Heliyon 9 (2023) e13386

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Structured mathematical modelling on innovation management in project-oriented small construction firms

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ARTICLE INFO

Keywords:
Innovation management
Networking
Organizational performance
Project-based firms
Small firms
SME

ABSTRACT

The significance of innovation management in triggering and sustaining increase in corporations of distinct size, age or enterprise type, is receiving growing attention, yet scant empirical research have been carried out in project-oriented service firms, in particular small-scaled enterprises. This study aims to identify how innovation management in small construction firms could enable them to pursue innovation and achieve greater business performance. Data collection comprises 157 empirical surveys leading to a conceptual framework modelled using the structural equation modelling approach. The findings show that entrepreneurship and networking have a direct and considerable influence on both technological and non-technological innovation, which consequently improves firm performance.

1. Introduction

With the increasing literature on service innovation, project-oriented industry is getting growing attention [1,2] for their unique and ideal setting in capturing the knowledge concerning service-centric innovation. In this respect, the features of project-based service firms have been identified in their distinct nature of organizing task around one-off projects, delivering specific services upon adaptable and flexible mechanism, and often co-creating outputs with the customer [3,4]. Most manufacturing firms have input and output innovations [5]. Different from functionally organized firms where innovation is largely an in-firm problem, the project-based innovations exclusively depend on the external complex environment inherited with in-situ production and temporary coalitions of varying businesses [6,7]. Despite the myriad discussions on innovative aspects of project-based service firms, several gaps require attention [8]. First, most attempts to conceptualizing innovation in project-based sectors are based predominantly on manufacturing orthodoxies [9]. Variables consistently linked with firms' innovative activities are the patentable, technical advancements [4] originating from traditional science-based output metrics. Reflecting characteristics unique to service settings such as the incremental and continuous nature of innovative endeavours and the absence of R&D-centred efforts [7]. Existing literature on innovation focuses on its technical content, including product and process innovation, but little is known about the impact of management innovation practices on other dimensions of innovation [10]. The project-based firms inherently innovate differently from those in manufacturing [11]. Innovation is not limited to a company's technological system, it is also recognized for changes in the organization itself and its structure [12]. Besides casting doubts on these approaches over their appropriateness for measuring

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https://doi.org/10.1016/j.heliyon.2023.e13386
Received 10 April 2022; Received in revised form 8 January 2023; Accepted 27 January 2023
Available online 31 January 2023

innovation [13], there is a need to clearly identify how project-based firms benefit from non-technological advances in order to better conceptualize this service-specific innovation [14].

Moreover, the construction innovation-based performance literature usually dominates on determining the innovation success factors. Rarely are these found to be connected with theoretical view of firms [15]. Specifically, the role of entrepreneurship in nurturing firms' capability to discern unique value to their customers, both in services context [16] and small-scaled firms [17], warrant further examination. Further, the capability to purposefully utilize external linkages with multiple actors has suggested to be beneficial to innovation practices in project-oriented environments [18–20]. Kafetzopoulos and Skalkos [21] point out that strategies based on the introduction and implementation of new management innovation processes are important predictors of small business marketing innovation. While the literature remains inconclusive in featuring such innovation strategy, this study intends to capture the essence of prior work in the project-based construction settings. Rather, in light of these gaps, this study aims to mould a theoretical framework that simultaneously examines antecedents and consequences of construction innovations by drawing on the theoretical capability-based view (CBV). Such view has established that how firms gain prominent role in continually changing environments through their build-up capabilities according to Wernerfelt [22]. This study, dealing with managerial innovation, finds that management innovation plays a central role in the effectiveness of different types of innovation and overall organizational performance [23]. In this view, we made a clear analysis of the relationships among entrepreneurship, networks, construction innovation and organizational performance, Fig. 1 illustrates the framework proposed in this study. Placing our findings within the SME setting, we conjecture that capabilities associated with the project-based construction firms enabling them to integrate greater opportunities in undertaking construction innovation, supported by theoretical and empirical evidences within a project-oriented regime.

1.1. Entrepreneurship and networking

Entrepreneurship is the primary strategic orientation that has always allowed businesses to succeed both locally and internationally [24,25]. Fundamentally, entrepreneurship is reflected in business behaviors, and small firms with a strong entrepreneurial mindset will be able to effectively identify and seize opportunities that will set them apart from their rivals [26]. This includes decisions, methods, and practices [27], which are essential to raising the firm's overall long-term performance [28]. Despite having limited access to capital, entrepreneurial firms are able to pursue opportunities regardless of the resources they currently possess [2], and to sustain a greater competitive advantage [29].

For decades, entrepreneurship has, both theoretically and empirically, received major interest for its correlation with innovation in a manufacturing context [30]. However, given the distinct operational characteristics of services, the relevancy of entrepreneurship in service firms has been increasingly emphasized in the literature [31]. In banking industries, entrepreneurial configurations are likely to result in active networking strategy [32] and management diversity [33], and eventually being indicative of higher firm performance. Similarly, entrepreneurship is robust predictor for firm growth in health care sectors, both of small [34] and large [35] organizations. The same focus is also provisioned in non-profit social organizations such that entrepreneurship strongly favours the growth of social value and organizational performance [36]. Innovation orientation has a strong mediating role between knowledge management practices and innovation performance in SMEs, especially in the context of SMEs, where a thoughtful and strategic approach to innovation management can be of great benefit [37]. This research further advances the analysis of entrepreneurial undertaking as part of the stance in seeking new value creation within the project-based service setting.

Moving a step further from extant research question, we contend that being highly entrepreneurial in the conduct of business does

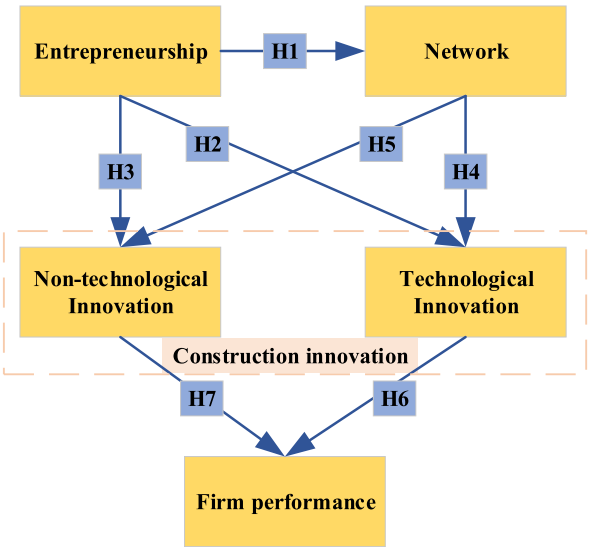

Fig. 1. Author proposed framework.

not constitute competitive strength, but coupled with networking it does. As entrepreneurs in a spatial cluster are not individualistic, they could pursue opportunities beyond the firms' boundaries for the strategic combination of existing resources to drive value creating changes [38]. Team innovation climate has a direct impact on innovation performance, rather than a moderating effect. Therefore, the creation of an innovative atmosphere at the team level should be emphasized, and the cross-level coordination should have a lasting impact on innovation performance [39]. This is compatible with the suggestion of Chetty & Holm [40] that networks can help firms expose themselves to new opportunities, obtain knowledge, learn from experiences and benefit from the synergistic effect of pooled resources.

True entrepreneurs, those who are willing to start a business, actively seek market risk, and implement self-directed investment behavior, as well as to grasp the future market opportunities more proactive than their opponents [28], require considerable resources to be successful [27]. In dealing with timely completed projects, firms persistently rely on temporary coalition of firms with extreme specialization of functions and professions for delivering superior value to clients [7]. Entrepreneurial networking shed light on the strategic conduit to overcome such discontinuities for accessing and exploiting additional resources throughout the prior established networks. In support, Manley [19] find that accessing complementary resources externally through relationship-building strategies, especially with advanced clients, are crucial for delivering strategic innovation and good project outcomes. From a strategic perspective, the notion of transferring entrepreneurship into feasible strategic activities is increasingly interwoven within multiple relationships since they are central and interconnected. Therefore, we hypothesize.

H1. Entrepreneurship is positively related to network in project-based firm

1.2. Entrepreneurship and networking in construction innovations

Innovation is seen as an important competence of firms in outperforming their rivals [2,41] through superior business performance [42], project outcome [19], and market penetration [41]. Within the complex system of construction, the ability to persistently secure innovation is critical for the improved outcomes of design-construction process and the completed structure itself [43]. Especially in uncertain markets, the projects upon which firms engaged offer a rich source of new ideas for physical process improvement and product developments [11]. Process innovation is the changes in the way organizations produce end products or services [44] whereas product innovation represents new products or services introduced to satisfy the clients' demands [45].

Despite the wide variations in conceptualizing innovation, five major technological innovations have been observed to lead substantial progress in the micro processes and the industrial structure as a whole [46]. In particular, innovations with different degree of radicalness require varying management approaches and implementation strategies [41]. Interestingly, small firms could also exert their competitive leverage to move towards better levels of technologies transformation [19,42,47,48]. When management and technological innovations are introduced into companies separately, they can have a positive impact on business performance [49]. However, their resource restrictions may impede the proper development of different types of innovative offerings [50]. Obviously, great importance has been assigned to the necessity of determining and solving technical problems [41,51] to improve the technical feasibility of projects. It is necessary to further understand how new management practices, organizational structures or management techniques affect technological innovation capabilities and firm performance.

Adopting a different approach, some scholars tracked on the findings originating from the non-technological advancements [14,52,53] that were found to be as crucial to firms' success as technological innovation [54]. Accordingly, the latest Oslo Manual [55] acknowledged the contribution of a composite index of innovative endeavours, including those not directly affiliated with products or production means. In this regard, advertising and marketing innovation entails new advertising strategies that require big adjustments in product sketch or packaging, product placement, product advertising or pricing, whilst organizational innovation refers to new organizational techniques in enterprise practices, place of business agency or exterior family members [55].

In project business, the distinction of both types of innovations is often obscured as projects usually include the integration of both tangible and intangible elements to provide effective solution for the customer [15]. A recent finding exposed that construction companies predominantly concentrated on improving the organizational aspects of operational practices to better organize projects and the associated activities, resources and actors [13]. From a practical standpoint, restructure of organizational framework would lead to organizational improvement in problem-solving and profitability on a regular basis [56]. Meanwhile, to improve the marketing functions, firms require a suite of systematic approaches for the planning, execution and assessment of marketing processes [57]. The integration of a well-developed marketing function into firms' operations can effectively add value to the overall success of business [58].

Much of the innovations occurring in construction rarely go along with the formal R&D indicators, scilicet, being partial explained in the innovative dynamism [7]. Importantly, little, if any, research exists on whether the two different forms of innovations exert equal, or different, impacts for firms considering them simultaneously. Following this line of enquiry, each dimension can vary independently in aiding the potential of business to succeed. Eventually, the conceptualization of innovation in construction should focus on the broader value of innovations, which is a combination of technological and non-technological innovations [14].

1.3. Entrepreneurship and innovation

The entrepreneurial process cannot be separated from innovation, which permeates all parts of the entrepreneurial process. And how innovation and entrepreneurial process can be actively integrated is the focus of scholars' research in recent years. Conceptually, innovativeness is one of the functions of entrepreneurship [24]. Entrepreneurial decision-makers would strive to capitalize on

innovative endeavours despite the risk of misjudging the prospect of likely outcomes [26]. Entrepreneurial orientation moderates the relationship between information management and innovative intellectual capital, and the regulating impact of leader education on the relationship between expertise administration and innovation is also demonstrated [59]. While entrepreneurship research at the firm level has primarily deciphering the benefits derived from manufacturing-based innovations, rarely are these to be found on service-based innovative efforts [16]. This is detrimental for the service firm, for they equally rely on entrepreneurial manner to motivate value creating changes via innovation [60].

With scarce resources, project-based firms are to persistently display entrepreneurial behavioural traits in the pursuit of market-based innovation as a mean to create superior value for their customers [61]. Along with the innovative outcomes resulted by recombining limited resources at hand [2], entrepreneurial persistence enables project-oriented firms to seize greater innovation-based competitive advantage [2]. Hence, innovations resulting from the potential value of entrepreneurship by considering the industry's unusual emphasis on projects to entirely complement their unique deliveries are hypothesized as follow.

H2. The greater the entrepreneurship orientation, the stronger is technological innovation

H3. The greater the entrepreneurship orientation, the greater is non-technological innovation

1.4. Networks and innovation

The benefits of network connections are well established in the innovation literature, such that firms operating in net are more likely to in developing and commercializing innovation. Given that firms usually operate under resource-constrained environments, networks have becoming an optimum solution for accessing inputs required for innovation activities, including resources, complementary skills, capabilities, and knowledge [62]. In SMEs, which normally lack of resources to develop new products on their own, a similar proclivity towards open innovation is demonstrated [38]. Accordingly, these resource-lacking companies could reap the benefits of larger companies [63] with higher innovation breadth sustained through the heterogeneity and intensity of exterior association [50].

In project-based productive networks, firms generally operate on the basis of one-off projects, with discontinuous and temporary modes of production, therefore constraining the rapid assimilation of new knowledge and opportunities [15]. To compete in environments with such broken learning and feedback loops, firms' effort to continuously anchor project-specific knowledge through establishing innovation networks is crucial for accentuating the innovative initiatives [64]. These findings were dovetailed with the concept of co-innovation [13,65], such that innovative opportunities are distributed throughout the intricate interactions of numerous dispersed actors [66,67]. Despite the inherent complementarity between innovation and network, the manner by which firms complements it as part of innovation endeavours remains contentious in the case of SMEs [68]. Further, extant studies remained ambiguous in their findings where both favouring [7,18] and opposing [69] results were found. Based on the previous ideas, we propose the following hypothesis.

H4. Network is positively related to technological innovation.

H5. Network is positively related to non-technological innovation.

1.5. Organizational performance and innovation

The susceptibility of the organization to the demands of the exterior surroundings has a higher affect on institutional pressures than the organization's coordination and manipulate mechanisms [70]. Generally, organizational performance can be manifested as financial elements that reporting on the past performance, and complementing with non-financial elements that concerning on future performance [71]. In this regards, there is confusion in the project business literature that scholars often use project-centric innovative delivery to explain organizational competitiveness, equating projects with firm performance [15]. Firms, not projects, are the only fulcrum credible for evaluating changes in the construction domain [61]. Enterprise performance means the running effectivity of enterprise operation and the performance of the manager in a certain duration of operation. The running effectivity is primarily mirrored in profitability, asset operation level, debt compensation capability and subsequent development ability. Here we mainly examine the innovation performance of firms. Firm innovation performance typically consists of two parts: process innovation and product innovation. It also refers to a significant increase in the business volume and economic benefits of a firm after implementing new technologies [72,73]. Yet previous studies have attracted criticism for not reaching a clear conclusion concerning the impact of innovations has on the performance of firms who based their business upon projects deliveries [74].

Moreover, papers addressing the linkages between innovations and its beneficial outcomes robustly considering the product or process enhancements [19,45,47,48], rather all innovation types as described earlier. In practice, the impetus for innovative solutions not only necessitates the integration of technological knowledge, but also mandates an in-depth investment into the intangible business routines. In this sense, the literature scarcely ever advocated the non-technological innovations in spite of their pivot role in integrating the information and coordination across portfolio of projects [14].

In essence, advanced business practices would provide firms, of all size, with greater competitive advantage [52]. Through new management practices, firms are able to mobilize central resources within firms to harness their technological capabilities in delivering projects [15]. Likewise, the business of construction sector would develop effectively promoted by strategic marketing management [75]. Echoing the marketing efforts as an important part of project-based organizations [57,58], however, the earlier literature did not specifically examine whether innovative marketing practices would sustain greater business performance [76]. Consequently, all these

arguments call for further empirical analysis to explain the impact of the non-technological measures. Therefore, we postulate that.

H6. The greater the technological innovation, the greater is the firm performance.

H7. The greater the non-technological innovation, the greater is the firm performance.

1.6. Research methods and procedures

After a thorough critical review of the existing literature, a questionnaire form was developed with valid scale variables. After pretesting the questionnaire with five academies and thirty project-based construction small-enterprises, modifications and improvement were made. A sampling frame comprising Malaysian project-based constructing firms, graded as G4 to G6, was assembled from the directory published by the Construction Industry Development Board (CIDB) Malaysia. According to Spanos & Lioukas [77], the sampling range was constrained to firms employing between 10 and 49 employees (i.e. small firms) and those with missing data, hence, yielded an initial sample frame of 750 firms.

The survey was distributed to 750 construction companies, 231 questionnaires were received, and 157 valid questionnaires were obtained through screening, with an effective response rate of 20.9%. The sorts of corporations in the sample are corporations running on main-contracting (53%) and specialist-contracting (47%) basis. The average age of the firms is 15 years, with the respondents served in the firms for approximately 8 years. In terms of firm's market configuration, the breakdown was 95% domestic base and 5% international base. Following Armstrong & Overton [78], we performed a sequence of Mann-Whitney U checks between the early and late responded groups and detected no considerable differences, scilicet, non-response bias was not found for all the variables blanketed in the study. This study used 13 reflective items developed by Nasution and Mavondo [79] to measure entrepreneurship. Respondents' opinions were collected by providing them with a five-point Likert scale. This scale was categorized as "strongly disagree". "Somewhat disagree", "Agree", "Somewhat agree" and "Strongly agree " and assumes that conservative and entrepreneurial orientations are on a continuum. According to Oerlemans & Knoben [80], networks were measured using eight categories of external partner contacts (customers, competitors, experts/consultants, suppliers, universities, innovation centers, and companies in other industries). All items were self-assessed by respondents on a five-point Likert scale.

To measure innovation, we followed the scales recommended by Hurley & Hult [81], Song & Xie [82], and Oslo Manual [55]. The variables were defined as molar second-order variables with reflective characters, distinguishing between four dimensions: process innovation, product innovation, marketing innovation and organizational innovation. Among them, process innovation is the introduction of new input materials, physical equipment or software systems in a company's production or service operations to deliver products and services [44]; product innovation is the creation of new products or services based on new or combined technologies [45]; marketing innovation is the implementation of a new marketing approach involving product design or packaging, product placement, major changes in product promotion or pricing [55]; organizational innovation refers to a new organizational approach in business practices, workplace organization, or external relations [55]. The scale concerning organizational innovation was adjusted by including only managerial advancement. Particularly, items overlapping the entrepreneurship and networking scale such as those related to the use of external relations and workplace innovation were excluded. The scale used in this study consists of 16 items on a five-point Likert scale: "never practice", "sometimes practice", "to a fair extent", "always practice" and "always practice". The scale of organizational performance was adapted from Keh et al. [83] that comprises two dimensions: economic and satisfaction measures. All 7 items were self-assessed by respondents on a five-point Likert scale (anchored by 'much worse' and 'much better' at the end points). While firm age might potentially confound the results, given that older firms tend to have more mature experience and competencies that allow them to engage in innovative activities [84], we controlled for this variable. Accordingly, the number of years since foundation was the firm age [54]. Table 1 suggests the descriptive information for all variables and the related correlation matrix.

1.7. Data interpretations and results

Fig. 1 illustrates the framework proposed in this study, including the four dimensions of entrepreneurship, network, non-technological and technological innovation, the firm performance objectives and six hypotheses, where innovation belongs to the construction engineering aspect. The developed framework was analyzed with partial least square estimation approach using PLS-Graph 3.0 software. To comprehend the quality of the results, two evaluation stages were used to respectively construct a measurement model and a structural model.

Table 1
Mean and standard deviation values and correlations among study variables.

	Variable	Mean	SD	1	2	3	4	5	6
1	Firm performance	3.812	0.848	1.000					
2	Non-technological innovation			0.721[a]	1.000				
3	Technological innovation	3.573	0.906	0.706[a]	0.815[a]	1.000			
4	Age	3.442	0.941	0.083	0.027	0.068	1.000		
5	Entrepreneurship	3.703	0.764	0.670[a]	0.702[a]	0.701[a]	−0.000	1.000	
6	Network	14.89	7.606	0.627[a]	0.628[a]	0.611[a]	0.021	0.598[a]	1.000

[a] Statistically significant at 0.01.

1.8. Measurement model

The sufficiency of the measurement model is evaluated by reliability and validity. Reliability includes the composite reliability of the model and the reliability of each factor. Validity contains convergence validity and discriminant validity. If the reliability of all factors in the project is acceptable, it means that the combined reliability of all constructs is satisfactory. Table 2 indicates the main measure values for each factor in the measurement model. As recommended by Nunnally [85], the minimum value of conformal reliability is 0.8, and this measurement model shows a good reliability because all factors' values are greater than 0.8. Based on research of Fornell and Larcker [86], the average variance extracted (AVE) greater than 0.5 means a good convergence, and this measurement model has AVE higher than 0.5 for all factors, indicating a good convergence. In addition, for discriminant validity, the square root of AVE for each construct must be greater than its higher correlation with any other construct [87]. According to Table 2, the SL and SE of the measurement model were satisfied and all factors were within acceptable error levels.

1.9. Structural model development

Next, the structural model is assessed by looking at two parameters: the explanatory power and the path coefficients. Instead of using traditional goodness-of-fit metric [88] as in covariance-based SEM, attention should be given to the explanatory power of the model. Particularly, the square multiple correlations (R^2) computed by PLS-graph 3.0 is similar to that of traditional regression [89] and foundational in evaluating a structural model [90]. The R^2 can be used to measure the fit of the PLS model and also to reflect the explanatory power of the variables. It is generally accepted that there is a better fit when R^2 exceeds the minimum value of 0.1 as suggested by Falk & Miller [91]. As shown in Table 3, the R^2 value for the latent constructs largely exceed the minimum of 0.1 recommended by Falk & Miller [91]. The R^2 value for the 'organizational performance' indicated that the framework explains 69% of the constructs variance, a very satisfactory level of predictability.

In this study, the paths were judged to pass or not from a combination of both hypothesis testing and theoretical hypotheses in terms of statistical aspects, that is, the important impact of the t-value and the reasonableness of the path coefficients. To proof the relationship of hypotheses, the path coefficients (β) of all variables were evaluated and expressed as t. Table 3 displays the relevant evaluation indicators. According to the results, a positive correlation was found for all hypothesized paths presented, and the path results for the structural model was summarized in Fig. 2. Among them, the path coefficient of H1 is 0.60 (t = 12.26) means there exists a significant positive correlation; the path coefficient of H2 is 0.22 (t = 3.666) means there exists a moderate positive relationship; the path coefficient of H3 is 0.51 (t = 8.310) means there exists a moderate positive relationship; the path coefficient of H4 is 0.11 (t = 1.856) means there exists a moderate positive relationship. The path coefficient of H5 is 0.32 (t = 4.619) means there is a moderate positive relationship; the path coefficient of H6 is 0.35 (t = 3.383) means there is a moderate positive relationship; the path coefficient

Table 2
Measurement model results.

Factors	SL	SE	t-value	CR	AVE
Entrepreneurial orientation (reflective)				0.875	0.502
EN1	0.722****	0.050	14.537		
EN2	0.738****	0.046	16.075		
EN3	0.725****	0.043	16.825		
EN4	0.717****	0.063	11.525		
EN5	0.708****	0.056	14.829		
EN6	0.746****	0.035	21.119		
EN7	0.684****	0.076	8.344		
Network (reflective)				0.834	0.570
NW1	0.831****	0.028	29.772		
NW2	0.843****	0.027	30.901		
NW3	0.788****	0.029	23.180		
NW4	0.730****	0.041	17.694		
Technological innovation (molecular 2nd-order factor)				0.887	0.529
Product innovation	0.732****	0.044	14.922		
Process innovation	0.765****	0.038	19.868		
Non-technological innovation (molecular 2nd-order factor)				0.922	0.598
Marketing innovation	0.778****	0.034	24.116		
Organizational innovation	0.767****	0.037	23.383		
Firm performance (reflective)				0.913	0.601
FP1	0.736****	0.048	11.454		
FP2	0.821****	0.027	30.455		
FP3	0.793****	0.031	25.653		
FP4	0.755****	0.038	19.972		
FP5	0.787****	0.029	27.236		
FP6	0.776****	0.029	27.153		
FP7	0.817****	0.025	32.124		
Age	1.000	0.000	0.000	1.000	1.000

Notes: SL, standardized loading; SE, standard error; CR, composite reliability; AVE, average variance extracted.
****$p < 0.001$, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 3
Structural equation model results.

		Path coefficient	t-value
Hypothesized links			
H1	Entrepreneurship→network	0.599****	12.2639
H2	Entrepreneurship→technological innovation	0.221****	3.6664
H3	Entrepreneurship→non-technological innovation	0.508****	8.3103
H4	Network→technological innovation	0.108*	1.8555
H5	Network→non-technological innovation	0.324****	4.6191
H6	Technological innovation→firm performance	0.345****	3.3827
H7	Non-technological innovation→firm performance	0.438****	4.2826
Non-hypothesized links			
Non-technological innovation→technological innovation		0.593****	7.2095

****p < 0.001. ***p < 0.01. **p < 0.05. *p < 0.1.

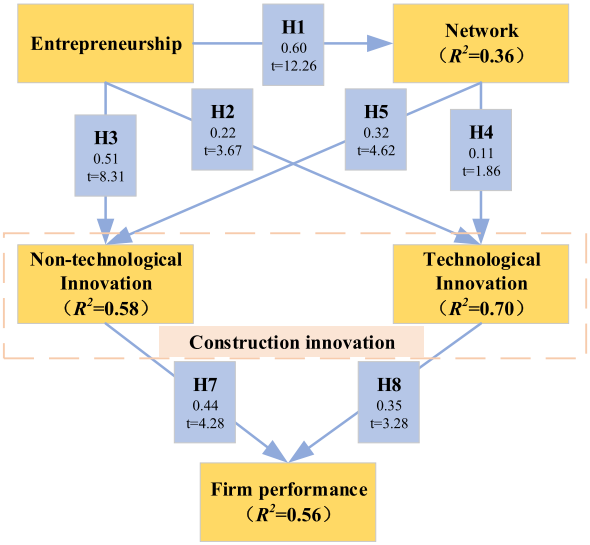

Fig. 2. Structural model on innovation management in small project-based firms.

of H7 is 0.44 (t = 4.283) means there is a moderate positive relationship. It is worth noting that there is a significant positive relationship between non-technological innovation and technological innovation with a path coefficient of 0.59 (t = 7.209), which was beyond our expectation.

Overall, the results support the proposed conceptual model. First, it is suggested that small constructing firms appear to engage in entrepreneurial and networking behaviours that positively impact on construction innovations. This is compatible with prior studies that demonstrated the vital role of capabilities in the development of technological innovations [19] as well as non-technological innovations [54]. Second, the direct effect of construction innovation on organizational performance is noteworthy; supporting theorists who address the possession of competitive superiority in some organizations depends on individual types of core innovations [55,92,93].

2. Discussions and limitation

In the empirical research part of the study, we systematically examine how innovation supports the business of small project-based firms, thereby providing valuable insights into the project business literature in several important ways. Consider the influencing factors that affect the innovation ability of small enterprises and the innovation performance of enterprises under four innovation dimensions. The mediating role of entrepreneurial orientation and external network between small firm innovation ability and firm innovation performance is verified. Entrepreneurial orientation and networking are included in the research scope to construct a theoretical framework that examines both the antecedents and consequences of architectural innovation. Furthermore, our research contributes to a better understanding of managerial innovation in the context of small construction firms. However, empirical studies can only take into account the logical connections between firm innovation, innovation orientation, external networks, and firm performance, and cannot explain the degree of interconnection among these factors. Therefore, through the structural equation modeling of the questionnaire data of small enterprises, the empirical research results are quantitatively analyzed, and the correlation analysis of the factors in the system is carried out while confirming the feasibility and reliability of the empirical research. For the

quantitative research results of empirical research, we make the following discussion.

First, the measurement and analysis of construction innovation as comprising both technological innovations (i.e., those relating to a new or significantly improved product, service and operational process) and non-technological innovations (i.e., those relating to new marketing and/or organizational method) advances the project-based innovation literature. The findings inform that while the emphasis towards the tangible, technological-based advancements are inherently valuable to outperform rivals, the existing innovative offerings have equally intertwined with intangible, non-technological-based innovations to be more robust in deciphering the potential values desired by firms. Put differently, this study is a starting point that substantiating the design of a dual-dimension of new services offerings especially relevant to the formulation of evidence on construction innovations. Not only do they occur in concurrent, as shown in their significant positive interrelationship ($\beta = 0.59$, $t = 7.209$), both aspects of innovations mutually complement each other ($\beta = 0.59$, $t = 7.209$). For firms that rely upon projects to deliver their services, the use of new forms of organisation is indispensable to sustain the increasing intricacy of production, communications and technology. Hence, solely focusing on managing either project or business processes per se would fail to build link between mechanisms at the business routines and project activities [15]. In line with these arguments, the findings strengthen the conventional innovative approaches with an additional dimensionality of non-technological innovation in association with project-based services provisioning.

Second, the findings draw entrepreneurship in the context of service domain, in response to the scholarly proposition for further research in this area [2], given that the need for attention is often overlooked by scholars who disproportionately incorporate their orientation towards manufacturing means. In this sense, entrepreneurial value discloses its specific effect with varying dimension of innovation postures. Based on the results, on the one hand, entrepreneurship plays a favouring role for technological innovative practices ($\beta = 0.22$, $t = 3.666$), and on the other hand, such capability robustly discover the significance of new managing approaches to the non-technological innovation ($\beta = 0.51$, $t = 8.310$). Interestingly, firms appear to better engage their entrepreneurial initiatives in achieving non-technological innovation. To remain opportunistically in the marketplace, firms with entrepreneurial response to external forces by quickly reconfiguring their actions and activities would possibly support themselves to move far in advance to their rivals [94]. Thereby, we add knowledge into the services literature by demonstrating entrepreneurship as distinct dynamic capability in driving construction innovation in project-based service firms.

Third, entrepreneurship appears to have a direct significant and positive relationship with networking. ($\beta = 0.60$, $t = 12.264$). It is clear from the survey findings that the entrepreneurship is indeed an integral component of organizational behavior in building and nurturing relational activities across firm boundaries to attain unbounded form of value creation. Particularly, the inclusion of networking provides firms with ample source of opportunities in a setting that require substantial time for satisfying the implicit needs and explicit wants of customer [38]. Further, the findings suggest that networking, akin to entrepreneurship, has a positive effect on technological innovation ($\beta = 0.11$, $t = 1.856$) and non-technological innovation ($\beta = 0.32$, $t = 4.619$). In this view, the more active the interaction path between firms and their other service providers, the greater the innovation breadth sustained within the firms. Our findings support the work by Gronum et al. [50] that through established linkages, small firm obtain advantages of potential feasibility of varying innovative activities, which in turn directed at disengage the performance value of the networks.

Finally, the paper addresses the foregoing knowledge gaps by considering the firm (in contrast to the project) as the fundamental unit for all strategic integrity of diverse innovation. As noted earlier, the extant studies frequently agree that organizational performances are unlocked by the beneficial outcomes derived through numerous delivered innovative projects. Such approach could be problematic, as the business performance does not evolve solely from the tangible innovations implemented across projects [14]. Expanding extant knowledge to a more complete picture, we answer the recent call by simultaneously explore the combinative effects of diverse innovations, which mobilised across project and within firms, in delineating the organizational performance. Compared with that of technological innovation ($\beta = 0.35$, $t = 3.383$), the results reveal a slight greater impact of non-technological innovation ($\beta = 0.44$, $t = 4.283$) have on organizational performance. This is somewhat unexpected findings such that when firms discern value with scarce resources to realize innovative offerings, the non-technological innovation would translate them into better business performance, rather than the technical changes.

In addition, there are several limitations in this study. First, current research background mainly concentrates on small and medium construction companies in the Malayan region, as such the applicability to other industry sectors needs to be further demonstrated. Second, this study does not test the causal relationship between longitudinal data and evaluation model factors. Therefore, the causality between up and down factors needs a deeper consideration.

3. Conclusions and recommendation

For practitioners, politicians, and scholars alike, this study has significant implications. Compared with previous similar studies, the originality of this study is that we provide a reliable and valid model that simultaneously presents the antecedents and consequences of innovation in small construction firms, and dialectically investigates how entrepreneurship, outside networks, and business performance are related. The analysis of innovation in construction firms includes both technological and non-technological innovations, and the findings show that while tangible, technology-based advancements have intrinsic value to occupying the market, existing innovative products are equally intertwined with intangible, non-technological innovations. This study emphasizes the impact of external networks and an innovation-oriented mindset on the ability of small construction enterprises to innovate. Due to the lack of resources, capital and knowledge of emerging technologies, the innovation of small enterprises is limited, coupled with the unique project format of construction enterprises, which is not exactly the same as enterprise innovation in manufacturing. As a result, small construction firms have become more open, and external networks and entrepreneurial orientation are more important in the impact of firm performance. The developed framework illustrates firm-level evidence on construction innovation, thereby offering valuable

inputs to scheme out a constructing firm-focused innovation policy, especially in smaller firm with finite organizational resources. Given that firm-level evidence is limited, the model favors firm managers' decision making to take appropriate path in adopting innovation. The managers should strive to foster and strengthen their strategic capabilities as they are important determinants of the occurrences of construction innovations and the resultant of enduring business performance. The ability of a firm to deliberately develop, expand, or adjust its resource base in order to constantly sustain the advantages of the strategy in building distinctive marketplace performance should be closely examined in such an endeavour.

Further research is encouraged to expand our proposition in several important ways. Further discussion of unobserved company and market characteristics. Additional efforts in developing multi-dimensional scale of non-technological innovations with regard to its conceptualization, of which they would help to reveal further investigation on the actual implication of these novel organizational and marketing arrangements. Besides, how non-technological innovations can complement the higher degree of technological innovative practices across portfolios of projects? How do large and small organizations vary in their central routine activities in seeking different range of innovative endeavours? Finally, future studies should examine the role of other important dynamic capabilities that drive both dimensions of construction innovations, such as knowledge management capabilities.

Author contribution statement

Cheng Wang: Analyzed and interpreted the data; Wrote the paper.
Yutong Tang: Performed the experiments; Analyzed and interpreted the data.
Yiyi Mo: Conceived and designed the experiments; Wrote the paper.
Merit M. Huang: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.
Hamzah Abdul-Rahman: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Funding statement

Dr. Yiyi Mo was supported by Fujian Provincial Department of Science and Technology [2018J05121], Huaqiao University [605-50Y14007].

Chen Wang was supported by Fujian Provincial Department of Science and Technology [2021I0014], Huaqiao University [17BS201].

Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of interest's statement

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2023.e13386.

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