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BENCHMARKING OFF-SITE CONSTRUCTION READINESS IN CANADA: A SURVEY- BASED ASSESSMENT OF ORGANIZATIONAL MATURITY ACROSS DESIGN, MANUFACTURING, AND CONSTRUCTION

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Abstract: Although construction is a cornerstone of economic and social development, the sector has lagged behind other industries in terms of productivity improvement. As digital transformation gains momentum, improving productivity in construction increasingly depends on the ability of organizations to adopt and integrate new delivery approaches, technologies, and workflows. In this context, assessing and benchmarking organizational readiness for off-site construction has become increasingly important within the Canadian construction landscape. This paper presents the development, pilot testing, and application of a national survey instrument designed to assess organizational maturity for off-site construction adoption in Canada, with the objective of supporting productivity-focused capability development. Three structured surveys were developed to evaluate maturity across the design, manufacturing, and construction phases, using the dimensions of People, Process, and Technology. The survey instrument was informed by established maturity frameworks and refined through expert review. A pilot testing phase was conducted with industry participants to evaluate clarity, relevance, and consistency of survey questions, leading to revisions that improved reliability and usability. The finalized surveys were implemented as a national benchmarking exercise through guided engagements with OSC-related organizations, capturing organizational characteristics, phase-specific involvement, and maturity levels on a five-point scale ranging from ad-hoc to innovative practices. Survey responses were analyzed using descriptive statistics to identify maturity patterns across phases and dimensions. At the national scale, maturity levels across the three project phases and performance dimensions were relatively consistent, suggesting a broadly uniform level of OSC capability development across organizations. However, at this preliminary stage, regional and organizational-type comparisons suggest increased variability, offering preliminary insight into potential differences in OSC adoption pathways. The findings providean initial exploratory survey-based benchmark of OSC organizational maturity in Canada and establish a scalable tool for ongoing benchmarking, longitudinal assessment, and evidence-based policy and investment decisions to support the advancement of off-site construction in Canada.

Keywords: Off-site construction; Organizational maturity; Survey methodology; Benchmarking, People, Process, Technology

1 INTRODUCTION

The construction industry plays a critical role in economic and social development, yet it continues to lag behind other sectors in productivity growth. In Canada, Statistics Canada (2026) reported that labour productivity in residential building construction fell by 37.3% between 2001 and 2023. These challenges are further intensified by a growing housing supply deficit and significant skilled labour shortages, creating an urgent need for more efficient ways of delivering buildings (Canada Mortgage and Housing Corporation [CMHC], 2022). As demand for housing and infrastructure increases, improving productivity has become a key priority for both industry and policymakers.

Off-site construction (OSC) has emerged as a promising response offering improved workflow stability, reduced material waste, and greater quality control compared with conventional site-based methods (Kamali & Hewage, 2016; Wuni & Shen, 2020). However, productivity gains from OSC are not achieved through adoption alone; they depend on organizations' ability to integrate these practices within existing systems. Despite increasing policy support, including federal investment through the 2024 Homebuilding Technology and Innovation Fund (Government of Canada, 2024), OSC adoption across Canada remains uneven, with significant variation in organizational capability across firms involved in design, manufacturing, and construction.

Addressing this gap requires assessing how prepared organizations are to adopt and implement OSC effectively. Research has consistently shown that the successful advancement of OSC depends on the alignment of people, processes, and technology within firms, not on technology adoption alone (Goulding et al., 2023; Tripathi et al., 2024). However, there is currently limited evidence of validated, national, survey-based frameworks to systematically assess and benchmark OSC organizational maturity across Canada. This paper presents the development, validation, and national application of a survey-based maturity assessment tool for OSC readiness in Canada, providing an initial national, evidence-based benchmark of organizational capability across design, manufacturing, and construction phases.

2 LITERATURE REVIEW

2.1 OSC and Productivity

OSC, also referred to as modular or prefabricated construction, involves producing building components in a controlled environment before transporting them to site (Off-Site Construction Research Centre [OCRC], 2024). While OSC has been widely associated with improvements in productivity and efficiency, its effectiveness depends on coordinated implementation across design, manufacturing, and construction processes. The productivity potential of OSC is closely linked to broader shifts toward industrialized and digitalized construction practices. While digital tools such as Building Information Modeling (BIM) support improved coordination (Wang et al., 2020), technology alone is insufficient. Organizations often face challenges integrating new tools into existing workflows and structures (Oesterreich & Teuteberg, 2016). As a result, achieving productivity improvements through OSC depends on the alignment of organizational capabilities across people, processes, and technology, highlighting the importance of assessing organizational readiness.

2.2 Organizational Maturity Models and the PPT Framework

Organizational maturity models provide a structured mechanism for assessing capability levels and guiding improvement pathways. The foundational Capability Maturity Model (CMM) developed by Paulk et al. (1993) introduced a five-level progression from ad hoc to optimized practices and has since been widely adapted to evaluate readiness in areas such as technology adoption, project management, and digital transformation. Subsequent research has extended this concept to project-based environments, demonstrating that higher levels of organizational maturity are associated with improved performance predictability and reduced variability in outcomes (Andersen & Jessen, 2003). In construction, maturity models have increasingly been used to assess organizational readiness for innovation and digital transformation initiatives.

A key advancement in maturity assessment is the integration of the People–Process–Technology (PPT) framework, which emphasizes that organizational performance depends on the alignment of workforce capabilities, operational processes, and technological systems (Leavitt, 1965). Recent studies highlight that focusing on technology alone provides an incomplete picture of readiness, whereas a multidimensional

PPT approach offers a more comprehensive assessment of implementation capability (Tripathi et al., 2024; Succar & Kassem, 2015). This perspective is particularly relevant for off-site construction (OSC), where successful adoption requires coordinated changes across design, manufacturing, and construction phases. The importance of this integrated approach is further reinforced by the CIB global report on offsite construction (Goulding et al., 2023), which calls for OSC-specific maturity frameworks that are scalable, context-sensitive, and capable of evaluating organizational capability across all three PPT dimensions.

2.3 Benchmarking in Construction and Research Gaps

Benchmarking has been widely used in construction to establish performance baselines and support evidence-based decision-making. Established programs, such as the UK Construction Industry KPI framework and the U.S. Construction Industry Institute benchmarking initiatives, demonstrate the value of standardized, survey-based data collection at both organizational and policy levels (Construction Industry Institute, 2023; KPI Working Group, 2000). In Canada, Rankin et al. (2008) developed a pilot benchmarking framework covering cost, time, quality, safety, and sustainability; however, it faced limitations in capturing innovation metrics and did not address OSC-specific organizational capability.

In the OSC context specifically, benchmarking is still in its early stages. Studies have struggled to collect consistent organizational data, partly because the industry lacks agreed-upon metrics for what OSC capability even looks like at the firm level (Wuni & Shen, 2020). Consequently, there is no national, survey-based benchmarking framework in Canada that assesses OSC organizational maturity across the design, manufacturing, and construction phases. Although maturity models and the PPT framework provide a strong theoretical foundation, their application to systematic, national-scale OSC capability assessment remains largely absent from the literature. This study addresses that gap directly by developing and applying a structured survey instrument to assess OSC organizational maturity across Canada, providing a scalable and evidence-based reference for industry capability development and policy investment.

3 RESEARCH METHODOLOGY

The study followed a multi-stage methodological framework as presented in Figure 1. The research followed a structured progression beginning with conceptual grounding in established organizational maturity frameworks, followed by survey instrument development, pilot testing and refinement, national deployment, and benchmarking analysis. This staged approach ensured theoretical rigor, instrument reliability, and consistency in data collection across participating organizations. The methodology is described in the following subsections.

3.1 Theoretical Foundation

The study was conceptually grounded in established organizational maturity and digital transformation frameworks. The People–Process–Technology (PPT) model and staged capability maturity logic (Goulding et al., 2023) informed the development of a five-level maturity structure ranging from ad-hoc to innovative practices. These frameworks ensured that the survey instrument reflected recognized patterns of organizational capability development while remaining adapted to the specific context of OSC across design, manufacturing, and construction phases (Khoteja et al. 2025).

3.2 Survey Instrument Development

Based on the conceptual framework, three structured surveys were developed to assess OSC maturity across the design, manufacturing, and construction phases. Each survey assessed organizational capability across the three PPT dimensions (People, Process, Technology), ensuring a consistent assessment approach across all project stages (Khoteja et al. 2025). Each maturity category was assessed using multiple phase-specific survey items, with validation focused on expert review, pilot testing, and interpretive consistency across respondents.

The survey questions were designed to capture the degree of formalization, integration, and strategic alignment of OSC-related practices within each phase. To enable consistent evaluation, responses were measured using a five-point maturity scale, ranging from ad-hoc to innovative practices. The maturity scale reflects progressive levels of organizational capability, from informal and reactive processes to fully integrated, innovation-driven systems. The maturity scale was adapted from established maturity frameworks for off-site construction (Goulding et al., 2023) and tailored to the context of this study. A summary of the maturity level definitions is provided in Table 1.

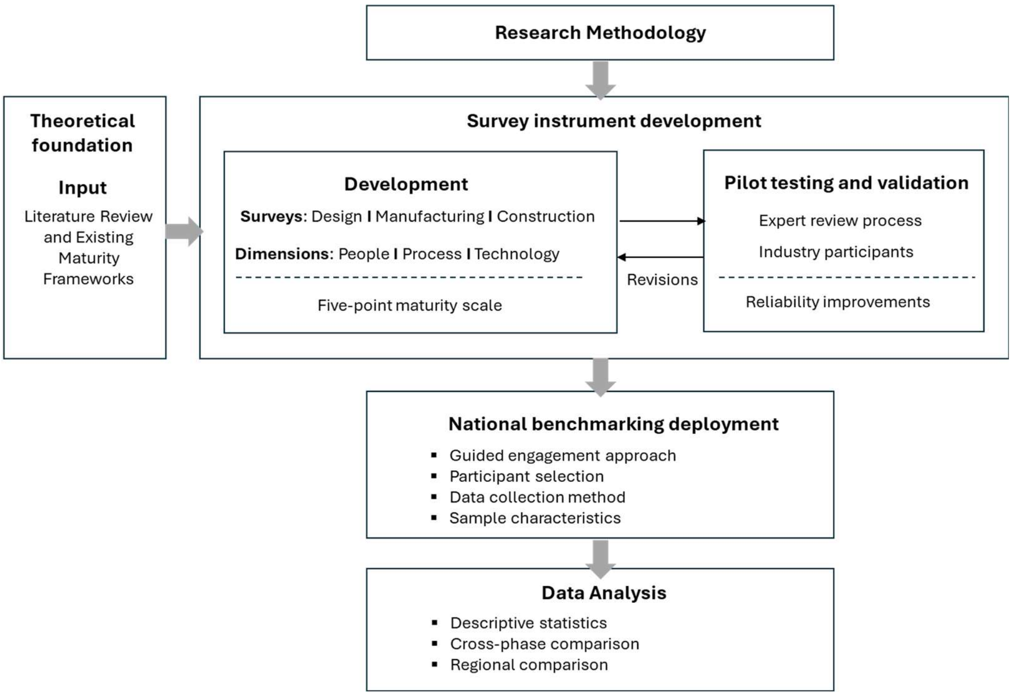

Figure 1: Multistage methodological framework

Table 1: Maturity scale definitions

Level	Description
1 – Ad-hoc	Informal, reactive processes with minimal consistency and limited technology integration
2 – Structured	Basic processes and initial technology adoption, with inconsistent implementation
3 – Standardized	Formal procedures and consistent use of technology across projects
4 – Optimized	Integrated processes and continuous improvement driven by skilled personnel
5 – Innovative	Advanced technology use and innovation-driven practices setting industry benchmarks

3.3 Pilot Testing and Validation

Prior to national deployment, the draft survey instruments underwent two rounds of validation. First, a panel of academic researchers specializing in OSC reviewed the surveys for content validity, relevance, and completeness. The draft survey instruments were reviewed by industry experts and pilot participants to evaluate clarity, relevance, and internal consistency. Feedback from this review led to the consolidation of overlapping categories, clarification of maturity level descriptors, and the addition of phase-specific terminology to improve respondent comprehension.

Second, a pilot test was conducted with nine industry participants representing design, manufacturing, and construction organizations actively engaged in OSC activities. Pilot participants completed the surveys under guided conditions and provided structured feedback on question clarity, response burden, and the interpretive consistency of maturity level definitions. The data collected during the pilot phase were used solely for instrument refinement and were excluded from the final study dataset. This phase led to further revisions including simplification of question phrasing and adjustment of scale anchors. These steps collectively improved the reliability and usability of the instrument prior to national deployment.

3.4 National Benchmarking Deployment

The finalized surveys were deployed nationally using a guided engagement approach to ensure consistent interpretation of maturity definitions across respondents. Organizations actively involved in OSC activities were purposively selected to provide representation across project phases and geographic regions. A total of 78 organizations were approached, of which 37 participated in the study, resulting in a participation rate of approximately 47%. Data were collected through facilitated sessions in which the researcher shared the survey instrument with knowledgeable organizational representatives, recorded responses on their behalf, and addressed any questions or clarifications in real time.

A total of 37 responses were collected across the three surveys: 12 responses for the design phase survey, 17 for the manufacturing phase survey, and 8 for the construction phase survey. Respondents were distributed across four regions: Atlantic Canada (New Brunswick), Quebec, Ontario and Manitoba (grouped as ON+MB), and Prairies and Western Canada. It should be noted that the purposive sampling approach, targeting only organizations already active in OSC, means the results reflect the maturity of OSC-engaged firms rather than the Canadian construction sector.

3.5 Data Analysis

Survey responses were analyzed using descriptive statistics to identify maturity patterns across phases and dimensions. A hierarchical aggregation approach was applied to ensure consistent scoring, as illustrated in Figure 2. Individual questions were rated on a five-point scale. Category scores were calculated as the median of question responses within that category. Dimension scores (People, Process, Technology) were calculated as the median of their constituent category scores, and phase scores as the median of the three-dimension scores.

The median was selected as the aggregation method because the maturity levels represent ordinal categories, where each score corresponds to a distinct stage and intermediate values do not carry meaningful interpretation. To validate this approach relative to the mode, a sensitivity analysis using Monte Carlo simulation and pilot-phase data was conducted. The median demonstrated lower sensitivity to variation and was therefore retained as the preferred scoring method. This approach also reduces the influence of outliers and provides a stable measure of organizational maturity. Comparative analysis was conducted across regions and organizational types. To ensure data privacy, results were grouped such that each region included a minimum of three respondents. The aggregated scores were used to establish a preliminary national benchmark of OSC organizational maturity in Canada.

4 RESULTS

Survey responses were analyzed to identify maturity patterns across phases and dimensions using descriptive statistics. The results provide a national benchmark of organizational readiness for OSC, highlighting both consistent trends and regional variations. Given the small sample sizes involved particularly at the regional level all findings should be interpreted as exploratory and indicative rather than statistically representative.

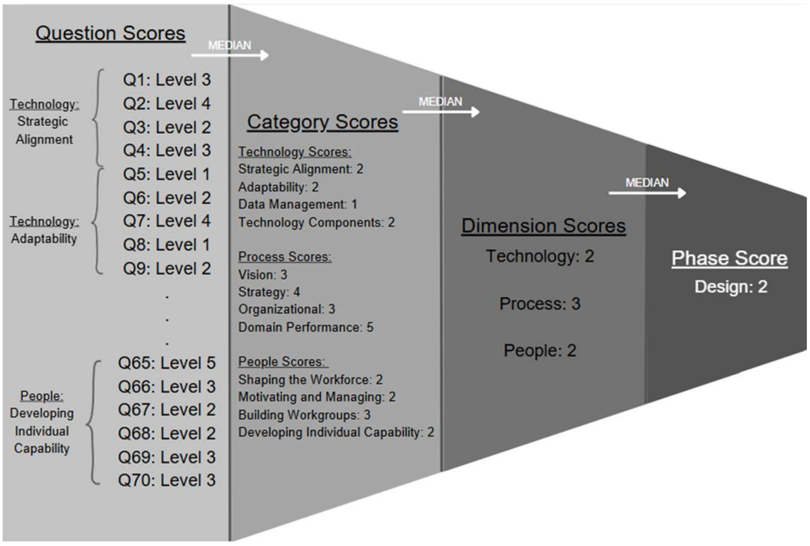

Figure 2: Scoring aggregation process from question level to phase maturity score.

4.1 Overall National Maturity Patterns

From the results, OSC maturity across Canada is concentrated at a moderate level, with most organizations operating between Structured (Level 2) and Standardized (Level 3) maturity. Only a small number of responses reach the Optimized level (Level 4), and very few achieve Innovative maturity (Level 5). This indicates that while OSC practices are being adopted among active firms, full integration across organizational systems has not yet been realized. Figures 3–5 illustrate the distribution of maturity levels across the three PPT dimensions and project phases.

In the People dimension (Figure 3), both Design and Manufacturing phases show relatively stronger maturity, with responses frequently reaching Standardized and, in some cases, Optimized levels. This reflects more developed workforce capabilities and clearer role structures in these phases. However, the Construction phase reports comparatively lower People-dimension maturity, particularly in areas related to workforce development and OSC-specific competency management.

In the Process dimension (Figure 4), maturity tends to be higher in the Design phase, where more responses are observed at the Standardized and Optimized levels. This reflects stronger alignment of workflows, planning practices, and documentation processes in early project stages. The Manufacturing phase shows a more consistent distribution centered around the Standardized level, indicating relatively stable but not fully optimized production practices. In contrast, the Construction phase shows greater variability, with a notable proportion of responses at the Structured level, suggesting inconsistent on-site implementation of standardized workflows.

In the Technology dimension (Figure 5), the Design phase again leads, with most responses at the Standardized level, reflecting broader adoption of digital tools and systems. The Manufacturing phase shows comparatively lower maturity, with many responses concentrated at the Structured level, highlighting gaps in technology integration within production environments. The Construction phase remains at a moderate level, with responses distributed between Structured and Standardized levels.

Overall, these findings indicate that OSC maturity in Canada is more advanced in early project stages and less developed in construction, suggesting that integration challenges persist beyond design and planning phases.

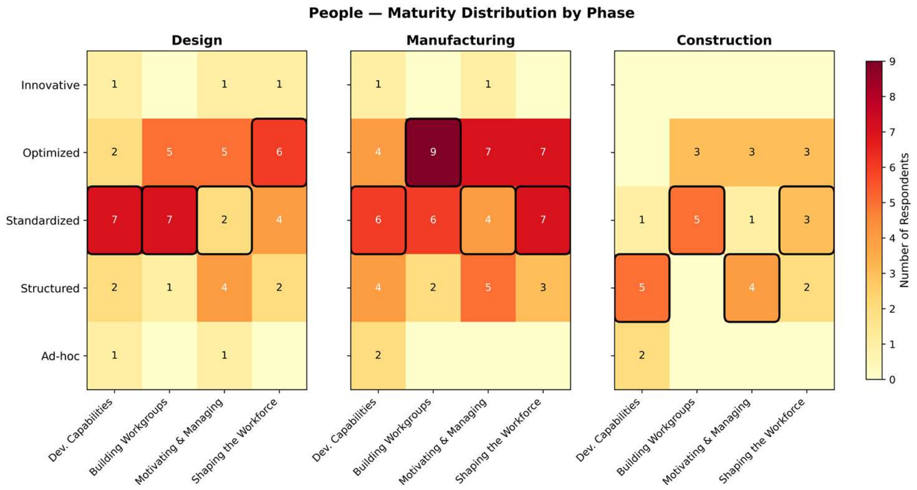

Figure 3: Distribution of People maturity levels across phases (cell values indicate respondent counts)

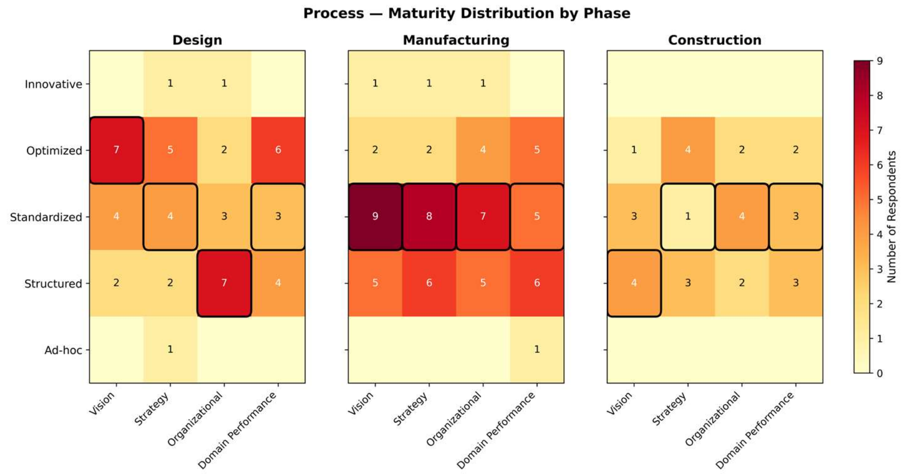

Figure 4: Distribution of Process maturity levels across phases (cell values indicate respondent counts).

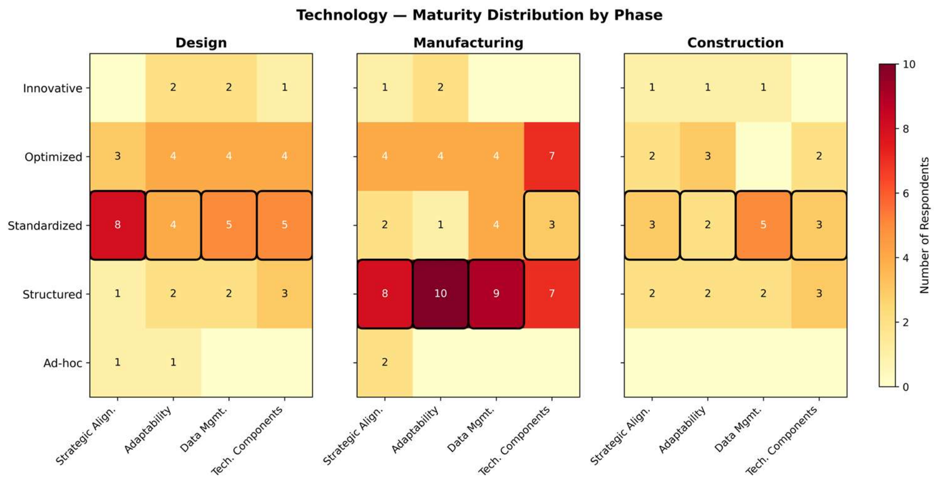

Figure 5: Distribution of Technology maturity levels across phases (cell values indicate respondent counts).

4.2 Regional Variability (Preliminary Insights)

For regional analysis, provinces were grouped based on geographic proximity and data distribution into the following categories: Quebec; Ontario and Manitoba (ON + MB); Central Canada; and Prairies and Western Canada. These groupings were used to enable consistent comparison across different project phases. This section presents preliminary observations on regional variability in OSC maturity across Canada.

Initial findings indicate that, although most regions fall within the Structured-to-Standardized maturity range, differences in specific dimensions highlight distinct regional pathways for OSC adoption. In the Design phase, Ontario and Manitoba generally demonstrate higher maturity across most categories, particularly in Process and Technology, while Quebec shows relative strengths in Data Management and workforce-related capabilities. In the Manufacturing phase, variability is observed across multiple regions, with Ontario and New Brunswick showing more consistent performance, while Prairies and Western Canada exhibit more uneven maturity levels across categories. In the Construction phase, Central Canada generally outperforms Prairies and Western Canada in Process and Technology dimensions, whereas Prairies and Western Canada demonstrate relatively stronger performance in workforce-related practices, particularly in motivating and managing personnel. These observations are indicative and will be refined as additional data becomes available and the analysis is further developed.

5 DISCUSSION

The results suggest that OSC maturity across Canada is relatively consistent at the national level, with most organizations operating between Structured and Standardized levels. This consistency can be explained by the shared industry context, including similar regulatory environments, market conditions, and increasing national awareness of off-site construction as a response to productivity challenges. The growing influence of federal initiatives and industry-wide discourse on digitalization and industrialized construction has likely contributed to a baseline level of capability development across organizations, regardless of region.

However, when examined at a regional level, the results reveal greater variability in maturity, particularly across phases and dimensions. This variation reflects differences in regional industry structure, supply chain maturity, and investment in OSC-related capabilities. Regions with stronger manufacturing ecosystems and higher exposure to industrialized construction practices to demonstrate more advanced maturity levels, particularly in the Manufacturing phase. In contrast, regions with more traditional construction practices or less integrated supply chains show lower maturity, especially in Technology and Process dimensions. These findings suggest that OSC adoption in Canada does not follow a single, uniform pathway. Instead, it evolves through region-specific trajectories, influenced by local capacity, market demand, and institutional support.

Across all three PPT dimensions, a consistent gradient was observed: the Design phase shows the highest maturity, the Construction phase the lowest, and Manufacturing sits between them. The relatively higher maturity of the Design phase likely reflects earlier adoption of digital tools such as Building Information Modeling (BIM), the presence of established professional workflows, and lower workforce mobility in design firms compared with construction. In contrast, the Construction phase's lower performance particularly in People and Process dimensions reflects structural features of site-based work: transient labour forces, contractual fragmentation, limited OSC-specific training, and a cultural emphasis on improvisation over standardized procedure. Notably, the Manufacturing phase shows the lowest Technology maturity of the three phases, despite factory environments being theoretically more amenable to digital integration than construction sites. This counterintuitive finding suggests that investment in digital manufacturing systems and production planning tools has not kept pace with workforce and process development in that phase and warrants targeted attention.

From an industry perspective, the results emphasize the need for better integration across project phases, particularly in aligning design practices with manufacturing and construction processes. For policymakers, the observed regional disparities suggest that targeted, region-specific strategies may be more effective than uniform national policies. Investment in manufacturing infrastructure, digital adoption, and workforce development should be tailored to regional needs to accelerate OSC implementation.

For capability development programs, the findings highlight the importance of adopting a holistic approach based on the People–Process–Technology (PPT) framework. While progress has been made in standardizing processes and introducing digital tools, gaps remain in workforce readiness and cross-phase integration. Training programs, knowledge transfer initiatives, and collaborative platforms can play a critical role in bridging these gaps and supporting more consistent capability development.

Similar patterns of uneven OSC capability development have also been reported internationally. Studies from countries such as the United Kingdom and Australia have highlighted that while design-related digital integration in OSC is relatively advanced, challenges remain in achieving consistent technology adoption and process integration across manufacturing and construction phases (Goulding et al., 2023; PrefabAUS, 2023). These similarities suggest that many of the barriers identified in the Canadian context reflect broader challenges associated with the transition toward industrialized construction. More broadly, the results are consistent with existing literature emphasizing that OSC adoption depends on the alignment of organizational capabilities rather than technology alone (Goulding et al., 2023; Tripathi et al., 2024), and that maturity is often uneven across dimensions and phases. However, this study extends prior work by providing a preliminary survey-based benchmark for Canada, offering empirical evidence of both consistency and variability in OSC maturity across regions and project stages.

6 CONCLUSION

This study developed and applied a survey-based framework to assess and benchmark organizational maturity for off-site construction (OSC) across Canada. Using the People–Process–Technology (PPT) framework, maturity was evaluated across the design, manufacturing, and construction phases, providing an initial national, evidence-based assessment of OSC readiness at the organizational level. The results indicate that OSC maturity in Canada is generally concentrated between Structured and Standardized levels, reflecting growing adoption of OSC practices while highlighting ongoing gaps in process integration, technology implementation, and workforce capability development.

The findings reveal that maturity is strongest in the Design phase and less developed in Manufacturing and Construction, indicating persistent challenges in achieving integration across the project lifecycle. While maturity patterns appear relatively consistent nationally, preliminary regional analysis identified variability across phases and dimensions, suggesting that OSC capability development is influenced by regional industry conditions and levels of institutional and technological support. The proposed framework provides an initial benchmarking foundation for assessing OSC organizational readiness in Canada and offers a structured basis for future industry-wide maturity assessments and capability development initiatives.

While this study provides valuable insights, several limitations should be acknowledged. The sample is drawn from organizations already active in OSC, which means results reflect the upper range of current industry capability rather than a sector-wide picture. While the guided engagement approach reduced the risk of misinterpretation, variability in responses may still exist due to differences in organizational context and participants' familiarity with OSC practices. Regional analysis was conducted as a preliminary exercise and, given the current sample sizes, should be treated as indicative rather than conclusive. Expanding regional coverage and increasing the number of respondents per region remains a priority for subsequent phases of this work.

Future research should prioritize expanding the dataset geographically and by organization type, increasing the number of respondents per region to enable more robust and conclusive regional comparisons. Longitudinal assessments and the integration of project-level performance metrics would further strengthen the framework, enabling tracking of maturity trajectories over time and validating the relationship between organizational readiness and OSC delivery outcomes.

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