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Critical Factors Influencing Business Model Innovation for Sustainable Buildings

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Abstract: Despite significant policy drives, the wide adoption of sustainable building (SB) is hindered by factors such as high upfront cost and long payback period. Business model (BM) innovation is therefore highly demanded to help SB professionals to cope with the challenges and convert the value of SB into profit. Nevertheless, few studies examined BM innovation in the building sector and factors influencing BM innovation for SB are unclear. This paper aims to identify the critical factors that propel companies to innovate BM for SB. First, a literature review and expert interviews were conducted to identify and filter the drivers for BM innovation within the SB context. Second, a questionnaire survey was conducted to collect data on the significance of the selected influencing factors from 132 SB professionals. Finally, a model based on fuzzy set theory was used to ascertain the critical factors influencing BM innovation for SB. Twenty-four critical influencing factors in six categories from the external environment and internal organization were finalized, namely, market and economic, policy and legislation, technology and industry structure, social-culture, entrepreneurship, and organizational learning. The findings illuminate the motivations when developing BM for sustainability and provide strategies on BM innovation for practitioners and policy makers.

Keywords: business model; innovation; sustainable building; influencing factor; entrepreneurship; fuzzy set theory

1. Introduction

During the past few decades, there has been an upsurge of interest in sustainable technologies and sustainable development [1]. It is well recognized that the construction industry is associated with a range of potentially detrimental effects, including the depletion of materials and resources, the effect on ecosystem, and the impact on greenhouse gas emissions [2,3]. According to International Energy Agency, the building sector is the largest final energy consumption sector, consumes around 35 percent of total final energy and thus represents approximately one-third of global greenhouse gas emissions [4]. With business-as-usual scenario, energy use in the building sector is expected to rise by 50 percent by 2050 due to an expected population increase of 2.5 billion and growth in energy-using devices [5]. Sustainable building (SB) is one of the measures to mitigate these negative effects associated with buildings across their life cycle. There have been extensive studies on various aspects of SB in different contexts, including technical feasibility (e.g., [6,7]), policy incentives and regulations (e.g., [8,9]), social awareness (e.g., [10–12]), and performance assessment (e.g., [13–15]).

However, a lot of challenges are faced by developers and building companies in their technological transition to SB, such as the lack of market demand, perceived risk and capital cost [16]. Firms face the challenge of how to develop a business model (BM) that transforms the attributes of SB into sources of economic value creation. BM is a description of how a business runs [17]. To keep competitive advantage and success in the long run, organizations should be able to exploit their existing capabilities while developing new competencies at the same time [18]. BM innovation acts as a strategic renewal mechanism for organizations facing changes in their external environment [19]. Schneider and Spieth defined BM innovation as the deployment of existing resources and capabilities to develop new value offerings or new methods of value creation [20]. Emerging literature on sustainable BM has suggested that BM innovation may offer a means to facilitating enhanced sustainability. Innovative technologies that have the potential to meet key sustainability targets are not easily introduced by existing BMs with in a sector [21]. BM innovative could convert sustainable technologies to new sources of value for customers and ultimately commercial value.

However, despite a growing amount of literature on BM and BM innovation (e.g., [22]), there is still limited understanding of how developers and other stakeholders can innovate their BMs to facilitate the successful delivery of SB. Existing literature provides little information on the prerequisites and critical factors influencing BM innovation within the context of SB. In the absence of a better understanding of BM innovation and its drivers, converting SB into revenue growth and improving the uptake rate of SB will remain difficult. This paper aims to formulate a list of the key influencing factor of the BM innovation for SB projects. Following this introduction the paper reviews the literature of influencing factors of BM for SB. It then describes the methodology of the study and presents the results of the expert interviews and questionnaire survey and fuzzy set-based analyses. The paper finally discusses the findings and draws its conclusions.

The study contributes to the body of knowledge from three aspects: Firstly, the challenges of SB uptake are mainly related to other than technical issues. The study connects project-based BM with SB to address these challenges. Secondly, from the managerial point of view, the research findings provide a tool for building developers and other key stakeholders to understand the mechanism of BM innovation. The identified set of critical influencing factors acts as a reference for building companies to evaluate their readiness for BM innovation in the context of SB. Thirdly, using the research outcome, policy makers can rethink current policies and regulations with the aim to foster a favorable external environment for SB development.

2. Literature Review

2.1. BM Innovation

BM can be perceived as an intermediate layer between business strategy and business processes [23]. Chesbrough and Rosenbloom described BM as a structural framework between technological artifacts and the realization of economic values [24]. Value-based perspective is mostly used to delineate the BM construct. V4 dimensions, namely, value proposition, value communication, value delivery and value capture, represent the primary dimensions of the BM concept [25]. Osterwalder and Pigneur developed a more detailed template for firms to conduct BM self-check, namely, the nine-part "BM canvas", which lays out the value proposition, key resources and key activities of an organization's value chain, customer segments, customer relationships, channels, cost structures and revenue streams [26]. As a management tool, the BM concept helps decision makers to design, implement, control and change their business [27].

Firms need to review and revisit its BM, either to pursue new opportunities in its industry or to respond to competitive or technology threats posed to its existing model. The role of BM in fostering innovation has received substantial attention. First, BM represents a vehicle for innovation and allows managers to commercialize innovative technologies/products in a market [28]. Second, BM itself can be a new dimension of systems innovation and as a source of competitive advantage [29]. The process of BM innovation consists of innovating the content, the structure, and governance of the transactions that a firm performs in cooperation with a network of external partners [30].

Literature shows that BM innovation for sustainable technologies/innovations has attracted scholars' attention. Richter investigated two types of utilities' BM for renewable energies, i.e., customer-side renewable energy BM and utility-side renewable energy BM [18]. Al-Saleh and Mahroum examined the interplay between green BMs and green policy instruments, and identified three types of green BM in the built environment, i.e., stick-induced, incentive-induced, and social norm-induced BM [31]. Bocken et al. provided a list of BM strategies for a circular economy, which include access and performance model, extending product value, encourage sufficiency, and industrial symbiosis [32]. Liu et al. investigated the BM innovation for the modular prefabrication in the Chinese construction industry [33]. Zhao et al. identified four alternative innovative BMs for SB projects, namely, extended operation and maintenance service, customer-oriented service, collaborative design and construction, and energy performance contracting [34]. Franca et al. explored how the BM innovate for strategic sustainable development by using BM canvas and supplementary tools such as creativity techniques, value network mapping, life-cycle assessment, and product-service systems [22].

2.2. External and Internal Prerequisites of BM Innovation for SB

BM innovations can be triggered in various ways and come from different sources. Most literature discriminates the influencing factors or stimuli of BM innovation into external and internal factors (e.g., [35]).

For the external influencing factors, the change of the business environment (such as globalization) and the technological development have been identified as drivers of organizations to innovate their BM [36]. Technology shifts require firms to reinvent their BMs, in order to bring discoveries to market and satisfy unrequited customer needs [37]. Changing market requirements and customers' needs have been identified as drivers of BM innovation (see e.g., [38,39]). Change in the competitive landscape, increased costs and innovation pressure may potentially force firms to change their established [35]. Moreover, interactions with other industries/business enterprises act as another stimulus of BM innovation [40]. As one of the essential requirement of BMs that cater to new customers, establishing strong connections among firms and conducting smooth collaboration grants the firm frameworks for reshaping itself. In addition, de Reuver et al. discussed that changing regulatory conditions force firms to reinvent their BMs [41]. Firms change their BM to catch the new opportunities brought about by various types of green policy interventions [31]. Nair and Paulose suggested that the external factors influencing green BMs include changing markets, customers' preferences, threats from competitors, changing customer needs, social pressures, environmental issues, and economic needs such as government reforms [42]. Antikainen and Valkokari identified that the drives of BM innovation for the sustainable innovation include legislation on sustainability, consumer environment consciousness, resource scarcity, and stakeholder involvement and collaboration [43].

Many earlier studies have supported the impact of entrepreneurial cognition and strategic agility on BM innovation. Strategic agility implies a firm's capability to proactively choose among different BMs, as well as create new BMs [42]. Firms in the dynamic environment should be flexible enough to respond effectively to changes, in order to be competitive. The timing of adopting innovation and pace of innovation are critical success determinants of BM for sustainable technologies. The strategic agility of a firm is determined by a list of meta-capabilities including strategic sensitivity, leadership unity, and resource fluidity [44]. Moreover, the effect of entrepreneurial cognition on BM innovation has been supported by ample evidence [33,45,46]. Chesbrough identified that obstruction and confusion hinder a firm's BM innovation, and proposed change leadership, as well as experimentation and effectuation to overcome these obstacles [28]. Aspara et al. emphasized the role of managers' cognition and strategic agility with the transformation of BM innovation and stressed the importance of inter-organizational cognitions [47]. The influencing factors in these previous studies are fragmental, and the application of BM innovation in the SB context is limited. Therefore this paper formulates a list of key influencing factors that integrate the external and internal dimensions for driving the BM innovation for SB, as summarized in Table 1.

Table 1. Summary of influencing factors of BM innovation in previous studies.

Category	Selected Factors	Reference
External factor	Technology development, the emergence of new products/service	[36,37,48,49]
	Emergence of low-carbon or low-energy materials	[50,51]
	Higher requirement of design for adaptability and durability	[51]
	Changing market requirements and customer needs	[37,38,42,52]
	Policy instruments an legislation on SB, Energy codes and standards	[31,41,43,53,54]
	Change in the competitive landscape, threat from competitors	[35,42]
	Increased cost and innovation pressure	[35]
	Environmental issues and awareness	[42,43]
	Stakeholder involvement and collaboration	[40,42,55]
	Economic needs	[36,42]
	Social pressure (e.g., occupant wellbeing improvement and social reputation)	[42,43,56]
	Change of industrial network and requirement	[34,57]
	Energy security	[49]
Internal factor	Managers' cognition	[33,35,46,47]
	Leadership (e.g., healthy and effective leadership behaviors)	[24,44,58]
	Companies' environmental knowledge and CSR programme	[58]
	Strategic agility	[42,47]
	Experimentation and effectuation	[24]

3. Research Methods

This study aims to identify critical factors influencing BM innovation for SB. For the development of critical influencing factors, this study follows four steps to identify the critical factors influencing BM innovation for SB.

At the first step, a list of proposed influencing factors was derived from a comprehensive review of BM literature and SB literature (e.g., [48,54]). A content analysis was used to identify optional factors influencing BM innovation. Content analysis is one of the classical and effective approaches used in social science to study research problems from documentary evidence [59]. These optional indicators are divided into two groups, external factors and internal factors.

At the second step, in-depth semi-structured interviews were conducted with eight academic and industry experts in the area of SB, with the aim to filter and validate the list of influencing factors. As a two-way methods of collecting data, semi-structured interview can get the full spectrum of participants' observation and obtain an in-depth understanding of the research subject. A theoretically informed interview provides an important mechanism to build structure into the following data collection process [60]. The details of the interviewees are shown in Table 2. The interview participants are selected from Building Environmental Assessment Method (BEAM) professionals that registered by Hong Kong Green Building Council. BEAM professionals are building professionals accredited by the Hong Kong green building council in various aspects of the entire green building life cycle, thus have rich experiences in decision-making, SB design and delivery. The six participants include two developers, four engineers and two academics. Nearly all of the respondents have over ten years of experiences in both international and local SB projects. These experts were asked to assess whether the proposed factors sufficiently represented the prerequisites of BM innovation in the context of SB if being examined; whether the wording was acceptable or whether they should be changed to make the factors understandable to the respondents. In detail, the following topics were discussed:

- History and progress in delivering SB for the interviewee's organization;
- Understandings on the BM innovation for SB;
- Solutions (in the components of value proposition, value delivery and value capture) the organization have adopted to deliver SB;
- Viewpoints on the capability of innovating BM for the organization;
- External factors that drive the organization investing and participating in SB project;
- Major challenges faced by the organization in the development of SB.

Table 2. A summary of the detailed information of interviewees.

Nature of Work	Role	Years of Work Experience in Building	Years of Experience in SB
Developer (2)	Executive director	10	3
	Business manager	10	6
Engineers (4)	Manager	13	2
	Managing director	12	7
	Project director	26	9
	Senior Engineering	10	5
University (2)	Professor	11	5
	Lecturer	6	4

Each interview lasted around one hour and the interviews were tape recorded and fully transcribed. The data thus collected were coded and qualitatively analyzed using MAXQDA software (VERBI GmbH, Berlin, Germany). The analysis process entailed a mixed deductive and inductive coding process. All the collected information was summarized into items, and the items with similar meanings were compiled into influencing factors. Based on the interview results, two factors "increased requirement on project duration", "requirement on work environment" were deleted from the preliminary framework of critical influencing factor.

At the third step, Table 3 presented the refined list of influencing factors of the BM innovation for SB. Based on the refined framework of influencing factors of BM innovation, a general questionnaire was designed to investigate the significance of the refined list of influencing factors. Among the various data collection methods, the questionnaire has been recognized as the most cost-effective and most popular mean to collect information relating to attitudes, opinions and behaviors and has been widely used by researchers in the area of construction management [59]. The suitability and comprehensibility of the questionnaire script were first tested through a pilot study. The participated experts include three engineers, one developer and one academic researcher. Questionnaire surveys were distributed to the professionals with SB credentials in Hong Kong from early October 2016, via the post, emails, and online survey tool. Hong Kong is a well-developed city with a high population density, high-rise buildings in the subtropical climate. The building sector is accountable for over 90% of total electricity use and 60% of greenhouse gas emissions in Hong Kong. Hong Kong government has set the target for reducing energy intensity by 40% by 2025. Lots of efforts have been made by the government and the construction industry to achieve carbon reduction. There are totally 1024 registered BEAM Plus Projects in Hong Kong up to date. Hong Kong therefore acts as a showcase of latest low or zero carbon building design, technologies and successful innovative BMs. Although the selected respondents are selected from Hong Kong, projects they have participated in are not limited to Hong Kong context. According to BEAM Pro Directory (as of 15 April 2017), excluding the disciplines/members of little relevance to this paper (landscape architect, town planner, water specialists, electrical engineer etc.), the valid number of BEAM Pros is 1880. In addition, snowball sampling strategy was used as a supplement by asking participants to recommend suitable developers and clients who have rich experience in SB.

Table 3. A refined framework of factors influencing BM innovation for SB.

Aspect	Category	Influencing Factor	Code
External environment (EN)	Market and Economic (ME)	Increasing requirement for building quality/customer satisfaction	ME1
		Potential higher return-on-investment of SB (e.g., sales price premiums)	ME2
		Change of industry's acceptance of SB	ME3
		Increasing market demand of SB	ME4
		Peers are racing to control the market of SB	ME5
	Policy and legislation (PL)	Government grants/fiscal incentives for SB	PL1
		Gross Floor Area compensate for SB	PL2
		Floor Area Ratio compensate for SB	PL3
		Mandatory energy efficiency/carbon emission standards for building projects	PL4
		Carbon emission reduction/energy use reduction rewards	PL5
	Technology and Industry (TI)	Sustainable technologies and capabilities of building contractors	TI1
		Know-how and SB solutions of architects and designers	TI2
		Manufacturers and suppliers that provide green products/materials	TI3
		Lower life cycle impact/cost of SB (e.g., lower energy bills)	TI4
	Social-cultural aspect (SC)	Public consciousness on sustainability/Corporate social responsibility information disclosure	SC1
		Building assessment and rating systems/carbon accounting	SC2
		Change of enterprises' competitiveness (e.g., protection of external environmental)	SC3
		Higher energy price	SC4
		Intangible benefits of companies (e.g., brand value, public image)	SC5
Intra-Organization (IO)	Entrepreneurship (E)	Company's green culture and consistent awareness to promote SB	E1
		Believe SB is the trend of future and have strategic plans to change	E2
		Our company should develop SB	E3
		Sensitivity to market change and actively explore new methods to do SB business	E4
	Organization learning (OL)	Constant reconfiguring and innovating BM and strategic plan in the organization	OL1
		Employees' knowledge sharing and awareness of SB	OL2
		Technology/knowledge transfer between organization itself and other partners/consultants	OL3
		Organization's R&D on new technology and product	OL4
		Organization's capability to mobilize both internal and external resources/knowledge	OL5

Respondents were invited to evaluate the level of significance of the selected influencing factors by assigning a score between 1 and 5. A score of "5" indicated most important, "4" important, "3" average, "2" unimportant, and "1" extremely unimportant. The questionnaire consists of two parts: first, the general information of participants, including the primary area of practice, role in the organization, year of work experience, and year of experience in SB area; second, the invited participants' perceptions on the significance of the factors. Until late March 2017, a total of 1910 questionnaires were sent out, and 138 responses were received. Six invalid responses were removed due to incomplete response or erroneous use of the rating scale, which yields a net response rate of 6.9%. The critical rating was fixed at scale "3" since ratings above "3" represent "important" and "most important".

At the fourth step, statistical analyses on the significance of influencing factors were conducted on the data collected from the survey. Analysis of variance and *t*-test were first conducted to test the validity of the collected data. This research grouped influencing factors into six groups: market and economic, policy and legislation, technology and industry, social-cultural aspect, entrepreneurship, and organizational learning. It is necessary to check the reliability of the classification. The Cronbach's alpha represents the reliability of the group classification for influencing factors, was used to test the internal consistency among factors under each category [61]. Shen et al. indicated that a value of Cronbach's alpha of 0.7 or higher normally indicates a reliable group classification set [62].

As shown in Table 3, the collected survey data are from different groups of experts. Since different roles of experts may have different perceptions about the priorities of the factors affecting BM. Moreover, experts' opinions generally are subjective and involve fuzziness. Hence, the fuzzy set theory is applied to assist in identifying the critical influencing factors. Previous studies have widely applied the fuzzy set theory in decision making of many areas, including the construction and engineering. Shen et al. applied the Fuzzy Set theory to establish the key assessment indicators for the sustainability performance of infrastructure projects [62]. Shan et al. used a fuzzy measurement model to assess the potential corruption in public construction projects in China [63].

According to the definition of the union operator on the fuzzy theory by Yager [64], the symbol $\widetilde{A}$ represents a fuzzy set of key influencing factors. Because the survey data came from five major groups of experts; namely, developers, contractors, professional consultants, government officials, and university academics, the set can be represented as:

$$\begin{aligned}\widetilde{A} = \; & \widetilde{A}_D \cup \widetilde{A}_P \cup \widetilde{A}_C \cup \widetilde{A}_G \cup \widetilde{A}_U = \\ & \mu_{\widetilde{A}_D}(x_i)/x_i + \mu_{\widetilde{A}_P}(x_i)/x_i + \mu_{\widetilde{A}_C}(x_i)/x_i + \mu_{\widetilde{A}_G}(x_i)/x_i + \mu_{\widetilde{A}_U}(x_i)/x_i\end{aligned} \tag{1}$$

where x_i = influencing factors listed in Table 3; $\mu_{\widetilde{A}}(x_i)$ = degree of membership of x_i in the fuzzy set $\widetilde{A}$. $\mu_{\widetilde{A}_D}(x_i)$; $\mu_{\widetilde{A}_P}(x_i)$; $\mu_{\widetilde{A}_C}(x_i)$; $\mu_{\widetilde{A}_G}(x_i)$; $\mu_{\widetilde{A}_U}(x_i)$ are the degree of membership of five expert groups in the fuzzy set $\widetilde{A} = \pi r^2$ and $\mu_{\widetilde{A}}(x_i) \in [0,1]$. "+" means "and" in the fuzzy set, $\mu_{\widetilde{A}}(x_i)/x_i$ means that the degree of membership of x_i in $\widetilde{A}$ is $\mu_{\widetilde{A}}(x_i)$.

The significance of each influencing factors is scored between 1 and 5, with a score of 3 as a neutral level that is used for differentiating significant and insignificant. If the mean of a factor's significance is less than 3, the possibility for the factor to be critical is less than 50%. In addition, the value of S_D needs to be incorporated when determining whether a factor belongs to the critical factor set. The larger the S_D, the less significant the concerned factor. *A* parameter *Z* is therefore be introduced to indicate whether a factor should be considered as critical:

$$Z = (Mean - 3)/S_D \tag{2}$$

If the distribution of a factor's score allocated by all respondents is in a normal distribution, based on the standard normal distribution table, a 84% probability exists that individual scores from a respondent falls within the range $mean - Z * S_D$ = 3; ∞ when *Z* = 1; a 95% probability exists that the scores fall within the range $mean - Z * S_D = 3; \infty$ when *Z* = 1.65. The normal distribution of a factor's score is presented in Figure 1.

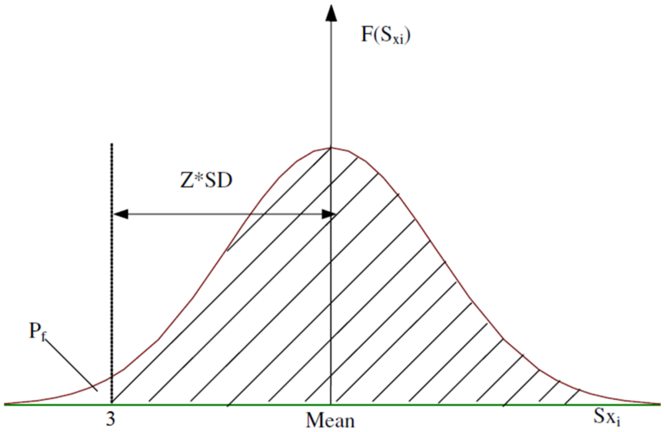

Figure 1. The normal distribution of a factor's significance score.

However, the scoring result from the questionnaire survey is actually not in a normal distribution, therefore a fuzzy distribution was adopted rather than a normal distribution. Based on the fuzzy set theory, the degree of the membership of a variable determines the possibility of the factor to belong to a group [65]. The membership of x_i in certain category A_Y can be described as:

$$m_{\widetilde{A}_Y}(x_i) = \mu_{\widetilde{A}_Y}(x_i) = \int_3^{\infty} f(S_{x_i})dx = 1 - P_f = P(X \leq Z) \quad (3)$$

where $Y \in (D, P, C, G, U)$; P_f = possibility that a factor does not belong to the group. The final integrated score of the degree of membership for an influencing factor can be obtained based on the equation:

$$m_{\widetilde{A}_D \cup \widetilde{A}_P \cup \widetilde{A}_C \cup \widetilde{A}_G \cup \widetilde{A}_U}(x_i) = \min\left\{1, \left(m_{\widetilde{A}_D}(x_i)^n + m_{\widetilde{A}_P}(x_i)^n + m_{\widetilde{A}_C}(x_i)^n + m_{\widetilde{A}_G}(x_i)^n + m_{\widetilde{A}_U}(x_i)^n\right)^{1/n}\right\} \quad (4)$$

where the union operator n = number of factors. The union operator will converge to the sum-operator when n = 1 and converge to the max-operator when $n \to \infty$. n = 28 in this research. In order to determine whether a factor is a critical influencing factor, a benchmark value λ should be adopted. If the $m(x_i)$ is larger than the preset λ value, the concerned factor x_i will be considered as a key influencing factor. The optimal value of $\lambda = 1$, while the worst value of $\lambda = 0$. A value of λ between 0.65 and 0.85 was suggested to be effective for analysis [66,67]. In this study, λ-cut value is set as 0.8 and used to select critical influencing factors.

4. A Refined Framework of Factors Influencing BM Innovations for SB

Based on the literature review, optional influencing factors of BM innovation for SB projects have been identified. The identified factors can be categorized into factors in external environment and intra-organization. Based on the results of interviews with eight senior personnel (Table 2), the selected influencing factors from the literature were filtered, while new collected indicators through interviews were summarized and added. After compiling, 28 influencing factors of BM innovation for SB were identified and coded, as demonstrated in Table 3. These factors have been categorized into two aspects and six groups: market and economic, policy and legislation, technology and industry, social-cultural aspect, entrepreneurship and organization learning.

5. Results and Analyses

Table 4 shows the demographic information of the questionnaire survey's respondents, including the role of the participants, nature of work, job position, years of experience, and experience in the SB area. In total, 132 valid questionnaires were received with the response rate of a net response rate of 6.9%, and five major groups constitute the majority of respondents, representing 98.5 percent of the total response. Among which, 27 respondents were from developers, 30 from contractors, 31 from professional consultants, 14 from government officials, and 28 from university educators and researchers.

Table 4. Demographics of valid survey respondents.

Parameter	Value	Frequency	Percentage (%)
Nature of work	Developers, clients and investors	27	20.5
	Contractors	30	22.7
	Professional consultants	31	23.5
	Financers, bankers and mortgage lenders	2	1.5
	Suppliers and Manufacturers	3	2.3
	Government officials	14	10.6
	Universities and professional bodies	28	21.2
	Estate and facility manager	3	2.3
	Industrial institutions	2	1.5
Role	Senior manager/Decision maker	27	20.5
	Project manager/Divisional manager	28	21.2
	Staff/Workers	78	59.1
Years of work experience in building	1–2	31	23.5
	3–4	31	23.5
	5–6	18	13.6
	7–8	11	8.3
	9–10	3	2.3
	11 and above	38	28.8
Years of work experience in SB	1–2	76	57.6
	3–4	24	18.2
	5–6	9	6.8
	7–8	3	2.3
	9–10	4	3.0
	11 and above	16	12.1
	Total	132	100

5.1. Reliability of the Framework and Collected Data

As stated in the research methodology, the reliability of the structured framework of influencing factors is tested by Cronbach's alpha coefficient. Cronbach's alpha of the two aspects and six categories were calculated, the results of which are shown in Table 5. The Cronbach's alpha coefficient for the six categories is larger than 0.7. The Cronbach's alpha for all the factors across the two aspects is 0.856. Hence, the structured framework is considered to be reliable.

Table 5. Cronbach's alpha of collected data.

Aspect	Cronbach's alpha	Category	Cronbach's alpha	Factor Code	Scale Mean If Deleted	S_D If Deleted	Alpha If Deleted
EN	0.896	ME	0.826	ME1	99.73	11.61	0.851
				ME2	99.89	11.45	0.848
				ME3	99.95	11.56	0.850
				ME4	99.92	11.52	0.848
				ME5	100.03	11.56	0.851
		PL	0.707	PL1	99.65	11.64	0.854
				PL2	99.70	11.73	0.855
				PL3	99.83	11.68	0.854
				PL4	99.55	11.85	0.858
				PL5	99.76	11.62	0.851
		TI	0.795	TI1	99.89	11.49	0.847
				TI2	99.80	11.54	0.850
				TI3	99.90	11.49	0.848
				TI4	99.80	11.57	0.850
		SC	0.813	SC1	100.02	11.46	0.848
				SC2	100.01	11.48	0.849
				SC3	100.23	11.37	0.845
				SC4	99.97	11.49	0.848
				SC5	100.09	11.45	0.846
IO	0.847	E	0.726	E1	100.25	11.65	0.856
				E2	100.11	11.61	0.854
				E3	100.22	11.73	0.856
				E4	100.28	11.64	0.855
		OL	0.778	OL1	100.15	11.66	0.854
				OL2	100.38	11.69	0.856
				OL3	100.29	11.65	0.854
				OL4	100.30	11.59	0.854
				OL5	100.31	11.75	0.858

5.2. Significance of Influencing Factors of BM Innovation for SB

The descriptive statistics were explored to analyze the survey results on the critical influencing indicators, including mean scores, ratings, and standard deviations of all proposed influencing factors under five groups of respondents. The results of the analysis are shown in Table 6. The *t*-test analysis was first employed to select the critical factors [59,68]. The null hypothesis ($H_0 : \mu_1 < \mu_0$) against the alternative hypothesis ($H_1 : \mu_1 > \mu_0$) were tested, where μ_1 represents the mean of the survey sample, the critical rating μ_0 was fixed at '3'. The value above '3' represents "fairly important" and "most important" factors. The null hypothesis H_0 can be rejected when the result of the observed *t*-value (t_O) is larger than the critical *t*-value $t_C(n-1, \alpha)$. t_O can be calculated using the following equation:

$$t_O = (\overline{\chi} - \mu_0) / \left(S_D / \sqrt{n}\right) \tag{5}$$

where $\overline{\chi}$ is the sample mean, S_D is the standard deviation of difference score in the sample population, n is the sample size, $n-1$ represents the degree of freedom, α represents the significant level which was set at 5%. $t_C(131, 0.05) = 1.98028$ at 95% confidence interval. As shown in Table 5, all the observed t-values t_O of the 28 factors are larger than t_C, which indicates the significance of these influencing factors.

Different groups of respondents gave different scores for individual factors. For instance, according to developers, "mandatory energy efficiency/carbon emission standards for building projects" (PL4) has an average score of 4.22 with first rank, whereas according to government officials, the average score of PL4 is 4.14 with sixth rank, it is ranked eighth by university researchers with an average score of 3.86. "believe SB is the trend of future and have strategic plans to change" (E2) has an average score of 4 with the fifth rank, whereas according to contractors, its average score is 3.43 with 24th rank. This demonstrates that experts in different groups have different perceptions about the priorities of the identified factors influencing BM innovation.

5.3. Critical Influencing Factors Based on Fuzzy Set Theory

Due to the divergence of opinions for five groups of experts, the parameter Z and the degree of membership $m(x_i)$ of each factor have been calculated in each group. Z_D, Z_C, Z_P, Z_G, Z_U, $m_{A_D}(x_i)$, $m_{A_C}(x_i)$, $m_{A_P}(x_i)$, $m_{A_G}(x_i)$, $m_{A_U}(x_i)$ are calculated according to Equations (2) and (3). The integrated $m(x_i)$ for individual influencing factors is calculated based on Equation (4). The results are shown in Table 7. The λ-cut value 0.8 is adopted to filter the critical influencing factor.

The degrees of membership of "Employees' knowledge sharing and awareness of SB" (OL2), "Technology/knowledge transfer between organization itself and other partners/consultants" (OL3), "Organization's R&D on new technology and product" (OL4), and "Organization's capability to mobilize both internal and external resources/knowledge" (OL5) are smaller than 0.8, therefore these four factors are not considered as key influencing factors. The left 24 factors are found to be critical in influencing BM innovation for SB, as presented in Figure 2.

Table 6. Significance scores and ranks of influencing factors under different classification of respondents.

Factor	Developer (N = 27)			Contractor (N = 30)			Professional Consultant (N = 31)			Government (N = 14)			University (N = 28)			All (N = 132)			*t*-Value
	Mean	S_D	Rank	Mean	S_D	Rank	Mean	S_D	Rank	Mean	S_D	Rank	Mean	S_D	Rank	Mean	S_D	Rank	
ME1	4.00	0.88	5	3.97	0.85	3	3.87	0.88	8	4.00	0.88	11	4.18	0.86	1	3.97	0.86	4	12.90
ME2	3.78	1.05	12	3.73	1.05	9	3.84	1.04	11	3.79	0.97	18	3.96	0.88	3	3.81	1.01	9	9.20
ME3	3.52	0.94	22	3.67	0.92	12	3.71	0.90	16	3.93	0.73	13	3.93	0.77	5	3.76	0.88	13	9.98
ME4	3.70	0.95	17	3.63	0.85	13	3.65	0.91	20	4.29	0.61	2	3.75	0.75	12	3.78	0.88	12	10.23
ME5	3.63	0.88	19	3.63	0.93	13	3.87	0.85	8	3.71	0.83	19	3.57	1.10	16	3.67	0.96	17	8.01
PL1	4.19	1.00	2	4.00	0.87	2	4.23	0.80	1	4.21	0.70	3	3.89	1.13	7	4.05	0.97	2	12.46
PL2	4.07	0.83	3	3.80	0.85	7	4.06	0.85	3	4.21	0.70	3	4.04	0.92	2	4	0.84	3	13.71
PL3	3.85	1.03	8	3.60	0.89	18	4.06	0.81	3	4.21	0.70	3	3.93	0.98	5	3.88	0.91	8	9.93
PL4	4.22	0.89	1	4.37	0.72	1	4.06	0.73	3	4.14	0.86	6	3.86	0.85	8	4.16	0.81	1	16.47
PL5	3.85	0.86	8	3.93	0.74	4	3.90	0.83	6	4.43	0.65	1	3.96	0.92	3	3.95	0.83	5	13.12
TI1	3.74	0.81	16	3.63	0.89	13	3.87	0.72	8	4.07	0.83	8	3.79	0.99	11	3.81	0.86	9	10.86
TI2	3.78	1.01	12	3.77	1.04	8	4.23	0.62	1	4.14	0.77	6	3.57	1.00	16	3.9	0.92	7	11.20
TI3	3.78	0.75	12	3.73	0.94	9	3.84	0.82	11	4.00	0.68	11	3.75	1.08	12	3.8	0.90	11	10.27
TI4	4.07	0.78	3	3.83	0.83	5	3.90	0.98	6	4.07	0.62	8	3.82	0.94	9	3.91	0.86	6	12.16
SC1	3.70	1.07	17	3.63	0.93	13	3.74	0.89	15	3.86	1.10	15	3.46	1.00	19	3.68	0.98	16	7.95
SC2	3.93	0.96	7	3.60	1.00	18	3.55	0.93	26	3.86	0.86	15	3.64	0.99	15	3.7	0.97	15	8.33
SC3	3.41	1.15	24	3.47	0.97	23	3.58	0.89	23	3.93	0.73	13	3.29	1.05	26	3.48	0.99	21	5.56
SC4	3.81	0.92	10	3.60	0.86	18	3.65	0.95	20	3.86	0.66	15	3.82	0.94	9	3.73	0.90	14	9.34
SC5	3.81	0.96	10	3.43	0.86	24	3.58	0.62	23	4.07	0.47	8	3.39	0.99	22	3.61	0.87	18	8.05
E1	3.56	0.97	20	3.83	0.87	5	3.68	1.08	18	3.00	1.30	28	3.36	1.22	23	3.45	1.09	23	4.76
E2	4.00	0.88	5	3.43	1.30	24	3.84	1.00	11	3.29	1.33	21	3.36	0.78	23	3.59	1.07	19	6.34
E3	3.56	0.85	20	3.70	0.84	11	3.48	0.93	28	3.21	0.70	24	3.57	1.14	16	3.48	0.93	21	5.94
E4	3.22	1.19	26	3.63	1.03	13	3.77	0.92	14	3.29	0.99	21	3.25	0.97	27	3.42	1.02	24	4.73
OL1	3.78	0.93	12	3.57	1.04	21	3.58	0.76	23	3.21	0.97	24	3.68	0.77	14	3.55	095	20	6.64
OL2	2.93	0.96	28	3.43	0.90	24	3.71	0.90	16	3.14	1.29	26	3.36	0.95	23	3.33	0.99	28	3.82
OL3	3.44	0.89	23	3.50	0.86	22	3.52	0.93	27	3.14	0.95	26	3.46	0.96	19	3.42	0.99	24	4.88
OL4	3.37	0.97	25	3.43	1.10	24	3.68	1.01	18	3.29	0.61	21	3.25	1.40	27	3.40	1.10	26	4.16
OL5	3.22	1.01	26	3.27	1.08	28	3.61	1.05	22	3.36	1.01	20	3.43	1.03	21	3.39	1.05	27	4.25

Table 7. The degree of membership of key influencing factors of BM innovation for SB.

Factor Code	Developer		Contractor		Professional Consultant		Government		University		Integrate $m(x_i)$	Rank
	$Z_D(x_i)$	$m_{A_D}(x_i)$	$Z_C(x_i)$	$m_{A_C}(x_i)$	$Z_P(x_i)$	$m_{A_P}(x_i)$	$Z_G(x_i)$	$m_{A_G}(x_i)$	$Z_U(x_i)$	$m_{A_U}(x_i)$		
ME1	1.140	0.873	1.137	0.872	0.984	0.837	1.140	0.873	1.366	0.914	0.935 *	10
ME2	0.741	0.771	0.700	0.758	0.810	0.791	0.806	0.790	1.094	0.863	0.870 *	17
ME3	0.554	0.710	0.723	0.765	0.787	0.784	1.272	0.898	1.212	0.887	0.916 *	13
ME4	0.738	0.770	0.745	0.772	0.705	0.760	2.103	0.982	0.998	0.841	0.983 *	5
ME5	0.713	0.762	0.683	0.753	1.029	0.848	0.865	0.806	0.518	0.697	0.857 *	19
PL1	1.184	0.882	1.148	0.875	1.524	0.936	1.736	0.959	0.788	0.783	0.977 *	6
PL2	1.296	0.903	0.945	0.828	1.247	0.894	1.736	0.959	1.123	0.869	0.970 *	7
PL3	0.830	0.797	0.671	0.749	1.308	0.905	1.736	0.959	0.949	0.829	0.966 *	9
PL4	1.371	0.915	1.902	0.971	1.464	0.928	1.322	0.907	1.010	0.844	0.989 *	2
PL5	0.986	0.838	1.262	0.897	1.087	0.861	2.211	0.986	1.046	0.852	0.990*	1
TI1	0.911	0.819	0.712	0.762	1.212	0.887	1.293	0.902	0.790	0.785	0.920 *	12
TI2	0.768	0.779	0.737	0.769	1.987	0.977	1.484	0.931	0.573	0.717	0.985 *	4
TI3	1.036	0.850	0.776	0.781	1.022	0.847	1.472	0.929	0.697	0.757	0.935 *	11
TI4	1.376	0.916	0.999	0.841	0.923	0.822	1.740	0.959	0.869	0.808	0.969 *	8
SC1	0.659	0.745	0.683	0.753	0.831	0.797	0.780	0.782	0.465	0.679	0.816 *	22
SC2	0.967	0.833	0.598	0.725	0.593	0.723	0.992	0.839	0.650	0.742	0.858 *	18
SC3	0.354	0.638	0.480	0.684	0.655	0.744	1.272	0.898	0.272	0.607	0.898 *	15
SC4	0.884	0.812	0.702	0.759	0.679	0.751	1.293	0.902	0.869	0.808	0.905 *	14
SC5	0.847	0.802	0.505	0.693	0.936	0.825	2.257	0.988	0.395	0.654	0.988 *	3
E1	0.577	0.718	0.954	0.830	0.630	0.736	0.000	0.500	0.292	0.615	0.831 *	20
E2	1.136	0.872	0.331	0.630	0.840	0.800	0.218	0.586	0.458	0.677	0.875 *	16
E3	0.659	0.745	0.833	0.798	0.516	0.697	0.300	0.618	0.503	0.693	0.803 *	23
E4	0.185	0.573	0.612	0.730	0.837	0.799	0.293	0.615	0.259	0.602	0.801 *	24
OL1	0.839	0.799	0.548	0.708	0.763	0.777	0.216	0.586	0.879	0.810	0.831 *	21
OL2	−0.073	0.471	0.478	0.684	0.789	0.785	0.109	0.543	0.375	0.646	0.786	25
OL3	0.494	0.689	0.581	0.719	0.559	0.712	0.147	0.558	0.483	0.685	0.741	27
OL4	0.381	0.648	0.391	0.652	0.673	0.750	0.475	0.683	0.178	0.571	0.752	26
OL5	0.218	0.586	0.250	0.599	0.581	0.719	0.356	0.639	0.415	0.661	0.723	28

* represents the value of $m(x_i)$ which is higher than the λ-cut value (0.8) indicating the significance of the influencing factors.

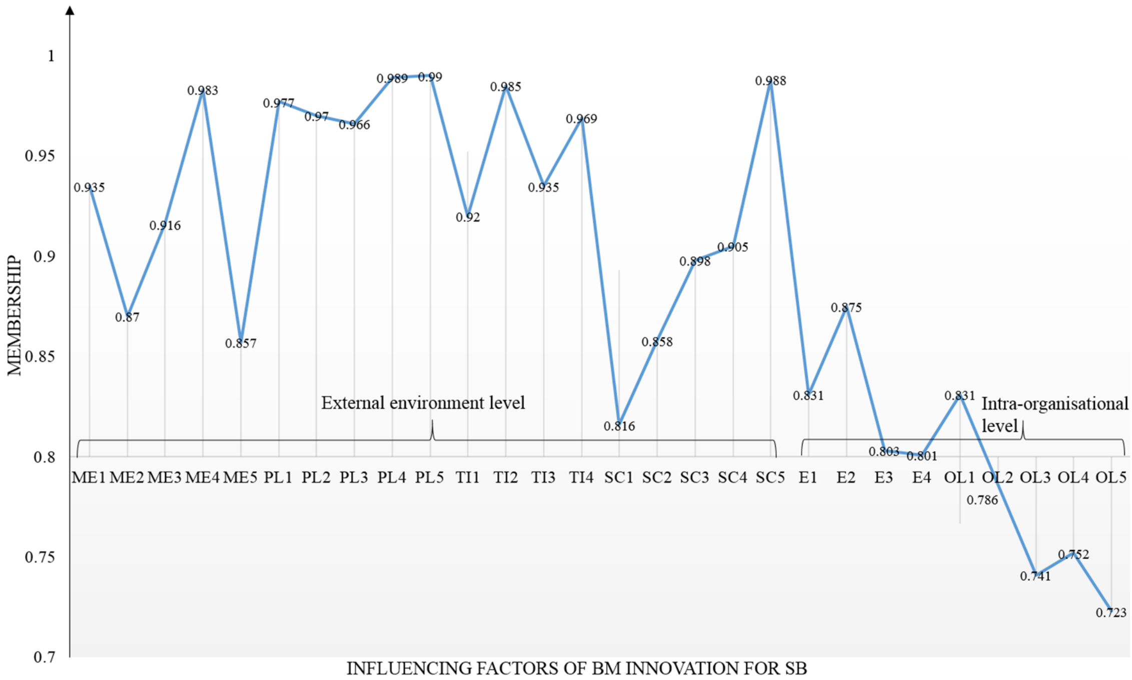

Figure 2. The set of critical influencing factors of BM innovation for SB with integrated membership.

6. Discussion of Findings

In total 24 critical influencing factors of BM innovation for SB were identified, which are grouped in 6 categories. These factors and the resultant themes of findings are discussed hereinafter.

6.1. Policies and Legislations

Ranked by the integrated membership of the identified factors, the category "policies and legislations" is ranked first among the six categories. "Carbon emission reduction/energy use reduction rewards" (PL5) and "mandatory energy efficiency/carbon emission standards for building projects" (PL4) have been ranked first and second respectively. "Government grants/fiscal incentives for SB" (PL1) "Gross Floor Area compensate for SB" (PL2) "Floor Area Ratio compensate for SB" (PL3) are also included in the top ten factors with highest priorities. Policy instruments are always considered above any other drivers when deciding whether SB should be implemented. The impact of policy instruments to promote SB have been widely discussed in the general literature (e.g., [69]). The bulk of policy instruments have sought to influence green BM innovation by either incentivizing customers to adopt a sustainable solution, or forcing the market to behave in certain ways using compulsory SB codes [31]. Moreover, surpassing such a narrow trade-off mentality, a sustainable BM innovation may emerge under an extant policy regime, and create "shared value" that links business success with social progress [70].

6.2. Technology and Industry

"Technology and industry" is another important category that influence BM innovation for SB. Previous studies have shown that technological change [71] and new capabilities [30] enable the development of new BM. "Know-how and SB solutions of architects and designers" (TL2) is ranked as the fourth important factor. It is ranked first by professional consultants (see Table 5). Multiple studies have strengthened different stakeholders' role in BM innovation. BM is nested between the focal firm and network levels. Leveraging resources and capabilities among actors within the business ecosystem can serve as a source of inspiration for BM innovation [72]. "Lower life cycle impact/cost of SB (e.g., lower energy bills)" (TL4) are ranked eighth in the set of critical influencing factors. Developers, contractors and consultants all gave TL4 relative high priorities, with third, fifth and sixth rank respectively. It reflects that the differentiation of value proposition to customers considered as an important stimulus of BM innovation for SB. Energy cost savings are commonly considered as the most important types of savings incurred in SBs (e.g., [34]).

6.3. Market and Economic

In the five critical influencing factors at "market and economic" category, "increasing market demand of SB" (ME4) got the highest rank with the integrated membership of 0.983. SB has been increasing considered as a long-term business opportunity. According to Dodge Data & Analytics, the percentage of firms expecting to have more than 60% of their projects certified green is expected to increase from current 18% to 37% by 2018 [73]. "Increasing requirement on building quality/customer satisfaction" (ME1) is also included in the top ten influencing factors of BM innovation. Previous studies have demonstrated that increasing customer demand and satisfaction is consistently an important driver for developing SB [74]. The opportunities for new BM exist in designing innovative solutions to fulfill the perceived customer needs. Despite the existence of opportunities, BM innovation for SB also faces a number of challenges. The benefits of SB cannot easily turn into short-term monetized return, which hinders the industry's shifting towards sustainability. Hence, compared to ME4, "potential higher return-on-invest of SB" (ME2) and "peers are racing to control the market of SB" (ME5) are ranked relatively lower.

6.4. Social and Cultural Aspect

"Intangible benefits (e.g., brand value, public image)" (SC5) brought by SB is ranked as the most important driver of BM innovation in the category of "social and cultural aspect". Large companies in particular, are perceived as willing to cultivate a green image. The business with an ethical stand/green image may seems to be more appealing to customers and investors [75]. Due to the limited or inconsistent cost-benefit data regarding SB [3], industry practitioners may be uncertain about the direct economic return of SB and may be more concerned with the long-term strategic benefits brought about SB projects. Compared to SC5, the other factors such as "increasing public consciousness on sustainability" (SC1), "Building assessment and rating systems/carbon accounting" (SC2) and "higher energy prices" (SC2) are ranked relatively low, which suggests that sustainability is not yet one of the primary criteria in the choice of a building despite the growing interests on SB.

6.5. Entrepreneurship and Organizational Learning

The influencing factors discussed above are consistent with the institutional theory [76], and suggest that the feasibility of a new BM depends in part on the degree to which it complies with external factors such as policy, technological and industrial requirements. Recent studies on institutional entrepreneurship have emphasized the importance of "institutional entrepreneurs" in BM innovation [55]. In response to the changes in the external environment, companies should build their dynamic capabilities in innovating BMs for SB. Individuals or organizations that make or change institutional arrangement should counter external constraints and create novel BM. "green culture and consistent awareness to promote SB" (E1), "Believe SB is the trend of future and have strategic plans to change" (E2), "intention to develop SB" (E3), and "sensitivity to market change" (E4) and "Constant reconfiguring and innovating BM and strategic plan in the organization (OL1)" reflect an organization's agility to sense opportunities and threats, seize opportunities, and maintain competitiveness through enhancing, combining and reconfiguring organizations' intangible and tangible assets [37].

7. Conclusions and Recommendations

BM innovation plays a very important role in the successful design and delivery of SBs. To understand the factors influencing BM innovation in a systems manner will help developers and other building stakeholders better set their business strategies and convert the value of SB into economic value. This paper has identified and ranked the key factors influencing BM innovation for SB based on a comprehensive literature review, expert interviews and a questionnaire survey with 132 SB professionals covering major stakeholder groups. In total 24 critical factors are identified, which cover two aspects and are grouped in six categories. External environmental and intra-organizational attributes are found to have the impact on BM innovation for SB. The six categories are: market and economic, policy and legislation, technology and industry, social-cultural aspect, entrepreneurship, and organization learning. The integrated degree of membership of the identified influencing factors are then examined using fuzzy set theory to determine the critical influencing factors.

Influencing factors at the external environment are prioritized compare to intra-organizational attributes. Ranked by the final integrated membership of influencing factors, top three constructs of influencing factors are policy and legislation, technology and industry, market and economic related factors. The top five critical factors influencing BM innovation for SB are: carbon emission reduction/energy use reduction rewards, mandatory energy efficiency/carbon emission standards for building projects, intangible benefits of companies (e.g., brand value, public image), know-how and SB solutions of architects and designers, and increasing market demand of SB.

The identified critical influencing factors should help developers, designers and contractors to better understand the opportunities for SB in both external environment and internal organization and thus cultivate innovative BMs for SB delivery. The findings also have implications for policy makers. Since BM innovation is highly dependent on the regulatory framework, policy makers should rethink current policy instruments and legislations with a goal to foster a favorable environment for SB development.

The limitation of the study may be attributable to the limited scope of this study in the survey context. Nevertheless, the findings derived can be valuable references for studying BIM innovation for SB in other regions. Future research should test the applicability of the model with a larger sample size and examine the model in different regions. Future research should also examine how BM components evolve and reconfigure over a time period under the influence of the identified critical factors.

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