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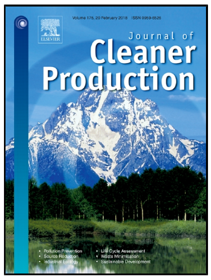

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Disentangling the relationships between business model innovation for low or zero carbon buildings and its influencing factors using structural equation modelling

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Abstract

Whilst low or zero carbon buildings (L/ZCBs) are espoused in many policy instruments, with many examples constructed to demonstrate their technical feasibility, there is a scarcity of effort examining the role of business models (BMs) in the delivery of L/ZCBs. BM innovation plays a decisive role in improving a company's competitiveness because it could quickly convert emerging technologies into commercial values by reorganising company's internal structure and offers. This paper aims to identify the factors influencing construction firms' BM innovation in the context of L/ZCBs, and measure the relationships between BM innovation for L/ZCBs and its influencing factors. This paper first identifies the influencing factors of BM innovation for L/ZCBs at both external and internal organisation levels and conceptualizes the constituting elements of BM innovation through a critical literature review. The paper then conducts a questionnaire survey with 132 building professionals in Hong Kong, and analyses the collected data using Structural Equation Modelling (SEM). Results from the survey show that favorable external environment towards L/ZCBs has a positive impact on BM innovation. Entrepreneurship of top managers and organisational learning capability of a firm are positively correlated with BM innovation for L/ZCB. Entrepreneurship and organisational learning capability mediate the relationships between external environment and BM innovation. The paper provides novel insights for building developers, contractors, and designers that wish to develop alternative business strategies and BMs. Research findings provide practical guidances on the process and elements of BM innovation for industry practitioners, and support the accelerated diffusion of L/ZCBs.

Keywords: Business model; Innovation; Low carbon building; Zero carbon building;

Entrepreneurship; Influencing factor.

1. Introduction

The construction industry has been often accused of causing environmental and social problems ranging from excessive consumption of non-renewable resources to the pollution of the surrounding environment. Buildings account for more than two fifths of global primary energy use and one third of greenhouse gas emissions (Zuo and Zhao, 2014). Low- or zero- carbon building (L/ZCB) has emerged as an innovative and important approach to the reduction of carbon emissions and energy consumption in the building sector. Many terms describing L/ZCB differ in terms of their extents, periods and contexts. "Net" is emphasized in the L/ZCB concept. L/ZCB can be defined as a building with (nearly) zero net energy consumption or zero net carbon emissions on an annual basis over a period of time, nominally a year (Pless et al., 2014). It has been defined by the recast EPBD of 2010 as "a building that has a very high energy performance … The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (European Commission, 2010). An increasing number of countries (e.g., the United States, Australia and Hong Kong) have established regulatory targets to achieve ZCBs. For example, the European Union Directive on the energy performance of buildings specifies that all new buildings shall be nearly zero energy by the end of 2020 (European Commission, 2010).

Although much of the literature on L/ZCB has focused on technical feasibility and design strategies, little evidence has been presented to demonstrate the business strategies and viability of L/ZCB. A significant challenge to the adoption of L/ZCB is to achieve trade-offs amongst many often-conflicting decision criteria, e.g. business performance and construction costs (Pan et al., 2012). Generally, the L/ZCB measures that have greater potential for carbon reduction may lead to higher initial costs- this is a concern of both developers and end-users (Berry and Davidson, 2015). The relatively low uptake of L/ZCB solutions to date reveals the need for innovative solutions to unlock the market. Business model (BM) is an integral part of economic behaviour and depicts the rationale of how an organisation creates, delivers and captures value (Teece, 2010; Massa and Tucci, 2013). The BM has become an important unit of analysis in innovation studies because it allows managers and entrepreneurs to connect innovative products/ technologies to a realized market output (e.g. Bocken et al., 2014). BM innovation offers a 'systems innovation' approach to the delivery of sustainable innovation by re-conceptualising the purpose of the firm, reconfiguring the logic of value creation and rethinking perceptions of value (Zott and Amit, 2010; Porter and Kramer, 2011). Therefore, with careful BM redesign, it is possible for building companies to more readily integrate L/ZCB.

However, an understanding of innovative BMs that stimulate the uptake of L/ZCB projects seems limited at present. The literature provides little information on the factors that influence BM innovation in the L/ZCB context and the relationships amongst BM innovation and its influencing factors. This paper thus aims to explore (1) the key factors that influence BM innovation for L/ZCB projects and (2) the relationships amongst the innovative components of BM for L/ZCB and their key influencing factors. The structure of the paper is as follows. First, a hypothesised BM innovation model is developed based on a comprehensive literature review; second, the results of a survey of L/ZCB professionals are reported; and third, the hypothesised relationships amongst BM innovation and its key influencing factors are analysed and validated using the structural equation modelling (SEM) approach.

2. Literature review and theoretical background

2.1 BM innovation for L/ZCB

BM, as a manifestation of business strategy (Lambert and Davidson, 2013), articulates the rationale of how an organisation creates and captures value (Osterwalder and Pigneur, 2010). BM can be perceived as an intermediate layer between business strategy and business processes. Researchers have depicted the constituent elements of BM from different perspectives, for example, the activity system perspective (Zott and Amit, 2010), value chain perspective (Zhao and Pan, 2017). Existing research mainly concerned business at organisational level, while neglecting business with project specificity. BM at building project level typically crosses organisational boundaries and knowledge bases (Kujala et al., 2010). Hence, it is necessary to consider the specific relational context, value creation properties, complexity and uncertainty of L/ZCB project in exploring BM.

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 (Chesbrough, 2010). Second, BM itself can be a new dimension of systems innovation and as a source of competitive advantage (Massa and Tucci, 2013). BM innovation refers to the design of novel BMs for newly formed organisations or the reconfiguration of existing BMs (Massa and Tucci, 2013). A BM evolves overtime through "progressive refinements to create internal consistency or to adapt to its environment" (Teece, 2010; Demil and Lecocq, 2010). Numerous case studies have reported positive relationships between BM innovation and improved enterprise performance (e.g. Liu et al., 2017). BM innovation acts as a market device to unfold the potential of sustainable innovations, and overcome the barriers of innovations in the external business environment and institutionalized organisational aspect (Boons and Lüdeke-Freund, 2013).

Rauter et al. (2017) adopted value-centered approach and decomposed BM innovation for sustainability from four aspects, i.e. value proposition (target customer, distribution channel relationship), value configuration (core competency, partner network), and revenue and cost structure. Cavalcante (2014) chose process-based perspective and organized the BM innovation into three stages, namely, Phase 1-central components and processes of BM, Phase 2-change initiatives and affected BM components/processes, Phase 3-challenges associated with change initiatives and solutions to them. In addition, BM concept was nested into sociotechnical transition theory from a multi-level perspective (Wainstein and Bumpus, 2016). The literature above either uses a dynamic view and conceptualize BM innovation as an organisational change process, or adopts a static view and treat BM innovation as new types of innovative ventures. BM innovations for sustainable technologies/innovations have attracted scholars' attention. For example, Al-Saleh and Mahroum (2015) 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. Bocken et al. (2016) provided a list of BM strategies for a circular economy, which include access and performance model, extending product value, encourage sufficiency, and industrial symbiosis. However, few studies have examined project-based BMs, even less probed the BMs for L/ZCB projects.

2.2 Influencing factors of BM innovation for L/ZCB

BM innovations can be triggered in various ways and come from different sources. The stimuli of BM innovation in the literature can be grouped into two aspects: external environment of an organisation and intra-organizational attributes. In a constantly changing environment, an organisation needs to identify and anticipate relevant developments in a timely effectively manner, in order to explore perceived business opportunities through business model innovation. In addition, the internal attributes of an organization such as strategic agility, competences, resources and capabilities, are commonly considered as the crucial prerequisites for the organization to innovate its BMs. These intra-organisational attributes enable an organisation to pro-actively anticipate and quickly react to changes in its environment.

For influencing factors in the external environment, the change of business environment and technological development have been in as drivers of organisations to innovative their BM. Technology shifts require firms to reinvent their BMs, in order to bring discoveries to market and satisfy unmet customer needs (Teece, 2010). Changing market requirements and customers' needs have been identified as drivers of BM innovation (Rajala et al., 2016). Change in the competitive landscape, increased costs and innovation pressure may potentially force firms to change their established BMs. Interactions with other industries/enterprises act as another stimulus of BM innovation (Jolly et al., 2012). Establishing strong connections among firms and conducting smooth collaboration grant firms frameworks for reshaping themselves. Moreover, changing regulatory conditions force firms to reinvent their BMs (e.g. Nair and Paulose; 2014). Firms change their BM to catch the new opportunities brought about by green policy interventions (Al-Saleh and Mahroum, 2015). Changing social and environmental issues were also considered as drivers of BM innovation for sustainable innovation (e.g. Nair and Paulose, 2014).

Earlier studies have also supported the impact of entrepreneurial cognition and strategic agility on BM innovation. Literature on dynamic capability (e.g. Zott and Amit, 2010) and open innovation (e.g. Chesbrough, 2010) provides new insights into firms' ability to innovate BM in response to major changes in the external environment. Strategic agility implies a firm's capability to proactively choose among different BMs as well as to create new BMs (Nair and Paulose, 2014). The strategic agility of a firm is determined by a list of meta-capabilities including strategic sensitivity, leadership unity, and resource fluidity (Doz and Kosonen, 2008). Moreover, the effect of entrepreneurial cognition on BM innovation is supported by ample evidences. Chesbrough (2010) found that change leadership helps overcome obstruction and confusion that hinder a firm's BM innovation. Aspara et al. (2012) emphasised the role of managers' cognition and inter-organisational cognitions within the BM transformation. Despite the literature above, few studies systematically theorized the influencing factors of BM innovation. Even less studies applied a BM approach to investigate the organisational and management issue of L/ZCB. Most literature examined BM from firm level rather than project level (Kujala et al., 2010).

3. Development of constructs, unobserved variables and observed indicators

Based on a review of the factors that influence BM innovation, this paper constructs preliminary construct of the BM innovation of L/ZCB and its influencing factors. The optional list of constructs and their corresponding indicators was first derived from a comprehensive review. The extracted indicators should be quantifiable, understandable and usable by the practitioners. A pilot study was first undertaken to test the potential response, suitability and comprehensibility of the questionnaire. Five academics in the areas of real estate and construction management were selected. The selected academics are honorary and adjunct professors who participated in numerous building projects and thus have decades of practical experiences, therefore could provide in-depth understandings on BM and L/ZCB. These experts were asked to assess whether the proposed constructs and indicators sufficiently represented the prerequisites and attributes of BM innovation for L/ZCBs; whether the indicators should be changed; and whether additional indicators should be added. Comments were received and minor amendments were made to the original instrument. Based on the pilot study results, two indicators "increased requirement on project duration", "requirement on work environment" were deleted from the preliminary framework of critical influencing factor.

Table 1 lists the detailed construct, the variables and the indicators for each unobserved variable based on the literature and experts' viewpoints. The factors that influence BM innovation are categorised into external environment factors and internal organisation related factors. The external influencing factors have been categorised into four groups: market and economic, policy and legislation, technology and industry, social-cultural aspect. Entrepreneurship and organisational learning refer to the internal capability of an organisation to proactively anticipate and react to changes in its external business environment. Based on the value-based perspective adopted by most studies, this paper examines BM innovation for L/ZCB from innovations in value proposition, value delivery and revenue and cost structure.

Table 1. Development of constructs, unobserved variables and observed indicators

Construct	Unobserved variable	Observed indicator	Reference
External environment (EN)	Market and economic aspect (ME)	Increasing requirement on building quality/ customer satisfaction (ME1) Potential higher return-on-investment of L/ZCB (e.g. sales price premiums) (ME2) Change of industry's acceptance of L/ZCB (ME3) Increasing market demand of L/ZCB (ME4) Peers are racing to control the market of L/ZCB (ME5)	Abuzeinab et al. (2017); Shi et al. (2017); Zhao et al. (2016); Moore (2012); Chan et al. (2009)
	Policy and legislation (PL)	Government grants/fiscal incentives for L/ZCB (PL1) Gross Floor Area compensate for L/ZCB (PL2) Floor Area Ratio compensate for L/ZCB (PL3) Mandatory energy efficiency/carbon emission standards for building projects (PL4) Carbon emission reduction/energy use reduction rewards (PL5)	Abuzeinab et al. (2017); Zou et al. (2017) Liu et al. (2017); Pan and Ning (2015); Yuan and Zuo (2011)
	Technology and industry (TI)	Technologies and capabilities of building contractors (TI1) Know-how and L/ZCB solutions of architects and designers (TI2) Manufacturers / suppliers that provide green products/materials (TI3) Lower life cycle impact/cost of L/ZCB (e.g. lower energy bills) (TI4)	Moore (2012); Pan and Goodier (2011); Chan et al. (2009)
	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	Osmani and O'Reilly (2009); Shilei and Yong (2009)

		value, public image) (SC5)	
Intra-organisation (IO)	Entrepreneurs-hip (E)	Company's green culture and consistent awareness to promote L/ZCB (E1) Believe L/ZCB is the trend of future and have strategic plans to change (E2) Our company should develop L/ZCB (E3) Sensitivity to market change and actively explore new methods to do L/ZCB business (E4)	Abdelkafi and Täuscher (2016); Bohnsack et al. (2014);Schneider and Spieth (2013)
	Organisational learning (OL)	Constant reconfiguring and innovating BM and strategic plan in the organisation (OL1) Employees' knowledge sharing and awareness of L/ZCB (OL2) Technology/knowledge transfer between organisation itself and other partners/ consultants (OL3) Organisation's R&D on new technology & product (OL4) Organisation's capability to mobilize both internal and external resources/knowledge (OL5)	Abuzeinab et al. (2017); Wong and Zapantis (2013); Schaltegger et al. (2012)
BM innovation	Value proposition (VP)	Company can better meet customers' requirements when delivering L/ZCB. (VP1) Company can provide new product/service to customer by delivering L/ZCB. (VP2) Company should explore new market opportunities when delivering L/ZCB. (VP3)	Abdelkafi and Täuscher (2016); Richter (2013); Bocken et al. (2014)
	Value creation (VC)	To deliver L/ZCB, company should use new governance structure and project delivery mode. (VC1) Company should set up new core capability for delivering L/ZCB. (VC2) Company should set up a new channel for passing values to customers. (VC3) Company should set up new relationships with other stakeholders (e.g. designer, contactors). (VC4) Company should shift focus from building construction to whole life cycle-based planning and management. (VC5) Company should cooperate with other organisations to import external technologies and share risks. (VC6)	Paiho et al. (2015); Bocken and Allwood (2012); Lützkendorf et al. (2011)

Revenue and cost structure (RC)	By developing L/ZCB, company can find new ways to reduce cost. (RC1) By developing L/ZCB, company can find alternative revenue generation methods. (RC2)	Zhang et al. (2017); Roome and Louche (2016); Paiho et al. (2015)

4. Research methods

As depicted in Fig. 1, the paper takes five steps to clarify the relationships amongst BM innovation for L/ZCB and its influencing factors on both the external environment and internal organisation levels. In the first stage, a preliminary construct is developed to describe BM innovation for L/ZCB and its influencing factors based on a literature review (Table 1). In the second stage, seven hypotheses are proposed to describe the relationships amongst BM innovation and its influencing factors. In the third stage, survey data are examined to illuminate the viewpoints of L/ZCB professionals on the observed indicators of BM innovation and its influencing factors. In the fourth stage, SEM is used to estimate the relationships amongst the constructs and the relationships amongst the constructs and their latent unobserved indicators. Finally, the structural model is adjusted and verified via goodness of fit.

[**Insert Fig. 1.** Flowchart of the proposed research methodology]

4.1 Research hypotheses

Seven hypotheses were developed to describe the relationships amongst the influencing factors of BM innovation and the innovative components of BM for L/ZCB. The theoretical framework and the proposed hypotheses are shown in Fig. 2.

[**Insert Fig. 2.** Hypothesis model of the BM innovation for L/ZCB]

H1: A favourable external environment is positively correlated with BM innovation in the context of L/ZCB.

The external business environment has been identified as one of the key elements influencing BM innovation. Institutional theory (e.g., Hargadon and Douglas, 2001) suggested that the viability of a BM depends in part upon the degree to which it complies with external technological, legal, regulatory and industrial framework. The theoretical model of BM innovation process developed by Zhao et al. (2016) showed that changing environmental and social expectations for ZCB have an effect on the central components and processes of a BM, and result in a new set of strategic options and visionary business opportunities. . Liu et al. (2017) found that favorable business environment positively impact the BM innovation of construction when the industry faces the shift of construction method. Amit and Zott (2015) stated that legal, regulatory, technological, and industry norms may exert their impacts on the viability of a new BM. These external factors affect the range of design alternatives of BM that may be considered.

H2: A favourable external environment towards L/ZCB has a positive effect on the entrepreneurship of building companies.

Amit and Zott (2015) suggested that environmental constraints serve as a source of inspiration and creativity for designing innovative solutions, which is one of the premise of entrepreneurship. Demil and Lecocq (2010) stated that top managers should foresee environmental changes, such as the arrival of aggressive new entrants or the increasing cost of some resources, and change their BMs. Casadesus-Masanell and Zhu (2013) argued that changes in technology, globalization and deregulation provide opportunities for firms to search for new virtuous value chains, and the favorable public policy should support entrepreneurial activities that can develop new BMs.

H3: Entrepreneurship is positively correlated with the BM innovation of building companies for L/ZCB.

Literature on the entrepreneurship (e.g. Shane and Venkataraman, 2000) and organisation theory (e.g. Gartner, 1988) have emphasized the importance of entrepreneurship in the exploration of opportunities and the creation of new organisations. Institutional entrepreneurs may view constraints in business environment as stimuli, bring novelty to existing BMs, and create new BMs that attract stakeholders (Amit and Zott, 2015). Nair and Paulose (2014) argued that entrepreneurs enable the emergence of BM for sustainable energy, and bring new product, venture and network into existence.

H4: A favourable external environment towards L/ZCB has a positive effect on the organisational learning capability of building companies.

Earlier studies have demonstrated the impact of external environment on a firm’s underlying core logic and strategic choice. As one of the basic enablers of BM for sustainable energy, flexibility grants an organisation dynamic capabilities for choosing the most productive way of keeping sustainable in the ever-changing socio-technical situation (Nair and Paulose, 2014). BMs for sustainable product/service are often associated with uncertainties and risks in business ecosystem, which cause challenges to current BM and decision making. Learning capability is rooted in an organisation via experimental learning, team building, and participation in brainstorming workshops (Rajala et al., 2016).

H5: The organisational learning capability of building companies is positively correlated with the BM innovation of building companies for L/ZCB.

The concept of organisational learning capability has been suggested as a crucial prerequisite for firms in the need to innovate their BMs (e.g. Doz and Kosonen, 2010). Schneider and Spieth (2013) argued that a firm needs to overcome its internal inertia from various sources throughout its BM transformation process. The firm therefore needs to cultivate its strategic agility and learning capability to proactively foresee and quickly respond to changes in its business environment (e.g., changing market, new technology and competitor). A firm requires strategic agility to accelerate its BM renewal (Doz and Kosonen (2010). The underlying determinants of strategic agility include strategy sensitivity, leadership unity and resource fluidity. Nair and Paulose (2014) stated that a firm's success can be measured by its transitional ability. This dynamic capability enables the firm to implement innovative strategies in the most efficient, cost-effective way and to avoid business slow down.

Based on the prior theoretical knowledge and the hypotheses above, it is indicated that three primary constructs influence BM innovation: 1) external environment, 2) entrepreneurship, and 3) organization learning. In addition, external environment exert its influence on entrepreneurship and organization learning. Hence an indirect causal relationship between external environment and BM innovation may exist. A mediation model can be proposed that external environment influences entrepreneurship and organisation learning, which in turn influences the dependent variable BM innovation. This paper presents the following hypothesis to describe the moderating role of entrepreneurship and organisation learning capability.

H6: The positive relationship between the external environment and BM innovation for L/ZCB will be enhanced when entrepreneurship is high.

H7: The positive relationship between the external environment and BM innovation for L/ZCB will be enhanced when organisational learning capability is high.

4.2 Data collection method for the survey

Questionnaire approach was considered appropriate to collect a team of experts who have rich knowledge and experience in L/ZCB, and analyse individuals' attitudes. Questionnaire was adopted in this paper to achieve two objectives: (1) develop and validate key constructs and indicators and to construct the analytical framework; (2) to prioritize the indicators and elicit experts' assessment of the seven hypothesis in Fig. 2. Based on the refined framework (Table 1), a general questionnaire was designed to investigate the significance of the observed indicators. Questionnaires were distributed to professionals with green building credentials in Hong Kong from early October 2016 via the post, email and an 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 target for reducing energy intensity by 40% by 2025 (Environmental Bureau, 2015). Lots of efforts have been made by the government and the construction industry to achieve carbon reduction. There are totally 1024 registered Building Environmental Assessment Method (BEAM) Plus Projects in Hong Kong up to date. Hong Kong therefore acts as a showcase of latest L/ZCB design, technologies and successful innovative BMs. Hong Kong can also add value to a low carbon development of other Chinese cities. The location map of Hong Kong is presented in Fig. 3. 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 LZEB design and delivery. BEAM professionals were selected as survey target group. According to the BEAM Pro Directory (as of 22 May 2017), excluding the disciplines/members with little relevance to this paper (e.g., landscape architects, town planners, water specialists, electrical engineers), there are 1,880 BEAM Pros. In addition, a snowball sampling strategy was used as a supplement by asking the participants to recommend suitable developers and clients who have rich experience in L/ZCB projects.

[**Insert Fig. 3.** Location map of Hong Kong]

A 7-point Likert scale was used to solicit the L/ZCB professionals' attitudes towards the observed indicators. The respondents were invited to evaluate the level of significance of indicators by assigning a score between 1 and 7 (7 = most important and 1 = extremely unimportant). The questionnaire includes two parts: first, participants' general information, including primary area of practice, role in the organisation, work experience and experience in L/ZCB; second, participants' perceptions of the significance of the indicators. By late March 2017, 1,910 questionnaires had been sent out and 138 responses had been received. Six invalid responses were removed due to incomplete responses or erroneous use of the rating scale, which yielded 132 valid responses and a net response rate of 6.9%. The critical rating was fixed at 4. Table 2 shows the demographic information of the respondents.

Table 2. 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 L/ZCB	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	

4.3 Data analysis of the survey

SEM is a multivariate modelling method that is used to evaluate the validity of substantive theories with empirical data. SEM extends the general linear modelling methods (such as analysis of variance and multiple regression analysis) and accounts for the modelling of interactions, nonlinearities, correlated independents, measurement error, correlated error terms and multiple latent independents, each measured by multiple indicators. SEM can be understood as a powerful combination of factor analysis, multiple regression, path analysis, time series analysis and analysis of covariance. The measurement model in SEM can be used to estimate relationships amongst latent constructs and their observed indicators, and the structural model in SEM allows estimation of the relationships amongst constructs. SEM has been applied in research studies on L/ZCB development and business management and could thus be used to achieve the research objectives: first, to validate the measurement model and estimate the relationships amongst unobserved variables and observed indicators with confirmatory factor analysis (CFA), and second, to examine the structure model and explain the causal dependencies amongst the constructs via path analysis. The overall fit of the measurement model is determined according to reliability and goodness-of-fit indices. Based on a satisfied model fit, the next step is to test the structural equation model and the hypothesised causal relationships amongst unobserved variables. Low correlation paths and associated variables are systematically eliminated to refine the structural equation model. In this study, SPSS 24.0 was used for initial data treatment and AMOS 22.0 for modelling tool.

The data were then randomly split into calibration and validation samples for exploratory factor analysis (EFA) and CFA, respectively. The Shapiro-Wilk normality test was conducted to check the data's normality. For the data to be appropriately normal, the significance values on the Shapiro-Wilk test should be greater than 0.05 (Royston, 1982).

5. Analysis results of the survey data

The adequacy of the initial structural model hypothesised in Fig. 1 was tested using individual variable reliability analysis, convergent validity measures of the indicators and the discriminant validity of the measurement model. The results are shown in the following sections.

5.1 Data normality and suitability

EFA was used to explore the latent factors that underlie the observed indicators in Table 1 and to verify the variables set in the preliminary model. The suitability of the collected data was analysed to determine whether the data were suitable for EFA. First, the factorability of the dataset was examined. The significance value of the Bartlett test of sphericity should be smaller than 0.05, and the measure of sampling adequacy calculated using Kaiser-Meyer-Olkin (KMO) value should be greater than 0.5. A KMO value of 0.5 or above is acceptable, 0.7 or above is middling and 0.8 or above is meritorious. The results of the Bartlett and KMO tests are shown in Table 3. The results show that substantial correlations exist amongst some of the observed indicators. Moreover, in the correlation matrix, correlation coefficients of 0.3 and above were found amongst the indicators. According to Oladinrin and Ho (2015), the results suggest that the data set was suitable for EFA.

Table 3. KMO and Bartlett Test for observed indicators

Measure of sampling adequacy	Value
Kaiser-Meyer-Olkin (KMO)	0.852
Bartlett test of sphericity	-
Approx. chi-square	357.002
Degrees of freedom	354
Significance	0.000

5.2 Indicator grouping and construct scale

EFA was used to explore the latent factors that underlie the observed indicators in Table 1 and to verify the variables that are set in the preliminary model. First, the principle components of the external environment were examined. The calibration sample of 132 was almost eight times that of the observed indicators and above the safe threshold of 5:1 (Oke et al., 2012). Varimax rotation of the factor axes was conducted with Kaiser normalisation to clarify the pattern of the loadings. Second, the principle components of BM innovation for L/ZCB were extracted. The cut-off threshold of factor loading was set as 0.4, with values above 0.5 considered to be more significant (Zahoor et al., 2017; Hair et al. 2014). The EFA results are tabulated in in Tables 4 and 5. Eigenvalues and the scree test were used for factor retention. For the influencing factors of BM innovation in the external environment, the four-factor solution comprising 17 items explained a total variance of 91.64%. The construct of the external environment consisted of four components: market and economic, policy and legislation, technology and industry and sociocultural aspects. For the BM innovation for L/ZCB, the three-factor solution comprising 10 items explained a total variance of 59.27%, which is nearly 60% (Oladinrin and Ho 2015). The three major factors 1, 2 and 3, representing value proposition, value delivery and revenue and cost structure, respectively, explained variances of 41.18%, 10.19% and 7.90%, respectively. Similarly, the EFA results show that 'entrepreneurship' and 'organisation learning capability' are single-factor constructs.

Table 4. Rotated factor matrix of influencing factors in external environment

Influencing factors[a] in external environment	Factor				Communalities
	1	2	3	4	
ME1	**0.645**	0.097	0.269	0.200	0.591
ME2	**0.748**	0.308	0.094	0.109	0.681
ME3	**0.556**	0.203	0.328	0.268	0.608
ME4	**0.755**	0.191	0.177	0.164	0.663
ME5	**0.695**	0.181	0.096	0.147	0.527
PL1	0.212	0.103	0.010	**0.636**	0.598
PL2	0.050	0.084	0.148	**0.813**	0.736
PL3	0.129	0.169	0.011	**0.782**	0.678
PL4	0.199	0.029	0.114	**0.748**	0.685
TI1	0.428	**0.633**	0.093	0.113	0.743
TI2	0.279	**0.727**	0.128	0.080	0.734
TI3	0.127	**0.778**	0.266	0.007	0.675
TI4	0.104	**0.665**	0.221	0.227	0.616
SC1	0.129	0.193	**0.866**	0.015	0.787
SC2	0.282	0.244	**0.653**	0.117	0.542
SC3	0.379	0.265	**0.673**	0.122	0.656
SC4	0.164	0.028	**0.649**	0.279	0.754

Note[a]: Codes of influencing factors are defined in Table 1.
Note[b]: KMO measure of sampling adequacy=0.874; Bartlett's test of sphericity: approximately Chi-Square=922.771, df=153, Significance=0.000.

Table 5. Rotated factor matrix of BM innovation for L/ZCB

Innovative components of BM for L/ZCB[a]	Factor			Communalities
	1	2	3	
VP1	**0.860**	0.109	0.128	0.582
VP2	**0.491**	0.141	0.285	0.571

VP3	**0.706**	0.130	0.253	0.572
VD1	0.264	**0.672**	0.152	0.561
VD2	0.264	**0.445**	0.307	0.434
VD3	0.112	**0.670**	0.165	0.591
VD4	0.081	**0.658**	0.060	0.584
VD5	0.173	**0.578**	0.309	0.422
RC1	0.313	0.388	**0.496**	0.489
RC2	0.298	0.241	**0.658**	0.528

Note[a]: Codes of components of BM are defined in Table 1.

Note[b]: KMO measure of sampling adequacy=0.867; Bartlett's test of sphericity: approximately Chi-Square=436.612, df=55, Significance=0.000.

5.3 Validity and reliability of the measurement model

The measurement model entailed the postulated factor associations amongst the observed indicators and first-order latent variables. CFA was conducted on the validation sample to determine whether the data fit the hypothesised measurement model. Two tests – indicator reliability and convergent reliability – were used to determine the validity of the measurement model. Indicator reliability is measured by the correlation of an indicator with its respective construct (Hair et al., 2014). Higher loadings on a construct suggest that the associated indicators have much in common and that they are captured by the construct (Mojtahedi and Oo, 2017).

Convergent validity is estimated to ensure that the indicators are assumed to measure each respective construct and not another construct (Hulland, 1999). Two indices were used to determine convergent validity: (1) the composite reliability score and Cronbach's alpha for the constructs and (2) the average variance extracted (AVE). It was calculated using:

$$\text{CR}=SSI/\left(SSI+SEV\right) \quad (1)$$

$$SEV=\sum_{i=1}^{K}\left(1-\text{factor loading}_i^2\right) \quad (2)$$

where SSI = square of the sum of all factor loadings of a construct, SEV = sum of all error variances of a construct, and error variance is equal to one minus squared multiple correlation. CR should preferably be higher than AVE (Awang, 2012). Cronbach's alpha values were calculated for each extracted factor and for the complete dataset to test the internal consistency reliability of the dataset. A conservative value of 0.7 was set as the benchmark (Tavakol and Dennick, 2011). The AVE measures the level of variance captured by a construct versus the level due to measurement error. AVE can be calculated as follows:

$$\text{AVE}=\sum_{i=1}^{K}\text{factor loading}_i^2/(\sum_{i=1}^{K}\text{factor loading}_i^2+\text{SEV}) \quad (3)$$

An AVE value of greater than 0.5 is acceptable, which indicates that the construct explains more than half of the variance of its indicators. The results are summarised in Table 6.

Table 6. Construct reliability and validity test

Construct	CA	CR	AVE	Indicator item	Factor loading
Business environment	0.896	0.951	0.538	M1	0.69
				M2	0.75
				M3	0.72
				M4	0.71
				M5	0.59
				P1	0.79
				P2	0.81
				P3	0.77
				P4	0.87
				T1	0.77
				T2	0.73
				T3	0.70
				T4	0.60
				SC1	0.71
				SC2	0.63
				SC3	0.78
				SC4	0.79
Entrepreneurship	0.726	0.843	0.520	E1	0.83
				E2	0.75
				E3	0.68
				E4	0.64
				E5	0.69

Organisation learning	0.778	0.837	0.510	OL1	0.76
				OL2	0.71
				OL3	0.80
				OL4	0.57
				OL5	0.71
BM innovation	0.856	0.919	0.535	VP1	0.70
				VP2	0.65
				VP3	0.86
				VD1	0.80
				VD2	0.71
				VD3	0.64
				VD4	0.67
				VD5	0.67
				RC1	0.78
				RC2	0.80

The Cronbach's alpha value for the complete set (0.893) was higher than 0.7, and the Cronbach's alpha values for each construct are also higher than 0.7. The result of AVE and the composite reliability scores are also above the threshold. Moreover, the factor loadings of all of the indicators exceed the minimum loading requirement of 0.5 (Fornell and Larcker, 1981), which indicates that internal reliability and validity was achieved.

In addition, the discriminant validity was tested by comparing the square root of AVE for each construct with the latent variable correlations according to the Fornell-Larcker criterion. The largest correlation between BM innovation and another construct (0.59) is smaller than the square root of its AVE (0.731). The greatest correlation between the external environment and another construct (0.71) is smaller than the square root of its AVE (0.733), which suggests discriminant validity. These results indicate that all indicators loaded distinctly on their specified construct and thus demonstrate a satisfactory discriminant validity of the constructs.

Because formative constructs are estimated as the linear combination of their variables, the collinearity problem should be tested. The variance inflation factors of all of the indicators range from 1.590 to 2.849, which are below the threshold level of 5.000 (Wong 2013). The results indicate that collinearity is not a concern. Taken together, these results suggest that the developed measurement model is valid and eligible for structural model estimation in the next step.

5.4 Structural model optimisation

The structural model represents the relationships amongst four first-order latent constructs and seven second-order latent variables. The regression weights amongst the constructs are shown in Table 7.

Table 7. Regression weights among constructs and latent variables in structural model

Parameters	Relationships among constructs and variables	Weights	
		Initial model	Revised model
γ_{11}	ME ← External environment	0.83***	0.86***
γ_{12}	PL ← External environment	0.48***	0.78***
γ_{13}	TI ← External environment	0.80***	0.77***
γ_{14}	SC ← External environment	0.86***	0.77***
β_{21}	VP ← BM innovation for L/ZCB	0.96***	0.69***
β_{22}	VC ← BM innovation for L/ZCB	0.94***	0.95***
β_{23}	RC ← BM innovation for L/ZCB	0.93***	0.86***
H1	BM innovation for L/ZCB ← External environment	0.71***	0.74***
H2	Entrepreneurship ← External environment	0.16^{ns}	0.39***
H3	BM innovation for L/ZCB ← Entrepreneurship	0.04^{ns}	0.59***
H4	Organisational learning ← External environment	0.06^{ns}	0.24**
H5	BM innovation for L/ZCB ← Organisational learning	0.30**	0.68***

Note: ***p<0.01; **p<0.05; ns- not significant.

Table 7 shows that H2, H3 and H4 are unacceptable in the initial hypothetical model. To refine the model, low correlation paths and associated indicators were systematically eliminated from low to high. OL2, OL4 and VC3 were eliminated successively by their regression weights. Although this step can be continued to obtain a more significant level of probability, key indicators and relationships could be lost in this process.

A list of goodness-of-fit indices was used to assess the fitness of the structural model (Wang et al., 2016), including the minimum discrepancy divided by its degrees of freedom (χ2/df), root mean square error of approximation (RMSEA), goodness-of-fit index(GFI), adjusted goodness-of-fit index (AGFI), normed fit index (NFI), Tucker-Lewis index (TLI), comparative fit index (CFI), and incremental fit index (IFI). The test results are used to evaluate whether the structural model is appropriate or requires optimisation. The results are shown in Table 8.

Table 8. Goodness-of-fit

Index	Reference	Initial model	Revised model
χ^2 / df	1-2	1.046	1.040
RMSEA	<0.05, close approximate fit; 0.05-0.08, reasonable approximate fit; 0.08-0.1, acceptable fit	0.019	0.017
GFI	>0.90	0.866	0.886
AGFI	>0.70	0.831	0.849
NFI	>0.70	0.775	0.816
TLI	>0.90	0.985	0.989
CFI	>0.90	0.987	0.991
IFI	>0.90	0.982	0.991

Table 8 shows significant improvement of the goodness-of-fit in the revised model. The results show that all the goodness of fit indices in the revised model possess a score of over 0.8, indicating good validity. The index χ^2 / df should not exceed 2. RMSEA is an index sensitive to the number of parameters estimated in the model, so it help choose a parsimonious model. An RMSEA index 0.017 shows a good fit. GFI measures the proportion of variance that can be accounted for by the model. A cutoff value of 0.9 is normally recommended, therefore a value close to 0.886 suggests the improved goodness of fit. CFI, as one of the incremental fit indices, is used to examine the discrepancy between the data and the hypothesized model. A value over 0.95 can ensure a poorly specified model is detected and not accepted. The estimates and significance levels in the path diagram of the revised model of BM innovation for L/ZCB are presented in Fig. 4.

[**Insert Fig. 4.** Estimates and significance levels in the path diagram of the revised model]

The results show that five research hypotheses (H1 through H5) were fully supported. For H1, the positive effect of the external business environment on BM innovation for L/ZCB was shown to be significant, with a path coefficient of 0.75 ($p<0.01$). A path coefficient of 0.59 ($p<0.01$) between the external business environment of L/ZCB and the entrepreneurship of an organisation supports H2. A path coefficient of 0.34 ($p<0.05$) also supports the positive effect of the external environment on organisational learning capability (H4). For H3, the entrepreneurship of an organisation proved to have a positive effect on BM innovation for L/ZCB (path coefficient of 0.59; $p<0.01$). For H5, the results show a significant relationship between an organisation's learning capability and BM innovation (path coefficient, 0.88; $p<0.01$).

5.5 Analysis of mediation effects

Under the influence of certain external environment of L/ZCB, an organisation with better entrepreneurship can lead to better performance in BM innovation for L/ZCB. Likewise, an organisation with better learning capability can lead to better performance in BM innovation. The reason can be investigated through a mediation model. The extent to which the variance of the dependent construct (BM innovation for L/ZCB) was directly explained by the independent construct (external environment) and how much of the construct's variance (BM innovation) was explained by the indirect relationship via the mediator constructs (i.e. entrepreneurship and organisational learning capability) could be determined. Direct and indirect effect and significance of each path were tested using the Bootstrap procedure, the results of which are summarized in Table 9.

Table 9. Results of mediating effects

Hypothesis	Direct effect (External environment→ BM innovation)	Indirect effect	R-square	Result
External environment→ Entrepreneurship→ BM innovation for L/ZCB	0.206**	0.702***	0.533	Partial mediation
External environment→ Organisational learning→BM innovation for L/ZCB	0.391***	0.750***	0.660	Partial mediation

Note: ***p<0.01;**p<0.05

Table 9 shows that the external environment had a significant effect on an organisation's entrepreneurship and learning capability, which in turn had significant effects on BM innovation for L/ZCB. The indirect effect of the external environment (i.e., 0.702; $p<0.01$) via the mediator construct 'entrepreneurship' was significant, and the effect of entrepreneurship on BM innovation remained significant (path coefficient, 0.206; $p<0.01$). Hence, the construct entrepreneurship partially mediated the relationship between the external environment and BM innovation, which provides empirical evidence for H6.

Similarly, the indirect effect of the external environment (path coefficient, 0.750; $p<0.01$) via the mediator construct 'organisational learning' was also significant. Thus, the construct 'organisational learning' fully mediated the relationship between the external environment and BM innovation; thus, H7 is accepted.

6. Discussion

The results of the SEM analysis confirm the positive effects of the external business environment, entrepreneurship and organisational learning capability on BM innovation for L/ZCB. All regression weights amongst the parameters in the measurement and structural equation models are nonzero at the level of 90% probability. The two parts of the structural model are discussed in following sections.

6.1 Effect of external influencing factors on BM innovation

The market and economic category receives the highest weight (0.86), which suggests that the market- and economic-related factors are amongst the key determinants of the uptake of L/ZCB. The results are consistent with those studies that argued that a building market's demand for L/ZCB and customers' willingness to pay greatly affect the adoption of L/ZCB (e.g. Berry and Davidson, 20159). As investors and occupiers become more knowledgeable about and concerned with the social and environmental effects of buildings, L/ZCB will enjoy increased marketability. The policy and legislation category is ranked second (0.78) amongst the external influencing factors. It is commonly believed that policy instruments for low- or zero-carbon are amongst the key determinants of the L/ZCB development (e.g. Al-Saleh and Mahroum, 2014; Pan and Ning, 2015). Companies introduce BM reconfiguration or brand-new BMs to create and capture value from green-policy instruments. The industrial and sociocultural aspects were also considered significant in influencing BM innovation, which is consistent with the theoretical frameworks developed by Hofstede (2001) and Elenkov and Manev (2005). Sociocultural aspects such as uncertainty avoidance and long-term orientations act as factors at the external environmental level that influence managerial choices and organizational innovation. Although recent studies posited that organization innovation may greatly vary in different sociocultural contexts, it is commonly agreed that sociocultural context can explain a significant amount of variance in BM innovation for L/ZCB. The social cognition and the public's attitudes towards low or zero carbon technologies are important driving forces of L/ZCB.

6.2 Mediating roles of entrepreneurship and organisation learning capability

The results of the mediation effect not only validate the role of organisations' entrepreneurship (with path coefficient 0.59) and learning capabilities (with path coefficient 0.88) in influencing BM innovation for L/ZCB but also confirm the mediating role of entrepreneurship and organisational learning between the external business environment and BM innovation. The effects of entrepreneurship and organisational learning on an organisation's BM innovation are consistent with the findings of earlier management literature such as Schneider and Spieth (2013). The results proves that organisational learning capability has a greater effect than entrepreneurship on an organisation's BM innovation in L/ZCBs. The results highlight that an organisation's top manager must possess the ability and initiative to recognise the need for low- or zero-carbon transition promptly and must be willing to implement new technologies to successfully innovate their BM, which is consistent with previous studies (e.g. Cavalcante et al., 2014). In addition to top managers' influence, the results of this paper show that an organisation's dynamics, resources and capabilities strongly influence the creation and development of innovative business strategies and BMs for L/ZCBs. Research into BM dynamics could shed light on the phenomena (e.g. Chesbrough, 2010; Osterwalder and Pigneur, 2010). Inability to adapt existing resources and capabilities to complex change and the current BM's constraining effect on potential new ideas are the main barriers for BM innovation in organisations. For instance, current staff might unfamiliar with new low- or zero carbon technologies and complicated construction processes.

This study empirically evidences the mediating role played by entrepreneurship and the organisational learning capability on the relationship between the external environment and BM innovation in the context of L/ZCB. The results suggest that the effects of the external business environment on an organisation's BM innovation for L/ZCB may be partly explained in relation to the organisation's internal characteristics in terms of entrepreneurship and organisational learning capability. Without the entrepreneurship and organisational learning capability, external environment could only explain much less variance in the BM innovation (e.g. path coefficient 0.702 vs. 0.206 without the mediation of entrepreneurship). The results also explain why, under the same external environment on L/ZCB, some firms can succeed in innovating BMs for L/ZCB projects while others fail. A firm with better strategic sensitivity, leadership unity and resource fluidity can proactively anticipate and react quickly to changes in its external environment (e.g. Doz and Kosonen, 2010; Schneider and Spieth, 2013), and eventually facilitate the process of BM innovation.

6.3 Main innovative components of BM in the context of L/ZCB

This study provides empirical evidence to support the claim that the core components of BM innovation for L/ZCB can be categorised into innovations in value proposition, value delivery, revenue and cost structure. Innovation in revenue and cost structure is prioritised as the most important element in BM innovation for L/ZCB (with weight of 0.86), which is consistent with findings such as Torcellini et al. (2015) and Berry and Davidson (2015). Whether the company can convert L/ZCB and its related services into economic value is the main concern of developers and other key stakeholders. The respondents were willing to reconfigure their BMs as long as there is channels to commercialize L/ZCB. Therefore, a wide range of cost-control strategies is needed to inspire confidence in the broad feasibility of ZCB. Businesses can extract returns from their services/solutions provided to customers during the ZCBs' lifecycle stages. Previous studies (e.g. Zhao and Pan, 2017) have shown that means of revenue generation in BMs have evolved from building product transactions to long-term relationship-based services.

Innovation in value delivery is ranked second amongst the components of BM innovation (finalised weight, 0.78). Value delivery is at the heart of a BM and describes the conversion of a firm's resources and capabilities into new revenue streams. Previous studies have demonstrated that a sustainable BM solution for L/ZCB can be achieved by partnering with other stakeholders (Pless et al., 2014) and making use of collaborative designs and integrated solutions (Zhao et al., 2016). For example, as an innovative BM for L/ZCB, Energy Contracting BM incorporates Energy Service company as a general contractor and provide a customized service package to end user. The value proposition category is typically concerned with the innovative characteristics of L/ZCB and its related services that are offered to customers, which encompasses the ecological and social values of L/ZCB, the direct and indirect benefits of L/ZCB, target customer and customer relations (e.g. IEA-RETD, 2013). By choosing appropriate target customers and providing differentiated value to customers, the negative factors of L/ZCB (e.g., high up-front costs, longer payback period) can be overcome at some extent. For example, consumer cooperative BM provides and installs energy efficiency/renewable energy systems on building under a third party fee-for-service arrangement (APEC, 2009). It provides a means for environmental-motivated customers to support L/ZCB development at relatively low costs.

7. Conclusions

This study investigates the relationships amongst BM innovation for L/ZCB and its influencing factors in the external environment and organisation internal characteristics. Based on the results of EFA and CFA, 25 influencing factors were identified and categorised into six groups: (i) market and economic, (ii) policy and legislation, (iii) industry and technology, (iv) sociocultural aspects, (v) entrepreneurship and (vi) organisational learning. Nine indicators to measure BM innovations for L/ZCB were identified and categorised into three groups: (i) innovations in value proposition, (ii) innovations in value delivery and (iii) innovations in revenue and cost structure.

The path modelling results of SEM show that: (1) the external environment of L/ZCB has a significant effect on an organisation's BM innovation for L/ZCB; (2) the external environment of L/ZCB has a considerable effect on an organisation's entrepreneurship; (3) the external business environment has a positive effect on an organisation's learning capability; (4) an organisation's entrepreneurship has a considerable effect on its BM innovation for L/ZCB; and (5) an organisation's learning capability has a significant effect on its BM innovation for L/ZCB.

The results of the mediation model show that both entrepreneurship and organisational learning play mediating roles between the external business environment and BM innovation for L/ZCB. The results indicate that in the favourable external environment of L/ZCB, organisations with better entrepreneurship and learning capability perform better in innovating BMs for L/ZCB.

This study contributes a novel approach to disentangling the complex relationships amongst BM innovation and its influencing factors in the context of L/ZCB. Empirical evidence is provided for building companies and government agencies on the prerequisites and mechanisms of BM innovation in the context of L/ZCB.

Some limitations exist in this study. One of the limitations is the relative limited number of sample size. Although the 132 valid responses meet the requirement of the SEM analysis, a larger sample size helps strength the validity of the model. The other limitation is the demographics of the responses. The data were collected from BEAM professionals in the Hong Kong construction sector. Although the investigated influencing factors and BM innovation components were identified from a comprehensive literature review and are worldwide applicable, the conclusions derived might not be applicable to other regions. The change of respondents in other economies might influence the perceived impacts of external environment, entrepreneurship and organization learning on BM innovation. Future research therefore may test the applicability of the model in multinational sample.

References

Abdelkafi, N., Täuscher, K., 2016. Business models for sustainability from a system dynamics perspective. Organ. Environ. 29(1), 74-96.
Abuzeinab, A., Arif, M., Qadri, M. A. 2017. Barriers to MNEs green business models in the UK construction sector: An ISM analysis. J. Clean. Prod. 160, 27-37.
Al-Saleh, Y., Mahroum, S., 2015. A critical review of the interplay between policy instruments and business models: greening the built environment a case in point. J. Clean. Prod. 109, 260-270.
Amit, R., Zott, C., 2015. Crafting business architecture: The antecedents of business model design. Strateg. Entrep. J. 9(4), 331-350.
APEC, 2009. Successful Business Models for New and Renewable Energy Technology Implementation in APEC. APEC Energy Working Group, Singapore, October.
Aspara, J., Lamberg, J.-A., Laukia, A., Tikkaen, H., 2013. Corporate business model transformation and inter-organizational cognition: the case of nokia. Long Range Plan. 46(6), 459-474
Awang, Z., 2012. Structural equation modeling using AMOS graphic. Universiti Teknologi MARA Publication Centre, Shah Alam, Malaysia.
Berry, S., Davidson, K., 2015. Zero energy homes–Are they economically viable?. Energy Pol. 85, 12-21.
Bocken, N. M., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). "Product design and business model strategies for a circular economy." J. Ind. Prod. Eng.,

33(5), 308-320

Bocken, N. M. P., Short, S. W., Rana, P., Evans, S., 2014. A literature and practice review to develop sustainable business model archetypes. J. Clean. Prod. 65, 42-56.

Bocken, N. M. P., Allwood, J., 2012. Strategies to reduce the carbon footprint of consumer goods by influencing stakeholders. J. Clean. Prod., 35 118-129.

Bohnsack, R., Pinkse, J., Kolk, A., 2014. Business models for sustainable technologies: Exploring business model evolution in the case of electric vehicles. Res. Pol. 43(2), 284-300.

Boons, F., Lüdeke-Freund, F., 2013. Business models for sustainable innovation: state-of-the-art and steps towards a research agenda. J. Clean. Prod. 45, 9-19.

Casadesus‐Masanell, R., Zhu, F., 2013. Business model innovation and competitive imitation: The case of sponsor‐based business models. Strategic Manage. J. 34(4), 464-482.

Cavalcante, S. A., 2014. Designing business model change. Int. J. Innov. Manage. 18(02), 1450018.

Chan, E.H., Qian, Q.K., Lam, P.T., 2009. The market for green building in developed Asian cities- the perspectives of building designers. Energy Pol. 37(8), 3061-3070.

Chesbrough, H., 2010. Business model innovation: Opportunities and barriers. Long Range. Plann. 43(2/3), 354-363.

Demil, B., Lecocq, X., 2010. Business model evolution: in search of dynamic consistency. Long Range. Plann. 43(2), 227-246.

Doz, Y.L., Kosonen, M., 2010. Embedding strategic agility: A leadership agenda for accelerating business model renewal. Long Range. Plann. 43(2/3), 370-382.

Elenkov, D. S., Manev, I. M., 2005. Top management leadership and influence on innovation: The role of sociocultural context. J. Manage., 31(3), 381-402.

Environment Bureau, 2015. Energy Saving Plan for Hong Kong's built environment 2015~2025, Hong Kong S.A.R., May.

European Commission, 2010. Directive 2010/31/EU of the European Parliament and of the Council on the Energy Performance of Buildings. European Commission, Brussels.

Fang, D., Wu, C., Wu, H., 2015. Impact of the supervisor on worker safety behavior in construction projects. J. Manag. Eng. 31(6), 04015001.

Fornell, C., Larcker, D.F., 1981. Evaluating structural equation models with unobservable variables and measurement error. J. Mark. Res. 18, 39-50.

Gartner, W.B., 1988. Who is the entrepreneur? is the wrong question. American J. Small Bus. 12, 11-32.

Hair, J. F., Black, W. C., Babin, B. J., 2014. RE Anderson Multivariate data analysis: A global perspective, Seventh edition. Pearson Education, Harlow, Essex.

Hargadon, A.B., Douglas, Y., 2001. When innovations meet institutions: Edison and the design of the electric light. Admin. Sci. Q. 46, 476-501.

Hofstede, G., 2001. Culture's consequences: Comparing values, behaviors, institutions, and organizations across nations. Sage, Thousand Oaks, California.

Hulland, J., 1999. Use of partial least squares (PLS) in strategic management research: A review of four recent studies. Strategic Manage. J. 20(2), 195-204.

IEA-RETD, 2013. Business models for renewable energy in the built environment. Renewable Energy Technology Deployment, International Energy Agency, Routledge.

Jolly, S., Raven, R., Romijn, H., 2012. Upscaling of business model experiments in off-grid PV solar energy in India. Sustain. Sci. 7(2), 199-212.

Kujala, S., Artto, K., Aaltonen, P., Turkulainen, V., 2010. Business models in project-based firms–Towards a typology of solution-specific business models. Int. J. Proj. Manage. 28(2), 96-106.

Lambert, S. C., Davidson, R.A., 2013. Applications of the business model in studies of enterprise success, innovation and classification: An analysis of empirical research from 1996 to 2010. Eur. Manage. J. 31(6), 668-681.

Liu, G., Li, K., Zhao, D., Mao, C. 2017. Business model innovation and its drivers in the Chinese construction industry during the shift to modular prefabrication. J. Manag. Eng. 33(3), 04016051.

Lützkendorf, T., Fan, W., Lorenz, D., 2011. Engaging financial stakeholders: opportunities for a sustainable built environment. Build. Res. Inf. 39(5), 483-503.

Massa, L., Tucci, C.L., 2013. Business model innovation. The Oxford Handbook of Innovation Management, Oxford University Press, Oxford, 420-441.

Mojtahedi, M., Oo, B.L., 2017. The impact of stakeholder attributes on performance of disaster recovery projects: The case of transport infrastructure. Int. J. Proj. Manag. 35(5), 841-852.

Moore, T., 2012. Facilitating a transition to zero emission new housing in Australia: Costs, benefits and direction for policy, Doctoral dissertation, Royal Melbourne Institute of Technology University, Australia.

Nair, S., Paulose, H., 2014. Emergence of green business models: the case of algae biofuel for aviation. Energy Pol. 65, 175-184.

Oke, A. E., Ogunsami, D. R., Ogunlana, S., 2012. Establishing a common ground for the use of structural equation modelling for construction related research studies. Constr. Econ. Build. 12(3), 89-94.

Oladinrin, O. T., Ho, C.M., 2015. Critical enablers for codes of ethics implementation in construction organizations. J. Manag. Eng. 32(1), 04015023.

Osmani, M., O'Reilly, A., 2009. Feasibility of zero carbon homes in England by 2016: A house builder's perspective. Build. Environ. 44(9), 1917-1924.

Osterwalder, A., Pigneur, Y., 2010. Business model generation: a handbook for visionaries, game changers, and challengers. John Wiley & Sons, Hoboken, New Jersey.

Paiho, S., Abdurafikov, R., Hoang, H., Kuusisto, J., 2015. An analysis of different business models for energy efficient renovation of residential districts in Russian cold regions. Sustain. Cities Soc. 14, 31-42.

Pan, W., Dainty, A. R., Gibb, A.G., 2012. Establishing and weighting decision criteria for building system selection in housing construction. J. Constr. Eng. Manag. 138(11), 1239-1250.

Pan, W., Goodier, C., 2011. House-building business models and off-site construction take-up. J. Archit. Eng. 18(2), 84-93.
Pan, W., Ning, Y., 2015. A socio-technical framework of zero-carbon building policies. Build. Res. Info. 43(1), 94-110.
Pless, S., Scheib, J., Torcellini, P., Hendron, B., Slovensky, M., 2014. NASA Net Zero Energy Buildings Roadmap (No. NREL/TP-5500-60838). National Renewable Energy Laboratory (NREL), Golden, CO.
Porter, M. E., Kramer, M. R., 2011. Creating shared value: Redefining capitalism and the role of the corporation in society. Harvard Bus. Rev. 89(1/2), 62-77.
Rajala, R., Westerlund, M., Lampikoski, T., 2016. Environmental sustainability in industrial manufacturing: re-examining the greening of Interface's business model. J. Clean. Prod. 115, 52-61.
Rauter, R., Jonker, J., Baumgartner, R. J., 2017. Going one's own way: drivers in developing business models for sustainability. J. Clean. Prod. 140, 144-154.
Richter, M., 2013. Business model innovation for sustainable energy: German utilities and renewable energy. Energy Pol. 62, 1226-1237.
Schaltegger, S., Lüdeke-Freund, F., Hansen, E. G., 2012. Business cases for sustainability: the role of business model innovation for corporate sustainability. Int. J. Innov. Sustain. Dev. 6(2), 95-119.
Schneider, S., Spieth, P., 2013. Business model innovation: towards an integrated future research agenda. Int. J. Innov. Manag. 17(01), 1340001.
Shane, S., Venkataraman, S., 2000. The promise of entrepreneurship as a field of research. Acad. Manage. Rev. 25(1), 217-226.
Shi, Q., Chen, J., Shen, L., 2017. Driving factors of the changes in the carbon emissions in the Chinese construction industry. J. Clean. Prod. 166, 615-627.
Shilei, L., Yong, W., 2009. Target-oriented obstacle analysis by PESTEL modeling of energy efficiency retrofit for existing residential buildings in China's northern heating region. Energy Pol. 37(6), 2098-2101.
Tavakol, M., Dennick, R., 2011. Making sense of Cronbach's alpha. Int. J. Med. Educ. 2, 53.
Teece, D. J., 2010. Business models, business strategy and innovation. Long Range Plann. 43(2), 172-194.
Torcellini, P., Pless, S., Leach, M., 2015. A pathway for net-zero energy buildings: creating a case for zero cost increase. Build. Res. Inf. 43(1), 25-33.
Wainstein, M. E., Bumpus, A. G., 2016. Business models as drivers of the low carbon power system transition: a multi-level perspective. J. Clean. Prod. 126, 572-585.
Wang, Y., Han, Q., de Vries, B., Zuo, J., 2016. How the public reacts to social impacts in construction projects? A structural equation modeling study. Int. J. Proj. Manag. 34(8), 1433-1448.
Wong, K. K. K., 2013. Partial least squares structural equation modeling (PLS-SEM) techniques using SmartPLS. Mark. Bull., 24(1), 1-32.
Wong, P. S., Zapantis, J., 2013. Driving carbon reduction strategies adoption in the Australian construction sector- The moderating role of organizational culture. Build. Environ. 66, 120-130.

Yuan, X., Zuo, J., 2011. Transition to low carbon energy policies in China- from the Five-Year Plan perspective. Energy Pol. 39(6), 3855-3859.

Zhang, L., Li, Q., Zhou, J., 2017. Critical factors of low-carbon building development in China's urban area. J. Clean. Prod. 142, 3075-3082.

Zhao, X., Pan, W., 2017. Co-productive Interrelations between business model and zero carbon building: A conceptual model. Built Environ. Proj. Asset Manag., In press.

Zhao, X., Pan, W., Lu, W., 2016. Business model innovation for delivering zero carbon buildings. Sustain. Cities Soc. 27, 253-262.

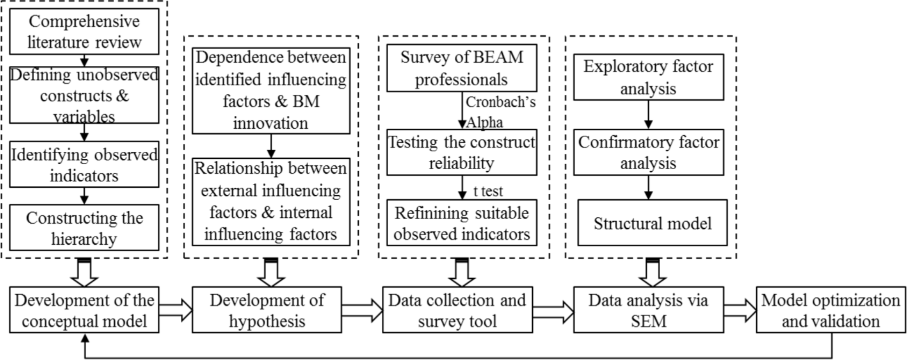
Zott, C., Amit, R., 2010. Business model design: an activity system perspective. Long Range Plann. 43(2), 216-226.

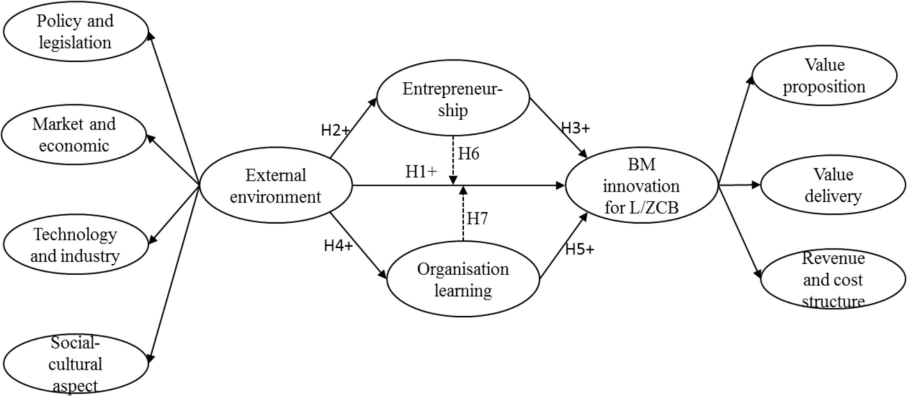
Zou, P.X., Morshed, A.L.A.M., Van Manh Phung, D.W., Stewart, R., 2017. Achieving energy efficiency in government buildings through mandatory policy and program enforcement 2017, Front. Eng. Manag. 4(1), 92-103.

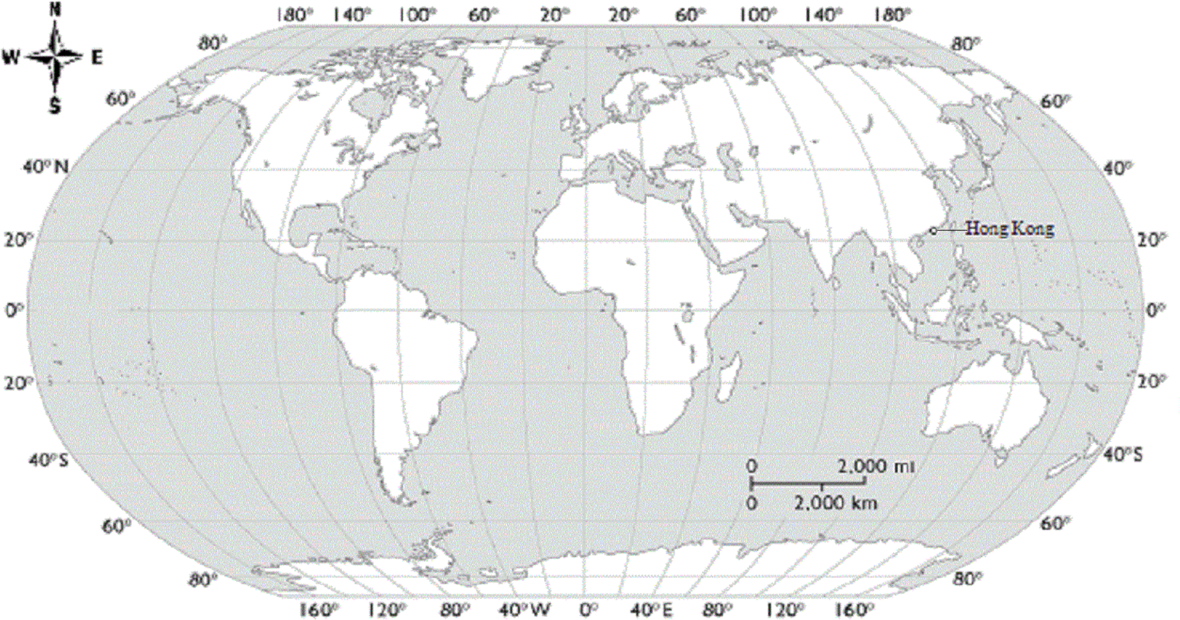
Zuo, J., Zhao, Z. Y., 2014. Green building research- current status and future agenda: A review. Renew. Sustainable Energy Rev. 30, 271-281.

Highlights

- Business model (BM) innovation helps deliver low or zero carbon building (L/ZCB).
- SEM is used to measure the relationships among BM innovation and its antecedents.
- External business environment influences firms' BM innovation for L/ZCB.
- Entrepreneurship and learning capability of a firm influence its BM innovation.
- Entrepreneurship and organisation learning mediate between BM and external environment.


Comprehensive literature review
Defining unobserved constructs & variables
Identifying observed indicators
Constructing the hierarchy
Dependence between identified influencing factors & BM innovation
Relationship between external influencing factors & internal influencing factors
Survey of BEAM professionals
Cronbach's Alpha
Testing the construct reliability
t test
Refinining suitable observed indicators
Exploratory factor analysis
Confirmatory factor analysis
Structural model
Development of the conceptual model
Development of hypothesis
Data collection and survey tool
Data analysis via SEM
Model optimization and validation


Policy and legislation
Market and economic
Technology and industry
Social-cultural aspect
External environment
Entrepreneur-ship
Organisation learning
H1+
H2+
H3+
H4+
H5+
H6
H7
BM innovation for L/ZCB
Value proposition
Value delivery
Revenue and cost structure



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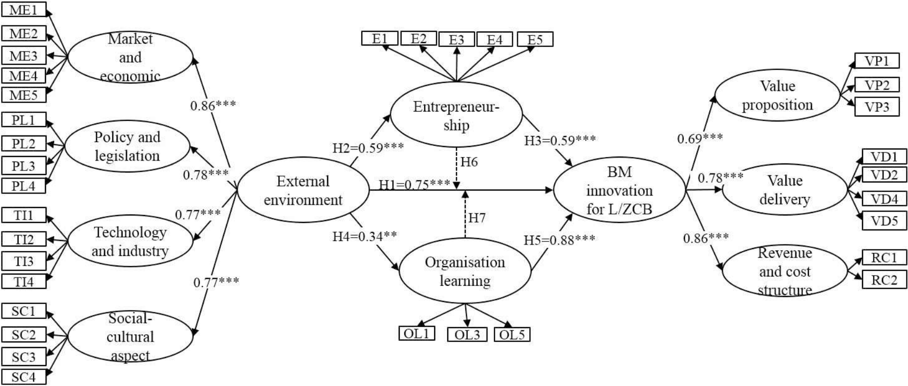
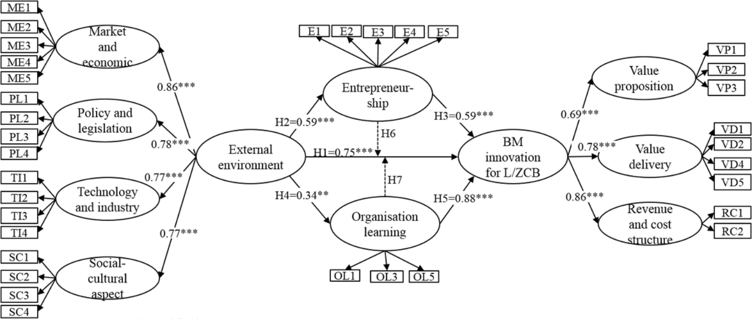


Note: ***p<0.01, **p<0.05, → mediating effect



Note: ***p<0.01, **p<0.05, → mediating effect