-0.29	0.78
b14	-1.59	0.11	d14	-0.05	0.96
b15	-0.19	0.85	d15	-0.61	0.55
b16	-0.96	0.34	d16	-2.47	0.01*
b17	-0.42	0.67	d17	-1.07	0.28
b18	-1.17	0.24	d18	-1.11	0.27
b19	-0.06	0.95	d19	-0.98	0.33
b20	-1.65	0.10	d20	-1.32	0.19
b21	-0.04	0.97			
b22	-0.95	0.34			

Note: * A p-value of less than 0.05 implies that distribution of a particular factor code is statistically different between the experts' groups. **Group 1:** Experts with 'Very low' - 'Low' awareness of LPD; and **Group 2:** Experts with 'Average' - 'Very high' awareness of LPD.

5. Discussion: Critical factors to LPD scheme implementation

The discussed drivers in this section are "*government involvement and support*" (d03, d04 and d05) and "*design and management*" (d14). Whereas the barriers discussed are "*finance and implementation time*" (b04) and "*end-user requirements*" (b11 and b21). Figure 3 summarises the overall outlook of the 20 identified critical factors determining LPD adoption.

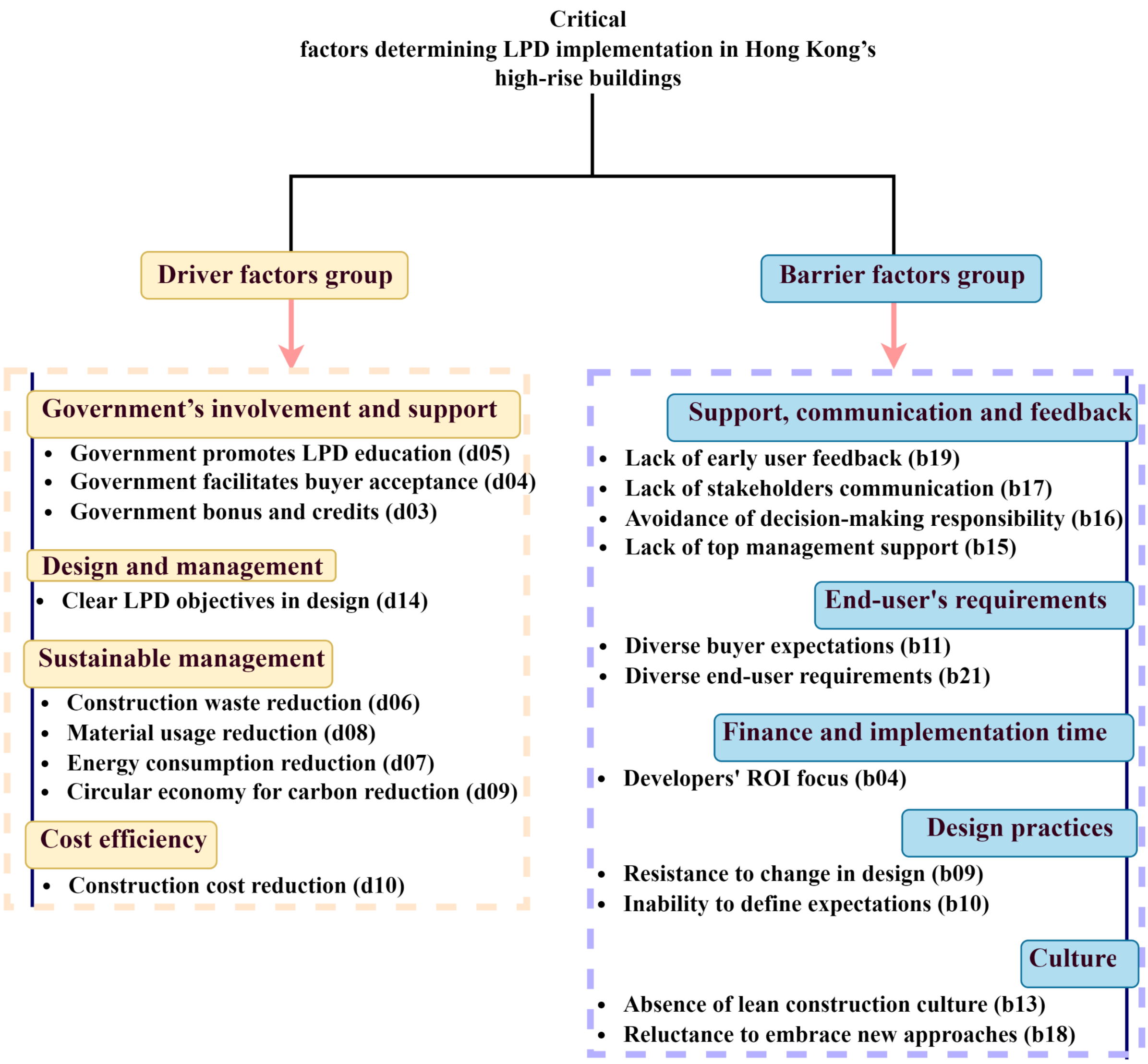

Figure 3: LPD critical factors

5.1 Drivers

5.1.1 Government's involvement and support

This factor component covers three critical drivers, namely: "*d05 – the government promotes public education in LPD*", "*d04 – the government facilitates buyers accepting LPD design*", and "*d03 – the government provides bonuses and credits to developers who adopt LPD*". The government's role in driving the adoption of the LPD scheme cannot be overemphasized. These critical barriers contribute to a three-dimensional support pattern for the government's participation in the LPD scheme.

First and foremost, the government must promote widespread public awareness of the LPD scheme. To raise public awareness of the LPD scheme, the government can implement various public education initiatives and campaigns. For example, seminars and workshops with public and private sector stakeholders to demonstrate the benefits of the LPD scheme and its potential impacts.

Second, the government's reduction in stamp duty for LPD-focused apartment purchases, for example, will go a long way toward attracting potential buyers to the LPD scheme. Beyond public awareness, the government should provide tangible, actionable assistance to potential buyers.

Third, the government should offer tax incentives, funding assistance to developers implementing the LPD scheme, and recognition awards. For example, the Hong Kong government's gross floor area (GFA) concession scheme can be incorporated into the LPD scheme. The GFA concession scheme provides developers with a 10% GFA discount if their buildings register for the Building Environmental Assessment Methods (BEAM) Plus or achieve any level of BEAM Plus, meet the Sustainable Building Design Guidelines (SBDGs), and include the required building features (Fan et al., 2018).

5.1.2 Design and Management

Driver d14 – "*clear definition of the LPD objectives in design stage*" is the only critical driver in this category. At the project's outset, the design and management teams must clearly define the goal and objectives of implementing the LPD scheme. Similar studies, such as Tsai et al. (2014), identified the capability of early defining the scope and contexts of new or innovative methods in the building industry. Furthermore, setting project goals allows project teams to make the necessary preparations and ensures success.

5.2 Barriers

5.2.1 Finance and Implementation Time

The only critical barrier in this subcategory is "*b04 – developers' ROI focus*". Building developers play critical roles in the development of HRBs. However, their primary goal is profit maximization. Developers reduce the cost of providing infrastructure to profit financially (Maryati et al., 2021). The LPD may arouse the interest of developers who want to experiment with a new building construction method. Building developers may find it challenging to adopt new ideas like LPD, especially if doing so could compromise their reputation and desire for financial gain. The attitude of developers has a significant impact on adopting the LPD scheme since they are crucial to the development of HRR buildings in Hong Kong.

5.2.2 End-user's requirements

End-users use the final product or artefact to complete a task or reach a goal (Abras et al., 2004). User-centred design (UCD) is a multidisciplinary approach that relies on user participation to improve understanding of user and task requirements and design and evaluation iteration (Mao et al., 2005). Building stakeholders have different perspectives on the success criteria for a project (Lam et al., 2008). As production management success depends on motivated and skilled individuals committed to organizational goals (Gao & Low, 2014), people, needs, and experiences are central to UCD (Baha et al., 2021). To emphasize human values and deep empathy with users (Koen, 2015), designers must consider the complexities of building end-user requirements. Butera (2013) identified that buildings, like cars, should have a dashboard and user manual to facilitate end-user information and education.

This category has two critical barriers: "*b11 - buyer expectations in different price ranges are diverse*" and "*b21 - end-user requirements are too diverse*". The LPD concepts are centred on the end user. In Hong Kong, potential buyers of lower to middle-priced buildings may prefer ready-to-move-in apartments, whereas buyers of luxury buildings prefer to renovate the newly purchased apartment. As a result, meeting the various expectations of the various categories of potential end-users based on their taste and income levels will take much work. Similarly, the fact that end-user needs are too diverse must be addressed. As end-user satisfaction is the best way to evaluate a building's performance (Seshadhri & Paul, 2017), the need to satisfy the requirements of different end-users in the LPD scheme poses a barrier to its adoption. A viable solution to this problem could be to group users with similar characteristics and requirements into the same categories, which will aid in providing the typical requirements for each category.

6. Conclusions and future research

The research has explored the potentiality of implementing the LPD scheme in HRR buildings in Hong Kong. As identified from the stakeholder interviews, there is a need to propose, develop and integrate new sustainable residential building design concepts into the existing codes and guidelines in Hong Kong. Additionally, there is a need to set up a framework for sustainable building design. The LPD scheme considers the users' behaviour patterns, expectations, social needs, green maintenance techniques and government initiatives in the context of residential buildings. The mean score ranking, FA, and M-W U test were conducted to achieve the research objectives.

Some of the current study's findings are consistent with recent findings on the critical success factors of identified sustainability concepts in the building industry. For example, Balkhy et al. (2021) identified critical barriers to lean and innovative sustainable practices, which include workforce expertise, cultural issues—such as reluctance to change traditional working practices, technical know-how, organizational issues, lack of top management support, insufficient worker training, and a lack of adequate lean awareness and understanding. It also corroborates Lam et al.'s (2007) findings on the primary success criteria for design and building projects in Hong Kong, as this study highlights design management as the top driver factor group that drives LPD scheme adoption.

Implementing the LPD scheme ensures sustainable management via construction waste reduction, energy consumption reduction and circular economy. In Hong Kong, enormous amounts of C&D waste are generated annually (Hossain et al., 2017). However, the LPD scheme implementation can reduce the amount of C & D waste, thus easing the landfill space constraints in Hong Kong (Wu et al., 2020). Similarly, by overcoming the barriers identified, the construction industry in Hong Kong can improve the shortage of effective communication and feedback and foster a lean culture that integrates differing buyers’ expectations and requirements to achieve a more sustainable design practice. Additionally, HRB designers, particularly architects and engineers, can gain encouragement to involve potential users during the conceptual and preliminary stages of the design projects to request detailed information that can facilitate sustainable building designs.

The highlighted critical factors could be a consultative study for other researchers to explore other studies focusing on sustainable design and lean construction. It would also be helpful for the government and local authorities as a policy instrument towards developing LPD-friendly regulations in Hong Kong. The long-term impacts of this research include the potential to drive real-world changes in building practices, resulting in more sustainable and efficient HRBs.

Also, the study’s findings will help build a strategic framework for the LPD scheme and sustainability practices in Hong Kong, similar to the British Construction Industry Association's Design Quality Indicator (DQI) toolkit (Lu & Juan, 2023). Furthermore, the findings of this research can serve as a blueprint for other regions with similar built environment configurations and spatial characteristics in adopting sustainable building practices. Future research should investigate how to balance end-user needs with buyer and builder design detail goals. Also, future studies could explore practical ways of bridging communication gaps between stakeholders such as developers, designers, building managers, and end-users in HRBs to facilitate sustainable development.

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Data availability

The data supporting this study's findings are available from the corresponding author, [K.K.O], upon reasonable request.

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