

Project Title

Enhancing the performance and productivity of the New Brunswick construction industry through appropriate digital technology adoption

Final Report

Prepared by

The Construction Engineering and Management Group
Department of Civil Engineering
University of New Brunswick

Supported by

The Digital Technologies Adoption Pilot Program (DTAPP)

April 2013



UNB CEM Project: DTAPP-1

Executive Summary

This report contains the results of a study for the New Brunswick Construction Industry under the project entitled “Enhancing the performance and productivity of the New Brunswick construction industry through appropriate digital technology adoption.” The project is supported by the Digital Technology Adoption Pilot Program (DTAPP), delivered by the National Research Council of Canada Industrial Research Assistance Program (NRC IRAP).

The study was completed by the University of New Brunswick Construction Engineering and Management (UNB CEM) Group over the period of August 2012 – March 2013. The researchers that undertook the work were Jeff Rankin (UNB CEM), Lloyd Waugh (UNB CEM), and Dhirendra Shukla (UNB Technology Management and Entrepreneurship). The general purpose of the study was to develop tools to assist the construction industry in the successfully adoption and implementation of new technologies.

The study was accomplished by completion of the following steps:

- A framework was developed for the assessment of management practices at the project level for general contractors in the construction industry.
- The assessment was administered to eight organizations, resulting in the identification of potential opportunities for improvement.
- Opportunities for improvement were validated with six organizations.
- The assessments were aggregated to provide an initial benchmark of the level of implementation of management practices.

The results are summarized as follows:

- Five organizations have indicated a desire to further pursue adoption and implementation projects to improve their management practices.
- At an industry level, management practices in need of improvement include: managing safety information; developing schedules; managing materials on-site, and capturing the impact of rework.

Future steps are to assist organizations in their pursuit of adoption and implementation projects; and collect additional data to expand the usefulness of the industry benchmarks for management practices.

Table of Contents

Executive Summary	i
Table of Contents	ii
List of Figures and Tables	ii
1 Introduction.....	1
2 Development of a Framework for Diagnostics Assessment	1
2.1 Practices.....	2
2.2 Protocols for Data Collection.....	2
3 Initial Assessment	3
3.1 Overall Assessment.....	4
3.2 Individual First Stage Analysis	5
3.3 Validation and Final Analysis	7
4 Aggregation as a Benchmark.....	7
5 Conclusions and Further Steps	11
5.1 Next Steps	11
6 References	12
Appendix A: First Stage Analyses	A1
Appendix B: Aggregated Potential Opportunities.....	B1
Appendix C: Survey Introduction and Questionnaire	C1

List of Figures and Tables

Figure 1: Average scoring of practices aggregated by management area.	4
Figure 2: Example of initial results provided to individual organizations.....	6
Figure 3: Graphical statistics of planning versus controlling practices.....	7
Figure 4: Descriptive statistics of all practices at the management area level.	8
Figure 5: Descriptive statistics for all planning practices at the management area level.....	9
Figure 6: Descriptive statistics for all controlling practices at the management area level.....	9
Figure 7: Descriptive statistics for all planning and controlling practices.	10
Figure 8: Descriptive statistics example indicating an individual organization against all others.	11
Table 1: Practices by management area with groupings.	2
Table 2: Overview of survey questions for initial data collection.....	3
Table 3: Low scoring practices upon initial assessment.	5
Table 4: Example of opportunities identified for individual organizations.	6

1 Introduction

One of the dominant impediments to increasing the rate of innovation and improving productivity in the Canadian Construction Industry is the ability to access knowledge in the appropriate form to support decision-making necessary to successfully adopt and implement new technologies (or methodologies). This research project has developed and applied solutions to overcoming these barriers in support of Digital Technologies adoption. The solutions include a method to complete an assessment of construction organizations' operational processes and capacity with respect to digital technologies, and to identify areas with the potential to improve firm performance and productivity through successful adoption. The method is applied to a series of diagnostic projects with construction companies that operate in New Brunswick with the intention of: (1) providing ample data to allow the establishment of a benchmark of project management practices for the construction industry; and (2) identifying candidates for technology adoption projects.

The project is accomplished through the completion of the following objectives:

1. Develop a framework for conducting a diagnostic assessment of digital technologies in the construction industry at an organization level.
2. Identify willing organizations that will form a representative group of organizations in the construction industry.
3. Assess each individual representative organization to determine both current capabilities and potential opportunities for improvement.
4. Determine the opportunities for improvement to pursue with each individual organization.
5. Aggregate the analysis of the individual assessment to an industry level to identify the management practices status of organizations, and current capabilities.

This project is intended as the first phase of an overall research project that includes: (1) a series of diagnostic assessments; (2) a series of digital adoption and implementations; and (3) a series of dissemination and awareness activities. Support for this first phase was provided by the Digital Technologies Adoption Pilot Program (DTAPP). DTAPP enabled the completion of a series of diagnostic assessments with a common approach allowing the results to be more valuable from a broader industry perspective.

2 Development of a Framework for Diagnostics Assessment

The framework was developed based on the foundation provided by previous work in the assessment of organizational management practices within the construction industry. In summary, the following efforts were used to support the development of the framework:

- The Canadian Construction Sector Council's National Performance and Productivity Benchmarking Program (Fayek et al. 2010; Fayek et al. 2008; Nasir et al. 2012).
- The Nova Scotia Construction Sector Council's Functional Information Technology Project (Rankin 2010).
- The researchers' previous research in assessing management practice maturity (Goggin et al. 2010, Willis and Rankin 2012).

- Standard references for organizational maturity (PMI 2005).

The framework was developed by tailoring previous assessment methodologies to focus the assessment on the intent of the study. The result was a grouping of nine management practice areas. Each category of management practices is a synthesis of numerous sources of commonly employed best practices within the construction industry. The following notes describe the scope and context of the practices assessed:

1. Practices are intended within the scope of a design-bid-build type project versus any form of design-build-operation project (e.g., less emphasis on financial management).
2. Practices being examined are common to general contractors in commercial, institutional and infrastructure projects (e.g., equipment management is excluded as it is considered heavy civil specific).
3. Although some practices are normally performed in a home-office scenario (i.e., planning practices), the emphasis is project (site) level practices.

2.1 Practices

Table 1 is a summary of the nine practice areas and the grouping of practices under the basic management categories of planning and controlling. Each grouping contains multiple practices.

Table 1: Practices by management area with groupings.

Management Area	Practices Grouping	
	Planning	Controlling
1. Time	Schedule development; Resource management; Schedule analysis	Schedule control
2. Cost	Cost estimating; Estimate analysis	Cost control
3. Quality	Quality planning; Quality assurance	Quality control; Quality assurance
4. Scope	Scope planning; Risk management	Scope control; Contract closeout
5. Safety	Health and safety planning; Safety equipment; Hazard management	Safety equipment; Hazard management
6. Human Resources	Human resource planning	Human resource analysis
7. Materials	Materials planning; Materials coordination	Materials control; Materials coordination; Materials inspection and maintenance
8. Information and Communication	Information and communication planning	Information and communication analysis; Information and communication control
9. Environmental and Waste	Environmental and waste planning; Environmental and waste analysis	Environmental and waste control

2.2 Protocols for Data Collection

The practices were then converted to a survey format to serve as a script for face-to-face interviews for data collection. Table 2 summarizes the format of the survey and provides examples of the questions. The structure of the survey allowed for assessment of each practice for its level of implementation on a typical project on a five point Likert scale of 1 to 5 (never to always). In addition, the extend of the definition, documentation and review of

practices within each practice area are assessed with two general questions. Finally, an open-ended question solicits information on additional practices in each practice area.

Table 2: Overview of survey questions for initial data collection.

<p>Section 1: The practices within an area are grouped and each practice is assessed for its level of implementation on a typical project:</p> <hr/> <p><i>Schedule development</i></p> <p>1. A standard work breakdown structure (e.g., CSI MasterFormat) is used to define the activities/tasks for project schedules.</p> <p><input type="radio"/> never <input type="radio"/> rarely <input type="radio"/> sometimes <input type="radio"/> often <input type="radio"/> always</p> <p>...etc.</p>
<p>Section 2: The extend of the definition, documentation and review of practices within each practice area are assessed with two general questions:</p> <hr/> <p>1. The organization has policies and procedures defined for the time management of projects?</p> <p><input type="radio"/> strongly disagree <input type="radio"/> disagree <input type="radio"/> neutral <input type="radio"/> agree <input type="radio"/> strongly agree</p> <p>2. The policies and procedures for the information and communication management of projects are reviewed and improved on a timely basis?</p> <p><input type="radio"/> strongly disagree <input type="radio"/> disagree <input type="radio"/> neutral <input type="radio"/> agree <input type="radio"/> strongly agree</p>
<p>Section 3: An open-ended question solicits information on additional practices in each practice area:</p> <hr/> <p><i>Are there project management practices in the area of time management that you do not feel are captured in the statements provided?</i></p>

The data collection protocols (i.e., basis of the study, method of data collection, and survey questions) were reviewed and approved by the UNB Research Ethics Board, per the Canadian Tri-Council (CIHR, NSERC, SSHRC) policies for research involving humans. The survey method was then trialed with an organization identified as a large general contractor and therefore not eligible for additional consideration under DTAPP. Minor modifications were made to the survey following the trial and the resulting script is included as Appendix C.

3 Initial Assessment

An initial list of 14 contractors was identified as potential participants for assessment. Of this initial list, eight were able to participate in the timeframe available for the project. Upon first contact with each organization the general intent of the project was explained and survey/interview respondents identified. This was sometimes followed by a face-to-face meeting to further describe the study but in most cases the next step was administering the scripted interview for initial data collection on practices. All participants in the interview were senior managers in the organization with direct experience in the execution of all management practices at the project level. Each scripted interview session lasted between three to four hours and was conducted by the same researcher for consistency. To protect

the confidentiality of participating organizations, none are directly or indirectly identified in this report.

3.1 Overall Assessment

Subsequent to the completion of the initial data collection a summary analysis was provided to each participant. The results provided are an aggregation of scores based on the initial assessment of eight organizations. These results in Figure 1 are summarized by management areas to give a general overview of the average level of implementation. Each practice is weighted equally with a maximum score of 5 corresponding with the highest level of implementation and a score of 1 corresponding to the lowest level of implementation.

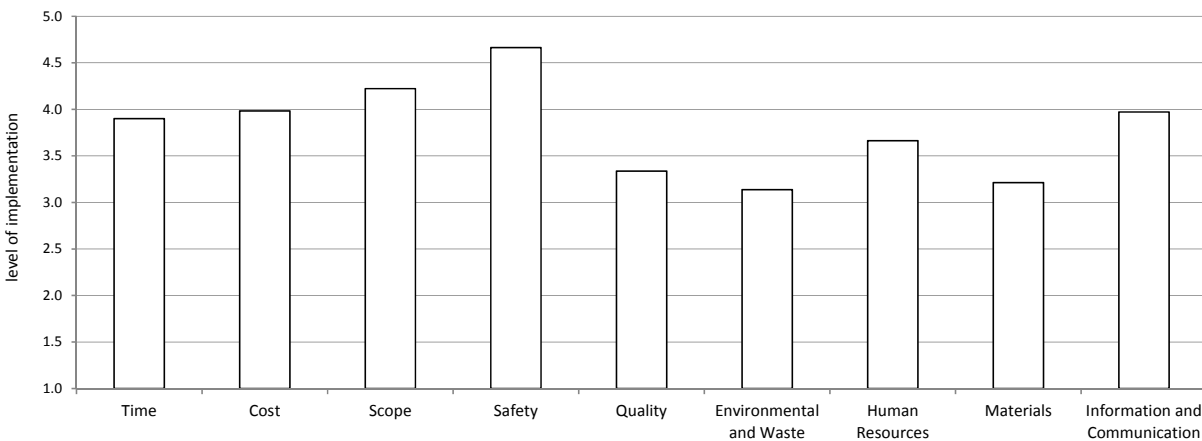


Figure 1: Average scoring of practices aggregated by management area.

The following interpretation notes were provided with the initial summary assessment:

1. For the management areas of **Time, Cost, Scope, Safety** – these standard management areas are higher, as expected, whereas safety is even higher, as it is mandated (legislated) to all.
2. For the management areas of **Quality, Environmental** – these less tangible management areas indicate lower values and anecdotal evidence is that they remain largely client driven.
3. For the management areas **Human Resources, Materials** – the values indicate less emphasis on managing resources.
4. For the management area **Information and Communication** – the values were higher than expected.

In addition to the high level summary, the low scoring practices (average) were also identified. Specific practices that scored an average value of **neutral** or below (less than 3) are provided in Table 3.

Table 3: Low scoring practices upon initial assessment.

Management Area	Grouping	Practice	Score
Time	Schedule control	- Progress against the project schedule is analyzed (e.g., progress curves) as a project performance measure.	2.38
Cost	Cost estimating	- Estimated project costs are integrated with project schedule activities (integration with time) to form project budgets.	2.63
Scope	Scope control	- A claims prevention strategy is defined for each project.	2.63
Safety	n/a	n/a	n/a
Quality	Quality assurance	- Project performance is assessed independently through an internal auditing process.	2.13
	Quality control	- Numerical analysis tools (e.g., statistical) are used to support the quality control of work items on a project.	1.88
Environmental and Waste	Environmental and waste analysis	- The quantity of waste materials produced on projects is examined and compared to expected values.	2.38
		- Projects are analyzed to identify opportunities to reduce waste in construction processes (e.g., work improvement).	3.00
	Environmental and waste control	- Project participants receive training on waste reduction practices.	2.13
		- Audits of the environmental impacts of projects are conducted on a timely basis.	2.75
Human Resources	Human resource control	- Project performance from a human resource perspective is captured at completion (e.g., exit interviews).	2.50
		- Each project practices team development (e.g., conducts team building exercises) to foster teamwork and build trust among project participants.	2.63
Materials	Materials control	- Each project uses automated data collection technologies (e.g., barcodes, RFID tags, GPS systems) for automated on-site location tracking.	1.25
		- The materials control system is available for use by all project participants and is integrated throughout the supply chain.	2.75
	Materials coordination	- Projects have a process that separates materials into stages of the receipt process (e.g. awaiting inspection, storage area restocking, scrap, and/or awaiting shipment).	2.00
		- Projects have a documented materials delivery schedule.	2.88
	Materials planning	- Projects have a separate materials management organizational group or a single person responsible for it.	2.13
		- Project materials management plans address the effects of change orders on site materials management.	2.50
		- Each project has a comprehensive written materials management plan.	2.88
Information and Communication	Information and communication control	- Project materials management plans examine the impact of alternatives of materials and suppliers.	2.88
		- Project performance is compared (benchmarked) across projects.	2.75

3.2 Individual First Stage Analysis

At the same time the overall summary of practices was provided, each organization also received an overview of their scores at the management area level and a more detailed description of where opportunities for improvement were identified. This was captured in a

single page, which contained a radar chart (Figure 2) that measured the organization against the average of all organizations and a summary of opportunities for improvement (Table 4). These results were used to further engage each organization on their practices and to validate the potential opportunities for improvement.

All individual radar charts are provided in Appendix A. The opportunities for improvement have been aggregated and provided in Appendix B under each management area with the frequency of common opportunities also indicated. The most frequently identified opportunities included:

- Managing safety information.
- Defining and managing time uncertainty in planning.
- Capturing the impact of rework.
- Managing on-site materials.

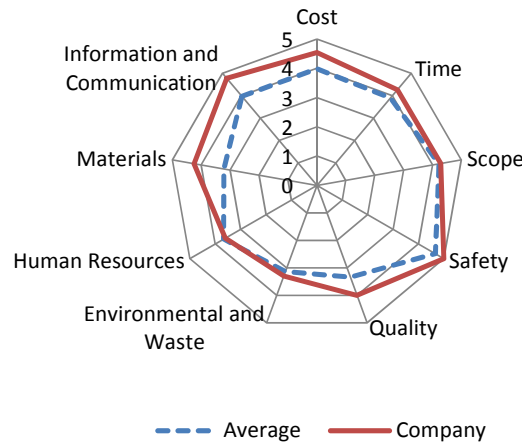


Figure 2: Example of initial results provided to individual organizations.

Table 4: Example of opportunities identified for individual organizations.

Management Area	Potential Opportunity	Proposed Follow-up
Time	- Time uncertainty in planning - Progress against schedule	- MS Project examples of templates used and extent of integration with shop drawing logs and materials procurement. - Examples of short term schedules developed by superintendents.
Cost	- Tracking at site against cost codes	- Examples of costs tracked against code of accounts for a project.
Scope	- Risk management process	- Examples of risk management steps. - Examples of process for project close-out.
Safety	- Information control	- Examples of tasks performed by third party paperwork control.
Quality	- Project performance assessment - Capturing of rework - Commissioning process	- Examine quality control procedure. - Examine shop drawing process.
Environmental	n/a	n/a
Human Resources	- Formal performance (project) evaluation	- Examples of documentation of performance.

Materials	- Purchasing across projects	- Examples of materials management processes (e.g., receiving records). - Examine the how to purchase guide.
Information	- Consistency in use of tools	- Examine the common server set-up, scope of use and connectivity of superintendents.

Note: "n/a" refers areas where there are no opportunities identified.

3.3 Validation and Final Analysis

Of the eight organizations that completed the initial assessment six were available to further validate the results and opportunities for improvement identified. This was completed by another face-to-face meeting at which the overall results were reviewed and addition insights provide, followed by a discussion of each individual opportunity. Each validation meeting was completed in a single session of 2 to 3 hours. Following the validation meetings, the results were prepared for each organization as a final report which included the more detailed analysis of the aggregated results (following section).

In general, the initial opportunities were classified into three groups:

- identified as an opportunity and ready to pursue
- identified as an opportunity but not ready to pursue
- at this point not able to rationalize the investment to improve in the area identified
- currently satisfied with practices in the management area identified

4 Aggregation as a Benchmark

As noted, Figure 1 summarizes the average score for an aggregation of practices in each management area. This was used for the purpose of validating opportunities for improvement. However, more commonly used descriptive statistics in benchmarking can provide additional insight with respect to the practices assessed. It should be noted that at this point the results are not considered statistically significant due to the current sample size.

Figure 3 provides a "box and whisker" diagram of the aggregated practices in the management step categories (i.e., planning and controlling). The conventions indicated are common to all of these types of figures that follow (Figures 4 to 8) indicating the maximum and minimum values, as well as average and variance of scores. At this aggregated level the assessment indicates that overall there are higher scores for the level of implementation for planning practices and conversely overall more variance in the scores for level of implementation of controlling practices.

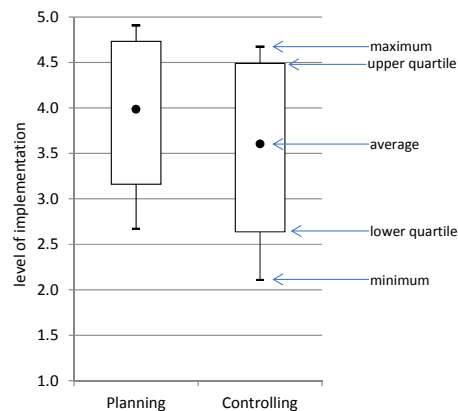


Figure 3: Graphical statistics of planning versus controlling practices.

The assessment of management practices reported at an aggregate level for each management area is provided in Figure 4. Apart from the observations noted earlier on the average values for each management area, general observations on the variance of the resulting scores is offered. Management areas with lower variance in the scoring of their level of implementation include *Scope* and *Safety*, groupings of management areas with higher variance include *Quality Human, Resources, and Materials*.

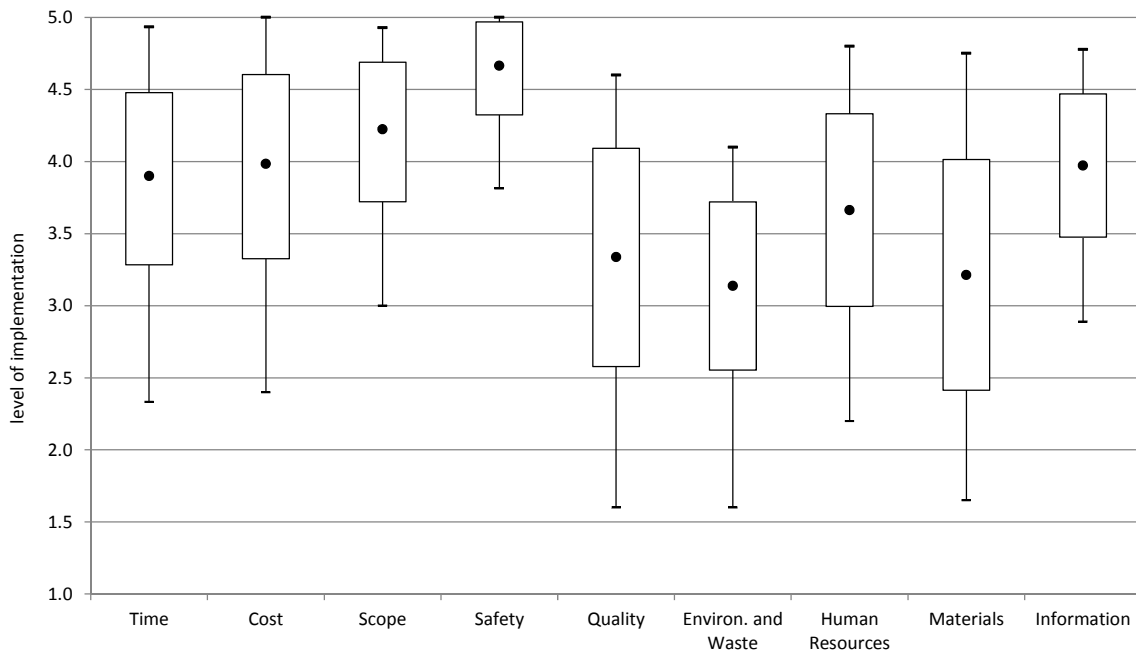


Figure 4: Descriptive statistics of all practices at the management area level.

Figures 5 and 6 filter the practices further into the categories of planning and controlling practices respectively. General observations for planning practices are the higher variances in the scoring of level of implementation for *Quality* and *Materials*. Whereas for the controlling practices, there are a number of management areas with higher variance in the scoring of level of implementation including: *Cost, Quality, Materials, and Human Resources*.

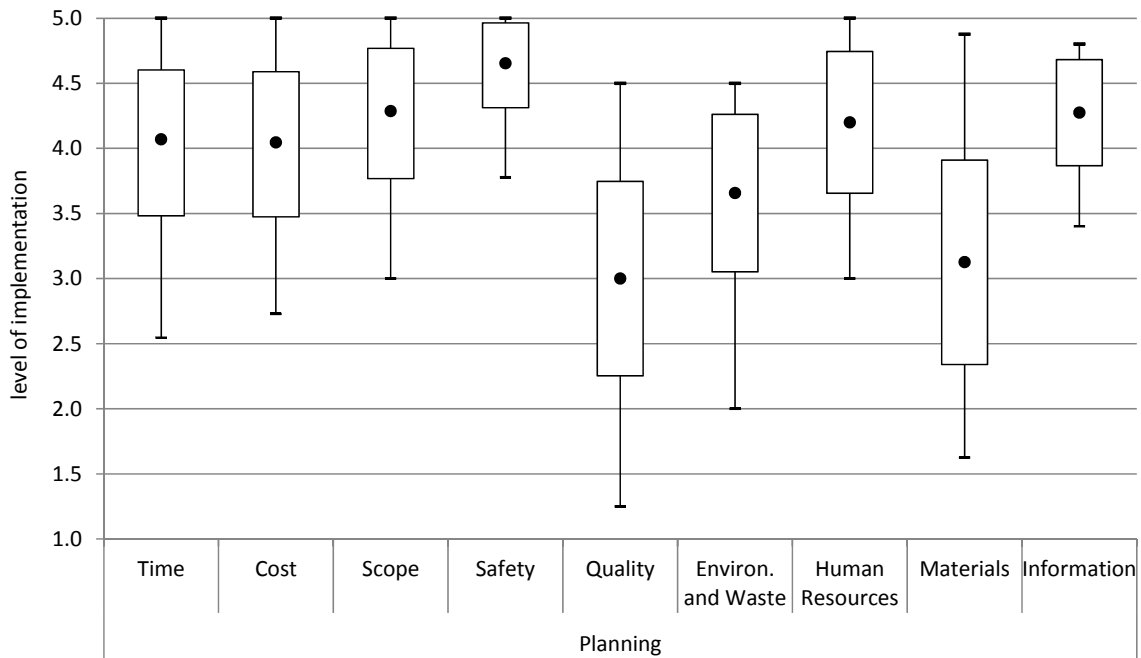


Figure 5: Descriptive statistics for all planning practices at the management area level.

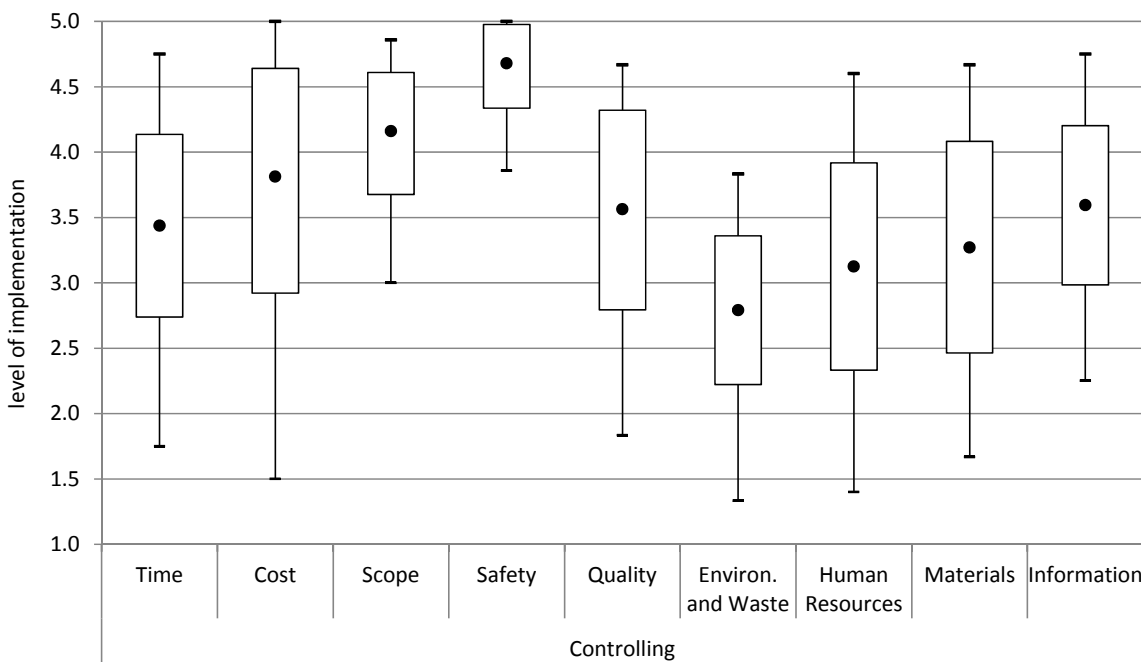


Figure 6: Descriptive statistics for all controlling practices at the management area level.

Figure 7 combines the results of the two previous figures to display the planning and controlling practices for each management area. As is displayed through the previous figures, the majority of management areas have lower scores and higher variance when moving from planning to controlling. However, there are a few exceptions, where *Safety* remains close to the same value and the average score for *Quality* increases quite a bit (from planning to controlling) relative to all other management areas.

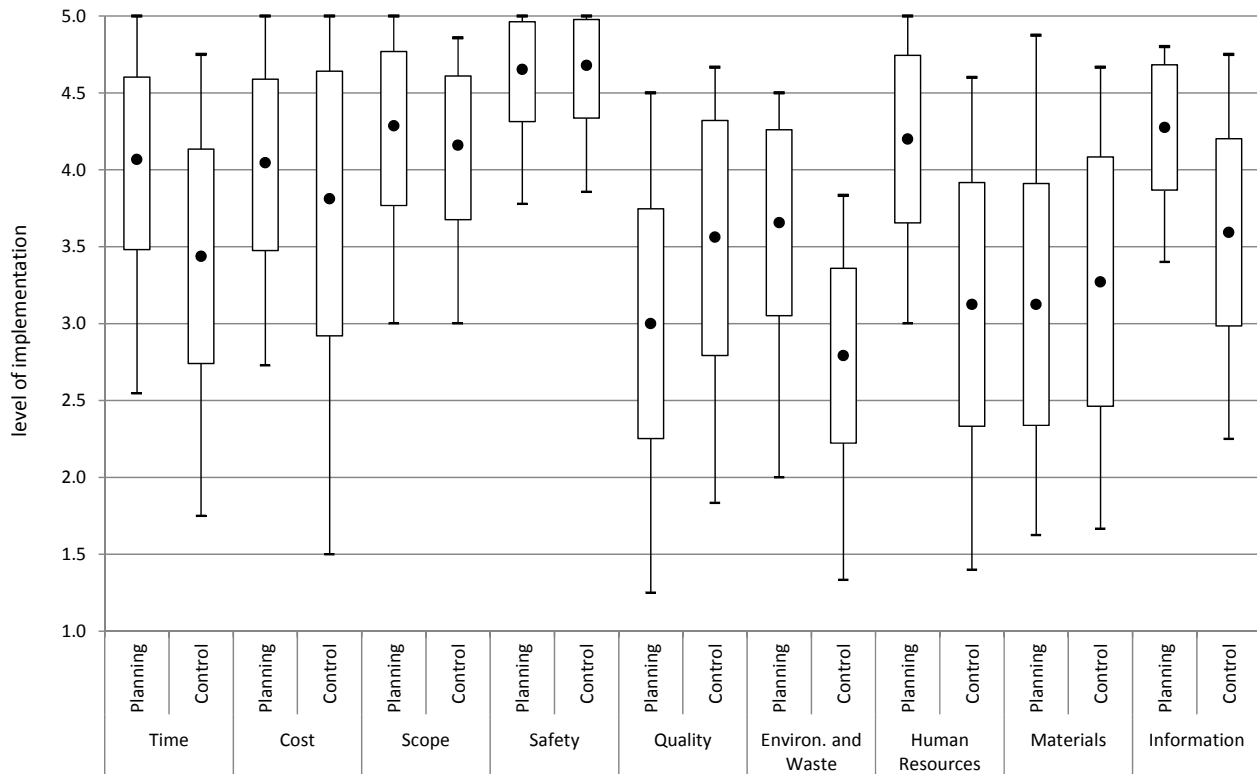


Figure 7: Descriptive statistics for all planning and controlling practices.

As part of the final analysis, each individual organization is also provided with a more detailed comparison of their practices against the aggregated group. Figure 8 depicts an example of this comparison.

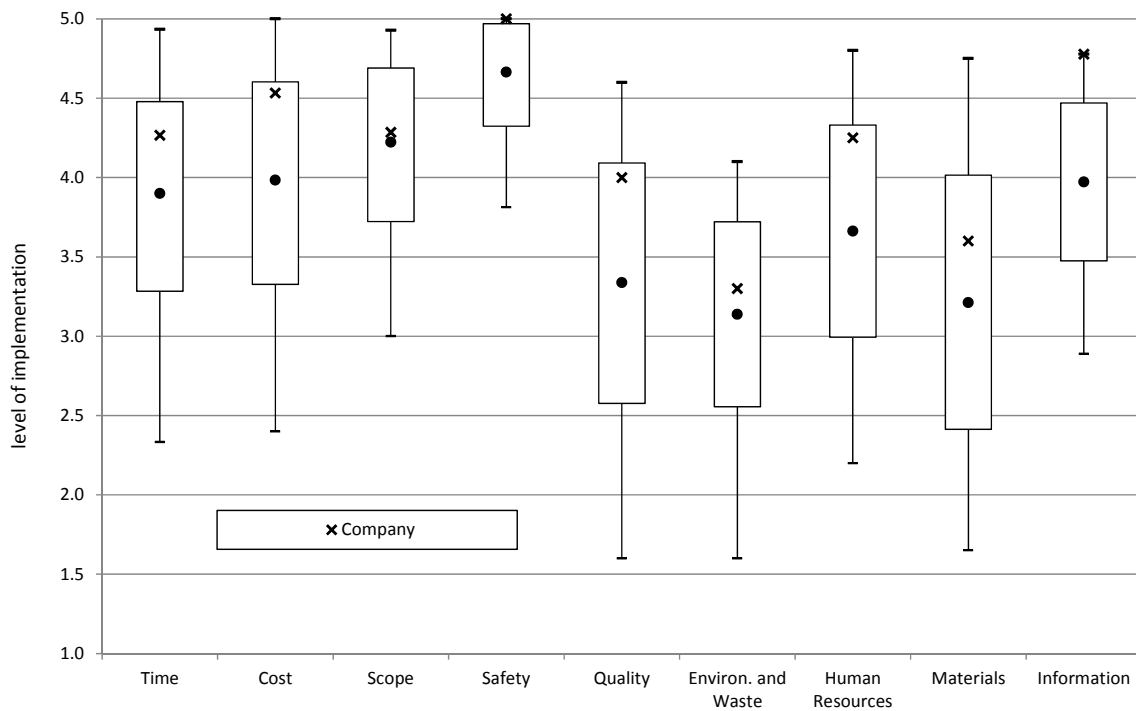


Figure 8: Descriptive statistics example indicating an individual organization.

5 Conclusions and Further Steps

The project resulted in knowledge in a form that is usable to the potential adopter (industry practitioners) for decision making purposes. When aggregated, the results demonstrate evidence of the common issues that need to be addressed at an industry level.

Also to note is the challenge presented in developing a mechanism of assessing with a common structure, while also providing enough depth to be useful for each organization. One of the more positive aspects of the research project was the reaction of members of the construction industry to the research project. Although there were some challenges due to timing, all participants were quite willing to participate and saw the value in having an independent review of their practices, as well as an opportunity to further exploit technological solutions.

5.1 Next Steps

Of the six organizations for which the validation step was completed, five have indicated a desire to further explore solutions for the opportunities for improvement identified. This will be completed with a follow-up meeting with an NRC IRAP Industrial Technology Advisor (ITA). The capture of successful implementations will serve as examples for the next phase of the overall research project.

The framework developed, and subsequent data collected and aggregated, serve as an initial benchmarking mechanism for industry management practices at the project level. The researchers intent is to further the application of the framework by adding additional participants on a regional basis, as well as exploring its application in other regions.

There is a great deal of expertise in the field of innovation within the Canadian construction industry and in particular the approaches to digital technologies. There are also many examples of successful applications across the country. However, as a whole they are lacking in their ability to transfer generally applicable knowledge and vary in the way that they are captured. The resulting information surrounding the identification of issues is anecdotal or too specific for the purpose of identifying gaps and developing best practices. This project has furthered the research required to understand the impacts and needs of individual organizations through a mechanism that allows an aggregation of requirements to an industry level. It is envisioned that subsequent case studies will help draw out the knowledge in a format that is useful for practitioners to ultimately increase their rate of adoption.

6 References

As noted, the following reference materials were used primarily in the development of the assessment framework.

1. Fayek, A., Haas, C., Forgues, D., Rankin, J., Ruwanpura, J., 2010. Report of pilot data collection phase, Construction Sector Council performance and productivity benchmarking program, CSC-CBR Technical Report P3-T24, September, 60 pages.
2. Fayek, A. Haas, C., Rankin, J. and Russell, A., 2008. Benchmarking program overview, Construction Sector Council performance and productivity benchmarking program, CSC-CBR Technical Report P1-T12, November, 23 pages.
3. Goggin, A., Willis, C., and Rankin, J., 2010. The relationship between the maturity of safety management practices and performance, ASCE Construction Research Congress, Banff, May.
4. Nasir, H., Haas, C., Rankin, J., Fayek, A., Forgues, D., and Ruwanpura, J. 2012. Development and implementation of a benchmarking and metrics program for construction performance and productivity improvement, Canadian Journal of Civil Engineering, Special Issue: Construction, 39(9), 957-967.
5. PMI, 2005. Organizational project management maturity model OPM3: Knowledge foundation. Project Management Institute, Pennsylvania, US, 179 pages.
6. Rankin, J., 2010. Functional information technology project part II: Detail results. A technical report for Nova Scotia Construction Sector Council-Industrial Commercial Institutional, March, 70 pages.
7. Willis, C. and Rankin, J. 2012. Demonstrating a linkage between construction industry maturity and performance, Canadian Journal of Civil Engineering, 39(5), 565-578.

Appendix A: First Stage Analyses

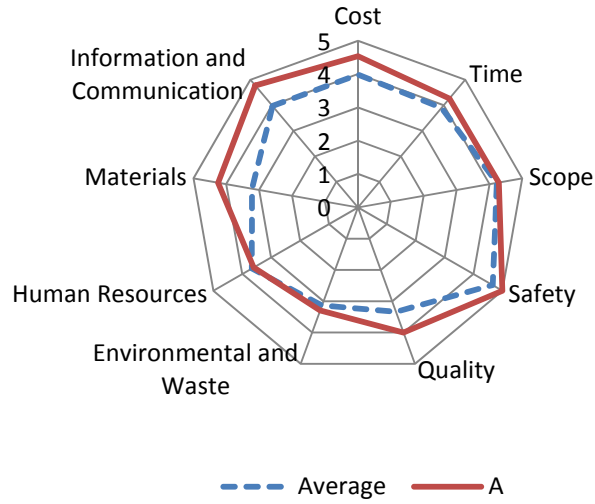


Figure A1: High level results for Contractor A.

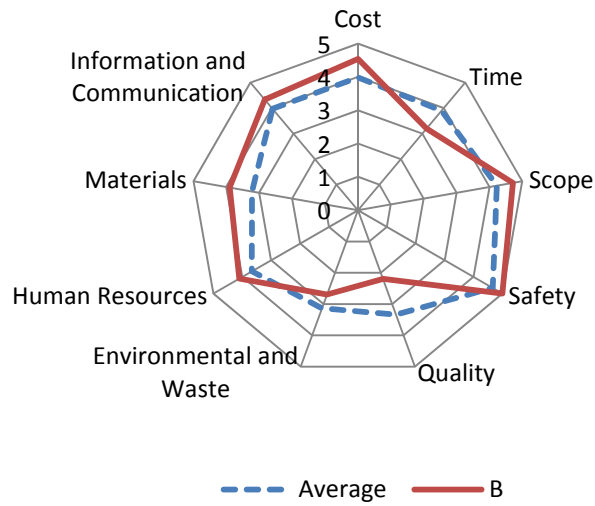


Figure A2: High level results for Contractor B.

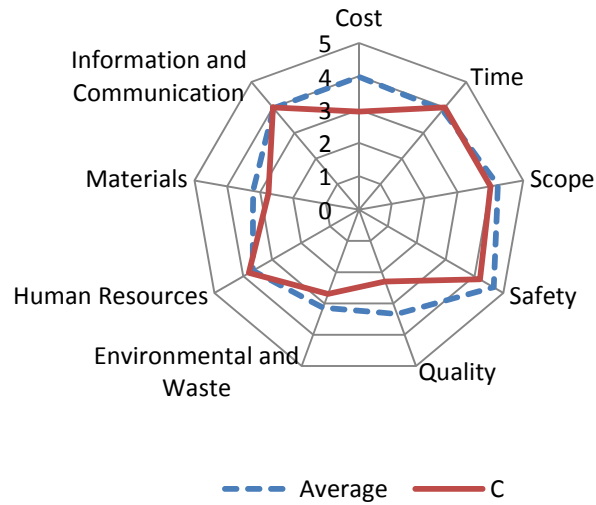


Figure A3: High level results for Contractor C.

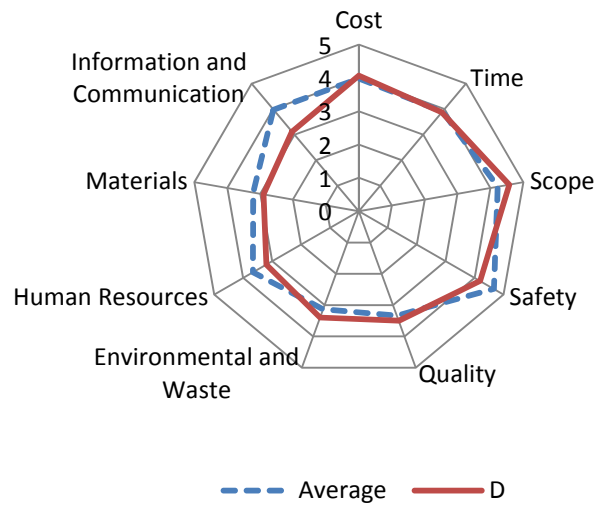


Figure A4: High level results for Contractor D.

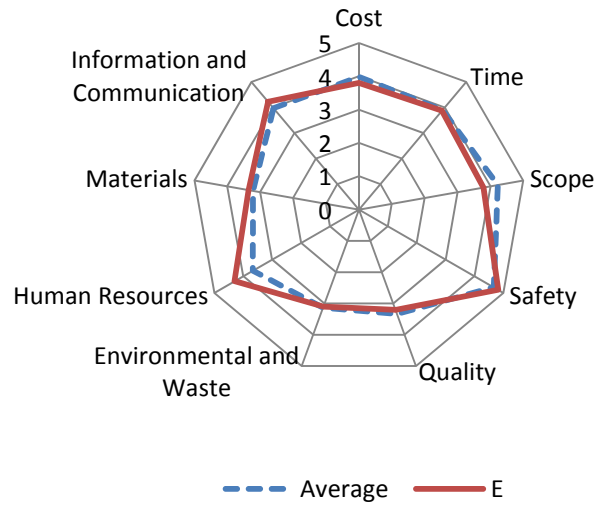


Figure A5: High level results for contractor E.

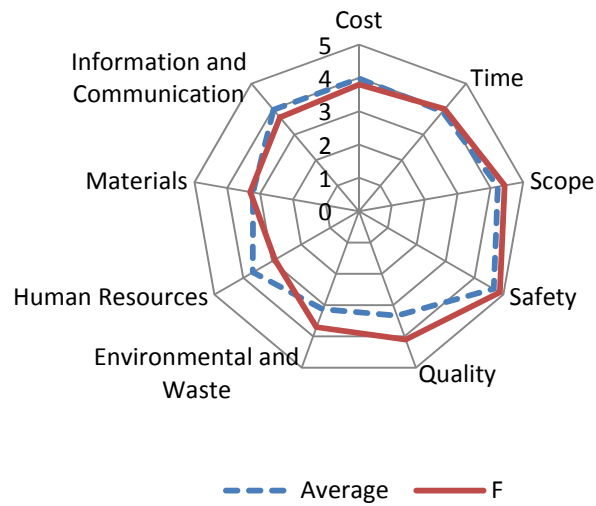


Figure A6: High level results for contractor F.

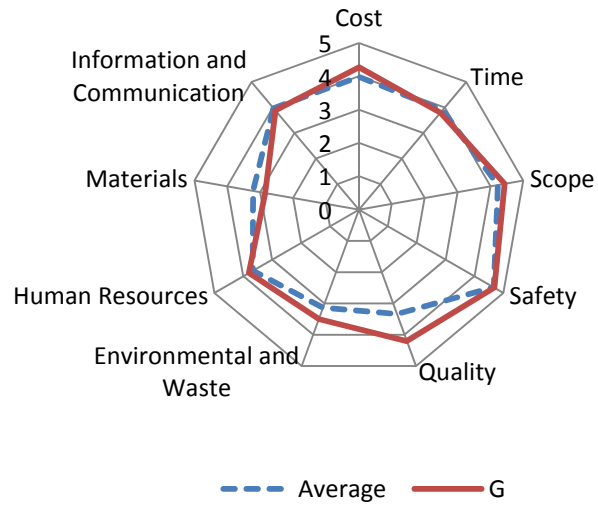


Figure A7: High level results for contractor G.

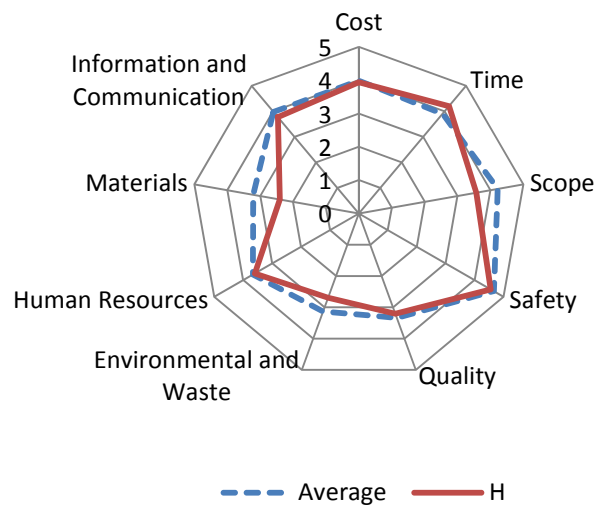


Figure A8: High level results for contractor H.

Appendix B: Aggregated Potential Opportunities

The following summarizes the aggregation of potential opportunities for validation. The number in parenthesis for each potential opportunity indicates the number of organizations for which it was identified.

Management Area	Potential Opportunity	Proposed Follow-up
Time	<ul style="list-style-type: none"> - Defining and managing time uncertainty in planning.(5) - Updating actual progress and comparison against planned schedule.(3) - Developing short term schedules.(2) - Managing resources in planning.(1) - Using standard planning structure across projects.(1) 	<ul style="list-style-type: none"> - Examine the extent to which scheduling applications (e.g., MS Project, Primavera) are implemented. - Examine the link between job cost accounting and schedules. - Examine short term schedules developed by on-site personnel superintendents. - Examine the extent to which scheduling applications (e.g., MS Project, Primavera) are implemented. - Examine the consistency is structuring schedules.
Cost	<ul style="list-style-type: none"> - Timing and accuracy of on-site cost control and progress.(4) - Capturing project context with project costing for reuse.(2) 	<ul style="list-style-type: none"> - Examine the process for job cost accounting; examples of costs tracked against code of accounts for a project; check integration between accounting on site costs. - Examine the process for capturing costing information on-site and comparisons against actual.
Scope	<ul style="list-style-type: none"> - Identifying and updating risks.(4) - Capturing of as-built information and documenting the impacts of change.(2) - Improving closeout and commissioning practices.(1) 	<ul style="list-style-type: none"> - Examine processes and documentation for managing risks. - Examine process and documentation for submittals, shop drawings and as-built information. - Examine examples of closeout and commissioning documentation.
Safety	<ul style="list-style-type: none"> - Managing safety information.(6) 	<ul style="list-style-type: none"> - Examine the process of managing safety information.
Quality	<ul style="list-style-type: none"> - Capturing the impact of rework.(5) - Assessing and benchmarking project performance.(3) 	<ul style="list-style-type: none"> - Examine quality control procedure; examine process for managing non-conforming work.. - Examine process and documentation for project evaluation; examine documentation for capturing lessons learned
Human Resources	<ul style="list-style-type: none"> - Formalizing an evaluation and performance process.(3) - Assessing site management skills.(3) 	<ul style="list-style-type: none"> - Examine process of documenting performance. - Examine skill assessment process.
Materials	<ul style="list-style-type: none"> - Managing on-site materials.(5) - Purchasing across projects.(2) - Planning and integration of materials with other planning.(1) 	<ul style="list-style-type: none"> - Examine process for managing materials on-site; materials receiving and storage process and documentation. - Examine project materials procurement practices. - Examine integration of procurement with construction activities.
Information	<ul style="list-style-type: none"> - Improving the flow of information.(3) - Improving consistency in the process and use of tools.(2) 	<ul style="list-style-type: none"> - Examine internal and external framework for project information sharing and communication. - Examine the current information management and sharing process.

Appendix C: Survey Introduction and Questionnaire

Research Introduction and Informed Consent

This research is being conducted by the following members of the University of New Brunswick's Department of Civil Engineering and Centre for Technology Management and Entrepreneurship:

*Jeff Rankin (Research Chair in Construction Engineering and Management)
Dhirendra Shukla (Research Chair in Technology Management and Entrepreneurship)
Lloyd Waugh (Professor of Civil Engineering)*

This is an invitation to participate in this research project. The general purpose of the research is to increase the rate of adoption of digital technologies in the Canadian Construction Industry. A series of construction organizations are being assessed to determine their current organizational management capabilities and potential opportunities for improvement (identifying practices and processes that are lacking and those that could be enhanced through digital technology adoption). The opportunities for improvement to pursue will be determined with each individual organization. In addition, the analyses of individual assessments will be aggregated to an industry level to identify the status of digital technology adoption of organizations and their current capabilities. This aggregation will be made available as a benchmark for the industry.

Data collection is conducted through face-to-face interviews with key individuals, as identified by each individual construction organizations. The interviews follow a scripted data collection survey and subsequent verification of organizational practices and validation of preliminary recommendations to identify potential opportunities most relevant to the organization to pursue. The initial data collection interviews are comprehensive and are completed in a series of two-hour (maximum) sessions.

Individuals providing information for their organization should be aware that their participation is voluntary, and that they may decline to answer any question, that they are free to withdraw from the research, and to withdraw any data pertaining to themselves, at any time, without penalty.

Results of the data collection interviews will be reported as an overall assessment of the organization in combination with verification of organizational practices (an auditing of organizational processes) and with no results being attributed to specific individuals. All individual interview documentation will be retained by the interviewer and destroyed immediately upon its aggregation at an organization level. Individual organizational data will be considered proprietary to each organization and will only be released in aggregate form in such a way that individual organizations are not identifiable.

Should you have any questions or concerns regarding this research project, you are welcomed to contact the Chair of the University of New Brunswick's Department of Civil Engineering as follows:

*Bruce Wilson, PhD, PEng
Chair and Professor
Department of Civil Engineering
University of New Brunswick
Phone: (506) 453-5127
E-mail: wilsonbg@unb.ca*

By signing this document, I am indicating that I have read the information provided and have agreed to participate in the research:

Signature

Date

1 Time Management Practices

Time management includes practices that are generally accepted to contribute to the effective management of projects in the construction industry. Time management practices include: the development of schedules and estimation of durations; the allocation and management of project resources; the analysis of project schedules; and the subsequent monitoring and control of project time.

For the following statements of management practices please indicate the level of implementation for a typical project performed by your organization on scale of: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always).

1.1 Schedule development

2. A standard work breakdown structure (e.g., CSI MasterFormat) is used to define the activities/tasks for project schedules.
 never rarely sometimes often always
3. Those with expertise in managing and performing the project work are involved in the development of project schedules.
 never rarely sometimes often always
4. Estimates of best, worst, and most likely durations are developed when defining the activities/tasks for project schedules.
 never rarely sometimes often always
5. The assumptions used to sequenced activities/tasks are captured during the development of project schedules (e.g., precedence relationships between activities).
 never rarely sometimes often always
6. Project schedules are communicated with the support of a graphical representation (e.g., bar charts, network diagrams).
 never rarely sometimes often always

1.2 Resource management

1. Project resources (labour and equipment) are planned and assigned on an activity/task basis (resource allocation).
 never rarely sometimes often always
2. Project schedules are adjusted to account for changes in the level of resources required throughout the project (resource levelling).
 never rarely sometimes often always
3. Variations in resource capabilities and production rates are accounted for during the development of project schedules.
 never rarely sometimes often always

1.3 Schedule analysis

1. During the development of a project schedule, details of project specific constraints and assumptions are defined.

- never rarely sometimes often always
2. Uncertainty in the project schedule is accounted for and explicitly defined (e.g., addition of time contingencies, additional resource assignment).
- never rarely sometimes often always
3. Project schedules are examined for the potential of decreasing overall project costs through reductions in project time (e.g., time-cost trade-off analysis).
- never rarely sometimes often always

1.4 Time (schedule) control

1. Project schedules are updated with actual information on a timely basis during the project.
- never rarely sometimes often always
2. Short-term (look ahead) schedules are developed for projects on a timely basis.
- never rarely sometimes often always
3. Progress against the project schedule is analyzed (e.g., progress curves) as a project performance measure.
- never rarely sometimes often always
4. Project schedules are adjusted (e.g., new forecasts developed) throughout the project based on progress and performance.
- never rarely sometimes often always

1.5 General questions

1. The organization has policies and procedures defined for the time management of projects?
- strongly disagree disagree neutral agree strongly agree
2. The policies and procedures for the time management of projects are reviewed and improved on a timely basis?
- strongly disagree disagree neutral agree strongly agree
3. Are there project management practices in the area of time management that you do not feel are captured in the statements provided?

2 Cost Management Practices

Cost management includes practices that are generally accepted to contribute to the effective management of projects in the construction industry. Cost Management practices include: the planning of costs through estimating development and analysis; and cost control techniques.

For the following statements of management practices please indicate the level of implementation for a typical project performed by your organization on scale of: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always).

2.1 Cost estimating

1. Estimates of project costs are developed with the use of historical costing information (whether in-house, industry indices, or a combination).
 never rarely sometimes often always
2. A standard chart of accounts is used to develop and structure project cost estimates.
 never rarely sometimes often always
3. Cost estimates are developed to reflect the details of explicitly defined construction methods (work definition) selected for completion of the project.
 never rarely sometimes often always
4. Those with expertise in managing and performing the project work are involved in the development of project cost estimates.
 never rarely sometimes often always
5. Project estimates (developed in-house and received from subcontractors) are peer-reviewed internally.
 never rarely sometimes often always
6. Estimated project costs are integrated with project schedule activities (integration with time) to form project budgets.
 never rarely sometimes often always

2.2 Estimate analysis

1. Alternative construction methods are examined for projects to optimize total project costs.
 never rarely sometimes often always
2. Uncertainty in project estimates is explicitly defined and accounted for (e.g., addition of cost contingencies, additional resource assignment).
 never rarely sometimes often always
3. Subcontracting and procurement strategies are developed and used during the analysis of project costs.
 never rarely sometimes often always
4. Projects are analyzed to determine the cash flow requirements throughout the duration of the project.
 never rarely sometimes often always
5. Projects are analyzed to determine the return on investment of capital and/or human resources.
 never rarely sometimes often always

2.3 Cost control

1. Project cost control techniques include variance analysis of actual versus estimated costs.
 never rarely sometimes often always
2. Project cost control techniques include the analysis of trends over the completion of the project.
 never rarely sometimes often always

3. Earned value analysis is used to determine the time and costs status of projects.
 never rarely sometimes often always
4. Actual project costs are captured with supporting information so that they can be re-used to develop future estimates.
 never rarely sometimes often always

2.4 General questions

1. The organization has policies and procedures defined for the cost management of projects?
 strongly disagree disagree neutral agree strongly agree
2. The policies and procedures for the cost management of projects are reviewed and improved on a timely basis?
 strongly disagree disagree neutral agree strongly agree
3. Are there project management practices in the area of cost management that you do not feel are captured in the statements provided?

3 Quality Management Practices

Quality management includes practices that are generally accepted to contribute to the effective management of projects in the construction industry. Quality management practices include: the development of quality plans and specific tests and inspections; the control of non-conforming work; and assurance of project performance through measurement and corrective actions.

For the following statements of management practices please indicate the level of implementation for a typical project performed by your organization on scale of: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always).

3.1 Quality planning

1. Overall quality management plans are developed for each project.
 never rarely sometimes often always
2. Inspection and test plans are developed for a given scope of work where required.
 never rarely sometimes often always

3.2 Quality control

1. Inspection and testing is performed where specified in the project specifications and applicable work standards or as detailed in an inspection and test plan.
 never rarely sometimes often always
2. Non-conformances of work items are captured, documented and managed on each project.
 never rarely sometimes often always

3. The details of rework required as a result of non-conformances are documented on each project.
 never rarely sometimes often always
4. An acceptance process is used for work items on a project.
 never rarely sometimes often always
5. Numerical analysis tools (e.g., statistical) are used to support the quality control of work items on a project.
 never rarely sometimes often always

3.3 Quality assurance

1. Project performance is assessed independently through an internal auditing process.
 never rarely sometimes often always
2. When required, adjustments are made to project processes through a corrective action procedure.
 never rarely sometimes often always
3. Project performance is benchmarked against a variety of internal and external metrics.
 never rarely sometimes often always

3.4 General questions

1. The organization has policies and procedures defined for the quality management of projects?
 strongly disagree disagree neutral agree strongly agree
2. The policies and procedures for the quality management of projects are reviewed and improved on a timely basis?
 strongly disagree disagree neutral agree strongly agree
3. Are there project management practices in the area of quality management that you do not feel are captured in the statements provided?

4 Scope Management Practices

Scope management includes practices that are generally accepted to contribute to the effective management of projects in the construction industry. Scope management practices include: the planning and review of project scope and contractual requirements; the assessment of project risks; the control of changes in project scope; and the closing out of projects.

For the following statements of management practices please indicate the level of implementation for a typical project performed by your organization on scale of: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always).

4.1 Scope planning

1. Projects are selected (or pursued) based on organizational strategic goals and objectives.
 never rarely sometimes often always
2. A contract requirements review is completed for each project undertaken.
 never rarely sometimes often always
3. A contract administration plan is developed for each project.
 never rarely sometimes often always
4. A thorough technical review of the constructability of project designs is completed for each project.
 never rarely sometimes often always

4.2 Risk management

1. Project risks are identified for each project based on common risk categories and specific contract provisions.
 never rarely sometimes often always
2. Project risks are analyzed for their potential impact on the project and the likelihood that they will occur.
 never rarely sometimes often always
3. Risk responses are developed for risks that are considered a priority.
 never rarely sometimes often always

4.3 Scope control

1. A defined process is in place to verify the scope of a project and document requests for information.
 never rarely sometimes often always
2. A defined process is in place to manage scope changes and document change orders and change requests.
 never rarely sometimes often always
3. Documentation of extra work on a project due to changes is supported with complete estimates of impacts on time and cost.
 never rarely sometimes often always
4. A claims prevention strategy is defined for each project.
 never rarely sometimes often always
5. Project risks are re-evaluated throughout the execution of a project and where required the risk response plan is updated.
 never rarely sometimes often always

4.4 Contract closeout

1. A defined process is in place to manage the final inspection and completion of projects (e.g., punch list and close-outs).
 never rarely sometimes often always

2. A defined process is in place to capture as-built project information.
- never rarely sometimes often always

4.5 General questions

1. The organization has policies and procedures defined for the scope management of projects?
- strongly disagree disagree neutral agree strongly agree
2. The policies and procedures for the scope management of projects are reviewed and improved on a timely basis?
- strongly disagree disagree neutral agree strongly agree
3. Are there project management practices in the area of scope management that you do not feel are captured in the statements provided?

5 Health and Safety Management Practices

Health and safety management practices integrate common legislative requirements, as well as generally accepted practices that support a proactive approach to managing health and safety for construction organizations. Health and safety practices include: hazard recognition, reporting, control, and monitoring; methods of communicating health and safety; employee awareness and knowledge of health and safety; effectiveness of company health and safety policies and procedures; and work site organization, layout, and the use of equipment and handling of materials. (EMR – equipment, including personal protective equipment, materials, and resources)

For the following statements of management practices please indicate the level of implementation for a typical project performed by your organization on scale of: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always).

5.1 Health and safety planning

1. Health and safety roles and responsibilities are clearly outlined to include both work-related tasks, as well as the promotion of safe practices.
- never rarely sometimes often always
2. All project participants are involved in the development of the policy and procedures they participate in (e.g., identification of job task hazards).
- never rarely sometimes often always
3. All project participants are able to freely express their health and safety concerns and make suggestions for improvement.
- never rarely sometimes often always
4. Reviews of all project participants' current knowledge and understanding of health and safety are completed on a timely basis.
- never rarely sometimes often always

5. All members of the organization receive regular health and safety training/education (e.g., causes of workplace injuries).
 never rarely sometimes often always
6. A review of project participants' health and safety performance is completed on a timely basis.
 never rarely sometimes often always

5.2 Safety equipment, materials and resources

1. EMR health and safety requirements are considered during planning processes (e.g., risk associated with materials, safest tools).
 never rarely sometimes often always
2. EMR are selected based on job specific tasks, employee training and knowledge, as well as employee comfort, and other qualitative aspects such as noise level and impact on surroundings.
 never rarely sometimes often always
3. The proper use and handling of EMR on a project is strongly promoted in all situations and enforced where required.
 never rarely sometimes often always
4. EMR is thoroughly inspected and checked prior to the start of any task and on a timely basis during use.
 never rarely sometimes often always
5. The effectiveness of the EMR is monitored, and improvements are also actively encouraged from workers.
 never rarely sometimes often always
6. Defective EMR is replaced/repaired immediately upon detection of defects and the cause for the defect is investigated to prevent it from reoccurring.
 never rarely sometimes often always

5.3 Hazard management

1. Hazard management planning occurs prior to the start of a project resulting in a description of each hazard, its potential impact, and suggested control mechanisms.
 never rarely sometimes often always
2. Inspections are regularly performed per legislative requirements and all project participants are expected to perform daily inspections of their work area and on a timely basis.
 never rarely sometimes often always
3. All project participants are encouraged to implement hazard management controls and are recognized for their contribution when doing.
 never rarely sometimes often always
4. Hazard statistics are maintained and reviewed and incident data is regularly reviewed to identify trends and to seek possible areas in need of improvement.
 never rarely sometimes often always

5.4 General questions

1. The organization has policies and procedures defined for the health and safety management of projects?

strongly disagree
 disagree
 neutral
 agree
 strongly agree
2. The policies and procedures for the health and safety management of projects are reviewed and improved on a timely basis?

strongly disagree
 disagree
 neutral
 agree
 strongly agree
3. Are there project management practices in the area of health and safety management that you do not feel are captured in the statements provided?

6 Human Resource Management Practices

Human Resource management includes practices that are generally accepted to contribute to the effective management of projects in the construction industry. Human resource management practices include: planning of the structure and details of project staffing; assessing and evaluating project personnel skills; and improving project personnel skills.

For the following statements of management practices please indicate the level of implementation for a typical project performed by your organization on scale of: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always).

6.1 Human resource planning

1. Each project establishes a set of human resource practices.

never
 rarely
 sometimes
 often
 always
2. Organizational planning is completed for each project resulting in a staffing plan for the duration of the project.

never
 rarely
 sometimes
 often
 always
3. Each project has a defined team structure, where specific roles and responsibilities are defined and assigned.

never
 rarely
 sometimes
 often
 always

6.2 Human resource analysis

1. The approach to staff acquisition is developed for each project.

never
 rarely
 sometimes
 often
 always
2. Skills assessments are used in the selection of project personnel.

never
 rarely
 sometimes
 often
 always
3. Performance evaluations are conducted for all project participants.

never
 rarely
 sometimes
 often
 always

6.3 Human resource control

1. Each project practices team development (e.g., conducts team building exercises) to foster teamwork and build trust among project participants.
 never rarely sometimes often always
2. Project personnel are supported through personal and professional development and achievement activities (e.g., training programs).
 never rarely sometimes often always
3. A formal rewards and recognition program is in place for project personnel.
 never rarely sometimes often always
4. Project performance from a human resource perspective is captured at completion (e.g., exit interviews).
 never rarely sometimes often always

6.4 General questions

4. The organization has policies and procedures defined for the human resource management of projects?
 strongly disagree disagree neutral agree strongly agree
5. The policies and procedures for the human resource management of projects are reviewed and improved on a timely basis?
 strongly disagree disagree neutral agree strongly agree
6. Are there project management practices in the area of human resource management that you do not feel are captured in the statements provided?

7 Materials Management Practices

Materials management includes practices that are generally accepted to contribute to the effective management of projects in the construction industry. Materials management practices include: developing comprehensive materials management plans; implementing tracking tools for control; coordinating materials with the project schedule; and inspecting and maintaining materials before use.

For the following statements of management practices please indicate the level of implementation for a typical project performed by your organization on scale of: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always).

7.1 Materials planning

1. Each project has a comprehensive written materials management plan.
 never rarely sometimes often always
2. Projects have a separate materials management organizational group or a single person responsible for it.

- never rarely sometimes often always
3. Project materials management plans address the effects of change orders on site materials management.
- never rarely sometimes often always
4. Project materials management plans examine the impact of alternatives of materials and suppliers.
- never rarely sometimes often always

7.2 Materials control

1. There is a formal system available to track project materials' status (materials control system).
- never rarely sometimes often always
2. The materials control system is integrated internally with other project control systems.
- never rarely sometimes often always
3. The materials control system is available for use by all project participants and is it integrated throughout the supply chain.
- never rarely sometimes often always
4. Project lay-down areas for materials received are defined and their locations are recorded and updated on a timely basis.
- never rarely sometimes often always
5. Each project uses automated data collection technologies (e.g., barcodes, RFID tags, GPS systems) for automated on-site location tracking.
- never rarely sometimes often always

7.3 Materials coordination

1. Projects have a documented materials delivery schedule.
- never rarely sometimes often always
2. Projects have a documented procurement plan for materials and equipment.
- never rarely sometimes often always
3. Project procurement schedules are integrated with the construction schedule.
- never rarely sometimes often always
4. There is a mechanism to identify long-lead procurement items.
- never rarely sometimes often always
5. Projects have a list of authorized suppliers.
- never rarely sometimes often always
6. Does the project purchasing system have the capability of allowing field purchases of consumables?
- never rarely sometimes often always
7. Project procurement schedules are updated on a timely basis to coordinate with short-term (look-ahead) planning.
- never rarely sometimes often always

8. Projects have a process that separates materials into stages of the receipt process (e.g. awaiting inspection, storage area restocking, scrap, and/or awaiting shipment).
- never rarely sometimes often always

7.4 Materials inspection and maintenance

1. Projects have a documented materials inspection process for costly items (or for all materials) delivered to the site.
- never rarely sometimes often always
2. Projects have a process to verify that the materials confirm to project specifications.
- never rarely sometimes often always
3. Projects have a post receipt preservation and maintenance process in place for materials.
- never rarely sometimes often always

7.5 General questions

1. The organization has policies and procedures defined for the materials management of projects?
- strongly disagree disagree neutral agree strongly agree
2. The policies and procedures for the materials management of projects are reviewed and improved on a timely basis?
- strongly disagree disagree neutral agree strongly agree
3. Are there project management practices in the area of materials management that you do not feel are captured in the statements provided?

8 Information and Communication Management Practices

Information and communication management includes practices that are generally accepted to contribute to the effective management of projects in the construction industry. Information and communication management practices include: planning for the collection, distribution and storage of project information; reviewing the effectiveness of project communication; and assessment of performance.

For the following statements of management practices please indicate the level of implementation for a typical project performed by your organization on scale of: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always).

8.1 Information and communication planning

1. Projects have a plan in place for the efficient distribution of project information to all project participants.
- never rarely sometimes often always
2. Projects have a system in place for the collection of project information generated throughout their execution.

- never rarely sometimes often always
3. Projects have a standard structure in place for the storage of project records.
- never rarely sometimes often always
4. Project participants receive training to enhance their information management and communication skills.
- never rarely sometimes often always
5. Project participants have ready access to historical project information for reuse on current projects.
- never rarely sometimes often always

8.2 Information and communication analysis

1. Project information and communication is reviewed on a timely basis to determine its effectiveness (e.g., accuracy, timeliness, accessibility).
- never rarely sometimes often always

8.3 Information and communication control

1. The performance of projects is measured through a standard set of metrics (e.g., cost, time, production, quality, safety).
- never rarely sometimes often always
2. Project performance is compared (benchmarked) across projects.
- never rarely sometimes often always
3. Lessons learned throughout a project are captured and quantified based on other project objectives.
- never rarely sometimes often always

8.4 General questions

1. The organization has policies and procedures defined for the information and communication management of projects?
- strongly disagree disagree neutral agree strongly agree
2. The policies and procedures for the information and communication management of projects are reviewed and improved on a timely basis?
- strongly disagree disagree neutral agree strongly agree
3. Are there project management practices in the area of information and communication management that you do not feel are captured in the statements provided?

9 Environmental and Waste Management Practices

Environmental and waste management includes practices that are generally accepted to contribute to the effective management of projects in the construction industry. Environmental and waste management practices include: planning to address legislative requirements and

the impact on the surrounding environment; analyzing to identify mitigating solutions; and implementing measures to control environmental impacts.

For the following statements of management practices please indicate the level of implementation for a typical project performed by your organization on scale of: 1 (never), 2 (rarely), 3 (sometimes), 4 (often), 5 (always).

9.1 Environmental and waste planning

1. Environmental plans are developed for projects to account for legislative requirements and best practices.
 never rarely sometimes often always
2. Plans are in place for projects to optimize the reduction of the impacts on the surrounding environment (e.g., noise, dust, traffic).
 never rarely sometimes often always
3. Waste management plans are developed for projects to account for reuse, recycling and reduction opportunities.
 never rarely sometimes often always

9.2 Environmental and waste analysis

1. Projects are analyzed to identify opportunities to reduce waste in construction processes (e.g., work improvement).
 never rarely sometimes often always
2. The quantity of waste materials produced on projects is examined and compared to expected values.
 never rarely sometimes often always

9.3 Environmental and waste control

1. Audits of the environmental impacts of projects are conducted on a timely basis.
 never rarely sometimes often always
2. Project participants receive training on waste reduction practices.
 never rarely sometimes often always
3. Project participants receive awareness training surrounding environmental impacts of construction.
 never rarely sometimes often always
4. Environmental control measures are implemented to reduce the impact on the surrounding environment.
 never rarely sometimes often always
5. Waste control measures are implemented to minimize waste generation and maximize reuse of materials.
 never rarely sometimes often always

9.4 General questions

1. The organization has policies and procedures defined for the environmental and waste management of projects?
 strongly disagree disagree neutral agree strongly agree

2. The policies and procedures for the environmental and waste management of projects are reviewed and improved on a timely basis?
 strongly disagree disagree neutral agree strongly agree

3. Are there project management practices in the area of environmental and waste management that you do not feel are captured in the statements provided?