Identifying latent classes to successful AEC innovation through a survey of Finnish construction companies

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Abstract

Purpose – The purpose of this study is to describe latent classes explaining the innovation logic in the Finnish construction companies. Innovativeness is a driver of competitive performance and vital to the long-term success of any organisation and company.

Design/methodology/approach – Using finite mixture structural equation modelling (FMSEM), the authors have classified innovation logic into latent classes. The method analyses and recognises classes for companies that have similar logic in innovation activities based on the collected data.

Findings – Through FMSEM analysis, the authors have identified three latent classes that explain the innovation logic in the Finnish construction companies – LC1: the internal innovators; LC2: the non-innovation-oriented introverts; and LC3: the innovation-oriented extroverts. These three latent classes clearly capture the perceptions within the industry as well as the different characteristics and variables.

Research limitations/implications – The presented latent classes explain innovation logic but is limited to analysing Finnish companies. Also, the research is quantitative by nature and does not increase the understanding in the same manner as qualitative research might capture on more specific aspects.

Practical implications – This paper presents starting points for construction industry companies to intensify innovation activities. It may also indicate more fundamental changes for the structure of construction industry organisations, especially by enabling innovation friendly culture.

Originality/value – This study describes innovation logic in Finnish construction companies through three models (LC1–LC3) by using quantitative data analysed with the FMSEM method. The fundamental innovation challenges in the Finnish construction companies are clarified via the identified latent classes.

Keywords Innovation, Industry transformation, Construction sector, Organisational learning, Knowledge management, Management, Process, Construction management

Paper type Research paper

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Introduction

Innovation has long been understood as a driver of change in enterprise and market structures, which are associated with competitive firm performance, and is recognised as an impetus to economic growth (Shelton *et al.*, 2016). Innovation has also been recognised for its contribution to national economic growth, competitiveness and higher standards of living and is at the heart of the modern knowledge-based economy (Oslo Manual, 2005). Despite its benefits, management of innovation is a challenging task, and its measurement is complicated (Ozorhon *et al.*, 2016).

However, unlike other industrial companies, the conservative and fragmented construction industry has a reputation for being slow to adopt and integrate new technologies at scale (Slaughter, 2000; Winch, 1998) and has historically failed to generate and sustain economic growth through innovation (Gann and Salter, 2000; Harty, 2008; Murphy *et al.*, 2015; Winch, 1998). At the same time, construction industry is a very scattered combination of localised needs, various crafts, services, products and their professional providers (Kahkonen, 2015). Thus, construction has fared poorly in productivity development (Pekuri *et al.*, 2011). In fact, the slow productivity development has been attributed to the industry's low level and number of innovations (Hietajärvi *et al.*, 2017).

The role of innovation in the construction sector is rather complex (Zhang and Ashuri, 2018; Harty, 2008). To succeed, the construction innovations must produce added value for customers and have regard to social power and influence (Badi *et al.*, 2020). That means focus on quality products and/or services that customers are willing to pay for (Aibinu and Jagboro, 2002).

Partly for this reason, the construction industry has been the constant target of political criticism (Havenvid *et al.*, 2016) and is classified as a low-tech sector of manufacturing (Aouad *et al.*, 2010; Yearbook, 2017). Yet, one cannot deny that innovation is vital to successful and long-term company performance, even in the construction sector (Gambatese and Hallowell, 2011). The higher the levels of innovation, the greater the likelihood that it will increase the industry's contribution to economic growth. Unfortunately, in most countries, the industry is not perceived as innovative, thus offering much room for improvement (Blayse and Manley, 2004). This interpretation might explain the argument put forth by Harty (2008) that construction companies implement innovations originating elsewhere rather than developing their own applications. The construction industry is known for its highly divided organisational structure (Xia *et al.*, 2012) and could be one part of low innovativeness rate.

A transformation in the construction industry has been deemed complicated for a number of reasons (Havenvid *et al.*, 2016). Early studies discuss many lost opportunities, where technologies introduced were poorly implemented or managed, thus not generating innovation (Dodgson and Hinze, 2000; Glass *et al.*, 2008; King and Majchrzak, 1996; Van der Panne *et al.*, 2003). Thus, construction researchers are faced with the Herculean task of trying to devise solutions that address the concerns of industry, policymakers and academics (Schweber, 2015).

This study focuses on the innovation logics within Finnish construction companies. Finland is classified as an innovation leader, with its innovation performance standing well above the EU average (European Innovation Scoreboard, 2020). However, a distinct innovation culture in lacking in the construction industry (Hartmann, 2006). Therefore, scholars are challenged to develop an ideal strategy to motivate innovation, encourage participation and produce innovations that have true value (Stewart and Fenn, 2006).

The objective of the study is to find latent classes that explain the innovation logic at the company level. Our final contribution is based on the latent classes that describe the types of innovation logics and activities in construction companies. Because of the dearth of readily available data on the topic, we used the following approach. We reviewed literature to find theoretically sound research models, collected and analysed empirical data and finally generated latent classes from the data with the help of the finite mixture structural equation modelling (FMSEM) technique. Finite mixture modelling refers to using subpopulations or latent classes whose membership is unknown and cannot be determined a priori but can be estimated from the data (Juntunen *et al.*, 2015).

Background and research model

Innovation is central to the competitiveness of firms and, ultimately, firm survival (Çakar and Ertürk, 2010; Madrid-Guijarro *et al.*, 2009). Companies that embrace innovation will continuously introduce products and processes to meet changing consumer demands (Madrid-Guijarro *et al.*, 2013). Thus, innovation is broadly seen as an essential component of competitiveness, embedded in the organisational structures, processes, products and services (Gunday *et al.*, 2011).

Innovation studies focus on factors contributing to innovation (Laforet, 2013), and the process has traditionally been understood as a predefined sequence of phases: idea generation, selection, development and launch/diffusion/sales (Salerno *et al.*, 2015). In the construction sector, adopting innovations presents a challenge because of the fragmented and project-based nature of the work (Ozorhon *et al.*, 2014). That innovations in construction can form the backbone of a firm's long-term competitive strategy has been widely recognised and extensively reported in the literature (Alegre and Chiva, 2013; Slaughter, 2000). However, it is important to distinguish the concept from other related constructs such as invention and problem-solving (Shelton *et al.*, 2016).

Successful innovation depends on a firm's ability to combine a range of capabilities, including accessing finance, understanding market needs, recruiting high-skilled staff and establishing effective interactions with other actors (D'Este *et al.*, 2012). It also is based on the social and organisational contexts of a firm (Harty, 2005). For instance, if a firm lacks research capabilities, then it should focus on innovations linked to research alliances to acquire an advantage (Hitt *et al.*, 2004).

In innovation research, there are several well-established ways of describing the creation of innovation types and can prompt innovations in the construction company. Innovation can be divided, for example, industry-level innovation, firm-level innovation and project-level innovation (Meng and Brown, 2018). In this study, we discuss the enablers and obstacles to the four types of innovation defined by the Oslo Manual (2005): *product* innovation, *service* innovation, *process* innovation and *marketing* innovation.

Product innovation

Scholars have shown, over a sustained period, that product innovation is one of the main drivers of value creation (Visnjic *et al.*, 2016). Innovative firms continuously introduce new products and services that are more attuned to the current and emerging market needs, and they are able to quickly enter new markets that present a better strategic fit for their innovation-based capabilities (Dess *et al.*, 2003; Morris *et al.*, 2010). Product innovations use new knowledge or technologies, their combinations or their uses (Gunday *et al.*, 2011).

Product innovations have long been used to address the challenges involved in constructing innovative buildings, yet their significance for collaborative problem-solving in inter-organisational projects is rarely acknowledged (Naar *et al.*, 2016). Construction differs from most other discrete assembly industries in that the final product is assembled *in situ*, rather than shipped to its final point of use (Winch, 2003). The product development in the construction industry tends to be straightforward search for and productisation of the right products (Chen *et al.*, 2017). Product development type of innovations is more complex in other construction sectors (Gann and Salter, 2000).

Service innovation

In a world rapidly being dominated by services (Ostrom *et al.*, 2010), diverse types of services have become vital to the functioning of product firms (Cusumano *et al.*, 2015). One of the areas that have attracted significant attention is digital solutions-based innovation and the adoption of Building Information Modelling (BIM) technology (Saka and Chan, 2020; Ahmed and Suliman, 2020). Another focus has been on innovation leadership and management, exploring how companies organise their innovation activities (Markham and Lee, 2013; Antons *et al.*, 2016). Cusumano (2015) identified three categories of product-related services that may be offered by a product firm: smoothing and adapting services, which complement the products, and substitution services, which enable the customers to pay for the use of a product without buying the product itself. Increasingly, many engineering companies are using service offerings to add accompanying services to their product range (Carlborg *et al.*, 2014; Guajardo *et al.*, 2012; Neely, 2008; Ostrom *et al.*, 2010).

Digital technologies, tools and digital transformation offer the means to speed up innovation processes and allow for more flexible collaboration across places and times (Hanelt *et al.*, 2021; Marion and Fixson, 2021). Social media has been shown to enhance companies' visibility and reputation, improve communication with stakeholders and increase brand awareness (Etemadi *et al.*, 2022). The use of artificial intelligence has the potential to improve construction project management by automating routine tasks, providing real-time data analysis and enhancing project scheduling and cost control (Sacks *et al.*, 2020; Pan and Zhang, 2021). Virtual reality has also been studied in the context of construction project planning and visualisation (Getuli *et al.*, 2022; Ahmed, 2018).

These innovations are the result of a servitisation strategy, where a manufacturing firm with a product-based business model expands its offering to include services related to its products and, as a result, shifts from a product-related business model to a service-oriented model (Cusumano *et al.*, 2015). Servitisation has received growing attention within the innovation community over the recent years (Blindenbach-Driessen and Van den Ende, 2014; Harkonen *et al.*, 2017; Ostrom *et al.*, 2010).

Process innovation

A process innovation is the implementation of a new or significantly improved production or delivery method to decrease unit costs of production or delivery, increase quality or produce or deliver new or significantly improved products (Oslo Manual, 2005). According to Murphy *et al.* (2015), early insights into innovation modelling suggest that product innovations often lead to process improvements.

Lean in construction has been explored as a means of enhancing project efficiency, reducing waste and improving project quality, but its implementation requires a commitment to continuous improvement and a focus on stakeholder engagement (Suresh and Arun Ram Nathan, 2020). Innovations in construction safety, such as the implementation of safety management systems and the use of wearable technology, have also been studied (Li *et al.*, 2020; Awolusi *et al.*, 2018; Choi *et al.*, 2017). The use of agile project management in the construction industry, including the benefits and challenges of its adoption, has also been studied (Arefazar *et al.*, 2022). The role of collaboration in driving construction innovation (Chen *et al.*, 2021; McNamara and Sepasgozar, 2018), with effective collaboration being shown to lead to increased innovation, improved project outcomes and enhanced stakeholder satisfaction (Pablo and London, 2020; Ellwood and Horner, 2020), has also gained some attention.

Firm size is also more relevant to process innovations than product innovations, and firms that are guided by international markets tend to innovate more than those that focus on local and regional markets (Barata and Fontainha, 2017).

Marketing innovation

A marketing innovation is the implementation of a fresh marketing method with significant changes in product design or packaging, product placement, product promotion or pricing (Oslo Manual, 2005). Typically, the purpose of marketing innovations is addressing customer needs better, opening new markets or newly positioning a firm's product on the market with the intention of increasing the firm's sales (Gunday *et al.*, 2011). Marketing innovations are strongly related to the four Ps of marketing: pricing strategies, packaging design, product placement and promotion activities (Kotler and Armstrong, 2013). The impact of social media on construction marketing has grown rapidly. Etemadi *et al.* (2022) investigated the impact of social media and showed that social media can enhance a company's visibility and reputation, improve communication with stakeholders and increase brand awareness.

Innovativeness is, in fact, one of the fundamental factors that determines how firms can enter new markets, increase their existing market share and acquire a competitive edge (Gunday *et al.*, 2011). Thus, it affects a company's ability to adapt to changing market conditions through the introduction of new and refined products (Ireland *et al.*, 2009). While taking risks with new technology and marketing innovations can be costly, they provide a great advantage when successful (De Clercq *et al.*, 2005).

Within the construction industry, firms typically provide services to clients whose infrastructural needs trigger the design and production process (Hartmann *et al.*, 2008). This trend requires firms to assess their services in an attempt to clearly articulate their aspects of cost and differentiation (Hartmann, 2006).

Innovation enablers

Construction innovation is a joint activity, with several enablers involved in the process (Table 1), and many inter-organisational factors influence the success of an innovation (Ozorhon *et al.*, 2014).

Enabler	Item
Customer/Orderer	The customer or the constructor is interested in innovation and development activities
	The customer or the constructor gives time to develop new ideas
	The customer or the constructor sets innovative targets for the project
	The customer or constructor sets the budget for the innovations
Learning	Accumulated experience and the doctrine within the company are captured
	The company has practices to use the accumulated experiences and doctrines
	The company has practices for disseminating reforms
	The company uses new experiences and doctrines in the projects that follow
Management support	Innovations are a part of the business of the company
	Innovations are explored in line with the budget of the company
	The company practises innovation activities
	Budgets are created for development projects in the company

Source: Adapted from Ozorhon *et al.* (2014)

Table 1. Innovation enablers

Innovation obstacles

Based on their case study, Ozorhon *et al.* (2014) identified that the main barriers to innovation adoption are resistance to change, inexperience and the unavailability of advanced products. According to the Oslo Manual (2005), innovation activities may not be undertaken or may be adversely affected by several factors including economic (e.g. high costs or lack of demand), enterprise-specific (e.g. lack of skilled personnel or knowledge) and legal (e.g. regulations or tax rules). Table 2 summarises the four types of innovation obstacles.

D'Este *et al.* (2012) argued that most survey-based studies tended to focus on the effects of financial obstacles, where a number of non-financial barriers, such as market, knowledge and regulation, become crucial in the context of innovation policy and management. Therefore, it is a good practice to collect data on enablers and barriers to innovation and their relative importance during the period under review (Oslo Manual, 2005).

Accordingly on the basis of the literature review, we identified the enablers and obstacles to innovation in the construction industry. To examine how these factors influence each other in the context of the Finnish construction industry, we developed a research model that mapped the possible pathways of innovation. Figure 1 shows the theoretical research model used in this study.

Methodology

Research design and data

The purpose of this study is to increase our understanding of the factors involved in the formation of construction innovation logics. To test the research model, we collected data from professionals and experts working in various organisations within the Finnish construction industry.

We used a questionnaire for the innovation survey that followed the EU harmonised structure, prescribed by the Statistics of Finland, which ensures uniform data contents and methods across all EU countries. A snowball sampling method (Goodman, 1961) was used, and the survey was conducted using the Webropol online application. The snowball method allows a participant to forward or share the survey link with other subjects who are part of the targeted population (Berg, 2006).

The informants (Table 3) were selected based on their expertise and position in the formal contract of collaborative agreement. The importance of the availability and willingness to participate was secured before the interviews and survey. In addition, the

Type of obstacle	Obstacle items
Cost factors	Excessive perceived economic risks High costs of direct innovation Cost of finance Availability of finance
Knowledge factors	Lack of qualified personnel Lack of information on technology Lack of information on markets
Contract factors	Design-bid-build contracts
Regulation factors	Compliance with Finnish government regulations Compliance with EU regulations

Source: Adapted from Oslo Manual (2005)

Table 2.
Obstacles to innovation

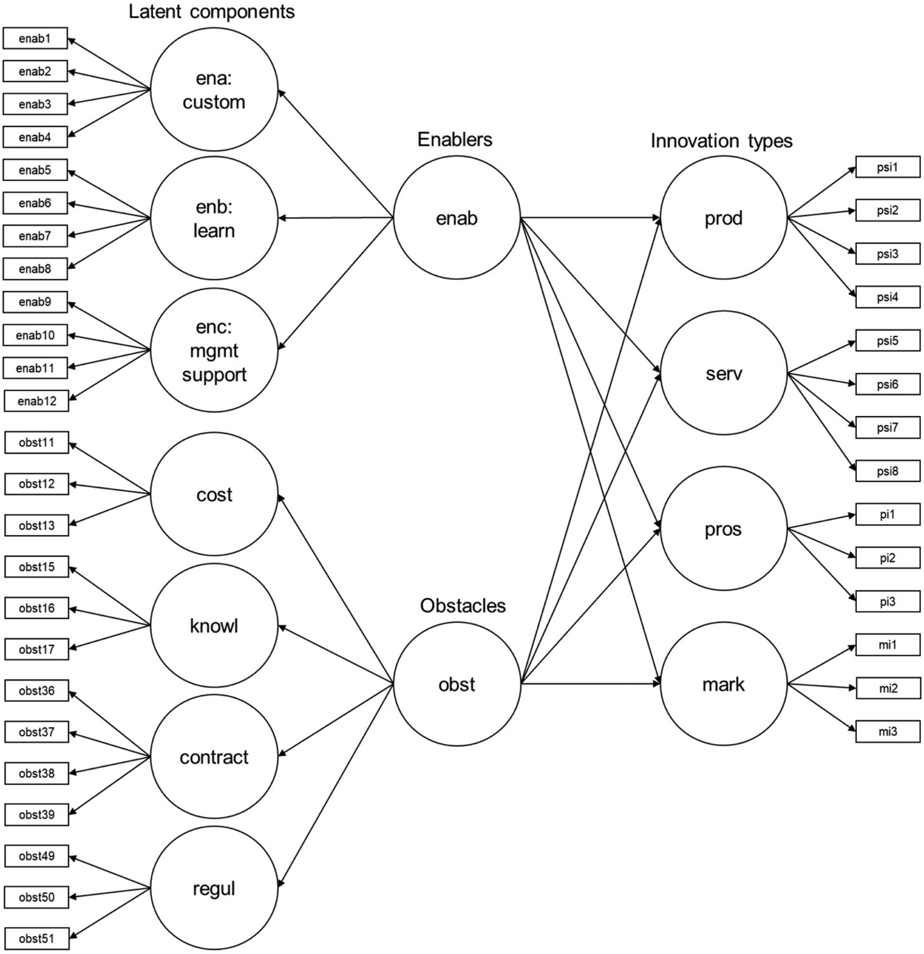

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Figure 1. Theoretical research model

Name of the organisation	Abbreviation
Association of Construction Agencies	RTL
Association of Finnish Construction Managers and Engineers	RKL
Confederation of Finnish Construction Industries	RT
Finnish Association of Architects	SAFA
Finnish Association of Building Owners and Construction Clients	RAKLI
Finnish Association of Civil Engineers	RIL
Finnish Association of Construction Engineers and Construction Architects	RIA
Finnish Association of Consulting Firms	SKOL

Source: Author's own creation

Table 3. Organisations from the Finnish construction sector participating in the survey

ability to communicate the experiences and opinions in an articulate, expressive and reflective manner was noted as advised in Palinkas *et al.* (2015).

Next, some information on informants: CEOs/Managing Director (#57) formed the largest single group of informants followed by specialist (#21) and directors (#10). A large proportion of informants (47%) have a long working experience of more than 30 years. Companies, #12, did not disclose the size of the R&D budget and #38 companies the budget is less than €20,000. We used multiple-choice questions to ask what kind of services informant's companies provide. The three largest service categories are the following: design (#43), consultancy (#34) and building construction (#30). All background variables of the informants are presented in Appendix. A total of 162 responses were received to the survey. Details of the participating organisations are listed in Table 3.

Structural model and measurements

The collected data were analysed in three steps. First, we used structural equation modelling (SEM) to test the research model. Assumedly because of data heterogeneity, the SEM results were not statistically sufficient; therefore, we continued the analysis with finite mixture SEM (FMSEM).

Finite mixture modelling (McLachlan and Peel, 2000) refers to modelling with latent variables that represent subpopulations, and it is used in cases where the population membership is not known a priori but is inferred from data (Muthén and Muthén, 1998/2007; van Horn *et al.*, 2009). Hence, instead of searching one homogeneous model, FMSEM accepts heterogeneity of the data and divides sample to subgroups revealing the number of unobservable heterogeneous segments and latent classes. Further, FMSEM estimates the path coefficients of each segment in the research model simultaneously (Bart *et al.*, 2005; McLachlan and Peel, 2000; Muthén and Muthén, 1998/2007).

In practice, in the FMSEM, the researchers let the slope of the linear regressions of the variables vary across the latent classes, which means that they allow each relationship between the factors in the model of each latent class to vary. This means that researchers estimate two (then three and four) normal distributions that together constitute one normal distribution from the data. Then researchers test these two (three and four) normal distributions against the research model, until the solution-fit information criteria reveal that the previous solution is better than the current one (Haapanen *et al.*, 2016).

In this research, previous steps helped us identify three latent classes. Finally, as the third step, we analysed each of the latent classes further. The structure of the SEM model is presented in Figure 2.

Fit indices of the model yielded different results (chi-square goodness-of-fit test; p-value 0.0000; root mean square error of approximation 0.069; comparative fit index 0.843; Tucker–Lewis index 0.829; and standardised root mean residual 0.080). The chi-square tests showed an unacceptable fit of the data to the models, with the minimum acceptable p-value being 0.05. However, unacceptable model fit would also require an root mean square error of approximation value over 0.10 (Browne and Cudeck, 1993) and/or Tucker–Lewis index/NNFI and comparative fit index values over 0.90 (Hu and Bentler, 1999; Jaccard and Wan, 1996). Our results showed that all the factor loadings were statistically significant, and the coefficients were substantial, which supported both the weak and strong conditions of convergent validity (Steenkamp and van Trijp, 1991). Hence, we accepted the measurement structure and assumed that the concerns were related to data heterogeneity.

Accordingly, as the second step, we maintained a mathematically equivalent measurement structure and ran latent classes among the relationships between the factors. In the analysis, each relationship between the factors of the model in each latent class is

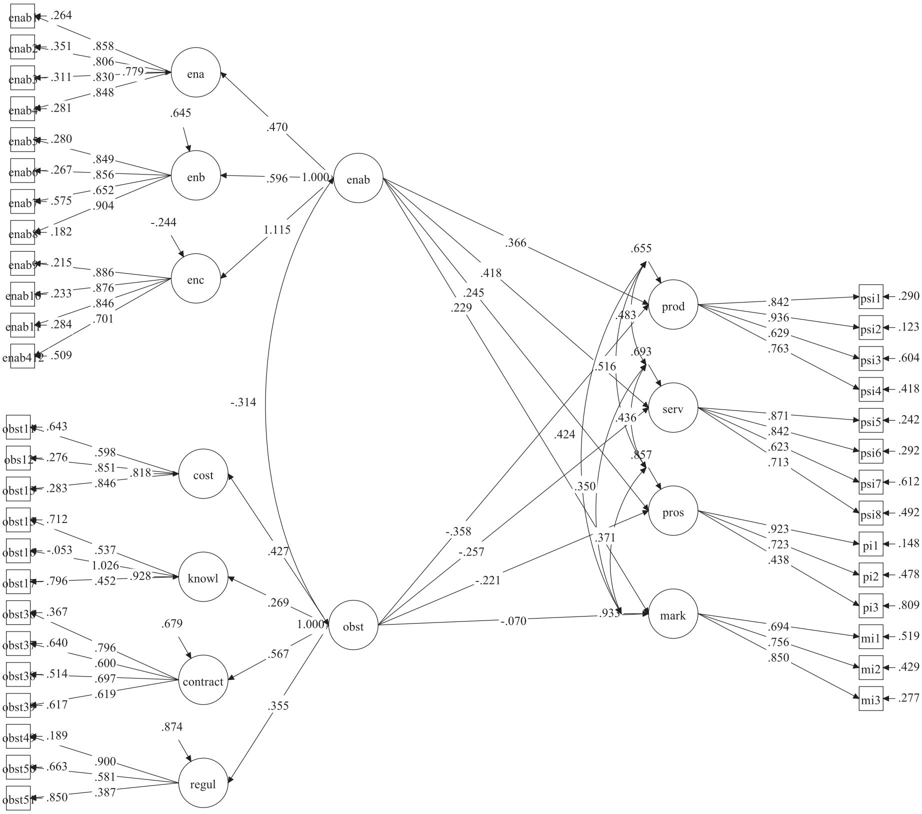

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Figure 2.
Structural equation model

allowed to vary. In practice, we estimated two (then three and four) normal distributions that together created one normal distribution and tested these two (three and four) distributions against the research model until the we found the best solution fit (Table 4).

The fit indices above point to different number of latent classes. Typically, better results are obtained with larger group sizes. For this study, a solution with four latent classes was computationally difficult to achieve; therefore, the solution with three latent

Classes	n	Entropy	LogLH	AIC	BIC	ABIC	VMLRLRT	LMRALRT	PBLR
1	162	n/a	10,340	20,958	21,387	20,947	n/a	n/a	n/a
2	33/129	0.933	10,263	20,916	21,518	20,901	0.240	0.240	0.000
3	25/26/111	0.924	10,204	20,888	21,629	20,869	0.240	0.240	1.000*
4	Analyses run 737 h with 18,183 starting values, no solution. Hence, analyses aborted								

Notes: *Bootstrap draws did not converge. Thus, the PBLR value may not be trustworthy
Source: Author's own creation

Table 4.
Finite mixture structural equation modelling fit indices

classes was accepted. Further, apart from FMSEM analyses and statistical fit, we also considered the theoretical fit of the model.

Results – description of the latent classes

The first latent class (LC1) consisted of 25 respondents. This class viewed innovations as an internal process, and they considered learning and top management support as enablers of innovations. Further, they favoured product and service innovations for their markets. While they did not specifically identify any obstacle to innovations, they agreed that many obstacles (cost, knowledge, contracts and regulation) together serve as a barrier to product innovations. This latent class was termed as *internal innovators* (Figure 3).

The second latent class (LC2) consisted of 26 respondents. LC2 considered other stakeholders, such as customers, as enablers of innovations. Although the results showed that top management support was not considered as an enabler of innovation, it was surprising to note that it had a negative impact on product and service innovations. This class did recognise neither process or market innovations nor cost or knowledge as obstacles to generating innovations. Finally, they did not perceive contractual regulations as a deterrent. This latent class was termed as *non-innovation-oriented introverts* (Figure 4).

The third latent class (LC3) comprised 111 respondents. LC3 recognised all enablers (customer, learning and top management) as facilitating different types of innovations (product, service, process and market). They identified knowledge and contracts as obstacles but not significant enough to hinder innovation. Costs and regulation were not

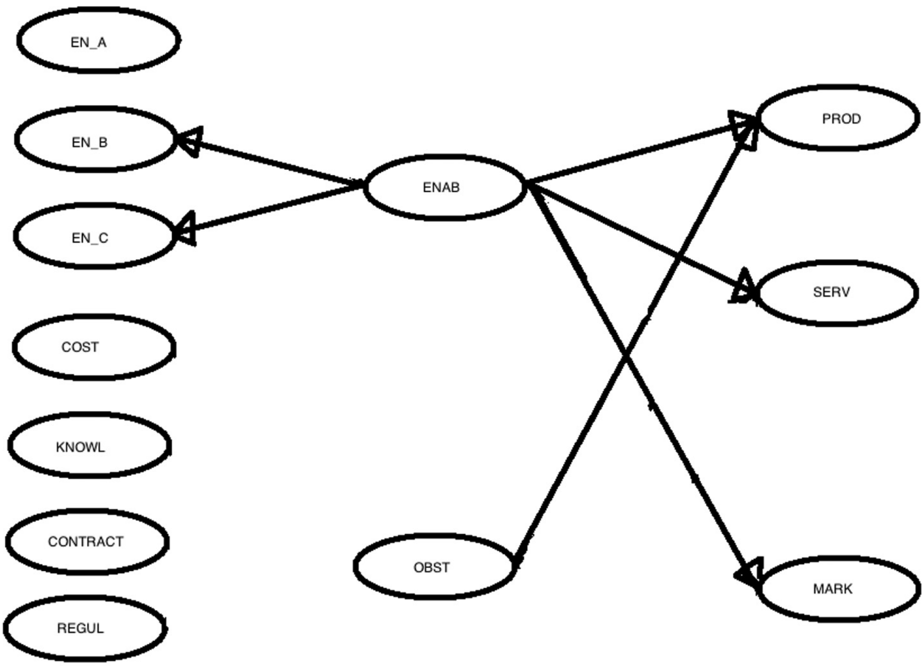

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Figure 3.
LC1: The internal innovators
(*n* = 25, 15, 43%)

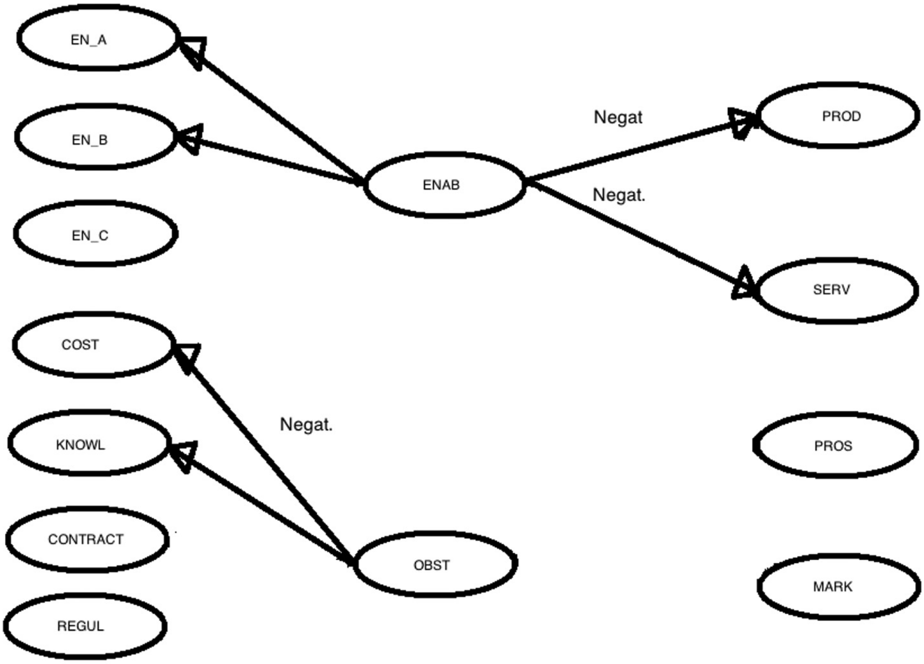

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Figure 4. LC2: The non-innovation-oriented introverts ($n = 26, 16, 5\%$)

considered as obstacles by LC3. This latent class was defined as *innovation-oriented extroverts* (Figure 5).

Figure 6 illustrates the statistical differences (in our data) measures between the three latent classes. Apart from the differences in latent classes, the graphs highlight the overall challenges in the construction industry. Questionnaire items that showed statistical differences across latent classes are listed in Table 5.

The results of this study confirm that even small data samples contain latent classes that signify different types of innovation mechanisms. Our analyses revealed the presence of three latent classes within the study sample – LC1: *the internal innovators* (*15, 43%*), LC2: *the non-innovation-oriented introverts* (*16, 5%*) and LC3: *the innovation-oriented extroverts* (*68, 52%*).

Discussion on the findings

Although a lot of interest and discussions have been around innovation systems and their activities, it seems that the industry is still too often mixing innovation processes, product development and technology development (Kahkonen, 2015) in project level configuration and design. This study explains the innovation logic in the Finnish construction companies. Without a new type of mindset, the construction companies may not renew themselves. Obstacles, such as lack of trust, unfair risk sharing and ineffective communication, are emphasised as challenges in the construction sector (Faris *et al.*, 2022) and can be seen in the LC1 and LC2.

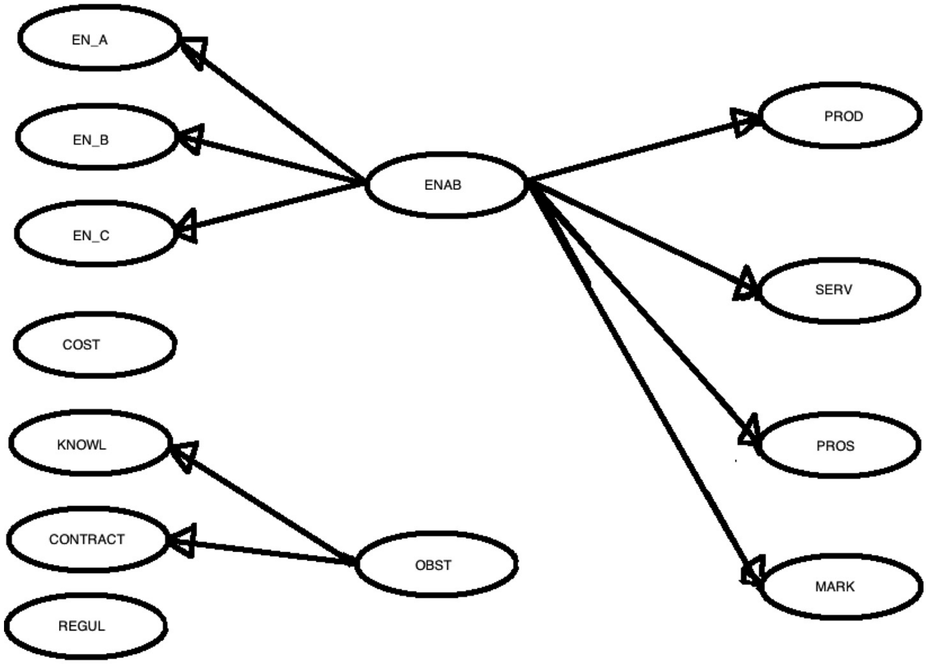

Figure 5.
LC3: The innovation-oriented extroverts (n = 111, 68, 52%)

Source: Author's own creation

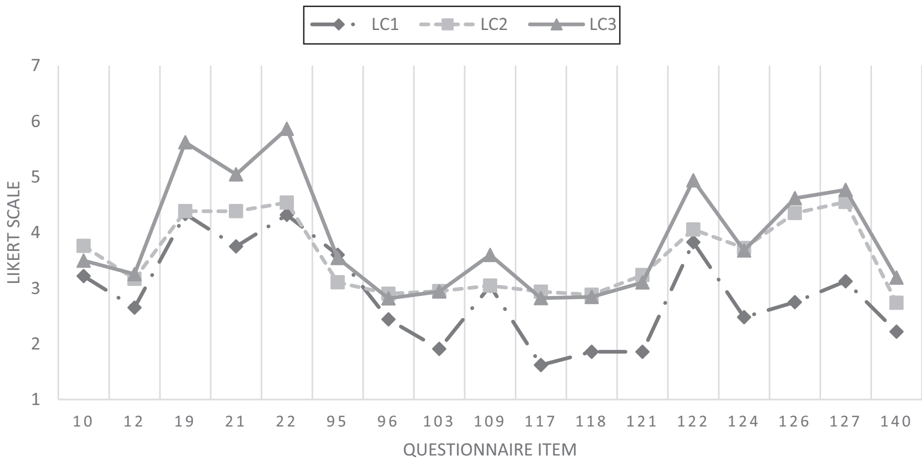

Figure 6.
Averages of statistical differences of latent classes

Source: Author's own creation

Table 5. Questionnaire items that differed statistically across latent classes

Nr.	Questionnaire item
10	Number of person-years of R&D personnel
12	Age of the company
19	The company has practices for using accumulated experience and lessons learned
29	The company has policies for developing reforms
21	The company has used the experience and lessons learned in the projects that followed
22	Innovation is a part of the company's operating model
95	The company has developed service innovations originating in other industries
96	Service innovations developed by other companies
103	Process innovations developed by other companies
109	Public sector customers play a key role in a company's innovation activities
117	Patents were an effective protection mechanism
118	The utility model was an effective protection mechanism
121	Trademarking was an effective protection mechanism
122	Speed of productisation was an effective protection mechanism
124	Confidentiality was an effective protection mechanism
126	Your company introduced organisational innovations by modernising business processes
127	Your company introduced organisational innovations by reforming information management
140	Marketing innovations use new pricing methods

Source: Author's own creation

Journey from an idea to the innovation is the outcome of people with different skills, knowledge, experience and perspectives collaborating to find new ways to solve problems or to reflect on current methods to finding more efficient and effective actions to goal accomplishment (Lloyd-Walker *et al.*, 2014). Many forces can drive construction firms to innovate, and many strategies can be applied to construction sector innovation (Meng and Brown, 2018). Nevertheless, construction industry needs to find a roadmap with modern technologies and delivery models, that can be seen in LC3.

Whereas innovation processes and their management can be seen as series of continual events, we identified three models that explained the company level innovation logic: *internal innovators*, *non-innovation-oriented introverts* and *innovation-oriented extroverts*. These classes adequately capture the innovation insights from the industry. The main question according to Hartmann (2006) is how the management used effort at managerial actions through which the importance of innovation related logic may be induced and reinforced.

The internal innovators

Being conservative and closed innovation providers, the internal innovators innovated inside the sector (Chesbrough, 2004). Further, they believed that the high levels of regulation imposed on construction industry were not conducive to either product or process innovation. Internal innovators were willing and eager to learn from outside the organisation but bit hesitant to innovate inside the organisation. In companies characterised by this type of innovators, the top management recognised the potential and provided possibilities for innovations through project-based learning, but they did not seem to recognise the scope for process innovation. Product, service and market innovations somehow offered a limited understating on innovations as a whole – or how they may contribute to the company. While this class did not seem to recognise the obstacles that could hinder innovations, they did perceive barriers to product innovations within the industry.

Internal innovators do not operate like the development of construction industry should do – as a network of collaborating companies (Shelton *et al.*, 2016). This is especially evident in situations where complex and innovative building designs are involved and flavoured with uncertainty, and there is an inherent need for collaborative problem-solving among project participants (Naar *et al.*, 2016). The better the uncertainties are managed, the better the project outcome is (Salerno *et al.*, 2015). However, the negative impact of associated industries, including the manufacturing industry, and consultants, such as engineers and architects, with a conservative approach act as hurdles to the implementation of an innovation (Shelton *et al.*, 2016). In summary, this class had a conservative approach to innovativeness and the innovation process.

The non-innovation-oriented introverts

The non-innovation-oriented introverts represented the class with the lowest innovation ranking. The data on this class was slightly confusing – they viewed knowledge as negatively affecting innovations and cost as an obstacle. From a practical point of view, this suggests that they anticipated an external body to fund their innovation activities. Such a scenario depicts a situation in which the top management does not support innovation activities or shows little interest in driving them. Innovators in this class found that obstacles had little relevance in terms of influencing innovations. Further, they perceived that even the enablers had a negative effect on generating innovations. Development within companies with such innovators possibly occurs on a project basis (i.e. customer requests), and such companies may not typically have a R&D budget.

Our data indicated that these organisations have no clear picture of how innovations emerge or what they could be. As process- and market-related innovations were not considered meaningful by these innovators, they were not seen as drivers of businesses or business models. In this class, a process or marketing innovation did not signify potential for development. Non-innovation-oriented introverts typically delivered to requirements, and their learning on projects tended to serve as a source of innovations.

Traditionally, competing relationships and a lack of collaboration are common in the construction industry (Faris *et al.*, 2022). Companies should recognise that innovation drivers can be either internal or external (Meng and Brown, 2018). A firm's network can be an important source of knowledge and competitive advantage (Dyer and Singh, 1998). Non-innovation-oriented introverts are unaware of the potential effects of networking on a firm's success, which has been endorsed by numerous experts (Granovetter, 1973; Hite and Hesterly, 2001; Ostgaard and Birley, 1996; Lechner and Dowling, 2003; Rogers, 2004; Watson, 2007; Park *et al.*, 2010). Further, it is highly likely that organisations engaged in temporary projects may be unable to apply specific project-related solutions to other projects across the board (Havenvid *et al.*, 2016).

Success in the construction industry requires effective inter-organisational management (Gambatese and Hallowell, 2011). For instance, Hartmann (2006) highlighted the significance of the company's top management: they should communicate the importance of innovative solutions thoroughly, offer employees the freedom to generate innovations and support innovative employees actively with their hierarchal potential. Improving performance calls for appreciating the limitations of objectivist and practice-based knowledge management within the context of construction projects (Addis, 2016).

Innovation-oriented extroverts

Innovation-oriented extroverts seemed to understand not only the importance but also the logic of innovations. They were in constant pursuit of innovations from all sources and recognised that innovations occurred at interfaces. They were also cognizant of the fact that the fragmentation within the construction sector could be solved through collaborations, which in turn could spur innovations (Tampio *et al.*, 2022). Because the traditional contract model did not enable innovations, many companies with this innovation approach are now shifting to collaborative projects to facilitate integrated deliveries.

The innovation-oriented extroverts use collaborative innovation projects as grounds to join forces for cooperation in the development and commercialisation of a new building product, system or service (Rutten *et al.*, 2014). Shelton *et al.* (2016) identified numerous barriers to innovation implementation, such as lack of in-house skills, financial constraints, resistance of associated industries and the culture within the construction industry. However, these barriers can be addressed by working like *innovation-oriented extroverts*. While this class of innovators recognised obstacles, they were not bothered by them (Tampio and Haapasalo, 2022). Overall, this class believed that the urgency of the business environment fuelled innovations, irrespective of regulations.

Tables 6 and 7 summarise the influence of enablers and obstacles within the Finnish construction companies. Essentially, anything can serve as a trigger for innovation once it is perceived as an opportunity. About obstacles, any industry that must follow normative regulations typically evolves slowly, partially because of the regulations themselves. Companies in such industries tend to limit themselves to fulfilling the requirements and not thinking beyond them.

Construction is a complex product and systems industry (Winch, 1998). Rightfully so, innovation in the construction industry has received considerable attention in recent literature, with various types of innovation research being explored (Lavikka *et al.*, 2021; Gledson, 2022; Agha *et al.*, 2021).

Enabler	Yes/No
Influence of the customer or contractor	Yes
Ability of the organisation to learn (experience and lessons learnt will be used later)	Yes
Support from the senior management for innovation and development activities	Yes

Source: Author's own creation

Table 6. Influence of enablers on a construction innovation

Obstacle	Yes/No
Management and leadership factors	No
Cost factors	Yes
Knowledge and experience factors	Yes
Policies and cooperation factors	No
General terms of contract or terms of delivery	Yes
Finance and business environment factors	No
Regulations and other factors	Yes

Source: Author's own creation

Table 7. Influence of obstacles on a construction innovation

According to Kahkonen (2015), it is important that the focus of innovation activities should be on understanding the business case, its dimensions and conveying this information to others involved.

Normative and regulatory nature of construction industry is rather similar globally, even the national or even regional regulations may vary in the detailed level. Our findings on the innovation bottlenecks within the construction industry are in line with those identified by Harty (2005):

- complexity characterised by inter-organisational collaboration;
- project-based approach;
- distributed power among collaborating organisations; and
- two modes of innovation: bounded (where the implications of an innovation are restricted to a single, coherent sphere of influence) and unbounded (where the effects of innovation implementation spill over to many spheres).

It is obvious that, a no-blame culture of organisation in construction industry is needed in which individuals do not fear repercussions from risk taking or problem identification, where employees feel free to contribute to discussions and raise issues (Lloyd-Walker *et al.*, 2014; Ali *et al.*, 2022).

While R&D undoubtedly plays a key role in the implementation of innovative solutions within a company, when viewed from a broader perspective, the innovation process encompasses much more than R&D. Businesses may innovate for varied reasons, but the main drivers are increased business performance and the need for a competitive advantage. Factors that encourage companies to innovate are suppliers and business growth (Barata and Fontainha, 2017). Because small and medium-sized enterprises (SMEs) have limited research budgets, they may be unable to develop new products or incorporate innovative technologies into existing products on their own. Therefore, SMEs may benefit from participating in research alliances (Brouthers *et al.*, 2015). At the same time, innovating companies are likely to face several challenges and experience several types of barriers (D'Este *et al.*, 2012). Therefore, conscious management of innovation in construction companies is an emerging need (Hartmann, 2006).

According to Barrett and Sexton (2006), innovations in small, project-based companies are closely tied to their operational activities, and they are pushed forward by the owners who use scarce resources to extend the boundaries of their normal business. Further, as every construction project is unique, it is difficult to apply an innovation that is specific to a building in another one (Murphy *et al.*, 2015). However, it seems that bigger companies do not have a separate systematic product development process (Pekuri *et al.*, 2014).

Unsurprisingly, the level of innovation within firms is positively associated with firm size (Arias-Aranda *et al.*, 2001); innovation is higher in large companies (Panuwatwanich and Stewart, 2012). Larger firms, or bigger alliances of companies, offer a more favourable and a more accepting environment into which new innovations may be introduced (Shelton *et al.*, 2016). Unbounded innovations are less discussed in the literature, where collaboration between many firms is required for successful implementation, although many innovations can be considered unbounded within construction company's inter-organisational context (Harty, 2005). In summary, the fragmented and project-oriented culture of the construction sector has not supported the creation and implementation of innovations in the past (Shelton *et al.*, 2016).

Conclusions

The objective of our study is to explain the innovation models prevalent within the Finnish construction company. By reviewing existing literature, we have generated a research model that has been verified with the help of empirical data.

Through FMSEM analysis, we have identified three latent classes that explain the innovation logic in the Finnish construction companies – LC1: *the internal innovators*; LC2: *the non-innovation-oriented introverts*; and LC3: *the innovation-oriented extroverts*. These three latent classes clearly capture the perceptions within the industry as well as the different characteristics and variables. The *internal innovators* are conservative; they innovate inside the company; and they typically try to learn from others, but keep the innovations within the company boundaries. This type of innovation logic results in only modest development in the industry executing a "closed innovation system". The *non-innovation-oriented introverts* have innovations in a very minor role, or they are not aware of the potential in innovations. These types of companies deliver only what has been asked in the bids, without any intention to change their operations. The *innovation-oriented extroverts* seem to understand the importance of innovations and are executing an "open innovation system" that results in productivity improvement in the industry. They also try to seek means to overcome obstacles, especially fragmentation, in the industry and aim on variety of collaboration that result in innovations. Our findings offer a glimpse into the emerging transformation towards collaborative contract models in the construction companies, encouraging firms to go beyond fulfilling requirements and actively drive the development and innovation.

Our main contribution pertains to the current state of innovation resulting in poor productivity development in the construction sector, characterised by heavy regulations, a conservative approach and a relatively low level of competence. Presented features of the three presented classes provide a starting point for increasing innovativeness in the construction industry and further increasing the productivity. Our research model and the logic inside the classes clarify the fundamental challenges in the industry. Construction industry is globally following normative regulations resulting in modest development. National or regional regulations may differ, but the logic seem to be similar globally. Further, by applying FMSEM analyses to the construction companies, this study has expanded the methodological practices available to scholars interested in studying innovation typologies in different industries and explaining the logic inside different classes that are described.

The limitation of the study is the small sample size, which in turn may influence the validity and reliability of the inferences and conclusions. Future research should focus on research topics that identified how systemic innovation gain maximum benefits using identified three latent classes that explain the innovation logic in the Finnish construction company. Further, additional research with qualitative methods would probably increase understanding in relation to more specific aspects that this kind of generalizable quantitative research may not capture.

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Appendix. Background information on informants

Table A1.
Title of the informants

Title	Respondents
Managing Director/CEO	57
Specialist	21
Director	10
Development Director	6
Development Manager	6
Project Manager	6
Designer	4
Regional Director	3
Developer	3
Architect	2
Production Manager	2
Design Manager	1
Foreman	1
Total	122

Source: Author's own creation

Table A2.
The professional experience of informants

Years	Respondents
> 30	57
≤ 30	34
≤ 20	24
≤ 10	3
≤ 5	4
Total	122

Source: Author's own creation

Table A3.
R&D budgets of the companies

Budget [€]	Companies
N/a	12
≤ 20,000	38
≤ 50,000	21
≤ 100,000	13
≤ 200,000	7
≤ 1 Milj.	13
≤ 2 Milj.	2
≤ 4 Milj.	2
≤ 5 Milj.	n/a
> 5 Milj.	3
Total	111

Source: Author's own creation

Industry	Amount
Design	43
Consulting	34
Building construction	30
Construction product industry	28
Construction	28
Infrastructure	17
Building ownership, operation and maintenance	9
Surface contracting	3
Education/Training	2
HPAC contractors	1
Total	195

Source: Author's own creation

Table A4. Services provided by the companies (multiple-choice)

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