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TOWARDS A STANDARDIZED FRAMEWORK FOR MEASURING PRODUCTIVITY IN THE CANADIAN CONSTRUCTION INDUSTRY: A SYSTEMATIC LITERATURE REVIEW

A. Kasundra,[1], A. Mehdipoor[1,*4], A. Niaz[1], M. Fawad[2], Q. Chen[2], and A. Thompson[1,*3]

[1] Construction Research Centre, National Research Council of Canada, Ottawa, ON, Canada
[2] School of Engineering, The University of British Columbia, Kelowna, BC, Canada
[*3] alexandra.thompson@nrc-cnrc.gc.ca
[*4] amirhossein.mehdipoor@nrc-cnrc.gc.ca

ABSTRACT: The construction industry is a key driver of Canada's economy, contributing approximately 7.2% to the Gross Domestic Product (GDP) and employing 7.9% of the national workforce, according to Statistics Canada. However, the sector faces a significant challenge: a steady decline in labour productivity, now at its lowest in three decades. One major obstacle in addressing this issue is the lack of a standardized framework for measuring productivity across projects. Inconsistent definitions and measurement practices hinder benchmarking and industry-wide improvement. This study tackles the problem through a systematic literature review, integrating both quantitative and qualitative methods to explore productivity frameworks and Key Performance Indicators (KPIs). The quantitative analysis, conducted using VOSviewer, revealed keyword linkages and research patterns, while the qualitative review examined existing frameworks, KPIs, and benchmarking strategies. Productivity measurement was categorized into three levels—industry, project, and activity—while KPIs were organized into six domains: cost, time, quality, health and safety, labour, and environment. Examples include cost predictability, construction speed, and CO_2 emissions per unit. These indicators are essential for evaluating performance and supporting Canada's sustainability goals. While this study does not develop a new framework, it offers valuable insights for future efforts. It highlights global models like the "A Seven-Step Framework for Success" and "C792" as adaptable tools suited to Canada's unique context, including remote work sites, severe weather, and environmental priorities. By building on these insights, Canada can move toward a standardized productivity framework that enhances benchmarking, boosts sector performance, and strengthens global competitiveness.

Keywords: Key Performance Indicators (KPIs), Canadian Construction Productivity, Standardized Framework, Benchmarking, and Systematic Literature Review

1. INTRODUCTION

The construction industry plays a vital role in Canada's economy, contributing $165.5 billion to GDP and employing over 1.57 million people (Statistics Canada, 2024). However, productivity has reached a near 30-year low, posing economic challenges (TD Economics, 2024). Since productivity in construction directly impacts the economy (Nasir et al., 2014), improving it is essential. Productivity is commonly measured as the ratio of output (work done) to input (labor, materials, tools) (Vogl & Abdel-Wahab, 2015; Ayele & Fayek, 2019). While standardized productivity measurement and benchmarking improve efficiency (Nasir et al., 2012), the Canadian construction sector lacks a unified approach, leading to inconsistent assessments and hindered improvements (Tiruneh & Fayek, 2021). Benchmarking refers to the process of comparing project-specific productivity metrics against aggregated industry data or standardized performance baselines to identify gaps, best practices, and areas for improvement. Some organizations, like the Construction Owners Association of Alberta (COAA) and the Construction Sector Council in Canada, have initiated productivity measurement programs. However, these studies have not fully addressed the need for a systematic unified approach, resulting in some major gaps in standardization processes (CII & COAA, 2019). The reviewed studies have mainly focused on different aspects of productivity, neglecting a comprehensive framework that integrates various performance indicators across different project domains.

This study aims to address these gaps by conducting a systematic literature review that combines quantitative and qualitative analyses to explore existing productivity frameworks and identify Key Performance Indicators (KPIs). The quantitative analysis is carried out utilizing VOSviewer maps research trends and categorizes productivity measurement into three levels: industry, project, and activity. Further, the study identifies the major domains for the selection of a structured KPIs list. These domains include cost, time, quality, health and safety, labour, environment, and local disruption. These domains are the backbone of KPI selection criteria that are crucial for assessing project performance and aligning with Canada's construction sector productivity enhancement goals. While this study does not propose a new framework, it lays the groundwork for future efforts, informing the development of a national benchmarking system to enhance construction productivity and policy alignment.

2. METHODOLOGY

This study employed a systematic literature review (SLR) combining quantitative and qualitative analysis of the identifies database. The quantitative analysis used bibliometric mapping using VOSviewer, a tool that identifies current trends within a given field (Li et al. 2021). VOSviewer generates bibliometric maps, such as keyword co-occurrence maps and author or journal co-citation networks (van Eck & Waltman 2010)). Scopus served as the primary search engine for this study. The list keywords included were “productivity frameworks”, “metrics”, “benchmarks”, “Canadian construction industry”, and “KPI” with a Boolean logic of “AND” and “OR”. Initial keywords were selected based on a review of prior research, and all relevant journalarticles, reports, conference papers, industry standards and searches within the engineering field were retrieved.The inclusion criteria were: (i) peer-reviewed journal articles, (ii) English language publications, (iii) studies focused on productivity measurement in the construction sector. The exclusion criteria included: (i) non-English publications, (ii) studies unrelated to the construction industry, (iii) editorials or incomplete conference abstracts, and (iv) duplicate records. Data from database was subsequently downloaded and imported into VOSviewer to create network maps of publications and keywords.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used in this study to screen out the relevant data. PRISMA promotes clear, transparent and consistant systematic reviews, ultimately improving the quality and reliability of evidence-based research (Sohrabi et al., 2021). Figure 1 illustrates the SLR process which details how the database was used to identify, screen, and include the data. A keyword map was generated using VOSviewer for the screen data, which highlighted key terms with strong linkage strengths. These terms were further analysed for qualitative data. The keyword map revealed the depth of prior research on specific topics, clusters of related terms, and patterns of collaboration, enabling a better understanding of research communities within the field. As part of the qualitative analysis, 17 productivity frameworks were identified, categorized across three levels—industry, project, and activity—and segmented into domains such as cost, time, quality, health and safety, labour, and environmental considerations. This structured approach provided a detailed understanding of productivity measurement within the construction industry in Canada and highlighted gaps and further research areas.

3. BIBLIOMETRIC ANALYSIS

The bibliometric map in Figure 2 is a part of the quantitative analysis which is based on journal co-citation data extracted from the Scopus database. Different colors denote different clusters, and five clusters were distinguished. This is a distance-based map, the closer the distance closer the relation it represents van

Eck & Waltman (2010). As this map is plotted based on the keywords it shows how closely two topics have been researched. The map is useful in understanding the trends in the research, the connectivity between the topics, and the research gap in productivity, which aligns with the objective of this study to establish a framework for productivity measurement.

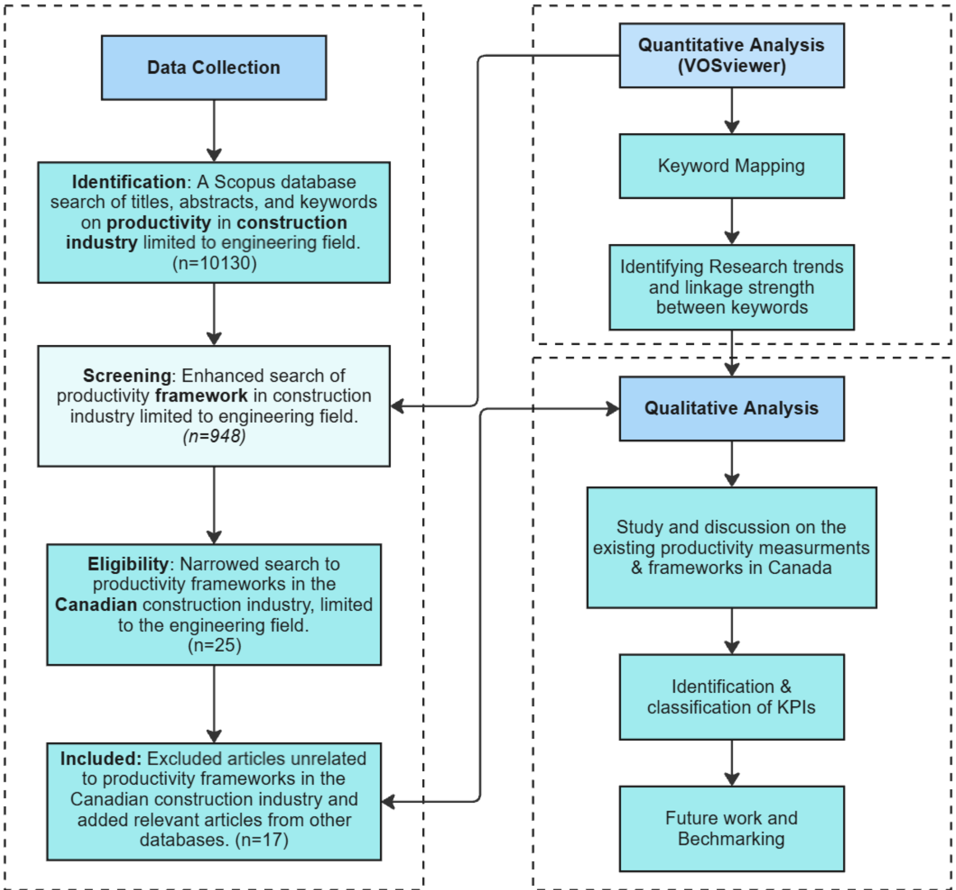

Figure 1: Methodology: SLR Process (n= represents the number of references)

The map clusters identified show the topical areas of construction productivity research and the areas of high and low interest. Thus, in addition to indicating where productivity metrics and frameworks are already in place, the map also reveals areas that deserve further research. These insights are useful in the creation of a standardized framework by identifying areas of focus and infer areas for improvements in performance measurement.

Different clusters are identified, and each cluster represents a distinct thematic focus within the productivity domain. A cluster is a group of closely related nodes representing a group of data points that automatically connects and groups together because of their shared relationships and similarities within the analyzed data set; this grouping shows distinct research areas or topics within the network. Each node is related to exactly one cluster and none of the clusters are overlapping (van Eck and Waltman 2010).

The map identifies five different clusters, each representing a thematic focus within the productivity domain. These clusters highlight key research areas, while their interpretation provides insights into their implications for construction productivity.

- Cluster 1 (Red): As per the map there is a linkage between the concepts like “lean construction”, “framework”, and “industry 4.0”. This cluster helps us to understand how these concepts are crucial for increasing the efficiency of projects at the single-project level and addressing the impact of technological changes.

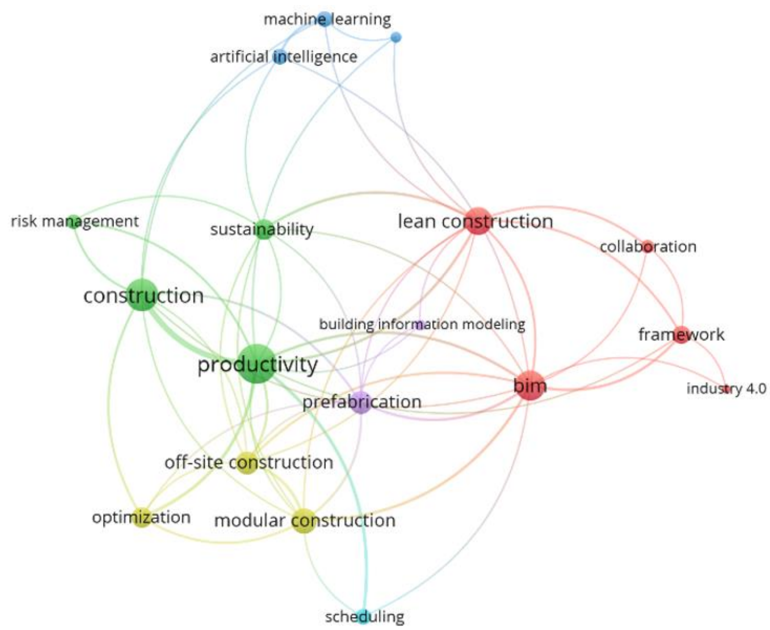

Figure 2: Bibliometric Map

- Cluster 2 (Green): This cluster shows sustainability and risk aspects of productivity research, as sustainability and risk management are becoming increasingly important in construction.
- Cluster 3 (Purple): This cluster links “prefabrication” and “BIM” and demonstrates developments in off-site construction processes and their implications for shortening construction time and decreasing costs.
- Cluster 4 (Yellow): This cluster links “optimisation”, “modular construction” and other “off-site techniques” which play a critical role in increasing activity level productivity through minimisation of waste.
- Cluster 5 (Blue): This cluster links the new technologies like ‘‘machine learning’’ and ‘‘artificial intelligence’’ are likely to transform productivity measurement and control.

The map also helps in the narrowing down of the database for the qualitative research process. Hence, high linkage strength keywords such as ‘Off-site construction’, ‘Modular construction’, ‘Sustainability’, ‘lean construction’, ‘BIM’, and ‘prefabrication’ were used along with ‘productivity’ to shortlist a few studies to conduct detailed qualitative research. This prioritization helps in achieving the objective of the qualitative analysis by identifying the most important and relevant topics. Therefore, in addition to presenting the current state of productivity research, the bibliometric map also forms the basis for structuring the qualitative analysis in terms of trends, and thematic areas as discussed above. The map also helps us identify the research gaps; the bibliometric analysis reveals several research gaps that must be addressed for the development of a comprehensive productivity framework. As reflected in Figure 2 the current research lacks sufficient linkage between AI and machine learning in productivity assessment while indicating the necessity for advanced technology integration. The direct relationship between sustainability and productivity benchmarking requires further development in existing research. Although there is a strong linkage between modular and off-site construction, it fails to establish equally strong connections with standardized productivity measures therefore creating space for additional investigation. Research into using Industry 4.0 tools particularly the Internet of Things and digital twins for productivity measurement remains a relatively uncharted area. Several studies on productivity exist but remain scattered which demonstrates the importance of the development of a standardized productivity framework for the construction industry in Canada.

4. QUALITATIVE ANALYSIS

The existing research done on the development of a framework for benchmarking productivity in construction suggests two very minutely differentiated models for the levels of measurement and development of productivity metrics. One model suggests a 3-level measurement system i.e., industry, project, and activity level (Ayele and Fayek 2019; Huang et al. 2009; Rankin et al. 2008; Robinson 2017), while the second suggests a 2-level measurement i.e., macro and micro level (Gebretekle et al. 2019; Robinson 2017; Yun et al. 2015). In the first, specific construction tasks, like pouring concrete and erecting steel, are evaluated using activity-level productivity metrics. On the other hand, project-level productivity metrics consider the specific tasks needed to build a facility. Industry-level productivity measures are derived from a comprehensive evaluation of productivity within the industrial sector; this methodology is also regarded as a macro-level measurement metric.

The qualitative analysis identified different results grouped into two themes, one identifies the input-output relationship to measure productivity, while the other identified different domains such as cost, time, quality, health & safety, labour, and environment and distributed KPIs amongst these domains to form metrics which then help measure productivity from different aspects.

4.1 Theme 1 - Input-Output Frameworks for Productivity Measurement

The first theme that emerged from the qualitative analysis is frameworks that define productivity in terms of inputs, including human and material resources, capital, and energy, and outputs in terms of structures, infrastructure, or operational production. These frameworks are designed to provide a comprehensive assessment of productivity at three different levels: industry, project, and activity. By defining relationships between inputs and outputs, they contribute to productivity measurement and benchmarking. The analysis below highlights the methodologies used to develop these frameworks, their contribution to productivity, and their applicability in standardizing productivity assessments across varying scales.

4.1.1 Industry–Level Framework

At the industry level, productivity frameworks assess sector performance by analyzing inputs and outputs to identify trends, gaps, and opportunities. Tiruneh and Fayek (2021) proposed a method to classify performance and competency indicators, highlighting strategic, stakeholder, and quality management as crucial to productivity. Their review categorized competencies into functional, technical, cross-functional, and behavioral, validated through focus groups. Robinson (2017) used the Total Factor Productivity (TFP) framework, measuring outputs relative to inputs like labour, materials, and energy. He demonstrated that aggregating these measures reveals macro-inefficiencies, aiding policy formulation and market comparisons aligned with broader industry goals..

4.1.2 Project–Level Framework

At the project level, frameworks provide mid-level productivity insights by evaluating construction projects through phases like planning, procurement, construction, and commissioning. Nasir et al. (2012) developed a project-level framework and benchmarking program for Canada’s construction industry, establishing standardized metrics for project planning, material management, and supervision using data from pilot projects. This initiative emphasized the importance of project-level metrics to enable benchmarking and identify best practices.

Robinson (2017) introduced methods for calculating single-factor and multi-factor productivity, including labor productivity (output divided by labor input) and capital productivity (output relative to capital expenditures). Ayele and Fayek (2019) further advanced this by creating a phase-based framework that classified inputs such as direct and indirect labor, material costs, and energy for more accurate productivity measurement. The framework’s usefulness was validated through expert surveys, demonstrating its ability to assess inefficiencies in project phases. This approach contributes to identifying areas for improvement and optimizing productivity throughout a project’s lifecycle.

4.1.3 Activity – Level Framework

At the activity level, productivity frameworks focus on the performance of tasks and offer detailed information on construction work. The CII (2013) proposed labor productivity being a direct ratio of installed quantities to direct work hours. This metric supplied activity-level performance review and analysis, offering a foundation for enhancing operational efficiency at the activity level. Chang & Woo (2017) defined labor productivity as the ratio of installed quantities to working hours, offering a direct metric for assessing task-level efficiency. Building on this, CII & COAA (2019) proposed measuring productivity using the ratio of actual direct design work hours to Issue for Construction (IFC) quantity, enabling a more precise evaluation of design efficiency.

4.2 Theme 2 - Domain-Specific Productivity Metrics and KPIs

The second theme that emerged from the qualitative analysis was frameworks emphasizing the development of productivity metrics categorized into distinct domains, each focusing on a specific aspect of construction performance. A domain-based system forms the core of a complete productivity framework that addresses different construction performance areas. As shown in Table 1, this study examines six core productivity domains: cost, time, quality, health & safety, labor, and environment. Each domain functions as a lens for measuring specific dimensions of productivity. For example, the health & safety domain includes metrics such as total recordable incident rates and lost-time injuries, which can significantly affect labor efficiency and schedule adherence. Similarly, the cost domain incorporates indicators like cost predictability and construction cost growth, reflecting budgeting accuracy and financial control. Additionally, the analysis integrates the concept of measurement across different levels—industry, project, and activity—allowing for a more granular and scalable evaluation of productivity. The integration of domains and levels enables a dual-layered framework, where each KPI is mapped to both its domain and the level of construction activity it addresses. This ensures that productivity is measured from activity-level metrics to the broader industry level, supporting comprehensive performance monitoring and targeted improvement strategies.

Table 1: List of KPIs

Domain	KPIs	Formula	*Ref.
Cost	Cost predictability	(Actual cost at specific phase - estimate cost at specific phase)/ (actual cost at specific phase) ×100	[1]
	Cost per unit	(Tendered cost)/(capacity measurement)	[1]
	Cost for defects-warranty	(Construction cost of rectifying all defects)/ (final cost for construction) ×100	[1]
	Cost in use	(Annual operating cost arranged over years)/ (final cost for construction & design) ×100	[1]
	Project cost growth	(Actual total project cost – Initial Predicted project cost)/ Initial Predicted project cost	[2]
	Total change cost factor	Total cost of scope change and development changes/ Actual total project cost	[3]
	Cost Performance Index	Budget cost/actual cost	[3]
	Labour cost Ratio	Indirect labour costs/direct labour costs	[3]
	Construction Cost Growth	(Actual construction cost – Initial Predicted construction cost)/ Initial Predicted construction cost	[4]
	Modularization	Cost of all modules/Total installed cost	[4]
Time	Time predictability	(Actual time taken at specific phase – estimate time taken at specific phase)/ (actual time taken at specific phase) ×100	[1]
	Time per unit	(Contract time for construction)/ (capacity measurement)	[1]
	Time for change - Demand/Supply	(Approved time for change originating from client/contractor)/(total project time) ×100	[1]

	Time for defects-warranty	Time taken to rectify all defects	[1]
	Average percentage finish on time	Number of Projects Finished on Time/ Total Number of Projects ×100	[5]
	Takt time	Available Production Time / Number of Ordered Units (Customer demand)	[5]
	Lead time	Completion Date−Order/Start Date	[5]
	Construction speed index	Percentage complete per day actual (avg.)/percentage complete per day baseline(avg.)	[3]
	% Scheduled growth	[(Total time – total as-planned time)/total as-planned time] *100	[3]
	Lost Time	Man-hours lost due to idle time such as waiting for materials, instructions, or daily work orders.	[3]
Quality	Total quality cost	TQC=Prevention Costs + Appraisal Costs + Failure Costs	[7]
	Rework factor	Total direct cost of rework/ Actual construction phase cost	[7]
	Customer retention/loyalty	Number of customers repeating	[7]
	Client satisfaction	Rating of performance from 1 to 7 with 1 being Extremely Dissatisfied and 7 being Extremely Satisfied	[1]
	Quality issues	Rating of performance from 1 to 7 with 1 being Extremely Dissatisfied and 7 being Extremely Satisfied	[1]
	Average variance to the standard	Actual total work hours/ Planned cycle time(work hours)	[5]
	Lost time	Number of Employees Affected × Hours Lost per Employee	[5]
	Defects-per-million-opportunities	A ratio of the number of defects in 1 million opportunities when an item can contain more than one defect	[3]
Health & Safety	Reportable incidents	(Number of reported incidents)/ (100 000 h worked)	[1]
	Incident rate	Time lost due to injury	[5]
	Near misses	(quantity near miss/working days) ×200,000	[5]
	Average overtime hours per person	Planned overtime percentage/actual overtime percentage	[3]
	Total recordable injury frequency	(Number of recordable incidents×200,000 h)/total project hours	[3]
Labour	The volume of workforce growth	Workforce at End of Period−Workforce at Start of Period/Workforce at Start of Period	[7]
	Employee satisfaction	On a scale of 1 to 10	[7]
	Earned Man-hour	(Completed work in place×Estimated unit rates by the amount of work completed)	[7]
	Employee turnover rate	(Number of employees who quit/total number of employees hired during a project) 100	[3]
	Average remuneration per employee	Money paid for labour / total number of employees	[6]
Environment	Construction water utilization rate	Total litres of water used/$ 1 M actual costs	[3]
	Waste (generated during construction)	Total cost of waste removal/$ 1 M	[3]
	Spill severity	Estimated volume spilled/10,000 worker hours.	[3]
	CO2 Emissions	Total amount of carbon emissions as a result of on-site activities / Total on-site area under Construction (m2)	[8]

*[1] Rankin et al. (2008), [2] Chanmeka et al. (2012), [3] Siddika and Masfiqul Alam Bhuiyan (2024), [4] CII and COAA (2019), [5] Zhang et al. (2020), [6] Cox et al. (2003), [7] Tiruneh & Fayek (2021), [8] Pons (2014)

These KPIs are crucial for assessing project performance and aligning with Canada's sustainability goals. These goals include targets set by the Pan-Canadian Framework on Clean Growth and Climate Change and Canada's commitment to achieve net-zero greenhouse gas emissions by 2050 (Government of Canada, 2016). Integrating environmental KPIs such as CO_2 emissions per unit, construction water utilization, and waste generation allows for real-time tracking of a project's environmental footprint, aligning project-level decision-making with national sustainability priorities.

5. RESULTS AND DISCUSSION

The analysis of the two identified themes—input-output frameworks and domain-specific KPIs—offers critical insights for productivity measurement in the Canadian construction industry. Input-output frameworks provide a structured method by linking inputs such as labor, materials, and capital to outputs like infrastructure or services, enabling productivity assessment from project to industry levels. Domain-specific KPIs complement this by measuring performance across key areas—cost, time, quality, safety, labour, and environment—ensuring a holistic view of productivity. Categorizing KPIs by domain and linking them to industry, project, and activity levels enhances the granularity of evaluation, helping identify both broad trends and detailed inefficiencies.

However, applying this dual-layered approach in Canada requires refinement. A major challenge is the absence of standardized data, which limits benchmarking. To address this, pilot studies across diverse project types—urban, remote, and large-scale—should test the framework's adaptability. A phased strategy is proposed: Phase 1 involves pilot testing with industry partners; Phase 2 refines KPIs using real-time data; and Phase 3 launches a national benchmarking dashboard via Power BI. Engagement with stakeholders like the Canadian Construction Association and government agencies is essential to align the framework with industry needs and promote widespread adoption..

Comparison with global benchmarking practices further underscores the need for a localized yet internationally aligned framework. The Construction Productivity Taskforce (2022)'s Seven-Step Framework offers a systematic approach to measure productivity at the site-level but lacks validation in extreme Canadian weather conditions and complex project delivery environments. Similarly, the UK Constructing Excellence Performance Measurement Framework aligns with sustainability goals but does not sufficiently address resource-sector productivity issues, such as workforce availability, equipment utilization, and regulatory constraints unique to Canada (Constructing Excellence 2024). The International Construction Measurement Standards (ICMS 2024) system helps organizations compare construction performance against others in the industry but lacks complete solutions for Canada's workforce restrictions and regulatory framework. And Ciria (2020)'s C792 framework quantifies the benefit of using off-site construction methods by identifying and measuring data for various KPIs but its application is limited only to off-site construction practices.

While emerging technologies such as Building Information Modelling (BIM), machine learning (ML), and Industry 4.0 tools appeared prominently in the bibliometric analysis, their presence was less emphasized in the domain-based KPI themes. However, these technologies act as cross-cutting enablers rather than isolated productivity domains. For example, BIM enhances planning accuracy (time), ML supports predictive maintenance (cost and safety), and IoT-driven tools improve real-time data collection across quality and environmental metrics. Future iterations of this framework could integrate these technologies either as standalone domains or embedded indicators within existing categories, recognizing their evolving influence on construction productivity. (Azhar, 2011; Florez-Perez et al., 2022).

To bridge current gaps, the proposed framework blends global best practices with Canada-specific productivity metrics, ensuring both international relevance and local applicability. A hybrid model using regionally tailored KPIs and international methods can improve benchmarking and policymaking. Integrating AI-driven analytics and digital twin technologies enables real-time tracking and enhances decision-making. Once validated through pilot testing, a national benchmarking system can support continuous productivity monitoring and evidence-based improvements. This system will help identify inefficiencies and drive targeted interventions, strengthening the Canadian construction sector's competitiveness while addressing its unique challenges and aligning with global standards.

6. CONCLUSION

This study provides a foundational understanding of productivity measurement in the Canadian construction industry through a systematic review of existing frameworks and KPIs. By analysing input-output frameworks and domain-specific KPIs, the research highlights their potential to inform the development of a standardized measurement approach and a scalable national benchmarking system. Input-output frameworks offer structured and scalable methods by linking construction inputs, such as labor, materials, energy, and capital to corresponding outputs like infrastructure, operations, and production. This supports comprehensive productivity evaluation across industry, project, and activity levels.

Domain-specific KPIs complement this approach by organizing measurable metrics across six core domains: cost, time, quality, health and safety, labor, and environment. Examples include cost predictability, construction speed index, and CO_2 emissions per unit, which provide actionable insights and ensure a holistic evaluation of project performance. Mapping these KPIs across all levels of construction activity enhances granularity, enabling identification of both macro trends and micro-level inefficiencies. However, challenges remain, including a lack of standardization, insufficient data granularity, and Canadian-specific adaptation. Addressing these limitations through localized research and pilot testing is critical for ensuring the practical implementation and relevance of the framework.Furthermore, global benchmarking systems—such as the Construction Productivity Taskforce's A Seven-Step Framework for Success and CIRIA's C792 can offer guidance but must be tailored to address Canada's unique challenges, such as remote logistics, extreme weather conditions, and sustainability priorities. To move toward implementation, the framework should be tested through pilot projects in collaboration with industry stakeholders. This will enable refinement based on real-world feedback and improve adaptability across diverse project types and regions. Once validated, a national benchmarking system can be established to support unified measurement practices, continuous productivity tracking, and evidence-based policymaking.

This study lays the groundwork for a comprehensive, standardized productivity framework—one that reflects the complexities of Canada's construction sector, promotes sustainable practices, and aligns with international best practices to enhance industry-wide performance.

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REFERENCES

Ayele, S., & Fayek, A. R. (2019). A framework for total productivity measurement of industrial construction projects. Canadian Journal of Civil Engineering, 46(3), 195–206. https://doi.org/10.1139/cjce-2018-0020

Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. Leadership and Management in Engineering, 11(3), 241–252.

Canadian Construction Association (CCA). (2022). Insight Report: Transforming Canada's Construction Industry with Innovation and Technology. Retrieved from https://www.cca-acc.com/wp-content/uploads/2022/06/Insight-report-June-2022.pdf.

Chanmeka, A., Thomas, S. R., Caldas, C. H., & Mulva, S. P. (2012). Assessing key factors impacting the performance and productivity of oil and gas projects in Alberta. Canadian Journal of Civil Engineering, 39(3), 259–270. https://doi.org/10.1139/L11-128

CII. (2013). The Construction Productivity Handbook.

CII, & COAA. (2019). COAA Major Projects Performance Assessment System - Alberta Report III.

Ciria. (2020). Methodology for quantifying the benefits of offsite construction C792. www.ciria.org

Constructing Excellence. 2024. Performance Measurement Framework for the UK Construction Sector. Constructing Excellence, London, UK. Available from: https://constructingexcellence.org.uk/groups/performance-measurement-group/.

Construction Productivity Taskforce. (2022). Construction Productivity Taskforce: Measuring Construction Site Productivity Measuring Construction Site Productivity A seven-step framework for success.

Cox, R. F., Issa, R. R. A., & Ahrens, D. (2003). Management's Perception of Key Performance Indicators for Construction. Journal of Construction Engineering and Management, 129(2), 142–151.
Gebretekle, Y., Gerami Seresht, N., & Fayek, A. R. (2019). Framework To Establish the Relationship Between Factors Influencing Construction Productivity Using Fuzzy Interpretive Structural Modeling.
Government of Canada. (2016). On Clean Growth and Climate Change : Canada's Plan to Address Climate Change and Grow the Economy. Pan-canadian Framework.
Florez-Perez, L., Song, Z., & Cortissoz, J. C. (2022). Using machine learning to analyze and predict construction task productivity. Computer-Aided Civil and Infrastructure Engineering, 37(12), 1602–1616.
Huang, A. L., Chapman, R. E., & Butry, D. T. (2009). Metrics and tools for measuring construction productivity : https://doi.org/10.6028/NIST.SP.1101
International Construction Measurement Standards Coalition (ICMSC). 2024. International Construction Measurement Standards: Global Framework for Consistent Measurement Practices. ICMSC, London, UK. Available from: https://icms-coalition.org/.
Lean Construction Institute. 2024. Lean Construction Framework: Principles and Practices for Optimized Project Delivery. Lean Construction Institute, Arlington, VA, USA. Available from: https://www.leanconstruction.org/resources/.
Li, M., Mou, J., Chen, L., Huang, Y., & Chen, P. (2021). Comparison between the collision avoidance decision-making in theoretical research and navigation practices. Ocean Engineering, 228.
Nasir, H., Ahmed, H., Haas, C., & Goodrum, P. M. (2014). An analysis of construction productivity differences between Canada and the United States. Construction Management and Economics, 32(6), 595–607. https://doi.org/10.1080/01446193.2013.848995
Nasir, H., Haas, C. T., Rankin, J. H., Fayek, A. R., Forgues, D., & Ruwanpura, J. (2012). Development and implementation of a benchmarking and metrics program for construction performance and productivity improvement. Canadian Journal of Civil Engineering, 39(9), 957–967.
Pons, O. 2014. Assessing the Sustainability of Prefabricated Buildings. Eco-efficient Construction and Building Materials. 434-456. Woodhead Publishing
Rankin, J., Fayek, A. R., Meade, G., Haas, C., & Manseau, A. (2008). Initial metrics and pilot program results for measuring the performance of the Canadian construction industry. Canadian Journal of Civil Engineering, 35(9), 894–907. https://doi.org/10.1139/L08-018
Robinson, A. (2017). CON015-1 Leadership in Sustainable Infrastructure Framework for Measuring Overall Productivity in Construction Projects.
Siddika, A., & Masfiqul Alam Bhuiyan, M. (2024). Methodological Analysis of KPIs to Evaluate Contractor Performance of the Construction Project. Lecture Notes in Civil Engineering, 367, 639–652.
Sohrabi, C., Franchi, T., Mathew, G., Kerwan, A., Nicola, M., Griffin, M., Agha, M., & Agha, R. (2021). PRISMA 2020 statement: What's new and the importance of reporting guidelines. International Journal of Surgery, 88, 105918. https://doi.org/10.1016/j.ijsu.2021.105918
Statistics Canada. 2024. Gross Domestic Product (GDP) at Basic Prices, by Industry, Monthly. Statistics Canada, Ottawa, ON, Canada. Available from: https://doi.org/10.25318/3610043401-eng.
TD Economics. 2024. From Bad to Worse: Canada's Productivity Slowdown is Everyone's Problem. TD Bank Group, Toronto, ON, Canada. Available from: https://economics.td.com/ca-productivity-bad-to-worse.
Tiruneh, G. G., & Fayek, A. R. (2021). Competency and performance measures for organizations in the construction industry. Canadian Journal of Civil Engineering, 48(6), 716–728.
van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3
Vogl, B., & Abdel-Wahab, M. (2015). Measuring the Construction Industry's Productivity Performance: Critique of International Productivity Comparisons at Industry Level. Journal of Construction Engineering and Management, 141(4). https://doi.org/10.1061/(asce)co.1943-7862.0000944
Yun, S., Mulva, S. P., & Kim, D. Y. (2015). Measuring High-Level Project Productivity for Alberta Capital Projects.
Zhang, Y., Lei, Z., Han, S., Bouferguene, A., & Al-Hussein, M. (2020). Process-Oriented Framework to Improve Modular and Offsite Construction Manufacturing Performance. Journal of Construction Engineering and Management, 146(9). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001909