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Exploitation of results of market survey

For

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Executive Summary

This report investigates the focus, motivations, and barriers to innovation, defined as the adoption and development of new methods, products, materials, or processes, among small and medium-sized enterprises (SMEs) in the construction sector. Innovation in this context includes a company's efforts to seek creative solutions, test new approaches, and integrate novel ideas while balancing the perceived risks that may accompany such changes. The report is based on interviews conducted with various companies and a survey performed across countries participating in Cosme Reno, including Belgium, France, Germany, Italy, Lithuania, and the Netherlands. The findings reveal three main areas of innovation: product, material, and process innovations, along with the characteristics of innovative SMEs and the factors influencing their capacity to innovate.

Common Types of Innovation for SMEs

Phase 1 focused on qualitative interviews with selected firms at the forefront of innovation, aiming to identify predictors of innovation, which will be evaluated quantitatively in Phase 2. The innovative firms interviewed were primarily engaged in product innovation, particularly in the field of energy systems. These firms focus on renewable energy technologies, plug-and-play solutions, and advanced heating, ventilation, and air conditioning (HVAC) systems. Some companies are integrating these innovations with building components, such as photovoltaic (PV) panels installed in facades and roofs. Material innovation is also significant, especially in the use of sustainable materials. Many SMEs conduct Life Cycle Analysis to optimize material usage and employ innovative combinations of materials, such as aluminum and glass in facades, to enhance energy efficiency. Process innovation is characterized by the adoption of modular construction methods, offsite building techniques, and an increasing reliance on automation and lean management practices. These companies aim to improve collaboration through standardized processes and co-creation, facilitating more efficient workflows and enhancing knowledge sharing, both in person and digitally.

Initial interviews with innovative SMEs suggest that they typically focus on larger projects and adopt a product-centric approach rather than a project-oriented one, meaning they focus on one specific part of the process, as opposed to the while project. They emphasize the importance of knowledge distribution both internally and externally, providing regular training for employees and fostering strong, trusted partnerships. These companies prefer to be involved in projects from

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the beginning, ensuring that each step of the construction or renovation process is well-coordinated. Transparent communication and documentation are essential for effective collaboration. Additionally, many SMEs are motivated by inspirational leadership, where passionate leaders drive innovation within their teams. Research and development (R&D) is also a priority for innovative SMEs, with some companies establishing dedicated R&D departments or collaborating with universities and research institutions on pilot projects.

Barriers & Enablers of Innovation

Despite a strong drive for innovation, several barriers impede progress. Financial constraints pose a significant challenge, with high initial costs and limited government support discouraging many SMEs from investing in new technologies. The rigid and conservative processes inherent in the construction sector, coupled with poor communication and established relationships within the value chain, further restrict innovation efforts. Client awareness is also a concern; many clients lack an understanding of innovative practices like modular construction, leading to diminished demand for these solutions. The current high demand for renovations in Europe reduces the incentive for companies to innovate, as they have sufficient work using traditional methods.

The motivations for innovation among SMEs in our interview sample are both intrinsic and extrinsic. Intrinsically, many participants feel a personal commitment to fostering change within the construction industry, particularly regarding sustainability. They view innovation as a pathway to personal fulfillment and professional growth. Extrinsic motivations often arise from frustrations with the inefficiencies of traditional construction practices. Legislative changes, especially those related to energy efficiency requirements, present opportunities for innovation, and some SMEs view innovation as a means to enhance scalability and attract new talent. A separate quantitative study examined factors influencing Innovation Capability at the company level, focusing on Network Building, Technological Innovativeness, and resistance to change. The results indicate that network building is the strongest predictor of innovation capability. Companies that prioritize external partnerships and actively develop networks are significantly better positioned to innovate, underscoring the importance of collaboration. Interestingly, Commitment to the Status Quo did not emerge as a significant barrier to innovation, suggesting that adherence to established practices does not strongly hinder innovation, especially in traditionally conservative industries like construction.

At the individual level, Technological Innovativeness was identified as a key driver of innovation. Employees who embrace new technologies significantly enhance a company's ability to innovate,

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highlighting the connection between digitalization and innovation potential. Additionally, a passion for problem-solving has a smaller but significant positive impact on innovation, indicating the importance of problem-solving skills in SMEs. The lack of a significant relationship between commitment to the status quo and innovation suggests that other barriers may play a more substantial role in constraining innovation efforts.

Types of Innovators

The study identified three distinct clusters based on innovation practices: Leaders, Adaptors, and Traditionalists. Leaders excel in both network building and technological innovativeness, placing a high value on internal R&D and collaboration with universities. In contrast, Adaptors find informal events valuable for gaining insights, while Traditionalists exhibit a more conservative corporate culture and may be apprehensive about the cost-effectiveness of innovation. Leaders are less influenced by full order books in their innovation efforts, while both Traditionalists and Adaptors perceive high customer demand as a factor that reduces the necessity to innovate.

Conclusion

In conclusion, this report highlights the essential roles of network building and technological adaptability in fostering innovation. It suggests that resistance to change, particularly in the form of commitment to the status quo, appears to be less of a barrier than previously anticipated. The findings indicate that firms should focus on external collaboration and embrace new technologies to enhance their innovation capabilities.

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Introduction

For Europe to reach the European Green Deal goals, accelerating the renovation speed is key. However, the challenge of retrofitting better and at a bigger scale can only be addressed if small and medium-sized enterprises (SMEs) are engaged since they constitute more than 90% of market players in the construction business. However, there are fears that there will be skilled labour shortages in the European construction sector, making it hard to reach the goals set by the EU. The Cosme Reno project aims to tackle this fear by focusing on SMEs, specifically in figuring out how to support them in developing joint offers, using prefabricated and off-site solutions, and delivering better warranties. In doing so, the Cosme Reno project aims to progress toward time- and energy-efficient renovations, by preparing the next stages of SME cooperation, methods, tooling, and co-investment. Cosme Reno is a complementary consortium from Italy, Belgium, Germany, Lithuania, The Netherlands and France.

To make the renovation and construction process more affordable and scalable, pioneer SMEs have an exemplary role in stimulating different kinds of SMEs to follow their lead and deploy new approaches in processes, materials, and products. Thus, the aim of WP3 is twofold:

1. Firstly, a mapping of the current barriers and drivers of innovation in the construction is proposed. This mapping is based on expert interviews with innovative pioneers in the construction business in Germany, France, The Netherlands, Belgium, and Italy. Additionally, a literature review was conducted to grasp an understanding of which barriers have been identified by earlier research in the context of the construction sector.
2. Second, a quantitative market survey was conducted among SMEs active in the construction sector in Europe, specifically in Germany, France, Belgium, The Netherlands, Lithuania, and Italy. In this phase, different types of SMEs were targeted, including more traditional companies. The survey was developed based on the insights of phase 1, in collaboration with the consortium partners, and focuses on identifying determinants of innovation for different types of SMEs.

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Phase 1: Mapping innovation factors in the construction business

Literature review

Innovation categories in the construction business

Past research on innovation in the construction business has focused on different types of innovation. Below, we present the most common innovation foci, grouped in different categories. This list is non-exhaustive and is based on research in the field of innovation in the construction business conducted after 2010.

Material innovation: focus on innovative use of materials, reusability, and sustainability of materials

- Life Cycle Analysis of materials (Giorgi et al., 2022; Marini et al., 2022; Passoni et al., 2021)
- Reduction of raw materials/resources & waste management (Marini et al., 2022)
- Sustainable material awareness/eco-efficient materials (Passoni et al., 2021)
- 3D printing (D'Oca et al., 2018)

Process innovation: focus on new forms of collaboration between construction partners, improving the efficiency of the construction process and workflow

- Cooperation between professionals (Passoni et al., 2021)
- Co-creation instead of linear collaboration process (Giorgi et al., 2022; Marini et al., 2022; Passoni et al., 2021)
- 4M modular process: mapping, modelling, making, monitoring (Piaia et al., 2019)
- Off-site construction of components (Giorgi et al., 2022)
- One stop shops (Bertoldi et al., 2021)
- Constructive technologies for reversible building (Giorgi et al., 2022)

Modularity: standardization of building components

- 3D prefab building components (D'Oca et al., 2018; Vavallo et al., 2019)

Energy systems: development of renewable energy systems, energy systems that can easily be integrated into new/existing buildings, extension of energy systems beyond heating

- Renewable energy systems (Hoppe, 2012)
- Plug & play energy technologies (Piaia et al., 2019)
- Integrated solar panels, façade-integrated sensors (Vavallo et al., 2019)
- Advanced heating, ventilation and air conditioning (D'Oca et al., 2018)

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- Smart connectors (D'Oca et al., 2018)

Financial: innovation in business models

- Circular business models and new service-oriented business models (Giorgi et al., 2022)

Tools: the use of (digital) tools that aid in improving the workflow or support sustainability practices

- Life Cycle Assessment tools (Giorgi et al., 2022; Marini et al., 2022; Passoni et al., 2021)
- Renovation collaboration platforms (Giorgi et al., 2022; Vavallo et al., 2019)
- Rating certification systems (Nearly Zero Energy Building, LEED) (Giorgi et al., 2022; Passoni et al., 2021)
- ICT support for building management systems (D'Oca et al., 2018)

Table 1: Innovative Approaches in Construction: Focus Areas, Examples, and Key References

Category	Focus	Examples	References
Material Innovation	Innovative use of materials, reusability, and sustainability of materials	Life Cycle Analysis of materials, Reduction of raw materials/resources & waste management, 3D printing	Giorgi et al. (2022), Marini et al. (2022), Passoni et al. (2021), D'Oca et al. (2018)
Process Innovation	New forms of collaboration, improving the construction process and workflow	Cooperation between professionals, Co-creation, 4M modular process, Off-site construction, Constructive technologies for reversible building, One stop shops	Passoni et al. (2021), Giorgi et al. (2022), Marini et al. (2022), Piaia et al. (2019), Bertoldi et al. (2021)
Modularity	Standardization of building components	3D prefab building components	D'Oca et al. (2018), Vavallo et al. (2019)
Energy Systems	Development of renewable energy systems and integration into buildings	Renewable energy systems, Plug & play energy technologies, Integrated solar panels, HVAC systems, Smart connectors	Hoppe (2012), Piaia et al. (2019), Vavallo et al. (2019), D'Oca et al. (2018)
Financial Innovation	Innovation in business models	Circular business models, Service-oriented business models	Giorgi et al. (2022)

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Tools	Digital tools to improve workflow or support sustainability	Life Cycle Assessment tools, Renovation collaboration platforms, Rating certification systems, ICT support for building management	Giorgi et al. (2022), Marini et al. (2022), Passoni et al. (2021), Vavallo et al. (2019), D'Oca et al. (2018)

Research on barriers preventing innovation in the construction sector

Past research has identified several barriers that prevent construction or renovation companies from innovating. Below, we address the most important ones, grouped per category. This is a non-exhaustive overview, based on qualitative and quantitative research done since 2010.

First of all, barriers can be related to clients. Here, one of the main barriers identified was that there is a **low awareness and a low demand** on the side of the client for more innovative practices, meaning they are often unaware of the benefits of innovation (Häkkinen & Belloni, 2011; Kirchherr et al., 2018).

Second, there are barriers related to the collaboration process. The value chain in the construction business is rather **conservative** and **linear** (Kirchherr et al., 2018), which prevents companies from pivoting or trying out new things. Additionally, there is a large **dependency** on other actors, implying some sort of **loyalty** (Kirchherr et al., 2018) and a strict division of **responsibilities** (Giorgi et al., 2022), making it hard to implement changes that affect the other companies in the value chain. Lastly, for a lot of companies, it is not worthwhile to change their entire process (Häkkinen & Belloni, 2011).

Third, different sources identified financial barriers. Innovation requires high upfront investment costs, and often, companies **lack** the **money** to invest in innovation (Chan et al., 2017; D'Oca et al., 2018; Häkkinen & Belloni, 2011; Hofman et al., 2022; Hoppe, 2012; Kirchherr et al., 2018). If companies are capable of investing, the payback time (ROI) is often very long (D'Oca et al., 2018). Additionally, there is a **lack of government support** to make innovation more affordable for smaller companies (Chan et al., 2017; Hofman et al., 2022), and often, companies are unaware of the existence of support measures (Chan et al., 2017; D'Oca et al., 2018).

Fourth, there are functional barriers to consider, related to the wider context in which companies operate. There is a **lack of uniform legislation** across Europe, but also within countries (Giorgi et al., 2022; Hofman et al., 2022). Additionally, research shows that **legislation** often **lags behind**, meaning it does not motivate innovation (Hofman et al., 2022; Kanters, 2020) or that it is **not**

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flexible enough to be applicable to the variety of projects in the construction landscape (Kanters, 2020). New legislation is often tailored towards new buildings but not applicable for renovations (Hofman et al., 2022), even though the existing building stock in Europe is in dire need of an upgrade. Lastly, it is hard to get certifications of quality for innovations (e.g. reusable materials or new products), which makes customers more cautious in trusting these solutions (Giorgi et al., 2022; Häkkinen & Belloni, 2011).

Fifth, research identified several knowledge barriers. On the one hand, there is a lack of knowledge on innovation in the construction business, specifically related to prefab and modular buildings (D'Oca et al., 2018; Giorgi et al., 2022; Hofman et al., 2022) and energy efficiency (D'Oca et al., 2018). On the other hand, the available information is often very complex (Hofman et al., 2022), making it hard to implement new processes and products in the current way of working.

Sixth, there is one people-related barrier that was identified in multiple research, being a lack of skilled labor and technical expertise in the construction sector (Chan et al., 2017; D'Oca et al., 2018; Giorgi et al., 2022; Häkkinen & Belloni, 2011). This implies that on the one hand, there are not enough people with the right knowledge available to distribute information and drive innovation. On the other hand, there are also not enough people to carry out renovation and construction work, let alone enough people that have the skills necessary to implement innovative processes or products.

Seventh, there were several psychological barriers. First, conservatism in the company means that there is a lot of resistance to change. Often, there is a commitment to status quo, i.e. an adherence to the current way of working, as well as resistance of stakeholders to change (Chan et al., 2017; Giorgi et al., 2022; Häkkinen & Belloni, 2011; Hofman et al., 2022; Kanters, 2020; Kirchherr et al., 2018). Additionally, companies will often use the argument that innovation takes too much effort for not enough/an uncertain return on investment (D'Oca et al., 2018; Häkkinen & Belloni, 2011), meaning that they don't know if the invested time will be won back in the future. Lastly, conservatism might be linked to a low acceptance of new technologies that could improve the working flow (D'Oca et al., 2018).

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Expert interviews

Methodology

To gather insights from pioneers in the construction business, **qualitative in-depth interviews were conducted with 19 SMEs** from the countries of the consortium partners. Interviews are an excellent way to gather an in-depth understanding of the types of innovation that SMEs are focusing on, as well as identify their motivations to do so and which barriers they encountered on the way. Additionally, this methodology enables us to identify common characteristics present in innovative SMEs across the value chain. Lastly, by interviewing people working in an SME, we can better understand the influence of the client side on the innovation process. Because of geographical limitations, all interviews were done digitally via Teams. Each interview was attended by two people from the Cosme Reno project: one interviewer and one notetaker. Before each interview, participants received an explanation of the project aim, as well as the chance to (dis)agree to record the interview for later analysis. All participants could interrupt or end the interview at any time.

Topic list

A full overview of the topic list can be found in **Appendix A**. First, the introductory part focused on characteristics of the SME related to size, country, the role of the interviewee within the company, and years of experience. Subsequently, we asked interviewees what innovation means for their SME, and in what way they are being innovative (e.g., process, product, material). Additionally, we asked about their motivations for innovation: why did they deviate from the traditional way of working, what sparked their decision, and who inspired or influenced them? We then focused on the more practical side, asking interviewees to talk about the current situation in the construction sector in their country and reflect on how changes were perceived within the company, by other companies that they collaborate with, and by clients. Lastly, we asked participants to reflect on what could hold other SMEs back from becoming more innovative, focusing on aspects such as financial limitations, conservatism within the company, client demands, and a lack of knowledge.

Sample

We selected all participants through the consortium partners active in WP3. An initial set of participants was selected, after which the snowball sampling method was applied to reach new profiles. In total, 19 participants were interviewed. Interviewees came from different types of SMEs,

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being a) an industrial SME producing integrated solutions, b) an SME installing solutions on site and maintenance, c) an SME active in maintenance, monitoring, or responsible for performance warranty, or d) engineering & architecture companies spread over the participating countries. A full overview of all interviewees can be found in Table 2.

Table 2: Overview of participants of expert interviews with country, company, focus, company size, and role

Country	Company	Size	Role
Renewable Energy Systems & Installation			
BE	Litobox	5	CEO
BE	Thermad/Climco	5	Project engineer
BE	Futech	50	Engineer
BE	Soltech	7	CEO
DE	GAP Solutions	15-20	Manager
DE	Renowate Earth	-	Business manager
Consultancy & Advice			
FR	Pouget Espace Consultancy	106	Business manager
BE	Embuild	15	Advisor
HU	Abud	25	Founder
Prefab & Construction			
BE	Skilpod	100	Engineering manager
DE	B&O Gruppe	1000	Branch manager
IT	Pozza Matteo Sas	30	CEO
IT	Imprendiroma	250	CEO
FR	Rabot Dutilleul	500-1000	Director of innovation
Ventilation, Monitoring, & Innovation			
NL	Brink Climate Systems	250	Consultant
ESP	Airzone	450	Business development manager
NL	TKI Urban Energy	35	Program manager

Results

Innovation within SMEs

There are several different types of innovation which emerged as most predominant for SMEs. First, there is innovation on a **product level**. Most companies that focus on product innovation were doing so around energy systems. On the one hand, there were companies focusing on (a combination of) renewable energy systems, plug-and-play energy technologies, or advanced heating, ventilation, and air conditioning systems. On the other hand, some companies focus

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specifically on the integration of energy systems, e.g., by producing PV panels integrated into facades, roofs, or other building components.

Second, there were companies active in material innovation. In that category, innovation was mostly linked to consciously using sustainable materials, focusing on the life cycle of materials through Life Cycle Analysis and using innovative materials that could produce energy gains, e.g., the combination of aluminium and glass in facades.

Lastly, most companies were active in process innovation. This could manifest itself in different ways. First, companies could focus on modularity, specifically using prefab 2D or 3D components and focusing on offsite construction. Second, in the collaboration process, there could be a focus on the standardization of collaboration, and co-creation instead of a linear flow and relationships with fixed and trusted partners. Third, when looking at the value chain flow, there could be more focus on either aftercare or the preparation phase, as well as introducing lean management on the construction site and adopting more automation and industrialization throughout the workflow. Lastly, looking at knowledge, companies could actively focus on knowledge documentation and sharing, both in-person and digitally, by for example providing affordable trainings and info sessions.

Based on the interviews, several characteristics seem to be prevalent in innovative SMEs in the construction sector. These characteristics can be divided into different categories.

Firstly, when looking at the focus of innovative SMEs, we see a focus on bigger projects, e.g. multiple homes or bigger buildings. Additionally, some SMEs mentioned that they adhered to product thinking rather than project thinking, meaning they focus on one specific part of the process. However, they also underlined the importance of diversifying their expertise, meaning that they combined their innovative product/process/material with more traditional alternatives. Companies also had a clear long-term vision for where they were heading in the future.

Second, when looking at the role of knowledge, we see that there is an active awareness in most innovative SMEs of the importance of knowledge distribution, both among employees and among external parties such as clients and other companies. Internally, most companies provided trainings for their employees.

Third, the network of companies plays an important role in boosting their innovation process. This can be by looking at other sectors for inspiration or being aware of how similar companies are moving in the (inter)national market. Additionally, creating a strong and tight network of trusted

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partnerships was key for most innovative SMEs, specifically to establish recurring collaborations with fixed partners.

Fourth, the process of most innovative SMEs diverges from the traditional linear construction process. As part of the recurring collaboration, these SMEs prefer to be involved from the very start of the project, to ensure that all steps of the construction or renovation process are adjusted to each other. To ensure that even more, they prefer close and frequent contact with other parties, through transparent digital documentation and communication.

Fifth, on a psychological level, an inspiring leader who can translate his or her enthusiasm to the employees seems to have a big impact on the company's motivation to innovate. In most SMEs, there was one person that had a high motivation to try something new and was able to ignite that spark among more people working at the company.

Lastly, these companies usually value R&D. There is a willingness to dedicate time to exploring new ways of doing things, and in some cases, there is even an R&D department present. Additionally, some of these companies participate in pilot projects or collaborations with universities or study offices to explore new ways of approaching challenges the construction sector is currently facing.

Motivations for innovation of SMEs

In the interviews, we first focused on the motivations of people working at innovative SMEs or the people founding innovative companies. On the one hand, interviewees mentioned being more intrinsically motivated, meaning that they innovate because they adhere personal importance to this type of behaviour or deem it relevant to their personal goals (Ryan & Deci, 2000). Participants mentioned that they wanted to make an impact on the construction business and that changing it creates a sense of personal achievement. For some participants, this was specifically linked to the ecological/sustainable aspect, wanting to make the construction sector more sustainable. Related to that, some interviewees mentioned that they started working for or founded an innovative company because it offered a personal challenge and a way to grow professionally.

On the other hand, interviewees mentioned more extrinsic types of motivations, related to external impulses (Ryan & Deci, 2000). One of the main catalysts for interviewees to switch to a more innovative workplace was being frustrated with the current way of working in the construction business. The traditional construction process is very rigid and inefficient, and additionally, there is a lack of aftercare, leading to frustrated customers and complaints after the work is

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finished. Thus, participants indicated that they saw innovation as a way to make the construction business more scalable and affordable. Additionally, changes in the legislation related to the construction and renovation of buildings were perceived as an opportunity for innovation. In Belgium, for example, the EPB legislation compels new homeowners with an EPC certificate of E or F to renovate their homes within five years of buying it to an EPC certificate of D or higher, creating a higher demand for energy-efficiency renovations. On the other hand, changes in the legislation were also perceived as an obligation for innovation, for example because contractors are obliged to comply with certain (energy-efficient) norms when renovating or constructing new buildings. Either way, there seems to be a general feeling of pressure from the market to focus more on innovation, specifically for serial renovations, because of the potential to increase the energy-efficiency of multiple home units at once. Lastly, for some SMEs, being innovative is a feature that they use to attract and motivate new employees.

Barriers preventing innovation in SMEs

In the interviews, we also focused on the barriers that could prevent SMEs from investing in or focusing on innovation.

First, many recurring barriers were financial. A lot of companies mentioned that there is a high investment cost to start innovating, and that even with subsidies, you must still make the investment upfront. Thus, for most companies, a lack of time and money to invest was one of the main reasons not to engage in innovation. Additionally, two SMEs mentioned that they have little knowledge on which innovation subsidies exist, and that often, the subsidies are not tailored to the needs of construction companies. Subsequently, there was a sense that the government does not support innovation enough to make it affordable for smaller companies.

Second, several barriers were related to the way in which companies collaborate in the construction or renovation process. One of the main barriers here was conservatism in the value chain. Companies mentioned that the construction process is a rigid one, with a lot of intermediaries and dependencies. When introducing innovation, that rigid structure needs to change as boundaries between stages blur, but construction companies often are not flexible enough to deal with those changes. Moreover, when the rigid structure changes, there is clarity on responsibilities and which company takes accountability for which steps, causing further frustration. This can be intensified by poor communication. Lastly, there is often a sense of implicit loyalty between actors in the value chain, making it hard to for example cut out an intermediary, even if that would make the construction process more efficient.

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Third, some companies mentioned clients as a barrier to innovation. The most prevalent remark from companies was that in general, their clients had low awareness of innovative construction practices such as modular building, which caused a low demand. Additionally, there currently is a high demand throughout Europe for renovations and constructions, so companies do not feel the need to innovate, as they have enough work as is. Additionally, innovation is perceived as more costly than the traditional way of working.

Fourth, the wider context in which companies operates poses functional barriers. For a lot of SMEs, legislation currently is not motivating innovation, because the minimum bar is set too low. If clients do not feel the need to reach the best energy efficiency as possible, companies will subsequently not feel the need to change their processes and products to reach those high standards. Additionally, legislation is not uniform across different European countries, making it hard for SMEs making for example modular building components, to scale beyond their local context. Some companies also mentioned that legislation either lags and is not up to date, which slows down the innovation process, or that legislation is tailored towards new buildings and not towards renovations. Lastly, if you use an innovative process or product, it is hard in some countries, such as France, to get that innovation certified.

Fifth, people play an important role in stimulating or preventing innovation. One of the main barriers preventing innovation here is the lack of skilled labourers and technical expertise in the construction business, making it hard to implement new products or ways of working. Additionally, SMEs focusing on product innovation mentioned the resistance of installers to work with a new product. This might be out of fear of losing a part of their commission, or because a new product requires time and effort to get used to it. Lastly, architects are also often hesitant to embrace more efficient building techniques such as modular building, because it compromises their creative freedom.

Sixth, a number of barriers mentioned were related to knowledge. Generally, almost all SMEs testified that there is a lack of knowledge on innovation in the construction sector, specifically concerning prefabricated components and buildings, more sustainable materials, and digital tools that can make the construction process more efficiently. Additionally, it is hard for companies to find the right information, because of a lack of resources and the complexity of the information available.

Seventh, the construction process is not built for innovation, because it generally moves at a slow pace, with people being involved in a very linear way. However, when working with a new product,

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such as modular components, it makes sense to create involvement of all parties from the start. Additionally, for renovations in specific, modularity and standardization are hard to apply because of the specific needs of different types of buildings and different types of renovations.

Lastly, there were several psychological factors that seem to play a role in preventing innovation from happening. One of the main psychological factors that plays a role is **conservatism in the company**. Interviewees mention that in some companies, management is averse to change. Often, this has to do with the fact that **strict processes** are in place and there are **long-formed habits** that companies hold on to. Subsequently, the argument is often made that innovation takes up **too much time and effort**, while it is not certain at all if all those efforts will pay off. Additionally, if a company is not involved early on, it is hard to catch up with innovative processes. According to the companies we interviewed, it is important that the company has a long-term vision, with companies with **no awareness of** what is coming also having no wish to change, because the current situation is comfortable. Lastly, there is an aspect of **fear**, both that the current way of working is lost, or that the innovation will fail when being placed in the market.

Impact of clients

When asking innovative companies why clients end up choosing them, they mention different motivations. Some clients choose a company because of the **innovative approach**, being attracted to the newness of a product or an approach, while other clients value **sustainability** and get in touch with a company because of their sustainable approach. Additionally, some companies mentioned that in their case, clients contacted them because their product or service makes the construction or renovation process more **efficient**. This is mostly the case for companies active in the prefab/modular construction business. According to the interviewees, financial motivations also play a role. For some clients, choosing a more innovative energy system would lead to **financial gains** because of savings in energy costs. Additionally, in some cases, the innovative approach is **more affordable** than the traditional way of renovating, especially when comparing new buildings being constructed traditionally or with prefab components.

We also focused on reasons why clients do not opt for more innovative construction companies. Here, we found that the financial cost plays a primary role. Often, it turns out that the more innovative approach is **more expensive**, mostly because it has not been scaled up yet. For example, using prefab in renovations as an individual is more expensive, but for multi-home units, it becomes more affordable. Second, clients often get **conflicting advice** on which approach to take in the renovation or construction process, and the **information** available on renovation and

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construction is **complex** and hard to understand. Additionally, some clients are afraid that innovations are **not mature enough** yet or need to evolve more before they can be used. Lastly, clients can change their mind because of **changing regulations on subsidies**, because they are no longer eligible for financial support for specific parts of the renovation process.

Phase 2: Quantitative market survey

Survey development

The survey structure and items were developed based on three input levels. First, we reviewed the **literature** and identified common innovation types and barriers. Second, we compared what was found in earlier research with the output of the **expert interviews**, identifying overlap in barriers and new barriers and drivers that were not present yet in the literature but were mentioned across different expert interviews. Lastly, we made a first **proposition** which was presented to all consortium partners within WP3. Their professional feedback was used to further streamline and prioritise the structure of the market survey.

Item development and translation process

Most of the items were formulated based on the output from the expert interviews. For all items, a first version was sent to all consortium partners for feedback. For the theoretical model, all items were selected from validated scales. After the first feedback round, alterations were made were necessary. Afterwards, the survey was pre-tested by people active in the construction sector, provided by the consortium partners. Subsequently, alterations were made to make sure that all items were understandable for the target audience.

The survey was distributed in 7 different countries, being Belgium, France, The Netherlands, Germany, Italy, Lithuania, and Spain. To make it as easy as possible for participants to fill in the survey in their native language, the survey was translated into 6 different languages: Dutch, French, Italian, German, Spanish, and Lithuanian. We translated the survey using a back translation method (Brislin, 1970) with help from the consortium partners. For each language, a native speaker of that language translated the survey into his or her language, after which the items were translated back into English. If any disparities with the original English items were identified, the process was repeated until a satisfactory translation was achieved.

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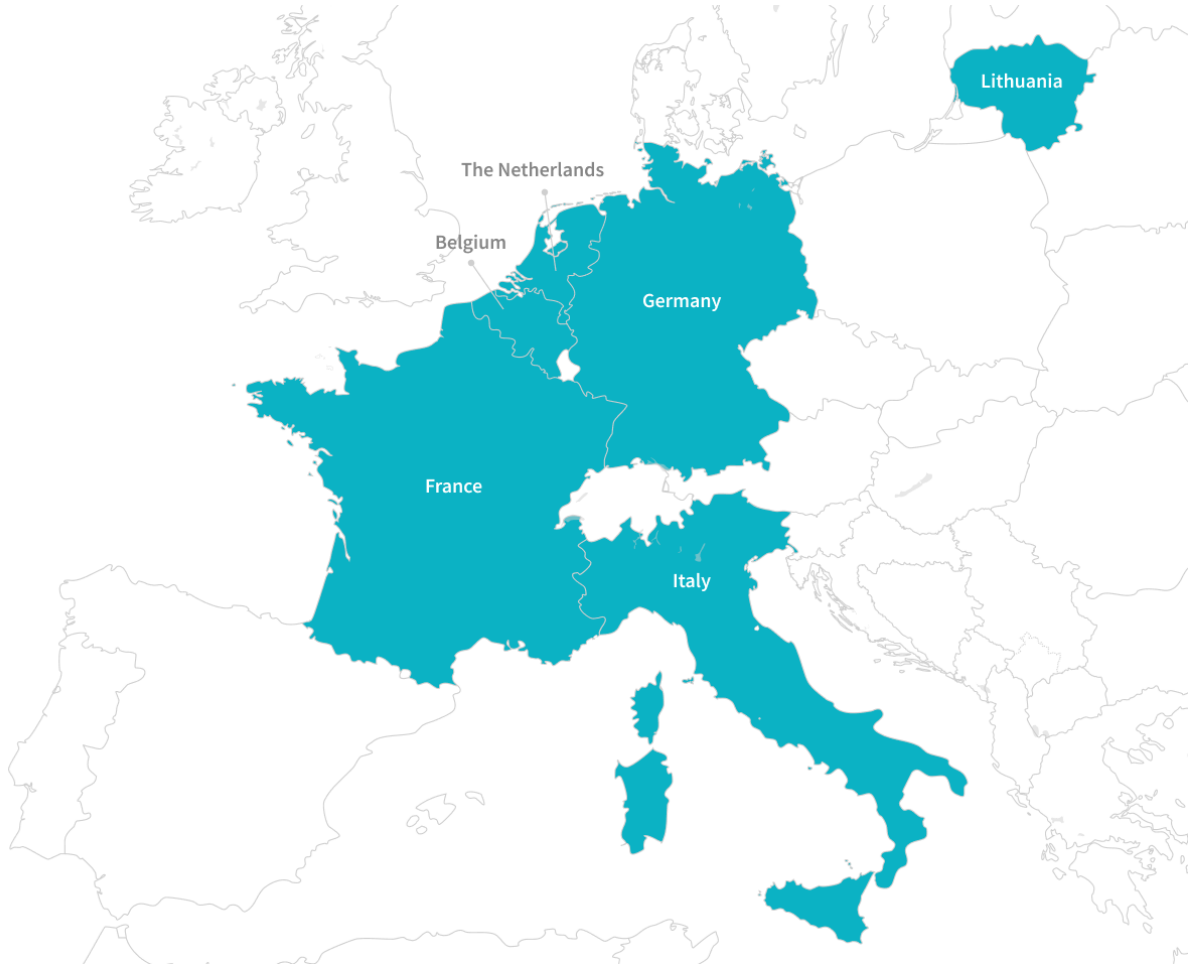

Figure 1: Geographic spread of participating SMEs

Data cleaning

For both age and SME size, we received entries that were not plausible (i.e. very high). To preserve as much of our sample as possible, these implausible values were replaced by the median ones within the sample. We additionally retained the 150 persons who completed the survey fully.

Survey structure and items

SME characteristics and workflow

First, we selected several characteristics that could be relevant for the clustering analysis. We included the size of the SME, how old the SME is, whether the company is family-owned, and whether the company is active on the stock market. We identify the SME focus, as being renovation,

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construction, or both. Additionally, we ask in which **category** the SME is primarily active, including the following categories:

- Design, architectural, or engineering firm
- Service provider (diagnostic analysis, 3D scanning, structural tests, digital twin, etc.)
- Manufacturer/producer of single components (windows, insulation, PV panels etc.)
- Manufacturer/producer of off-site composed/integrated systems (energy systems, prefab panels, etc.)
- General contractor, main construction company, one-stop-shop
- Craftsman, installer and/or maintainer of envelope components (provisional works, walls, facades, finishings, prefab panels, etc.)
- Installer and/or maintainer of technical systems (electricity, plumbing, ventilation, elevator systems, etc.)

Participants were also asked to indicate which **type of innovation** they were focusing on if they were innovating in some way. We categorized the innovation types into the following categories:

- Product: we design, sell, or install efficient energy systems, prefab elements, integrated technology systems…
- Process: we develop global renovation offers (one-stop-shop), we implement off-site construction, we cooperate with parties involved instead of subcontracting…
- Materials: we use sustainable materials, we focus on the circularity of materials…
- Sustainability: we offer energy performance guarantees, we integrate carbon footprint indicators to reduce the impact of our operations…

Additionally, we assessed the use of digital tools within SMEs. Participants were asked to indicate which **software** the company uses on a regular basis, with the option to share the name of the specific software program. We assessed software in the following categories:

- Design software
- Project management software
- Company management software
- Product management software
- Sustainability software
- Supply chain collaboration software

Participants were also asked where the company gets **new ideas** from, with the options extending from customers and suppliers/distributors to internal management or R&D, or even regulatory bodies or research institutes.

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Theoretical model – predicting innovation

Based on the literature review and the expert interviews, we identified several SME characteristics that could predict how likely it is for an SME to engage in innovative practices. We identified four predictive variables on two levels. On the one hand, we looked at the company level, because we assume that company culture and habits will have an impact on the innovation capabilities within that company. On the other hand, we looked at the individual level, because we assume that in the context of SMEs, individuals with decision-making power (e.g. the CEO or founder, a managerial employee) can play a decisive role in steering a company's innovation capabilities. An overview of the model can be found in Figure 2.

On the company level, we first selected 'Network Capability Building' (Parida et al., 2017). We selected this variable because both the literature review and the expert interviews identified the importance of partnerships and a strong network for innovation within companies. We selected a 3-item scale, which could be answered on a 5-point Likert scale with 1 being 'strongly disagree' and 5 being 'strongly agree'. An example item was 'The company can initiate a mutual relationship with new partners'. Additionally, we selected 'Commitment to Status Quo' as a second variable, because multiple experts identified this as one of the main barriers to innovation within companies, linked to the conservative nature of the construction business. We selected a commitment to status quo scale from Goyal et al. (2022) and adapted it to fit our research questions. The scale consisted of 4 items, which could be answered on a 5-point Likert scale with 1 being 'strongly disagree' and 5 being 'strongly agree'. An example item is 'changing the current way of working would require considerable sacrifice'.

On the individual level, we first selected 'Technological Innovativeness', because the existing research and literature suggest that being open to new technologies implies more digitalization, which could be related to innovation. We selected 4 items from the Technology Readiness Index (Parasuraman & Colby, 2015) which could be answered on a 5-point Likert scale with 1 being 'strongly disagree' and 5 being 'strongly agree'. An example item is 'other people come to me for advice on new technologies'.

For the second variable on the individual level, we selected 'Passion for Problem-solving', as a predictive variable. Based on the expert interviews, we assume that the presence of one person in an SME with a passion for problem-solving can impact the innovation capabilities of the company. We selected a 4-item scale that was used in the context of predicting SME's performance (Adomako & Ahsan, 2022). All items could be answered on a 5-point Likert scale with 1 being

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'strongly disagree' and 5 being 'strongly agree', with an example item being 'searching for new ideas for products/services to offer is enjoyable to me'.

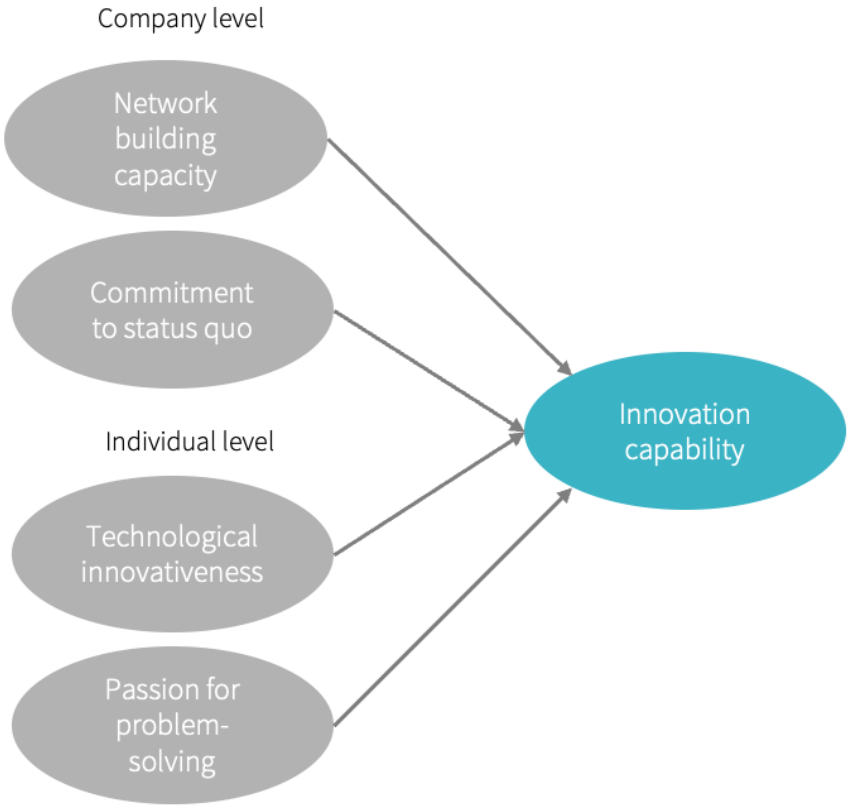

Figure 2: Theoretical model predicting innovation capability of construction/renovation SMEs

As an outcome variable, we have '**Innovation Capability'** as defined by Lin (2007) in research on knowledge sharing and firm innovation. In this research, 'innovation capability' is defined as organisational innovation, such as faster problem-solving capability and rapid reactions to new information. The scale used consisted of 4 items, which could be answered on a 5-point Likert scale with 1 being 'strongly disagree' and 5 being 'strongly agree'. An example item is 'the company seeks new ways of doing things'.

Barriers and drivers for innovation

In the second part, we assessed drivers and barriers of innovation within SMEs in the construction business. First, we asked participants to indicate **what motivates their company** to focus on innovation. We presented 10 items that could be ranked on a 5-point Likert scale, with 1 being

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'strongly disagree' and 5 being 'strongly agree'. The items were selected and phrased based on the expert interviews. Some example items are 'frustration with the inefficiency in the construction business, 'a passion for sustainability and environmental challenges' and 'making renovations more affordable'.

Second, we also asked participants what holds the company back from focusing on innovation. Here, we selected 14 items based on the literature review and the expert interviews. All items could be ranked on a 5-point Likert scale, with 1 being 'strongly disagree' and 5 being 'strongly agree'. Some example items are 'lack of innovation centres and support', 'there is a lack of consumer awareness and interest in innovation', and 'too high upfront investment costs'.

Client characteristics, barriers and drivers

Lastly, we gathered some information on the clients of construction/renovation SMEs. First, we asked for the primary country for clients, as well as the type of clients, distinguishing between homeowners, housing organisations, the tertiary sector, the industrial sector, public administrations and B2B services. Additionally, for companies working in the residential sector, we asked which type of housing they focus on: single-family housing, multi-family housing or both.

Additionally, we assessed the barriers and drivers of clients for contacting an SME. All items could be ranked on a 5-point Likert scale, with 1 being 'strongly disagree' and 5 being 'strongly agree'. For the barriers, we selected 4 items based on the expert interviews, with an example item being 'clients fear that our product or service is not yet mature enough'. For the drivers, we selected 5 items based on the expert interviews. An example item is 'our product or service makes the renovation more affordable'.

Open questions

At the end of the survey, we asked two optional open questions to the participants. First, we asked them whether they had experienced collaborating in the prefab market and if so, what their collaboration experience was like. Second, we asked them which changes they thought were necessary for the industry to make innovative renovations more accessible to smaller construction companies.

Context & participants

For the quantitative analysis, the focus was decisionmakers within SMEs, with an emphasis on the general (i.e. not frontrunner market), to establish more empirically which needs and barriers

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currently exist among the broader market. Therefore, we specifically targeted SMEs in the construction business with less than 250 employees. Decisionmakers could be the CEO, founder or someone in management, but in smaller companies, this could also be a regular employee with a specific profile.

The survey was launched by the consortium partners in six countries (Figure 1), i.e. Belgium, France, The Netherlands, Germany, Italy and Lithuania through their professional networks. The survey could be filled in by participants from other countries as well, but these countries were our primary focus. The aim was to reach an even number of participants for each country, aiming for 70 participants per country, with a total of 400 participants. This would ensure a clustering where the country as a variable could be included in the final analysis. Of course, the actual number of participants depends on the size of the country and the number of SMEs within the country.

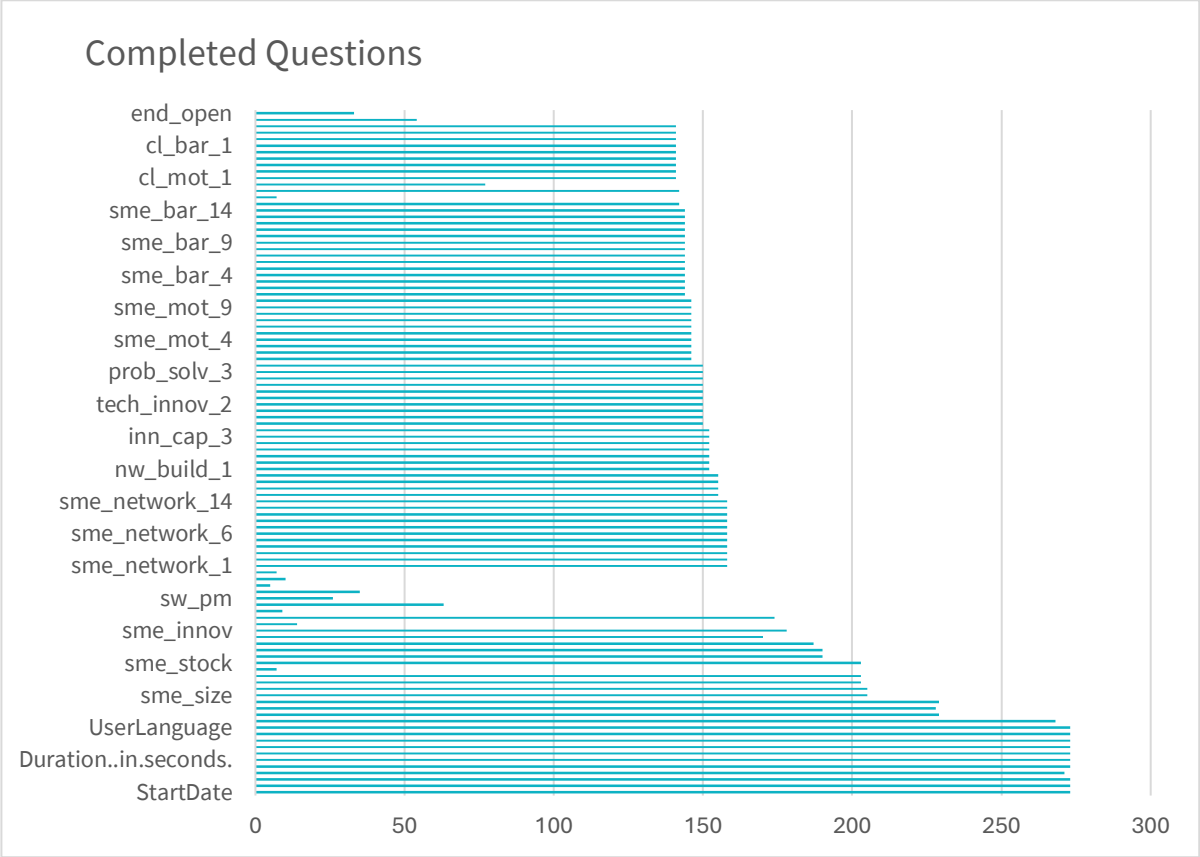

Figure 3: Drop-off rate of respondents (not all questions are shown)

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The survey was launched at the beginning of May 2024 and responses were collected throughout the entire summer. The last responses were gathered in September 2024. A total of 150 completed respondents were collected.

As seen in Figure 3, we see that 273 participants opened the survey, however, many did not go past the first page. This suggests that the survey was opened but not filled in. However, we see that once participants reach the sme_network_1 question, retention rates are high, with only 8 people not completing the survey.

Results

General sample composition

As presented in Table 3, the majority (76%) identified as men, while 23% identified as women. A small proportion (1.3%) preferred not to disclose their gender, and no respondents identified themselves as ''X''. The average age of respondents is 49 years, with a range from 19 to 77 years n terms of education levels, 53% of respondents reported having a Master's or equivalent degree, making it the most common level of education. Bachelor's or equivalent degrees were held by 22% of respondents, while 19% had completed upper secondary education. Lower secondary education was reported by 3.4%, and 1.4% of respondents had either primary education or no formal education. No respondents held a Doctoral or equivalent degree.

Table 3: General Sample Description

Characteristic	N = 150[1]
Gender	
Man	114 (76%)
Woman	34 (23%)
X	0 (0%)
I'd rather not say	2 (1.3%)
Age	49 (19 / 77)
Level of Education	
None	2 (1.4%)
Primary education	2 (1.4%)

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Lower secondary education	5 (3.4%)
Upper secondary education	27 (19%)
Bachelor's or equivalent level	32 (22%)
Master's or equivalent level	77 (53%)
Doctoral or equivalent level	0 (0%)
(Missing)	5
Decision-Making Role	4.09 (1/5)
Decision Influence	4.26 (1/5)

[1] n (%); Mean (Minimum / Maximum)

In **Figure 4**, the distribution of the participating companies from the different consortium countries can be found. Most SMEs are based in Italy (28%), followed by Belgium and France, both with 23%. Germany accounts for 12%, while Lithuania, the Netherlands, and other countries make up smaller portions (6%, 5.3%, and 3.3%, respectively). The list of other countries includes Algeria, Estonia, Austria (x2), Romania, and Sweden (x2).

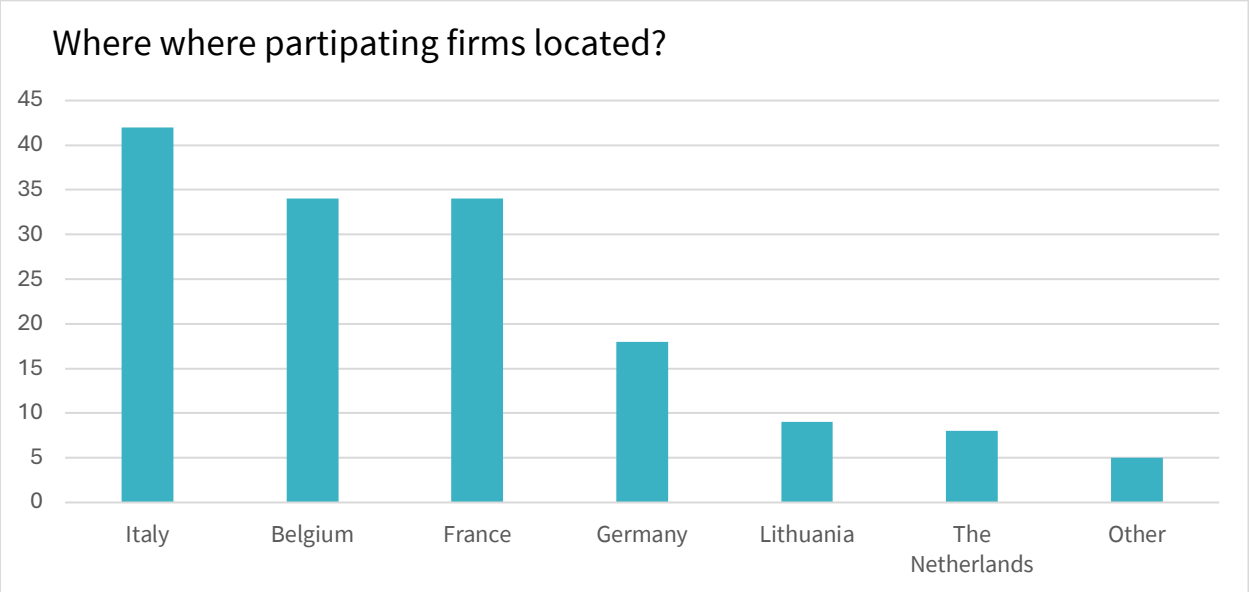

Figure 4: Location of participating firms

In **Table 4**, a more detailed sample description can be found. Regarding SME presence on the stock exchange stock, most companies (95%) are not listed, with only 2% indicating they were, and 2.7% being unsure.

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For the primary business category, 34% of companies identify as general contractors or one-stop shops, followed by 29% in design, architecture, or engineering. Smaller portions are involved in manufacturing single components (10%) or off-site composed systems (8.7%). For secondary business categories, 38% of respondents focus on a single primary activity, while 21% are involved in design, architecture, or engineering, and 17% are general contractors.

In terms of construction type, 79% of companies are active in both new construction and renovation, while 11% focus only on renovation and 9.3% only on new construction. The median size of companies is 35 employees, with an age range from 1 to 145 years.

Regarding innovation, 26% of companies focus on process innovations, such as global renovation offers or off-site construction. Another 22% focus on materials, while 19% work on products like energy systems or integrated technology. Sustainability accounts for 11%, while 14% of companies are not focusing on any innovation, and 7.3% identify other areas.

Table 4: Detailed Sample Description

Characteristic	N = 150[1]
Country	
Belgium	34 (23%)
France	34 (23%)
Germany	18 (12%)
Italy	42 (28%)
Lithuania	9 (6.0%)
The Netherlands	8 (5.3%)
Other	5 (3.3%)
Listed on the stock exchange?	
Yes	3 (2.0%)
No	143 (95%)
I don't know	4 (2.7%)
What is the primary focus/activity of the company?	
Design, architectural or engineering firm	43 (29%)
Service provider (diagnostic analysis, 3D scanning, structural tests, digital twin, etc.)	6 (4.0%)

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Manufacturer/producer of single components (windows, insulation, pv panels, etc.)	15 (10%)
Manufacturer/producer of off-site composed/integrated systems (energy systems, prefab panels, etc.)	13 (8.7%)
General contractor, main construction company, one-stop-shop	51 (34%)
Craftsman, installer and/or maintainer of envelope components (provisional works, walls, facades, finishings, prefab panels, etc.)	13 (8.7%)
Installer and/or maintainer of technical systems (electricity, plumbing, ventilation, elevator systems, etc.)	9 (6.0%)
What is the secondary focus/activity of the company?	
Design, architectural or engineering firm	31 (21%)
Manufacturer/producer of single components (windows, insulation, etc.)	4 (2.7%)
Service provider (diagnostic analysis, 3D scanning, structural tests, BIM, etc.)	13 (8.7%)
Manufacturer/producer of off-site composed/integrated systems (energy systems, prefab panels, etc.)	7 (4.7%)
General contractor, main construction company, one-stop-shop	25 (17%)
Craftsman, installer and/or maintainer of envelope components (provisional works, walls, facades, finishings, prefab panels, etc.)	7 (4.7%)
Installer and/or maintainer of technical systems (electricity, plumbing, ventilation, elevator systems, etc.)	6 (4.0%)
None, we focus on one primary activity	57 (38%)
Type of SME	
Only new construction	14 (9.3%)
Only renovation	17 (11%)
Both new construction and renovation	119 (79%)
Average SME size	35 (0 / 250)
Average SME age	34 (1 / 145)
Which innovation is the company primarily focusing on?	
Product: we design, sell or install efficient energy systems, prefab elements, integrated technology systems	29 (19%)

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Process: we develop global renovation offers (one-stop-shop), we implement off-site construction, we cooperate with parties involved instead of subcontracting	39 (26%)
Materials: we use sustainable materials, we focus on the circularity of materials	33 (22%)
Sustainability: we offer energy performance guarantees, we integrate carbon footprint indicators to reduce the impact of our operations	17 (11%)
We are currently not focusing on any innovation	21 (14%)
Other, namely	11 (7.3%)

[1] n (%); Mean (Minimum / Maximum)

In Figure 5 outlines which key factors are drivers for innovation. The strongest motivators are the evolution of market needs (4.03) and a passion for sustainability and environmental challenges (4.01). Companies are also motivated by the goal of making renovations more affordable (3.96) and increasing scalability (3.95), along with a desire to make a broader impact in the industry (3.93). Legislative and subsidy changes present further opportunities (3.67 and 3.66, respectively). Frustrations with inefficiency (3.64) and a lack of aftercare (3.49) are also contributing factors, though they are less influential.

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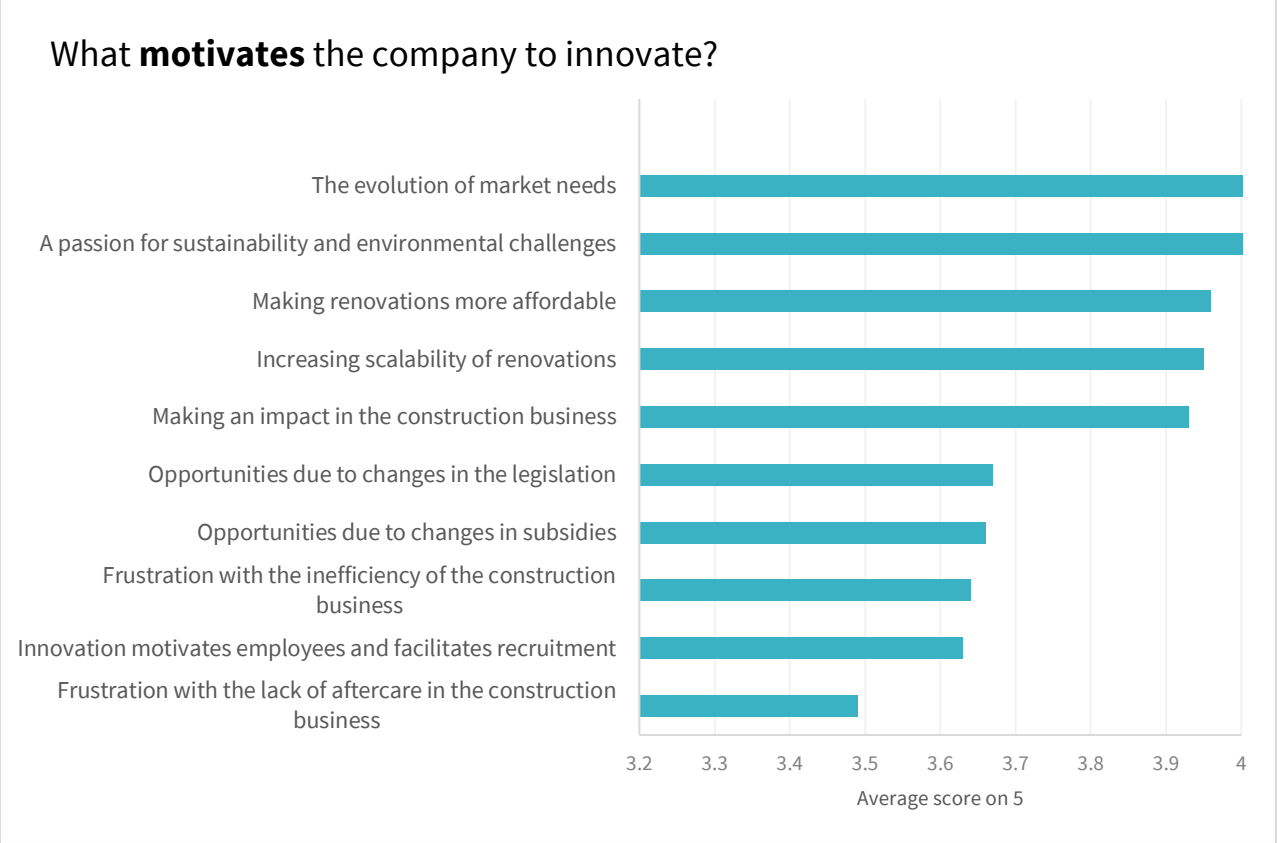

Figure 5: Motivators to Innovate

Figure 6 shows the sources from which companies draw new ideas for innovation. Interestingly, internal management (3.71) and online sources (3.57) are the most frequently cited, indicating that internal leadership and digital platforms are crucial for generating innovative concepts. Industry technical or trade associations (3.38) and suppliers or distributors (3.37) also provide valuable input, reflecting the importance of industry collaboration and partnerships. Meanwhile, traditional sources such as regulatory bodies (2.96) and consultants (2.99) appear to have less influence in the innovation process.

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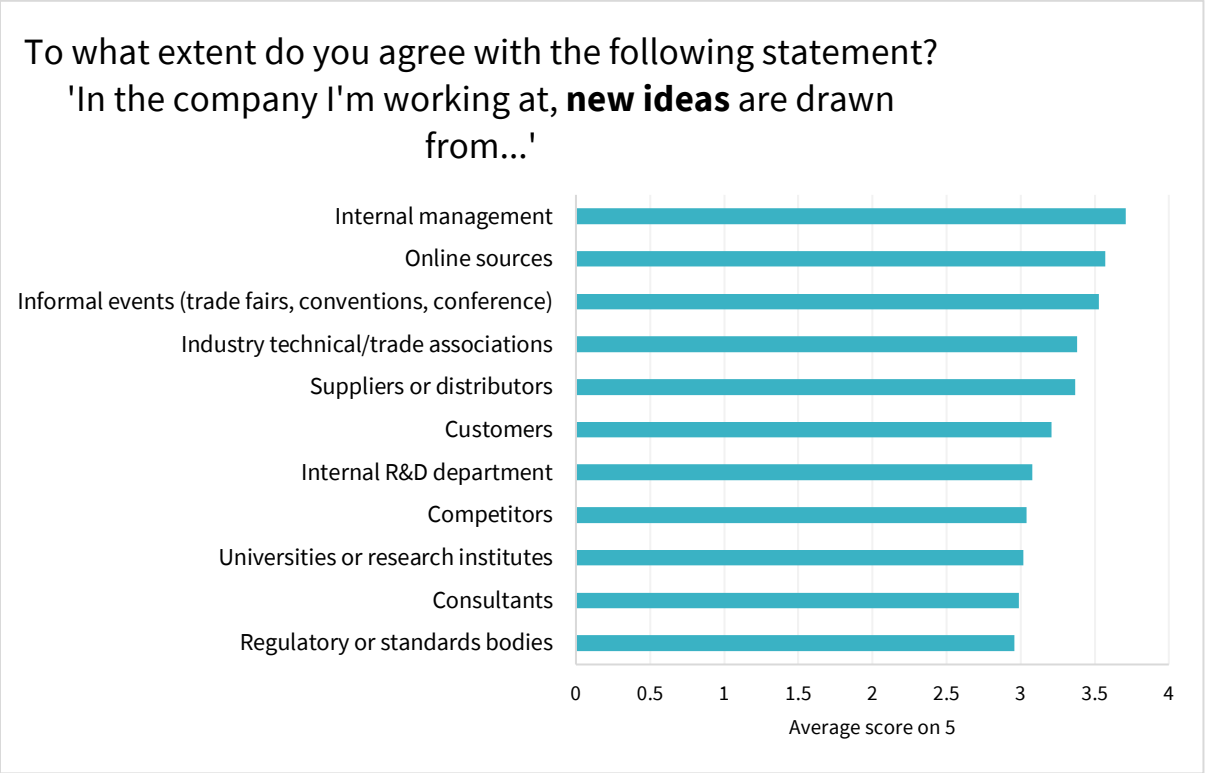

Figure 6: Sources of new ideas according to participating SMEs

The key barriers that hold companies back from innovation are represented in Figure 7. The most significant challenges include a **lack of skilled labour and technical expertise** (3.74) and the **high upfront investment costs** associated with innovation (3.6). Additionally, companies struggle with the **time and cost** required to obtain certifications for new products or services (3.69), as well as the **lack of uniform legislation** (3.64). **Financial constraints** (3.53) and **limited time for innovation** (3.42) further impede progress, while **rigid supply chain structures** (3.22) hinder collaboration and flexibility in adopting new methods.

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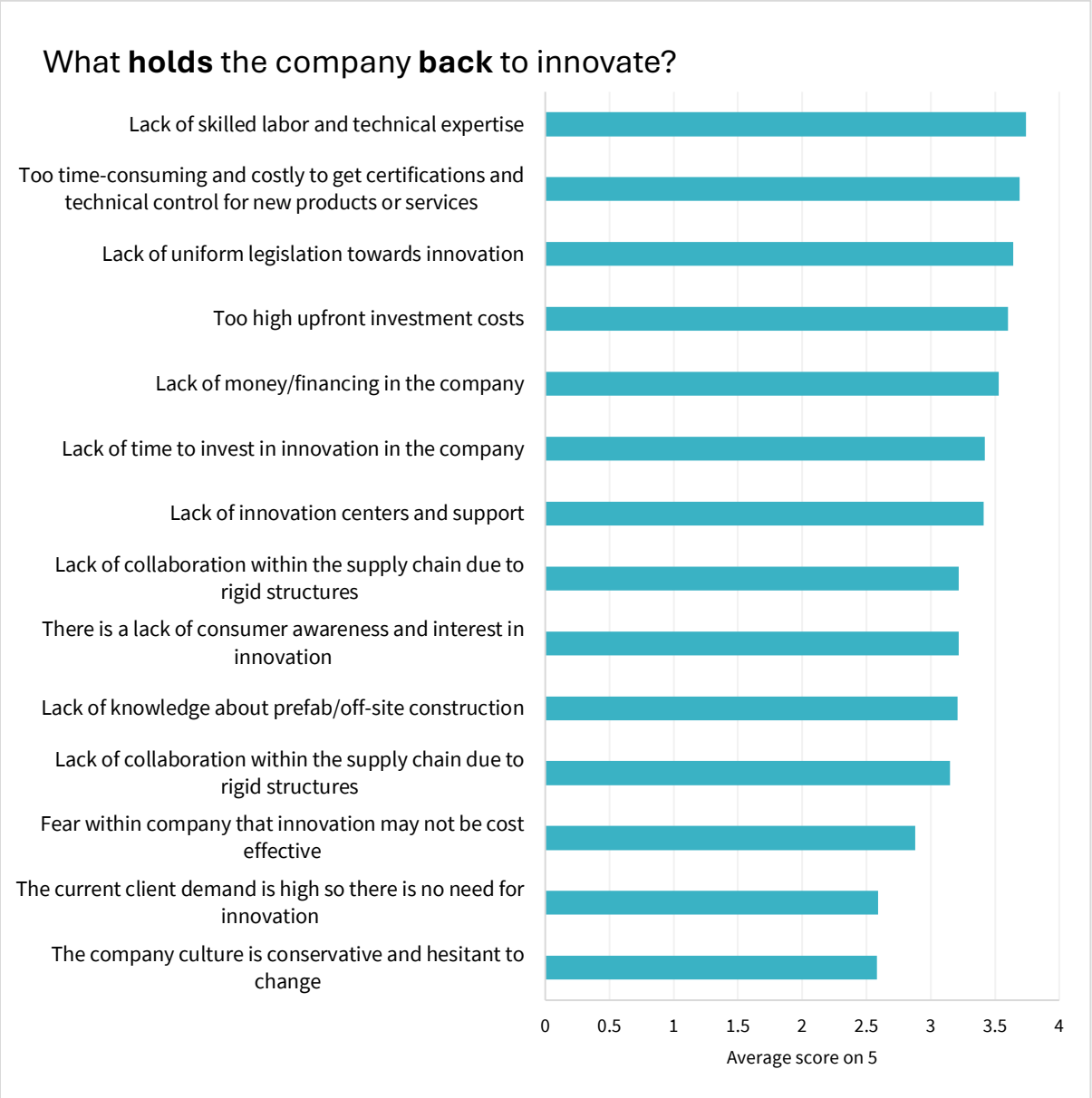

Figure 7: Barriers to innovation

Examining the types of software used, **design software, such as BIM**, is the most frequently used, with 81 instances of use. **Company management software**, including tools for accountability and resource control, follows with 56 participants. **Project management software** is used by 44 firms, while 31 respondents indicated that they do not use any **particular software. Sustainability software**, specifically for carbon tracking, is used by 19, while **product management software**

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(CAM, DfMA) has 17 users. Supply chain collaboration software is used by 15 individuals, and 9 respondents mentioned using other software (see Figure 8).

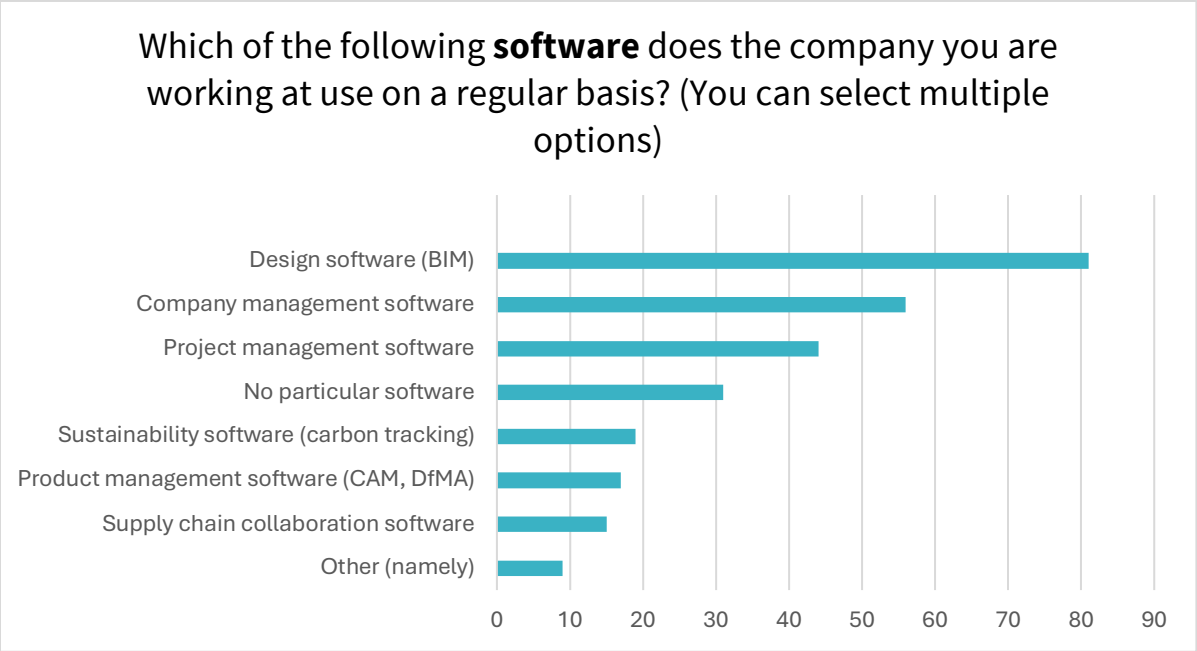

Figure 8: Software used by participants; multiple options possible

Open Questions

Our survey ended with an open question: *Do you have any remarks or questions about this survey? Overall, what changes do you think are needed in the industry to make innovative renovations more accessible to small construction companies?* Responses shed light on various critical issues that small construction companies encounter when attempting to adopt innovative renovations. Many participants voiced concerns about the complexity of current regulations and how they often hinder innovation rather than support it. The lack of clarity in both the regulatory framework and financial support options was a recurring theme, with respondents calling for more transparent and consistent communication from governmental bodies. They suggested that clearer guidelines, particularly around renovation standards, would help smaller firms navigate the bureaucratic maze and focus on delivering quality work without being overwhelmed by administrative hurdles.

Financial barriers also featured prominently in the feedback, with several respondents pointing out that SMEs struggle to afford new technologies or training, which is essential for adopting

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modern methods. Some respondents noted that large corporations are at an advantage, having more resources to invest in innovation, while smaller firms are left behind due to a lack of government incentives or subsidies. The respondents emphasised that subsidies should be better targeted towards bio-based and eco-friendly materials to encourage their use in the market, rather than allowing price considerations to dominate consumer choices. Additionally, calls for government support in acquiring innovative software tools highlight the financial strain smaller firms face when trying to stay current with technological advancements.

Another significant challenge identified was the rigidity of current industry practices, particularly concerning outdated norms like ventilation standards that no longer reflect modern construction realities. Respondents argued for a revision of such obsolete standards to simplify systems and reduce costs, thereby making renovation processes more feasible for smaller companies. Many also suggested that simplified approval processes for innovative systems would encourage widespread adoption, ultimately driving down costs through economies of scale.

Furthermore, training was cited as an essential area for improvement. Several respondents called for stronger training programs to improve the skills of the construction workforce, thereby enhancing the overall quality of renovations. This was particularly relevant in discussions about sustainability, with respondents emphasising the need to prioritise long-term durability and the environmental impact of renovation materials and methods, rather than focusing solely on short-term, cost-driven decisions.

The responses also revealed a broader sentiment that the construction industry remains highly traditional, with changes being difficult to implement. Many respondents suggested that industry-wide incentives, such as tax breaks or regulatory reforms, would be necessary to foster innovation on a larger scale. There was also mention of the importance of collaboration between small local companies, research centres, and government bodies to create a more supportive environment for the growth of innovative practices. By pooling resources and knowledge, regional projects could serve as demonstrators, showcasing the practical benefits of innovation and providing a template for others to follow.

Assessing our scale reliability

We proceed with the analysis of our hypothesized research model, presented in Figure 2. To do so, we first assess how reliable, our items are, followed by a correlation table (See Table 5). The mean

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value for Innovation Capability is 3.78, with a Cronbach's alpha[1] of 0.79, indicating a moderately high level of internal reliability. Network Capability Building scores the highest mean at 4.13 with a robust Cronbach's alpha of 0.92, suggesting very strong internal consistency. The variable Commitment to Status Quo has the lowest mean at 3.04, with a Cronbach's alpha of 0.67, reflecting a relatively lower level of reliability, but still broadly acceptable. Technological Innovativeness shows a mean of 3.61 and a Cronbach's alpha of 0.71, demonstrating adequate internal consistency. Finally, Passion for Problem-solving has the highest Cronbach's alpha of 0.93, with a mean of 4.11, indicating both a high average score and very strong internal consistency. Given the satisfactory scores for all items, we proceed to make average scores.

Table 5: Mean scores Cronbach's Alpha for the five latent constructs

Variable	Mean	Cronbach's Alpha
Innovation Capability	3.78	0.79
Network Capability Building	4.13	0.92
Commitment to Status Quo	3.04	0.67
Technological Innovativeness	3.61	0.71
Passion for Problem-solving	4.11	0.93

Examining the histogram for innovation capability in Figure 9, we also see that our sample is skewed towards firms that see themselves as innovative, possibly pointing to a sample bias.

[1] Cronbach's alpha is a measure of internal consistency, which assesses how closely related a set of items are as a group. It is used to evaluate the reliability of a scale, where reliability refers to the degree to which the items consistently measure the same underlying construct (i.e. Innovation capability). A high Cronbach's alpha (typically 0.7 or above) indicates that the items have a strong correlation and are likely to be measuring the same concept. Lower values suggest that the items may not be well aligned, possibly because they are capturing different constructs or there is noise in the data.

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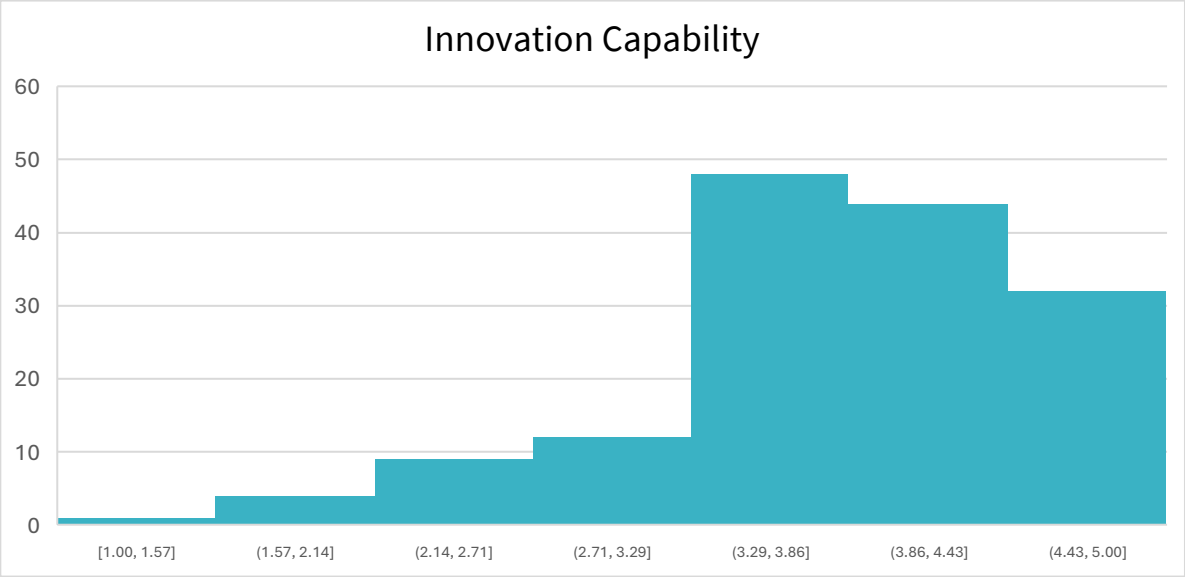

Figure 9: Histogram for Innovation capability

The Pearson Correlation Matrix (**Table 6**) illustrates the relationships between several organisational capabilities and attitudes. **Innovation Capability** is positively correlated with Network Capability Building ($r = 0.61$, $p < 0.01$) and **Technological Innovativeness** ($r = 0.46$, $p < 0.01$), indicating that higher levels of **Innovation Capability** are associated with stronger network capabilities and greater **Technological Innovativeness**. Conversely, **Commitment to Status Quo** shows a negligible correlation with the other variables, suggesting that it does not significantly relate to Innovation Capability, Network Capability, or Technological Innovativeness. **Passion for Problem-Solving** has a strong positive correlation with **Innovation Capability** ($r = 0.52$, $p < 0.01$) and Network Capability Building ($r = 0.60$, $p < 0.01$), as well as **Technological Innovativeness** ($r = 0.58$, $p < 0.01$), underscoring its significant association with these aspects. These correlations highlight that while commitment to maintaining the status quo does not strongly influence other capabilities, Passion for Problem-Solving is a key factor linked to higher levels of innovation and technological advancement.

Moreover, there are no problematic correlations of 0.8 or higher (P. Vatcheva & Lee, 2016) suggesting no issues with multicollinearity. The variance inflation factor (VIF)[2] analysis shows no

[2] Variance Inflation Factor (VIF) is a measure used to detect multicollinearity in regression analysis. Multicollinearity occurs when two or more predictor (independent) variables in a regression model are highly correlated, which can distort the statistical results.

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values exceeding 3, further confirming the absence of multicollinearity issues (Thompson et al., 2017).

Table 6: Pearson Correlation Matrix

	Innovation Capability	Network Capability Building	Commitment to Status Quo	Technological Innovativeness
Innovation Capability	1			
Network Capability Building	**0.61****	1		
Commitment to Status Quo	0.01	0.08	1	
Technological Innovativeness	**0.46****	**0.41****	-0.06	1
Passion for Problem-solving	**0.52****	**0.60****	-0.1	**0.58****

Notes: * p < 0.05 ; ** p < 0.01

Predicting Innovation Capability

Our regression analysis [3] presents several models examining the predictors of **Innovation Capability**. We choose to do a model where each variable is included individually (model 1 to model 4), followed by our final model that includes all predictors. This allows us to see the individual effects first, followed by the overall analysis, controlling for all variables.

In **Model 1**, Network Building emerges as a significant predictor (β = 0.62, $p < 0.001$), explaining 38% of the variance in innovation capability ($R^2 = 0.38$). **Model 2** includes Commitment to Status Quo, but the coefficient is small and insignificant (β = 0.06), offering little explanatory power ($R^2 = 0.003$).

Model 3 highlights Technological Innovativeness as a strong predictor (β = 0.62, $p < 0.001$), explaining 24% of the variance in innovation capability ($R^2 = 0.24$). **Model 4** focuses on Problem-

[3] Regression analysis is a statistical technique used to examine the relationship between one dependent variable (in our case, innovation capability) and one or more independent variables (predictors or factors). The main goal of regression analysis is to model and quantify how changes in the independent variables affect the dependent variable, making it useful for predicting outcomes and understanding underlying patterns in the data.

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Solving Ability, which also shows a significant positive effect (β = 0.59, $p < 0.001$) with a slightly higher explanatory power ($R^2 = 0.29$).

Model 5 combines all variables, where Network Building (β = 0.43, $p < 0.001$), Technological Innovativeness (β = 0.29, $p < 0.001$), and Problem-Solving Ability (β = 0.17, $p < 0.05$) remain significant predictors. Commitment to Status Quo remains insignificant (β = 0.05). The overall model explains 46% of the variance in innovation capability ($R^2 = 0.46$), with an adjusted R^2 of 0.44, indicating a good fit. The findings suggest that **Network Building, Technological Innovativeness, and Problem-Solving Ability** are key drivers of innovation capability, while **commitment to maintaining the status quo** is not a significant factor.

Table 7: Regression analysis (model 1 to model 5)

	Outcome: Innovation capability				
	Model 1	Model 2	Model 3	Model 4	Model 5
Network Building	0.62***				0.43***
Commitment to status quo		0.06			0.05
Technological Innovativeness			0.62***		0.29***
Problem Solving Ability				0.59***	0.17*
Constant	1.23***	3.61***	1.57***	1.37***	0.13
Observations	150	150	150	150	150
R^2	0.38	0.003	0.24	0.29	0.46
Adjusted R^2	0.37	-0.003	0.24	0.28	0.44
Residual Std. Error	0.63 (df = 148)	0.79 (df = 148)	0.69 (df = 148)	0.67 (df = 148)	0.59 (df = 145)
F Statistic	90.05*** (df = 1; 148)	0.51 (df = 1; 148)	47.18*** (df = 1; 148)	60.17*** (df = 1; 148)	30.72*** (df = 4;145)
Note:	*p < 0.05;**p < 0.01;***p < 0.001				

We perform **two** additional exploratory models. First, we include the participant's age, SME age and SME size into our model, keeping our four earlier variables. Our results broadly show **no statistically significant** effects on Innovation Capability. Finally, we test to see if there is any effect

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of being in a decision-making role or being able to influence decisions. Our results suggest that being in a decision-making role has no effect on the assessment whether the firm is innovative or not. By contrast, Decision Influence shows a moderate positive effect with a coefficient of 0.13 ($p < 0.05$), with both Problem-Solving Ability and commitment to status quo failing to reach statistical significance.

Table 8: Regression analysis (model 6 to model 7)

	Outcome: Innovation capability	
	Model 6	Model 7
Network Building	**0.41*****	**0.38*****
Commitment to status quo	0.03	0.04
Technological Innovativeness	**0.28*****	**0.25*****
Problem Solving Ability	**0.19***	0.14
Participant age	-0.001	
SME Size	-0.001	
SME Age	-0.002	
Decision-Making Role		0.04
Decision Influence		**0.13***
Constant	0.38	-0.12
Observations	150	150
R^2	0.47	0.49
Adjusted R^2	0.45	0.47
Residual Std. Error	0.59 (df = 142)	0.58 (df = 143)
F Statistic	**18.13***** (df = 7; 142)	**23.01***** (df = 6; 143)
Note:	*p < 0.05;**p < 0.01;***p < 0.001	

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Defining clusters

A large **overarching goal** within D3.2 is to discern **clusters in the data** to see how firms differ in their **Innovation Capability** and what characterises them. To identify clusters within our data, we employed three **clustering techniques**: **K-means**, **Latent Class Analysis (LCA)**, and **Hierarchical Clustering**. We used our **four key** innovation capability questions for clustering: "The company seeks new ways of doing things," "The company is creative in its operation methods," "Innovation is perceived as too risky in the company and is resisted" (reversed), and "The company frequently tries out new ideas." We selected these questions due to our **modest sample size**, which limits the feasibility of including additional variables.

To determine the **appropriate number of clusters**, we considered metrics such as the **Bayesian Information Criterion (BIC)** and **Akaike Information Criterion (AIC)**. These metrics help balance **statistical accuracy** with **practical implementation**. In our case, the sample size constrained our choices. More than three clusters would result in **too few members per cluster** (i.e., fewer than 20), while a **two-cluster solution** would be less informative (i.e., distinguishing only between high and low values for all metrics). Thus, we opted for a **three-cluster solution**, despite it not being statistically optimal

Table 9: Comparing the various clustering techniques

	Cluster X	Cluster Y	Cluster Z	Standard Deviation
K-means	43	41	76	19.66
Hierarchal clustering	62	62	26	20.78
LCA	14	44	93	39.83

We compared the clustering methods using the same data, as shown in **Table 9**. For k-means clustering, Cluster X has 43 companies, Cluster Y has 41 companies, and Cluster Z, the largest, contains 76 companies. The standard deviation of 19.66 indicates moderate variability in cluster sizes. Hierarchical clustering results in two clusters of equal size—62 members each—and a smaller third cluster with 26 companies. The standard deviation for hierarchical clustering is 20.78, showing a similar level of variability. LCA reveals a different pattern: Cluster X has 14 companies, Cluster Y has 44 companies, and Cluster Z, the largest, has 93 companies. The higher standard deviation of 39.83 for LCA suggests greater variability in cluster sizes compared to the other

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methods, i.e.: the clusters are uneven in size. As a result, we proceed with the k-means approach, with the lowest standard deviation of 19.66.

Cluster characteristics

As expected, the levels of Innovation Capability across the three clusters show strong and significant differences ($p < 0.001$), with each cluster differing from the others. We label the three clusters as follows: '**Traditionalists**,' who score the lowest on Innovation Capability; '**Adaptors**,' who rank in the middle, generally lagging but identifying as innovative in some areas; and '**Leaders**,' who consistently score the highest on innovation capability (See **Figure 10**).

These initial **characteristics** can be further detailed. To do so, we build on a variety of **data sources**. First, **categorical sources** such as **firm type** or **SME country** could be used. **Chi-square tests** are useful for analysing categorical data to determine if there are **significant differences** between observed and expected frequencies. For example, a chi-square test could be used to assess whether **design**, **architectural**, or **engineering firms** are more prevalent in the **Traditionalist group** compared to other groups.

However, given the **modest sample sizes**, it is challenging to draw **statistically robust conclusions** about the differences between these SME clusters, due to **limitations in analysing small cell sizes** (e.g., **German firms in the Leader group (N = 11)** vs. **Traditionalists (N = 5)**). As a result, we turn to **numerical data**, where we are less constrained to perform simple analyses such as **analysis of variance (ANOVA)**.

We can include in our data **binary variables** (i.e., yes or no), treating it as a ratio (1 or 0) and thus see if any **differences exist**. We discuss three distinct possible **differentiators**: the use of certain **software**, sources of **innovation**, and finally, our **model predictors** (**Problem solving**, **Technical Innovativeness**, **Commitment to Status Quo**, and **Network Building**).

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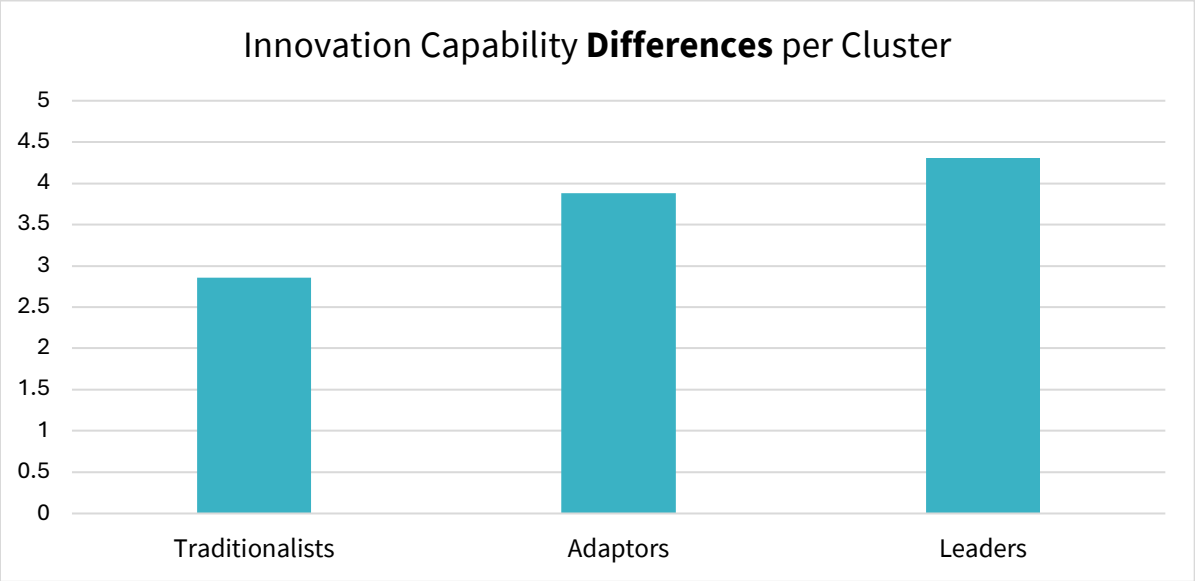

Figure 10: Cluster differences in Innovation Capability

Software differentiators

The analysis of software usage across different company types—Traditionalists, Adaptors, and Leaders—reveals distinct patterns and notable differences (Table 10). Leaders show a strong preference for design software (e.g., BIM), with 48 instances compared to 16 for Traditionalists and 17 for Adaptors, and this difference is statistically significant ($p = 0.02$). Similarly, Leaders also show a significant inclination towards sustainability software, with 14 instances, whereas Traditionalists use it 5 times and Adaptors none, a difference that is significant at $p = 0.03$.

On the other hand, there are no significant differences in the usage of project management software ($p = 0.82$), company management software ($p = 0.17$), product management software ($p = 0.25$), or supply chain collaboration software ($p = 0.98$) across the groups. The category "We don't use any particular software" also shows significant variation, with 14 Traditionalists and 7 Adaptors reporting this compared to only 10 Leaders ($p = 0.04$). Usage of the "Other" category is minimal and not statistically significant ($p = 0.18$). These results highlight that while Leaders are more likely to use specific advanced and sustainability-oriented software, other categories of software usage are more uniformly distributed across the company types.

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Table 10: Differences in software use among the clusters

Characteristic	Traditionalists N = 43	Adaptors N = 31	Leaders N = 76	*p*
Design software (e.g. BIM)	16	17	48	**0.02***
Project management software	12	8	24	0.82
Company management software (accountability, resource control)	11	13	32	0.17
Product management software (CAM, DfMA, lean manufacturing)	5	1	11	0.25
Sustainability software: carbon tracking tool	5	0	14	**0.03***
Supply chain collaboration software	4	3	8	0.98
We don't use any particular software	14	7	10	**0.04***
Other	2	0	7	0.18

Sources of Innovation as differentiator

Table 11 presents the mean scores of various sources of innovation as reported by three groups of firms: Traditionalists, Adaptors, and Leaders, along with the statistical differences between them. A significant difference is observed in how these groups value customers as a source of innovation, with Leaders assigning the highest importance (3.39), followed by Adaptors (3.26) and Traditionalists (2.84), reflecting a statistically significant difference ($p = 0.02$). This suggests that Leaders rely more heavily on customer input for innovation compared to the other groups.

Suppliers and distributors are rated similarly across all groups, with Adaptors slightly ahead (3.55) compared to Traditionalists (3.35) and Leaders (3.32), though no significant difference is found ($p = 0.53$). Competitors are also valued similarly, with Leaders placing slightly more importance on them (3.17) compared to Traditionalists (2.95) and Adaptors (2.84), but again, this difference is not statistically significant ($p = 0.24$).

Consultants are valued closely across groups, with Adaptors leading slightly (3.10), followed by Leaders (3.05) and Traditionalists (2.81), and the lack of significant difference ($p = 0.40$) indicates that consultants are similarly valued. However, internal management shows a marked difference, with Leaders attributing much more importance to it (4.08) than Adaptors (3.71) and

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Traditionalists (3.07), and this difference is highly significant ($p < 0.001$). This suggests that Leaders rely more on internal management for innovation.

Similarly, Leaders place significantly more value on **internal R&D departments** (3.57) than Adaptors (2.81) and Traditionalists (2.42), with a highly significant p-value (<0.001), indicating that investment in R&D is a key differentiator for Leaders. The importance of **universities** and **research institutes** also increases from Traditionalists (2.77) to Leaders (3.22), with a statistically significant difference ($p = 0.05$), suggesting that Leaders are more likely to collaborate with academic institutions for innovation.

In contrast, **regulatory and standards bodies** are rated slightly higher by Traditionalists (3.16) compared to Leaders (2.96) and Adaptors (2.68), though the p-value (0.20) indicates no significant difference. **Industry technical and trade associations** are similarly valued across all groups (Traditionalists: 3.42, Adaptors: 3.32, Leaders: 3.38), with no statistical difference ($p = 0.92$), suggesting uniform appreciation for these associations as innovation sources.

Table 11: Differences in sources of innovation among the clusters

Sources of innovation according to participating firms	Traditionalists N = 43	Adaptors N = 31	Leaders N = 76	Statistical significance
Customers	2.84	3.26	3.39	**0.02***
Suppliers or distributors	3.35	3.55	3.32	0.53
Competitors	2.95	2.84	3.17	0.24
Consultants	2.81	3.10	3.05	0.40
Internal management	3.07	3.71	4.08	**<0.001****
Internal R&D department	2.42	2.81	3.57	**<0.001****
Universities or research institutes	2.77	2.87	3.22	**0.05***
Regulatory or standards bodies	3.16	2.68	2.96	0.20
Industry technical/trade associations	3.42	3.32	3.38	0.92
Informal events (trade fairs, conventions, conference)	3.28	3.84	3.55	**0.05***
Online sources	3.28	3.84	3.55	0.49

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Adaptors place greater emphasis on informal events (3.84) than Leaders (3.55) and Traditionalists (3.28), with a significant difference (p = 0.05), highlighting the role of such events for Adaptors. Lastly, while Adaptors also rate online sources higher (3.84) than Leaders (3.55) and Traditionalists (3.28), the p-value (0.49) suggests no significant difference in how these groups view online sources for innovation.

To further explore the differences between profiles, a series of Tukey's HSD tests were conducted. For customers as sources, differences were found between Leaders and Traditionalists (p = 0.02). Significant differences were also detected in internal management, where Adaptors and Traditionalists differed significantly (p = 0.02), and Leaders vs. Traditionalists showed a strong statistical difference (p < 0.01). This pattern also appeared for internal R&D departments, where differences between Leaders and Traditionalists (p < 0.01) and Leaders and Adaptors (p = 0.02) were significant. For informal events, differences emerged between Adaptors and Traditionalists (p = 0.04), suggesting varying reliance on informal sources of innovation among these groups.

Barriers to innovation across the clusters

We proceed to analyse any differences in the barriers to innovation, as mentioned by our participants ("What holds the company back to innovate?"). The results, shown in Table 12, reveal several significant differences across company types in terms of barriers to innovation. The most notable is the strong variation in company culture, where Traditionalists (3.33) and Adaptors (3.07) report much higher levels of conservatism and hesitation to change compared to Leaders (1.94), with a statistically significant difference ($p < 0.001$). Additionally, the perception that high client demand eliminates the need for innovation is considerably more prevalent among Traditionalists (2.88) and Adaptors (2.80) than Leaders (2.33), also with a highly significant result ($p < 0.001$).

Table 12: Differences in barriers to innovation across the clusters

	Traditionalists N = 43	Adaptors N = 31	Leaders N = 76	*p*
There is a lack of consumer awareness and interest in innovation	3.26	3.57	3.06	**0.05***
The current client demand is high so there is no need for innovation	2.88	2.80	2.33	**<0.00****
The company culture is conservative and hesitant to change	3.33	3.07	1.94	**<0.00****

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Fear within company that innovation may not be cost effective	3.33	3.40	2.40	<0.00**
Lack of collaboration within the supply chain due to rigid structures	3.31	3.47	2.92	0.02*
Too high upfront investment costs	3.62	3.53	3.63	0.91
Lack of money/financing in the company	3.69	3.37	3.50	0.42
Lack of time to invest in innovation in the company	3.67	3.50	3.25	0.09
Lack of uniform legislation towards innovation	3.76	3.70	3.54	0.53
Lack of skilled labor and technical expertise	3.76	3.80	3.69	0.87
Lack of knowledge about prefab/off-site construction	3.45	3.47	2.96	0.03*
Lack of innovation centres and support	3.43	3.63	3.31	0.34
Too time-consuming and costly to get certifications and technical control for new products or services	3.76	3.83	3.60	0.54

Fear that innovation may not be cost-effective also shows a significant gap, with Traditionalists (3.33) and Adaptors (3.40) rating this barrier higher than Leaders (2.40) ($p < 0.001$). Finally, lack of collaboration within the supply chain due to rigid structures is more strongly felt by Adaptors (3.47) and Traditionalists (3.31) than by Leaders (2.92), which is statistically significant ($p = 0.02$). These findings suggest that while Leaders face fewer barriers in these areas, Traditionalists and Adaptors still experience notable obstacles related to company culture, cost concerns, and client demand.

Problem Solving, Technical Innovativeness, Commitment to Status Quo, and Network Building

Finally, we expand our analysis to examine how our hypothesised personal and company characteristics might impact membership of a cluster. Figure 11 highlights key differences in innovation-related characteristics among three groups: Traditionalists, Adaptors, and Leaders. Leaders score highest across most categories, including Innovation Capability (4.31), Network Building (4.47), and Problem-Solving Ability (4.42), all showing statistically significant differences compared to the other groups ($p < 0.001$). Adaptors also demonstrate stronger capabilities than Traditionalists, with notable scores in Innovation Capability (3.88) and Network Building (4.17). Interestingly, Commitment to the Status Quo does not differ significantly between the groups ($p = 0.22$), suggesting that this factor is not a key differentiator in innovation behaviour. Overall,

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Leaders exhibit the highest levels of innovation and problem-solving, while Traditionalists lag behind across most dimensions.

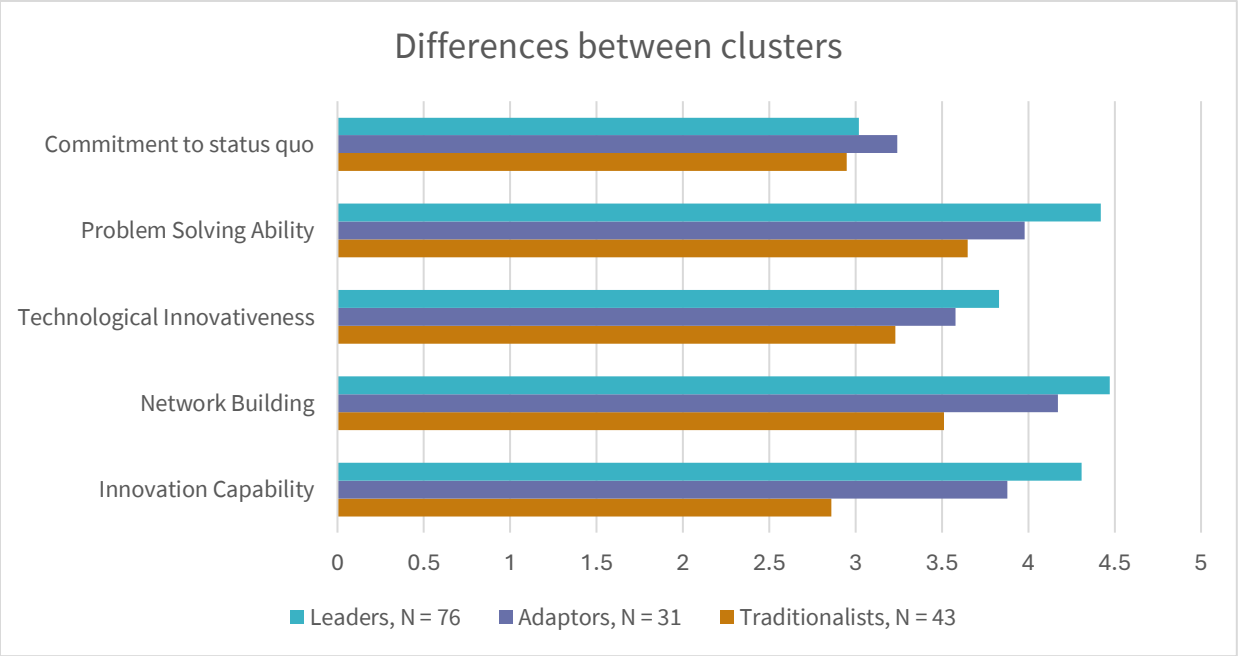

Figure 11: Cluster characteristics

Predicting class membership

Finally, we turn to a Multinominal Logistic Regression[4] analysis to identify the **predictors** of cluster membership. The dependent variables, **Adaptors and Leaders**, were compared to a reference category, **Traditionalists**. By and large, these results mirror what we have highlighted in **Table 13**.

For the Adaptors cluster, a higher level of 'Network Building', and higher 'Commitment to Status Quo' are significantly associated with the cluster membership, indicated by coefficients of 1.17 ($p < 0.01$) and 0.81 ($p < 0.01$), respectively. This indicates that organisations that engage in extensive Network Building and demonstrate a higher commitment to maintaining existing practices are more likely to be categorised as **Adaptors**.

[4] In multinomial logistic regression, the model estimates the probability of each outcome category given the independent variables. The categories of the dependent variable are compared against a reference category (or baseline, in our case Traditionalists), and the model provides the odds of each outcome relative to that reference.

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Nevertheless, the coefficients for 'Technological Innovativeness' and 'Problem Solving Ability' are not statistically significant, indicating that these variables do not significantly influence membership in the Adaptors cluster. In contrast, the Leaders cluster shows a strong positive association between 'Network Building' and membership, with a coefficient of 1.56 ($p < 0.01$), while 'Technological Innovativeness' and 'Problem Solving Ability' are also significant predictors, with coefficients of 1.28 ($p < 0.01$) and 0.99 ($p < 0.01$), respectively.

Table 13: Multinomial regression

	Adaptors†	Leaders†
Network Building	1.17**	1.56***
Commitment to status quo	0.81**	0.45
Technological Innovativeness	0.82	1.28**
Problem Solving Ability	0.11	0.99**
Constant	-10.66***	-15.69***
Akaike Inf. Crit.	261.16	261.16
Notes:	*p < 0.05;**p < 0.01;***p < 0.001	
	† = Traditionalists as reference category	

This suggests that high levels of Network Building, Technological Innovativeness, and Problem-Solving ability are strongly associated with being classified to the Leaders category. In contrast, the Commitment to the Status Quo is not a significant predictor for the Leaders cluster, indicating that maintaining the status quo does not significantly impact the likelihood of being in this cluster.

Discussion and Conclusion

Predicting Innovation Capability

The results of Model 5 (see Table 7) provide valuable insights into the factors influencing Innovation Capability at the company level, confirming several initial hypotheses. We hypothesised that Network Capability Building would be a key driver of innovation, as both the literature (Parida et al., 2017) and expert interviews emphasised the importance of partnerships

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and a strong network for fostering innovation. This is supported by the results, with **Network Building** emerging as the strongest predictor of **innovation capability** ($\beta = 0.43$, $p < 0.001$). Companies that actively build and maintain networks are better positioned to innovate. This validates importance of **external partnerships** in driving innovation.

In contrast, our hypothesis that **Commitment to Status Quo** would act as a major barrier to innovation, especially in the traditionally conservative construction industry, was not supported by the data. The results show that **Commitment to Status Quo** was not a statistically significant predictor of **Innovation Capability** ($\beta = 0.05$), suggesting that adherence to established practices may not have as strong an effect on limiting innovation as anticipated. This finding challenges the notion that **resistance to change** is a primary hindrance to innovation, at least in this context.

On the individual level, we expected **Technological Innovativeness** to positively influence innovation, based on existing research linking openness to new technologies with increased digitalization and innovation potential. The findings support this, with **Technological Innovativeness** being a significant predictor ($\beta = 0.29$, $p < 0.001$), indicating that employees who embrace new technologies contribute meaningfully to the company's ability to innovate.

Similarly, we predicted that **Passion for Problem-Solving** would positively impact innovation, particularly in SMEs, where one individual's problem-solving ability could influence the entire company's innovation capability. This is reflected in the results, with **Problem-Solving Ability** showing a significant but smaller effect ($\beta = 0.17$, $p < 0.05$), supporting the notion that having individuals with strong problem-solving skills is beneficial for fostering innovation. The overall model explains **46% of the variance** in innovation capability ($R^2 = 0.46$), with an adjusted R^2 of 0.44, indicating a good fit. These results highlight that while **Network Building** and **Technological Innovativeness** are critical drivers of innovation, **Commitment to the Status Quo** does not appear to be a significant barrier, suggesting that other factors may play a larger role in limiting innovation within companies.

In conclusion, the findings of this study underscore the importance of **building networks** and **embracing technological innovations** as key factors that drive **Innovation Capability** within companies. While **network building** emerged as the strongest predictor, confirming the value of external partnerships, **technological innovativeness** also plays a crucial role, demonstrating the benefits of adopting new technologies. On the other hand, **Commitment to the Status Quo** was not found to be a significant barrier, suggesting that resistance to change may not be as influential as previously thought. Overall, the results indicate that fostering innovation requires a focus on

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external collaborations and technological adaptability, while internal conservatism may have less of an impact than anticipated. Further research could explore other potential barriers to innovation not captured in this model.

Identifying innovative clusters

We conclude with a brief discussion on identifying the various clusters of firms. Starting from our research model, we see that Leaders score higher on Network Building and Technological Innovativeness, with only Commitment to the Status Quo not showing a statistically significant difference between the clusters. Leaders notably prioritize internal management as their most important source of innovation, alongside strong reliance on internal R&D departments and collaborations with universities or research institutes.

Interestingly, Adaptors tend to view informal events as valuable sources of innovation, a trend less pronounced among both Traditionalists and Leaders. This may suggest that Leaders, seeing themselves as more advanced, do not perceive these events as useful for gaining new knowledge, while Adaptors, slightly behind, still benefit from them. Traditionalists, on the other hand, may see these events as non-essential.

In terms of software as a differentiator, usage patterns suggest it may serve as a proxy for innovativeness. Leaders are more likely to use design software and carbon tracking tools, whereas Traditionalists are more likely to report not using any particular software at all. For both Traditionalists and Adaptors, company culture stands out as a key factor, with these groups more likely to describe their company culture as conservative and hesitant to change.

Additionally, "fear within the company that innovation may not be cost-effective" is significantly more prevalent among Traditionalists and Adaptors compared to Leaders. Another important differentiator is the perception that "current client demand is high, so there is no need for innovation." Leaders are much less likely to agree with this statement, suggesting that for both Traditionalists and Adaptors, full-order books may reduce the motivation to innovate.

Limitations

We note some limitations to this study. First, despite the best efforts of all participating partners, our sample remains modest. While we met the a priori pre-registration requirement of 150 participants, the sample size is still relatively small.

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A further challenge in our data is the possible overrepresentation of participants who consider their own firms to be innovative. While phase 1 of the research explicitly focused on a cohort of innovative firms, the goal of phase 2 was to include a more diverse set of firms. Our histogram in Figure 9 suggests a potential bias, as we similarly observe that firms identifying themselves as innovative often attribute their innovativeness to their internal management practices.

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Appendix A – Interview Guide

Introduction: tell us a bit about yourself and your company.

- Who are you?
- What company do you currently work for?
- Is it an SME? What does the company focus on?
- Size of the company?
- What is your role within the company?
- How many years of experience do you have in the construction industry?

- Innovation: what does innovative renovation mean in your SME?
  - Which types of innovation do you have experience with? Can you tell us a bit more about what your SME focuses on?
  - Usage of new materials
  - Adoption of new processes/new forms of collaboration
  - Adoption of new technologies
- Motivations: why did you adopt certain innovative practices
  - What motivated you to start adopting innovative practices?
  - In your company, who has the decision right on adoption of new practices?
  - Who gives advice to the decision-makers?
  - Were you influenced by other companies or people in the construction industry? (role models)
- Experiences in general: what is the current situation in your country? How successful are innovative renovation projects?
  - Which types of housing are mostly renovated in an innovative manner? Single-family homes, apartment buildings?
  - How common are these types of innovation in comparison to the status quo?

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  - Different types of roles
    - How are roles defined within a project?
    - Who takes on the coordination in a project?
- Experiences within the SME
  - How did you experience the change from old to new ways?
  - How did colleagues/other people in the SME react to new practices being introduced?
- Dependency on other actors: How do other actors influence your way of working?
  - Which actors do you need? Who do you rely on to successfully complete a project?
  - How do actors work together in the decision-making process?
  - How do actors work together in the operational phase?
  - How does communication work? What's the influence of architects/advisers in the decision process?
  - How could the collaboration process improve?
- Clients: how do clients react on innovative practices?
  - Do clients look for you because of your innovative character?
  - How high is the demand on client side?
  - Is innovation part of your image towards clients?
- Barriers and drivers: can you think of reasons why SMEs are not motivated to adopt more innovative processes? What problems did you run into? What are current challenges?
  - Lack of expertise within SMEs
  - Knowledge: role division, self-efficacy (feeling capable)
  - Conservatism in companies: attitude, resistance to change
  - Trust and knowledge, both within the SME and from clients
  - Collaboration between SMEs: communication
  - Regulatory limitations

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- Financial limitations
- Demand from clients
- Lack of environmental consciousness
- Lack of role models

Appendix B – Expanded Table with differences across clusters

Table 14: Differences across clusters for Country, Stock Exchange, Company focus, and innovation type

Characteristic	**Leaders**, N = 76[1]	**Adaptors**, N = 31[1]	**Traditionalists**, N = 43[1]
Country			
Belgium	16 (21%)	5 (16%)	13 (30%)
France	22 (29%)	5 (16%)	7 (16%)
Germany	11 (14%)	2 (6.5%)	5 (12%)
Italy	18 (24%)	12 (39%)	12 (28%)
Lithuania	2 (2.6%)	5 (16%)	2 (4.7%)
The Netherlands	5 (6.6%)	0 (0%)	3 (7.0%)
Other	2 (2.6%)	2 (6.5%)	1 (2.3%)
Listed on the stock exchange?			
Yes	3 (3.9%)	0 (0%)	0 (0%)
No	71 (93%)	31 (100%)	41 (95%)
I don't know	2 (2.6%)	0 (0%)	2 (4.7%)
What is the primary focus/activity of the company?			
Design, architectural or engineering firm	24 (32%)	8 (26%)	11 (26%)
Service provider (diagnostic analysis, 3D scanning, structural tests, digital twin, etc.)	3 (3.9%)	0 (0%)	3 (7.0%)
Manufacturer/producer of single components (windows, insulation, pv panels, etc.)	10 (13%)	1 (3.2%)	4 (9.3%)
Manufacturer/producer of off-site composed/integrated systems (energy systems, prefab panels, etc.)	9 (12%)	3 (9.7%)	1 (2.3%)

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General contractor, main construction company, one-stop-shop	22 (29%)	13 (42%)	16 (37%)
Craftsman, installer and/or maintainer of envelope components (provisional works, walls, facades, finishings, prefab panels, etc.)	5 (6.6%)	5 (16%)	3 (7.0%)
Installer and/or maintainer of technical systems (electricity, plumbing, ventilation, elevator systems, etc.)	3 (3.9%)	1 (3.2%)	5 (12%)
What is the secondary focus/activity of the company?			
Design, architectural or engineering firm	16 (21%)	7 (23%)	8 (19%)
Manufacturer/producer of single components (windows, insulation, etc.)	3 (3.9%)	0 (0%)	1 (2.3%)
Service provider (diagnostic analysis, 3D scanning, structural tests, BIM, etc.)	9 (12%)	1 (3.2%)	3 (7.0%)
Manufacturer/producer of off-site composed/integrated systems (energy systems, prefab panels, etc.)	4 (5.3%)	1 (3.2%)	2 (4.7%)
General contractor, main construction company, one-stop-shop	7 (9.2%)	8 (26%)	10 (23%)
Craftsman, installer and/or maintainer of envelope components (provisional works, walls, facades, finishings, prefab panels, etc.)	6 (7.9%)	1 (3.2%)	0 (0%)
Installer and/or maintainer of technical systems (electricity, plumbing, ventilation, elevator systems, etc.)	3 (3.9%)	2 (6.5%)	1 (2.3%)
None, we focus on one primary activity	28 (37%)	11 (35%)	18 (42%)
Type of SME			
Only new construction	5 (6.6%)	4 (13%)	5 (12%)
Only renovation	7 (9.2%)	3 (9.7%)	7 (16%)
Both new construction and renovation	64 (84%)	24 (77%)	31 (72%)
Which innovation is the company primarily focusing on?			
Product: we design, sell or install efficient energy systems, prefab elements, integrated technology systems	17 (22%)	5 (16%)	7 (16%)

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Process: we develop global renovation offers (one-stop-shop), we implement off-site construction, we cooperate with parties involved instead of subcontracting	22 (29%)	9 (29%)	8 (19%)
Materials: we use sustainable materials, we focus on the circularity of materials	16 (21%)	6 (19%)	11 (26%)
Sustainability: we offer energy performance guarantees, we integrate carbon footprint indicators to reduce the impact of our operations	7 (9.2%)	4 (13%)	6 (14%)
We are currently not focusing on any innovation	9 (12%)	4 (13%)	8 (19%)
Other, namely	5 (6.6%)	3 (9.7%)	3 (7.0%)

[1] n (%)

Appendix C – All items used in the survey

Table 15: All items used in the survey

gender	What is your gender (as mentioned on your ID or passport)?
age	What year were you born?
edu	What is the highest educational degree you have completed?
sme_size	How much employees are currently working at the company?
sme_age	How old is the company in years? (If you don't know, give your best estimation)
sme_family	Is the company family-owned?
sme_country	Which country is the company based in? - Selected Choice
sme_country_6_TEXT	Which country is the company based in? - Other, namely: - Text
sme_stock	Is the company listed on the stock exchange?
sme_cat_prim	What is the primary focus/activity of the company?
sme_cat_sec	What is the secondary focus/activity of the company?
sme_type	What type of construction is the company primarily active in?
sme_renotype	What type of renovation does the company focus on?
sme_innov	Which innovation is the company primarily focusing on? If the company focuses on multiple things, select the most prominent category. - Selected Choice

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sme_innov_6_TEXT	Which innovation is the company primarily focusing on? If the company focuses on multiple things, select the most prominent category. - Other, namely: - Text
sme_software	Which of the following software does the company you are working at use on a regular basis? (You can select multiple options) - Selected Choice
sme_software_6_TEXT	Which of the following software does the company you are working at use on a regular basis? (You can select multiple options) - Other, namely: - Text
sw_bim	Which design software does the company use specifically? (optional)
sw_pm	Which project management software does the company use specifically? (optional)
sw_compm	Which company management software does the company use specifically? (optional)
sw_prodm	Which production management software does the company use specifically? (optional)
sw_sus	Which sustainability software does the company use specifically? (optional)
sw_supply	Which supply chain collaboration software does the company use specifically? (optional)
sme_network_1	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Customers
sme_network_2	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Suppliers or distributors
sme_network_3	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Competitors
sme_network_4	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Consultants
sme_network_5	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Internal management
sme_network_6	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Internal R&D department
sme_network_8	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Universities or research institutes
sme_network_9	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Regulatory or standards bodies
sme_network_10	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Industry technical/trade associations
sme_network_13	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Informal events (trade fairs, conventions, conference)
sme_network_14	To what extent do you agree with the following statement? 'In the company I'm working at, new ideas are drawn from...' - Online sources

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statusquo_1	To what extent do you agree with the following statements regarding the current way of working of the company? - Right now, I strongly prefer sticking to the company's current way of working
statusquo_2	To what extent do you agree with the following statements regarding the current way of working of the company? - At the moment, the current way of working fits my needs and necessities
statusquo_3	To what extent do you agree with the following statements regarding the current way of working of the company? - Changing the current way of working would cause too much disruption
statusquo_4	To what extent do you agree with the following statements regarding the current way of working of the company? - Changing the current way of working would require considerable sacrifice
nw_build_1	To what extent do the following statements apply to the company regarding the form, care and use of relationships with partners? - The company is constantly open to new relationships with partners
nw_build_2	To what extent do the following statements apply to the company regarding the form, care and use of relationships with partners? - The company has the ability to initiate a mutual relationship with new partners
nw_build_3	To what extent do the following statements apply to the company regarding the form, care and use of relationships with partners? - The company keeps its eyes open for new partners
inn_cap_1	To what extent do the following statements apply to the company regarding innovation? Innovation could be in terms of materials, products or processes. - The company seeks new ways of doing things
inn_cap_2	To what extent do the following statements apply to the company regarding innovation? Innovation could be in terms of materials, products or processes. - The company is creative in its operation methods
inn_cap_3	To what extent do the following statements apply to the company regarding innovation? Innovation could be in terms of materials, products or processes. - Innovation is perceived as too risky in the company and is resisted
inn_cap_4	To what extent do the following statements apply to the company regarding innovation? Innovation could be in terms of materials, products or processes. - The company frequently tries out new ideas
dec_maker_1	To what extent do you agree with the following statements regarding yourself? - I am a decision maker in the company
dec_maker_2	To what extent do you agree with the following statements regarding yourself? - I can influence decisions in the company
tech_innov_1	To what extent do you agree with the following statements regarding yourself? - Other people come to me for advice on new technologies
tech_innov_2	To what extent do you agree with the following statements regarding yourself? - In general, I am among the first in my circle of friends to acquire a new technology when it appears

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tech_innov_3	To what extent do you agree with the following statements regarding yourself? - I can usually figure out new high-tech products and services without help from others
tech_innov_4	To what extent do you agree with the following statements regarding yourself? - I keep up with the latest technological developments in my areas of interest
prob_solv_1	To what extent do you agree with the following statements regarding yourself? - It is exciting to figure out new ways to solve unmet market needs that can be commercialized
prob_solv_2	To what extent do you agree with the following statements regarding yourself? - Searching for new ideas for products/services to offer is enjoyable to me
prob_solv_3	To what extent do you agree with the following statements regarding yourself? - I am motivated to figure out how to make existing products/services better
prob_solv_4	To what extent do you agree with the following statements regarding yourself? - Searching the environment for new opportunities really excites me
sme_mot_1	What motivates the company to innovate? - A passion for sustainability and environmental challenges
sme_mot_2	What motivates the company to innovate? - Making an impact in the construction business
sme_mot_3	What motivates the company to innovate? - Making renovations more affordable
sme_mot_4	What motivates the company to innovate? - Increasing scalability of renovations
sme_mot_5	What motivates the company to innovate? - Opportunities due to changes in the legislation
sme_mot_6	What motivates the company to innovate? - Opportunities due to changes in subsidies
sme_mot_7	What motivates the company to innovate? - Frustration with the inefficiency of the construction business
sme_mot_8	What motivates the company to innovate? - Frustration with the lack of aftercare in the construction business
sme_mot_9	What motivates the company to innovate? - Innovation motivates employees and facilitates recruitment
sme_mot_10	What motivates the company to innovate? - The evolution of market needs
sme_bar_1	What holds the company back to innovate? - There is a lack of consumer awareness and interest in innovation
sme_bar_2	What holds the company back to innovate? - The current client demand is high so there is no need for innovation
sme_bar_3	What holds the company back to innovate? - The company culture is conservative and hesitant to change
sme_bar_4	What holds the company back to innovate? - Fear within company that innovation may not be cost effective

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sme_bar_5	What holds the company back to innovate? - Lack of collaboration within the supply chain due to rigid structures
sme_bar_6	What holds the company back to innovate? - Lack of collaboration within the supply chain due to rigid structures
sme_bar_7	What holds the company back to innovate? - Too high upfront investment costs
sme_bar_8	What holds the company back to innovate? - Lack of money/financing in the company
sme_bar_9	What holds the company back to innovate? - Lack of time to invest in innovation in the company
sme_bar_10	What holds the company back to innovate? - Lack of uniform legislation towards innovation
sme_bar_11	What holds the company back to innovate? - Lack of skilled labor and technical expertise
sme_bar_12	What holds the company back to innovate? - Lack of knowledge about prefab/off-site construction
sme_bar_13	What holds the company back to innovate? - Lack of innovation centers and support
sme_bar_14	What holds the company back to innovate? - Too time-consuming and costly to get certifications and technical control for new products or services
cl_country	Which country are most of the clients from? (the primary sales market of your company) - Selected Choice
cl_country_7_TEXT	Which country are most of the clients from? (the primary sales market of your company) - Other, namely: - Text
cl_type	What types of clients does the company primarily work for?
cl_building	If you work for the residential sector, which type of housing do you focus on?
cl_mot_1	To what extent do you agree with the following statement: 'Clients contact us because...' - they know that we focus on sustainability
cl_mot_2	To what extent do you agree with the following statement: 'Clients contact us because...' - the product or service we offer is more efficient than the traditional way of working
cl_mot_3	To what extent do you agree with the following statement: 'Clients contact us because...' - they are interested in the innovative character of our product or service
cl_mot_4	To what extent do you agree with the following statement: 'Clients contact us because...' - our product or service speeds up the renovation process
cl_mot_5	To what extent do you agree with the following statement: 'Clients contact us because...' - our product or service makes the renovation more affordable
cl_bar_1	To what extent do you agree with the following statements? - Clients think our product or service is too expensive and are unwilling to pay for it
cl_bar_2	To what extent do you agree with the following statements? - Clients lack knowledge about our product or service

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cl_bar_3	To what extent do you agree with the following statements? - Clients fear that our product or service is not yet mature enough
cl_bar_4	To what extent do you agree with the following statements? - Financial support measures (subsidies, legislation) for clients change too often
collab_open	Do you have any experience collaborating in the prefab market? What was your collaboration experience like? (optional)
end_open	Do you have any remarks or questions about this survey? Overall, what changes do you think are needed in the industry to make innovative renovations more accessible to small construction companies? (optional)

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