Construction Innovation in the Province of Quebec: Barriers, Drivers, Enablers and Impact

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1 Introduction

The construction industry is a sector with significant economic weight at the global, national and provincial levels. In fact, relative capital expenditures represented 46.3 billion Canadian dollars in 2017, which corresponds to 12% of Quebec's GDP [6]. However, productivity studies agree that construction productivity rates have significant differences with those of other sectors [12, 19]. For instance, manufacturing or aerospace industries have indeed seen their growth and productivity increase considerably in recent decades, thanks to the investments in research and development (R&D) and the implementation of innovations used for the modernization of production lines and the digitization of their sector.

In comparison with other economic sectors, construction has traditionally been viewed as not innovative [11]. While some blame the lack of business experience and investment [16] or the lack of clear benefits from technologies [14], Barbosa and al., for the Mckinsey Institute (2017), state that the biggest barriers to the adoption of innovations in construction companies are underinvestment in technologies, especially IT, in addition to the lack of R&D processes. In fact, construction sector is one of the less digitalized and new investments models for technologies are required to enhance project performance [15]. In the construction industry, only 25% of companies have defined a strategy around digital and only 9% declare to be ready for digitization [4]. Moreover, investment in research corresponds to less than 1% of revenues for most companies, compared to 3.5–4.5% for the automotive and aerospace sectors [1]. This fact can be explained by lower margins in the construction sector on projects compared to other industries.

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The province of Quebec's construction industry faces many of the same issues as its Canadian counterparts: the lack of manpower, the globalization of the sector and sustainability concerns [3]. In this light, most agree that innovation across the project lifecycle and supply chain are critical in increasing the industry's productivity and performance [7]. There remains however, a significant gap between understanding the potential of innovation from a macro level and understanding the drivers and barriers of innovation in the field. Moreover, innovation is a broad topic which manifests itself in many ways. It is therefore relevant to understand its impacts and dynamics in an effort to take the appropriate measures to drive its adoption in the construction industry.

The study presented in this paper aimed to answer the following question: What are the dynamics of innovation in the Quebec construction industry? What impacts do they have, particularly on construction site productivity? The main objective of the study was to identify the characteristics of innovation in construction, the factors impacting its implementation and ways to improve its implementation in Quebec. Moreover, the perceived impact of innovation, specifically on productivity was measured. The study presented in this paper is part of a larger research project investigating the impact of technological innovation on productivity and construction performance. For this paper, the context and the dynamics of innovation in the Quebec construction industry are identified. The key drivers and barriers to innovation and its impact are then investigated. Findings reflect the well documented barriers to innovation, but also highlight the lack of support that other sectors benefit from in terms of subsidies and accompaniment. For the companies that have implemented innovation, a majority have reaped considerable benefits in terms of, among others, productivity increase. However, questions still abound on how to capture and measure this impact.

2 Review of Construction Innovation

2.1 Features of Innovation

The notion of innovation can be interpreted in different ways according to the sector in which it is deployed. The construction industry has well known characteristics, such as temporary projects involving several multidisciplinary stakeholders and finished products that have longer lifespan than most other sectors. Due to these characteristics, it would be logical to state that the features of innovation are different from other sectors. However, as with other sectors, technological transformation and innovation remain crucial in construction. Ottinger et al. [13] admit that "Technology is a dominant theme as it continues to reshape conventional property uses, while transforming the back office and construction supply chain" (p.7).

In current scientific literature, there exists to no universal definition of innovation. In fact, innovation remains a complex and multifaceted concept. Some consensus

exists around the fact that innovation can be described as a process, a product or a service, among others [8, 14]. Among these different characterizations, Ozorhon and al. [14] consider technological innovation to be new or a considerable improvement of existing technology. They linked it to improved business practices, workplace restructuring, and reconfiguring of external relationships. On the other hand, Kogabayev and Maziliauskas [8] describe technical innovation as "the knowledge of components, linkages between components, methods, processes and techniques that go into a product or service" (p. 64). Finally, Xue et al. [20] recognize three levels that reflect innovation in construction, namely, sector, project and company. Innovation in construction cannot be viewed solely as technologies for manufacturing as the industry has both a manufacturing and a service aspect.

Building on these different perspectives, and for the purpose of the research project, technological innovation is defined as any new (recent) or significantly improved product, service or process as compared to existing technology, that creates opportunities to improve factors such as production, speed of execution, sustainability, safety, etc. on construction sites. Moreover, technological innovation can be implemented on the construction site, remotely in the company's facilities or elsewhere.

2.2 Dynamics of Construction Innovation

The literature considers three categories of elements that influence the integration of innovation into a project: drivers, barriers or enablers. They act positively or negatively on organizations, companies and construction projects. The work of Ozorhon and al [14] identifies and evaluates the impact of drivers, barriers or enablers in the implementation of construction innovations, according to the results of a survey of construction actors in Turkey. Despite the lack of details on the proportion of respondents and the focus on the Turkish industry, their research on these factors allows us to better understand how innovation is implemented and what are the potential stakes.

Drivers of innovation correspond to the elements that would motivate companies or individuals to implement innovation on a project. There is a growing body of knowledge about the role of innovation drivers by considering the client [11], the contractor [10] or the supplier in association with market demand [16] as direct causes. Overall, the literature regularly discusses the role of the client as a driver, but no consensus has emerged from these discussions in recent years due to the lack of concrete studies on the subject. Table 1 summarizes several key drivers of innovation in construction found in the literature.

Obstacles or barriers to innovation are the issues and risks that stakeholders may encounter when implementing an innovation, and which may influence their decision-making. Several barriers are listed in Table 2. Barriers to innovation directly concern the core business, construction projects and market influence. Chowdhury et al.

Table 1 Drivers of innovation in construction sector

Drivers	Details	Authors
Environment and Sustainability	Use of sustainable construction techniques, reduction of environmental impacts and construction of sustainable buildings	Ozorhon et al. [14]
Design trends	Technical capabilities, market demands, opportunities	Ozorhon et al. [14] Reichtein et al. [16]
Project Performance Improvement	More success in terms of time, cost, quality and customer satisfaction	Ozorhon et al. [14] Chowdhury et al. [5] Lim and Ofori [10]
Technological developments	Use of ICTs and technological improvements	Ozorhon et al. [14]
Client requirements	Demands for higher standards in terms of time, cost, quality or performance	Ozorhon et al. [14] Loosemore and Richard [11]
Competition level	Demands for higher standards in terms of time, cost, quality or performance	Ozorhon et al. [14] Chowdhury et al. [5] Lim and Ofori [10]
Regulations and legislations	Improved performance standards	Ozorhon et al. [14]
Corporate Responsibility	Internal process and CSR strategy for better innovation performance and increase customer satisfaction and corporate image	Ozorhon et al. [14] Lim and Ofori [10]

[5] identify categories of barriers to innovation on technological, organizational, financial, psychological, governmental and procedural levels.

Finally, facilitators are elements that help overcome the challenges and obstacles that can arise when implementing innovations in construction projects, as detailed in Table 3. Collaboration in projects and guidance on innovation are the facilitators most often mentioned in the literature. However, the study by Ozorhon et al. [14] conclude that training policy and reward programs have a significant impact. Leadership remains a key enabler also. One key takeaway from this exercise is that there is no consensus on which facilitators has the greatest impact.

3 Methodology

The aim of this research was to understand the dynamics of innovation in the Quebec construction industry, with a focus on its impact on construction productivity. To do so, a survey was designed and distributed to construction actors across the province to take stock of the state of innovation in construction in Quebec. Data collection

Table 2 Barriers of innovation in construction sector

Barriers	Details	Authors
Lack of financial resources	Insufficient or unavailable resources for innovation	Ozorhon et al. [14] Kulatunga et al. [9] Chowdhury et al. [5] Reichtein et al. [16]
Temporary nature of projects	Participation of several teams on the short term or at different times. Difficult collaboration	Ozorhon et al. [14] Xue et al. [20]
Lack of experience and qualified staff	Absence of innovation director, technology managers, R&D sector managers, innovation training. Failure to take technology into account in recruitment	Ozorhon et al. [14] Tatum [18] Barbosa et al. [2] Reichtein et al. [16]
Lack of clear benefits or late return on investment	Lack of clear or quick benefits	Ozorhon et al. [14]
Unsupportive organizational culture	Reluctance to change, strategies not conducive to innovation, little management in the evolution of technologies	Ozorhon et al. [14] Kulatunga et al. [9] Tatum [18] Barbosa et al. [2]
Time constraints	In introducing new ideas and testing new technologies	Ozorhon et al. [14] Salter and Gann [17]
Contractual and legal aspects	Choice of companies with the lowest bidder, contractual constraints. Standards and regulations	Kulatunga et al. [9] Tatum [18] Reichtein et al. [16]
Lack of clients' requirements	Client unsure, unprepared or distrustful of innovation	Loosemore and Richard [11]
Poor digitalization in construction sector	Low investment in digital. Neglecting the potential of computer science in construction	Barbosa et al. [2]
Fear of innovation risk	Risks of counter-productive innovations, undervalued costs, poorly integrated processes, poorly evaluated benefits	Barbosa et al. [2] Loosemore and Richard [11]

took place between September 2020 to February 2021. A total of 280 responses were collected of which 161 were compiled. The response time varied between 5 and 15 min.

The target audience for the survey was general and specialized contractors. The respondents were questioned on the drivers, facilitators and barriers to innovation in their companies and on their projects. They were also asked about their perceptions on the level of support for innovation that is available in Quebec. Finally, they were asked to list specific innovations and technologies and discuss their impacts on project

Table 3 Enablers of innovation in construction sector

Enablers	Details	Authors
Cooperation between project actors	Cooperative environment, coordination and integration of companies	Ozorhon et al. [14] Kulatunga et al. [9] Loosemore and Richard [11]
Early contractors' involvement	Especially in the design phases	Ozorhon et al. [14] Loosemore and Richard [11]
Innovation Award Program	Recognition of efforts and personnel, promotion of innovation, employee involvement. Competitions to promote R&D	Ozorhon et al. [14] Barbosa et al. [2]
Stakeholder engagement	Alignment of motivations and interests. Partnerships with suppliers	Ozorhon et al. [14] Barbosa and al., 2017
Knowledge management	Retention and dissemination of ideas, resources and skills within the company and with stakeholders	Ozorhon et al. [14] Kulatunga et al. [9]
Leadership	Formation of team spirit, vision and goals	Ozorhon et al. [14] Xue et al. [20] Loosemore and Richard [11]
Training policy	Staff training on innovation and its use, internship and field learning	Ozorhon et al. [14]

and organizational outcomes. As such, the survey was structured in 4 main steps, namely:

- General information about the company and the respondent allowed the research team to identify the respondents profiles in relation to innovation in construction.
- Questions on internal processes for the implementation and adoption of technological innovations. Among them were questions around respondents' opinion on their interest in innovation and on the external support they receive for their technological implementation. In addition, respondents answered questions about their use and management of innovations.
- Data on the technologies implemented in companies and on their projects. This included the objectives driving implementation, the adoption rate and the fulfilment of the respondents' expectations. In this section, the respondent had the opportunity to report up to three technologies/innovations implemented in their company.
- Impacts of the technologies implemented on projects and companies. Each listed technology/innovation was then discussed by the respondent in terms of specific indicators such as productivity the return on investment.

Respondents that declared not to use technologies in their projects, they will be able to justify the reasons for not using them and will then be directed towards the end of the survey. The complete questionnaire consisted in 53 questions. The survey was published from respective websites of the two construction associations in Quebec, their newsletters, and their social media accounts.

4 Data Analysis

4.1 Profile of Respondents

The sample was composed at 79% of contractors, of which general 52% were general contractors, 27% were specialized contractors and 12% were suppliers. The rest of the respondents were composed of architecture and engineering firm and manufacturers.

The majority of responding companies had more than 50 employees, with 28% of respondents having between 101 and 500 employees. As far as revenue, a majority made more than 5 million dollars, with 29% declaring revenues between 5 and 25 million dollars and 22% between 50 and 250 million.

All construction sectors were represented, with the majority focused in the civil, industrial, commercial, and institutional sectors. Finally, 46% of respondents declared working everywhere in the province, whereas 40% were focused within a specific area, mainly Montérégie (10,5%), Montreal (10,1%), National capital region (9,2%), Estrie (9,2%) and Laval (7,1%). 15% of respondents declared conducting business outside of the province.

4.2 Innovation in the Quebec Construction Industry

Based on the definition provided above, 77% of respondents indicated a strong or very strong interest in innovation and the use of new technologies in their projects. By cross-referencing this data with the profile of respondents, the types of companies which were the most interested in innovation are suppliers (84% total for a strong (16%) or very strong (68%) interest), general contractors (84% total for a strong (38%) or very strong (46%) interest) and manufacturers (72% total for a strong (29%) or very strong (43%) interest). The rest of the panel, especially specialized contractors, seemed more hesitant about innovations and the implementation of new technologies. Companies with revenues higher than 50 million dollars were those which showed the most interest in innovation. On the other hand, companies which made less than 1 million were the least likely to innovate. This confirms a certain tendency for large corporations to be more interested in innovation. In the same manner, the results show a similar trend according to the size of the companies. In fact, companies with more than 100 employees showed a greater interest in innovation.

Delving deeper into the innovation process, 68% of respondents declared having already used one or more innovations on their projects. Of these respondents having implemented innovation, 55% indicated having at least one person responsible for innovation and its implementation within their organization. Moreover, the larger companies (more than 100 employees) have implemented one or more technological innovations in a strong majority. Indeed, 87% these larger companies had implemented one or more innovations against 56% of companies with less than 100 employees. With regards to revenue, companies earning more than 25 million dollars implement innovations in a higher proportion (82%) than those with lower revenues (54%). When considering the rate of implementation of technological innovations by sector, no one sector stands out as being "more innovative" than another. It can be explained by the fact that the same company may operate in several sectors, which may explain the small gap between the different sectors. According to the company type, the innovation rate is lowest among specialized contractors, while a strong majority of general contractors (68%) have implemented one or more innovations within their company or project. Finally, the 3 regions of the Greater Montreal area (Laval, Montérégie, and Montreal) were seen to have the highest response rate and show a high rate of implementation of innovation.

Moving on to the dynamics of innovation in construction in Quebec, respondents were asked to indicate their agreement with the following two statements on a scale from 1 to 5:

- Statement 01: External and government assistance is sufficient to allow construction companies to develop technologies in their projects.
- Statement 02: The company knows where to turn for help or advice in implementing the technology.

For the first statement, 56% of the panel showed a moderate or strong disagreement, considering that external or government assistance is insufficient to support the implementation of technologies or innovation in their projects. Likewise, regarding the second statement, 44% of respondents expressed moderate or strong disagreement with the statement whereas 27% had a neutral opinion. Delving a bit deeper into this statement, companies with more than 50 employees seem to know where to turn for support in their innovation and technology implementation process. However, no link was found for these companies between the second statement and the appointment of a person responsible for innovation.

4.3 Factors Influencing the Implementation of Innovation in Companies

The survey drew on the literature review to identify the most important factors in the implementation of innovation. For firms that did not implement innovation (32% of the total sample), the survey sought to identify the factors influencing this

Table 4 Barriers to innovation according to the survey (N = 52)

Barriers	Percent (%)	Barriers	Percent (%)
Lack of experience and qualified staff	16	Unsuitable internal structure of the firm	6
Time constraints	14	The company does not know how to do it	6
Lack of clear benefits for the firm	12	Adverse regulatory environment	6
Unfavourable contractual context	11	Insufficient technological maturity	5
Lack of demand from customers	10	Risks too high	1
The company feels that it does not need it	9	Other	1
Lack of financial resources	6		

choice. Table 4 ranks the factors most frequently mentioned by these companies. Thus, the lack of experience in this field (16%), time constraints (14%), the absence of clear benefits (12%) and an unfavorable contractual context to the implementation of innovations (11%) were among the most important factors. The factor "The company doesn't know how to do it" is related to the factor "Lack of experience", which reinforces the need for innovation support. Interestingly, the lack of financial resources and the regulatory context are not determining factors, even if they are to be considered in the innovation process. Another element to note is the influence of the contractual context, which is recognized as an obstacle to innovation in the construction industry.

For the respondents having implemented innovation (68% of the total sample), the authors tried to understand the enablers of their innovation process. Table 5 summarizes the highlights participation in training and conferences (16%), the use of consultants (13%), the integration of innovation into the company's business strategy (11%), the reinvestment of part of the profits in innovation (11%) and the recruitment of competent employees (10%).

As investment in innovation has already proven to have a positive impact in other sectors, this study has tried to identify how the Quebec construction industry fares in this regard. Thus, most respondents invest less than 0.5% of their annual revenue (66%) while 10% of respondents report reinvesting more than 3.0% of their revenue in innovation. By considering the type of company, it was possible to see that a majority of general and specialized contractors invested less than 0.5% of their revenues in innovations. On the other hand, a majority of suppliers and manufacturers invest more than 1% of their revenues in innovation. In addition, a majority of companies generating between C$50–250 million in revenue reinvest between 0.2 and 0.5% in innovation. Those generating between $5 and 25 million annually invest between 0.5 and 1.0% of their revenues. The biggest share of companies that invest more than 3% were companies generating more than $250 million in revenues. Finally, the

Table 5 Enablers of innovation according to the survey (N = 109)

Enablers	Percent (%)	Enablers	Percent (%)
Participation in training courses on innovation	16	No support implemented	4
Consulting	13	Partnerships with colleges or universities	3
Innovation integrated into the business strategy	11	Reward for innovation in the company	3
Reinvestment of part of the profits in innovation	11	Evaluation of the company's implemented innovations	3
Recruitment of employees with skills related to innovation	10	Innovation division/subsidiary	2
Innovation Committee	8	Formalized innovation process (Kaizen)	2
Business plan on innovation	4	Innovation manager appointed on projects	2
Research and development pole (R&D)	4	Other	1
Appointment of an innovation manager	4		

majority of companies counting between 101 and 500 employees, which represent almost a third of the sample, reinvest between 0.2 and 0.5% of their annual revenues in innovation. The highest proportions of very large corporations (more than 500 employees) invest in the 0.2–0.5% range and more than 3%.

Finally, the survey reveals the drivers of technological innovation for the respondents. As shown in Table 6, innovation was implemented mostly at the initiative of management (23%), due to the desire to improve performance on projects (19%) and

Table 6 Drivers of innovation (N = 109)

Drivers	Percent (%)	Drivers	Percent (%)
Management's decision	23	Need for technical elaboration	5
Willingness for Improvement	19	Design trends	3
Competitiveness	16	Environment and Sustainability	3
Innovation strategy	12	Laws and Regulations	2
Proven technology	10	New partnerships	1
Customer's request	5		

to increase the company's competitiveness on the market (16%). What motivated upper management to implement innovation requires more investigation. Surprisingly, the influence of the client as a motivation for innovation is minor, whereas the literature review gave them some importance as a driver of innovation.

4.4 Implemented Innovations and Their Impact

After having investigated the respondents' profiles, their willingness to innovate and the factors influencing the implementation of technological innovations in their company or on their projects, the survey then looked into specific innovations, their characterization and their impact. Each respondent was asked to identify and comment upon up to three specific innovations. A total of 109 instances of technological innovation were identified and analysed through the survey.

The principal expectations around the impact that the innovation, once implemented, would have were around gains in time (13%), productivity (12%), costs (11%) and quality (10%). The respondents were then asked to evaluate if these expectations were met. In this regard, 71% of respondents indicated that the innovation identified met their expectations to a high or very high level. At the same time, 58% of respondents indicated that they were satisfied with the return on investment (ROI) linked to the specific innovation. Conversely, 25% of respondents were still assessing the ROI on these specific innovations. Of these innovations where ROI was still being assessed, 81% had been implemented less than 2 years ago.

As productivity improvement is crucial in construction projects, and at the center of this research project, the respondents were asked to assess the impact of the innovations had on their productivity, on a scale from 1 to 5 (5 being the highest degree of impact). 57% of the technologies identified are perceived as having had a significant or major impact on productivity (4 or 5). On the other hand, 14% of the innovations identified were perceived as having little or no impact (1 or 2).

As a means to validate the respondents' capability to properly evaluate the impact of innovation within their organization, the survey was designed to investigate the means and methods used to track and measure their performance. In this regard, productivity (26%), costs (23%) and schedule (14%) were the 3 indicators that are most used by companies to evaluate the impact of technology implementation on the performance of their projects. Moreover, the means of measuring the impacts of technologies were done mostly through comparison with similar projects (29%), through comparison with project tasks to which the technology is not applied (22%), or through internal surveys (23%). 7% of the innovations identified were not tracked or measured.

5 Discussion and Conclusion

The research presented in this paper aimed to document the state of innovation and its impact on productivity in the Quebec construction sector. Several drivers, enablers, and barriers of innovation were identified and ranked. With regards to drivers, contrary to the literature, the results suggests that clients do not have the biggest influence on innovation. While inexperience in the field and time constraints were identified as major barriers, the lack of financial means was not a predominant one. Interestingly enough, reluctance to invest in innovation was tied to unclear benefits. Enablers such as training, consulting and integration into the company's business strategy are the most common. Once implemented technologies have shown considerably positive results with regards to productivity improvement, project management impacts and ROI. Generally, the results of the survey are encouraging with regards to the strong interest for innovation, and its implementation in the Quebec construction sector. The sample also was largely an innovative one, especially large organizations.

In terms of limitations, the size and revenue of the respondents' companies are not representative of the majority of construction companies in Quebec. Indeed, according to the Commission de la construction du Québec, 81% of Quebec construction companies had fewer than 5 employees in 2019 and the majority of companies operate in the residential sector [6]. The sample therefore does not reflect the reality of the majority of the Quebec construction industry. Even so, the results do provide an understanding of the technological situation of medium and large companies in Quebec. Analyses tend to show a causal link between the large size (financial or salary) of companies and the implementation of innovation. Future investigations on this type of statistics, including correlation analyses, would be relevant to validate the conclusions of this paper. Further research could be expanded to include other disciplines and focus on other sectors to expand the findings to encompass the broader construction industry as a whole.

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