Impact of Qualifications-Based Selection of Engineering Services on Project Outcomes

Executive Summary Report

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Preface

This research work is funded by the NSERC Collaborative Research and Development (CRD) Grant supported by the Consulting Engineers of Alberta (CEA). The investigators are experts in project and construction management and were asked to conduct this study to develop a decision-support system for consultant evaluation and selection. This research project received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Impact of Qualifications-Based Selection of Engineering Services on Project Outcomes", Pro00098198, on March 12, 2020.

Part 1 of the overall research project addresses the ensemble of Activities 1 and 2 as described in the proposal, and was conducted by Dr. Malak El Hattab, Dr. Lingzi Wu, Amira Eltahan and Maram Nomir to analyze the impact of qualifications-based selection of architectural and engineering consultants on project performance outcomes.

Part 2 addresses Activity 3 as described in the proposal and was conducted by Maram Nomir to develop a qualification-based selection procedure in the form of a decision-support tool that can be used by various organizations to fairly and transparently consider the quality of architectural and engineering services in procurement decisions.

Both Part 1 and Part 2 of the research project were conducted under the supervision of principal investigators Dr. Simaan AbouRizk and Dr. Ahmad Hammad. The liaison between the research team and industry participants was facilitated and coordinated by Maria Al-Hussein. The analysis and views presented in this report reflect those of the authors and research team.

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Executive Summary
Part 1

Analyzing the Impacts of Qualifications-based Selection of Engineering Services on Project Outcomes

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Governmental organizations are increasingly outsourcing architectural and engineering (A/E) services on public projects across Canada. Selecting the most qualified engineering consultants capable of effectively meeting unique project requirements is critical to project success. Price-based approaches are commonly adopted to ensure an objective procurement process assuming that the quality of all A/E services is similar across bidders. However, the performance of A/E consultants can influence the quality and cost of built facilities where innovative designs can reduce associated costs, improve facility life-cycle performance, and prevent process wastes while increasing stakeholder satisfaction. Although A/E performance can impact project delivery, the types of A/E qualifications and the magnitude by which they affect project outcomes remain relatively unexplored in construction engineering and management literature and practice.

This report presents the findings of a research project undertaken to define, evaluate, and predict the impacts of A/E qualifications on project outcomes as a pivotal step in establishing a wider adoption of qualifications-based selection (QBS) when procuring professional engineering services in Alberta. In this regard, 94 request for proposal (RFP) documents are examined to identify evaluation criteria used on projects, and questionnaire data from 50 Alberta-based projects are analyzed to determine the impacts of selecting engineering consultants based on qualifications on project performance. Encapsulating this knowledge as a decision-support tool for industry can aid various organizations in fairly and transparently making informed decisions when procuring professional engineering services to deliver the best value on public projects.

Background

QBS has been gaining momentum as the procurement approach capable of promoting the selection of professional A/E services that provide the best value for projects[1]. Since the United States (US) federal government mandated, through the Brooks Act, that A/E consulting services be procured through QBS for all federally funded projects, 47 state governments have been implementing QBS[2]. Canada has followed suit, where in early 2018, the government announced the launching of a pilot program for implementing QBS (Shelton, 2018). While some regions have already transitioned to a QBS approach, most jurisdictions have continued to consider different price-based evaluations for procurement. Price-dependent processes force firms to reduce their level of effort, which adversely impacts quality, innovation, and safety, particularly during the bidding stages of a project when scope is inherently vague. Consistency and transparency in the bidding process is a primary focus for organizations, particularly those that make use of public funds. A system capable of objectively analyzing project characteristics and A/E qualifications is crucial for ensuring that a QBS-approach can be applied fairly, consistently, and timely. However, the development of such system remains limited by the following factors:

FACTORS IMPEDNG WIDER QBS ADOPTION

▼ **LIMITED UNDERSTANDING OF QUALIFICATIONS AND CRITERIA TO BE CONSIDERED DURING PROCUREMENT**
The competencies of A/E consultants necessary to meet specific project needs should be matched to project characteristics. However, a unique set of selection criteria and qualification to be considered during procurement is essential for selecting a suitable A/E firm for each project.

▼ **DIFFICULTY IN QUANTIFYING IMPACT OF A/E QUALIFICATIONS ON PROJECT PERFORMANCE OUTCOMES**
The reliance on anecdotal and qualitative evidence of QBS implementation on projects has resulted in owners questioning QBS's validity. Without measurable results based on rigorous academic and analytical research, project outcomes of qualifications in Canada remain unknown.

▼ **LACK OF AN AUTOMATED AND OBJECTIVE DECISION SUPPORT SYSTEM FOR EVALUATING A/E SERVICES**
The multitude of project characteristics and variability in A/E qualifications between professionals renders the matching of optimum qualifications to specific project characteristics a challenging task. Methods capable of automating the objective A/E selection for a particular project will not only increase transparency of the QBS process but will also reduce time and cost associated with QBS procurement.

Current procurement practices and perceptions in Alberta

Interviews with public owners

The research team interviewed 11 public organizations in Alberta. Most of them usually adopt the lowest-price bid procurement approach for small-scale standard projects.

However, the alternatives used for large scale projects differ depending on the nature, scope, and disciplines. The chart on the right summarizes the participants' responses to their adopted procurement methods.

BVP (One envelope & interview) 18%
QBS 9%
BVP (Two envelopes) 18%
BVP (One envelope) 55%
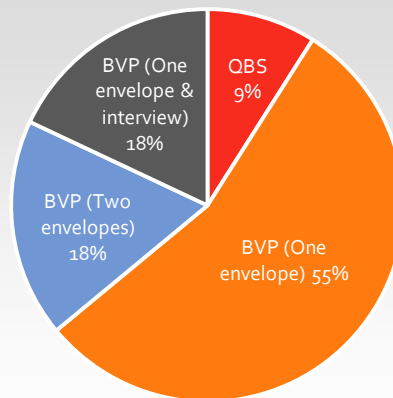
(a) **Fee competition:** 24% of participants stated that excluding the fee from the proposal would lead to over pricing due to the lack of competition. Yet, QBS can achieve better value where consultants compete based on qualifications to achieve lifecycle performance and savings while negotiating a reasonable fee.

(b) **Scope definition:** 23% of participants agreed that QBS can provide a clearer scope definition due to joint discussions and scope development between clients and consultants. A better-defined scope can make the estimated fee more accurate and subject to less changes.

(c) **Nature of QBS:** 23% of participants believe that the qualitative nature of evaluating qualifications under QBS discourages them from adopting this approach. This study, along with some standardized approaches, can help resolve the qualitative issue of QBS.

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[1] InfraGuide. (2006). Decision making and investment planning: selecting a professional consultant, Ottawa, Ontario.
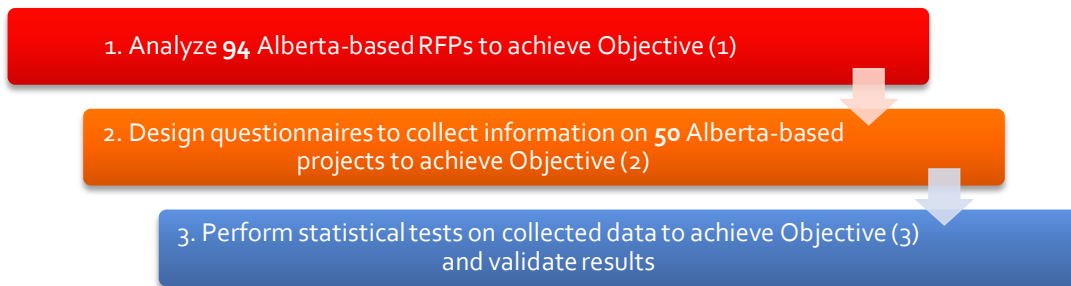[2] Chinowsky, P., & Kingsley, G. (2009). An analysis of issue pertaining to qualifications-based selection

Objectives & Approach

This research project aims at enhancing the procurement of A/E services in Canada and objectively evaluating the qualification of A/E consultants. This study provides robust quantitative results based on structured academic research towards supporting QBS adoption and attaining the best value for public projects. The specific objectives of this study are:

(1) To identify criteria used for evaluating A/E qualifications during the selection process
(2) To assess the impact of A/E qualifications on project outcomes
(3) To explore associations between A/E qualification and project outcomes

The research approach followed, depicted below, comprises 3 main steps aimed at achieving the objectives of the study.

1. Analyze **94** Alberta-based RFPs to achieve Objective (1)

2. Design questionnaires to collect information on **50** Alberta-based projects to achieve Objective (2)

3. Perform statistical tests on collected data to achieve Objective (3) and validate results
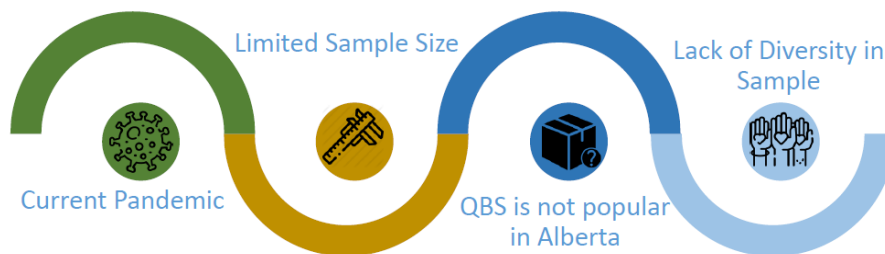
Questionnaire design and administration

The total number of organizations participating in the questionnaires at the time of this report submission was three, which due to Covid-19, was decreased from seven. Each firm was asked to nominate 3-5 projects where the selection of the A/E firm was mainly based on qualifications, and 3-5 projects where selection was driven by fee considerations. For each project, firms have been asked to complete a two-part questionnaire (refer to Appendix A in the detailed report).

The first part of the questionnaire focuses on project characteristics (type, location, design procurement method, construction delivery method, and project completion phase, project risks, design and complexity, and social factors considered) and project performance outcomes (cost and schedule performance, changes to the project, and the overall satisfaction of the management team with the consultant's performance and project outcomes). The second part of the questionnaire includes three sections and addresses questions pertaining to the procurement processes and the qualifications of the selected A/E firm on a given project. The first section requires participants to rate the selected consultant's qualifications, namely the firm's experience, project team composition and expertise, project comprehension and methodology, and relevant project experience and prior performance. The second section involves questions about the relationship between the owner and the consultant firm such as number of years the two parties have worked together as well as they dynamics and trust between them. The third section focuses on the procurement process and overall satisfaction of the procurement team with the process, A/E performance, and project outcomes.

Challenges and Limitations

Current Pandemic

Limited Sample Size

QBS is not popular in Alberta

Lack of Diversity in Sample

Key Findings

The analysis of collected data helped identify the most common evaluation criteria adopted by public owners in Alberta, analyze the behavior of projects when qualifications are the primary and only criterion used when selecting the A/E under QBS in comparison to price-dependent approaches, and assess then validate the significance of correlations between qualifications and project performance outcomes. The preliminary key findings are summarized below.

Evaluation criteria intrinsic to Alberta

The analysis of the 94 RFPs revealed the 7 most commonly used A/E evaluation criteria among Alberta-based public owners as ordered under column 1 of the table below with respective average weights varying between 26% and 9%. The variability of weights indicates a lack of standardized evaluation practices across different owners and RFP documents currently used in Alberta. Additionally, project characteristics were analyzed against evaluation criteria to identify any changes in occurrence and weighting of criteria. Results show, for instance, that project type can influence the weight ranking and frequency of occurrence of evaluation criteria in RFPs. The table demonstrates these variations across the two common project types, Land Development and Roads. These findings further support the variances in practices among owners and across project types when evaluating A/E consultants during procurement.

EVALUATION CRITERIA	OCCURRENCE IN RFPs		AVERAGE WEIGHTS (%)	
	LAND DEVELOPMENT	ROADS	LAND DEVELOPMENT	ROADS
PROJECT COMPREHENSION AND METHODOLOGY	93%	98%	28%	26%
TEAM COMPOSITION AND EXPERIENCE	89%	100%	27%	24%
FINANCIAL SCORE	93%	92%	16%	17%
FIRM'S EXPERIENCE AND QUALIFICATIONS	63%	35%	27%	19%
PAST PERFORMANCE	33%	53%	22%	26%
TIME, SCHEDULE, & PROJECT CONTROL	33%	41%	17%	9%
INNOVATION AND VALUE ADDED	26%	22%	9%	8%

QBS impacts on project performance outcomes

Preliminary findings of statistical tests and correlation analysis of the 50 project questionnaire data are summarized in the sections that follow. Detailed analysis of these primary findings is presented in the extended report and will be updated as more project responses are received from participating public organizations.

QBS can result in better project schedule and cost performance
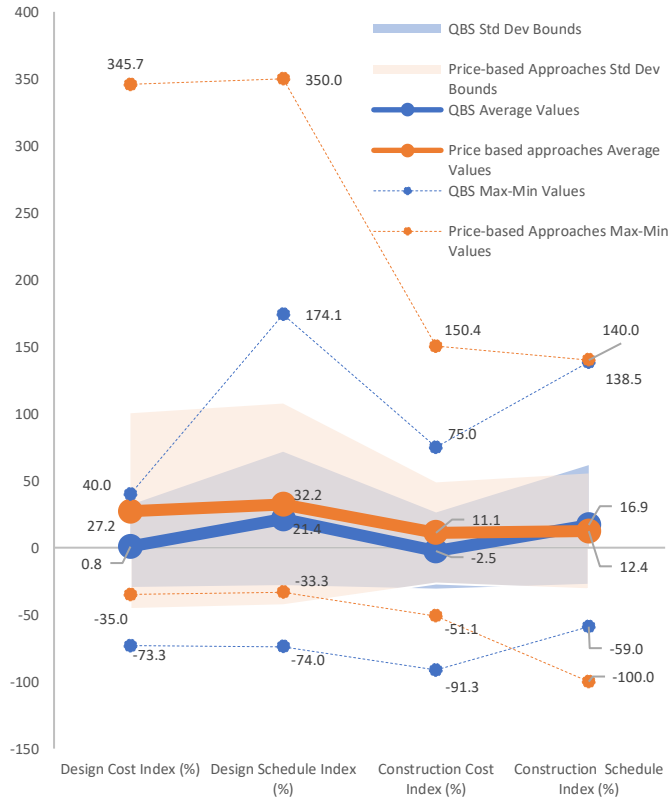
QBS projects were linked to better schedule and cost performance during design and construction of projects. While price-based approaches were associated with higher cost overruns and schedule delays in design and construction, QBS projects exhibited lower deviations from budgeted costs and schedules. Additionally, QBS enabled cost savings during construction as opposed to price-based ones. These preliminary findings indicate how selecting A/E firms based on qualifications instead of price can yield better project performance in the key areas of schedule and cost performance.

Design Cost Index: QBS projects had an average value of only 0.8%, significantly lower than that of price-based approaches (27.2%).
Design Schedule Index: QBS projects had an avg. value of 21.4%, 35% less than that of price-based projects (32.2%).
Construction Cost Index: QBS projects had -2.5% cost savings compared to 11.1% increase on price-based projects.
**Construction Schedule Index**: QBS projects had an avg. value of 24.7%, slightly higher than price-based ones 15.4%.
*Maximum, minimum values and standard deviations of design cost index, design schedule index, and construction cost index under QBS are notably lower than price-based ones.

QBS can be associated with a more cost and time effective procurement process

Preliminary results from the questionnaire data analysis revealed that (1) although the average duration of the QBS procurement process (17.3 weeks) was slightly longer (1.5 weeks) than average durations associated with price-based procurement methods (15.8 weeks) (2) the sampled duration of the QBS procurement process demonstrated slight less variation (smaller standard deviation), while the sampled duration of the price-based procurement methods showed a wider dispersion. Additionally, Shelton[3] showed that QBS costs were lower than those resulting from price-based proposal development. These observations pertain to an effective joint scope development between the owner and A/E as well as performing meaningful negotiations with only one or two most qualified A/Es instead of individually reviewing detailed proposals from many A/E firms, those of which are or are not qualified.

Further questionnaire analysis revealed that a positive procurement process and overall satisfaction of owners with the A/E's performance yielded higher return business with the A/E, where on average, a selected firm under QBS had one and a half times higher number of projects awarded to them than firms procured through price-based methods. Similar results were found for the number of years owner and A/E have worked together where it was higher for QBS.
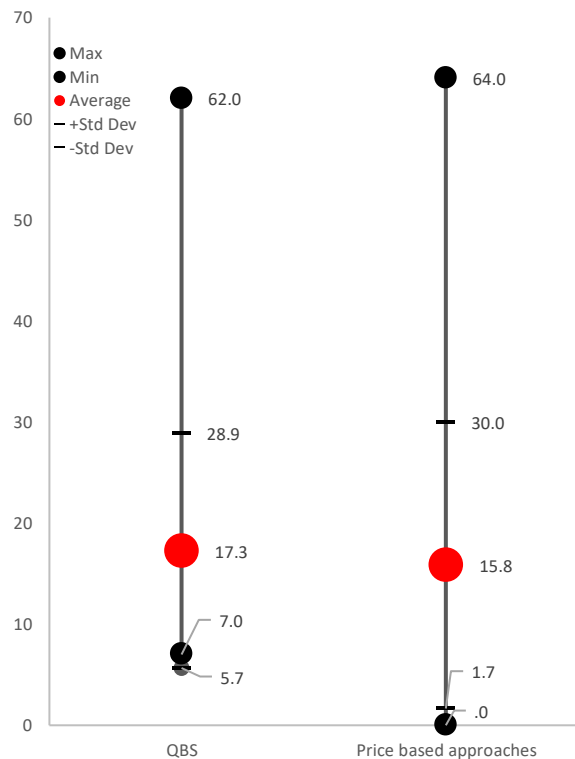
QBS can decrease the impact of adjustments issued on projects
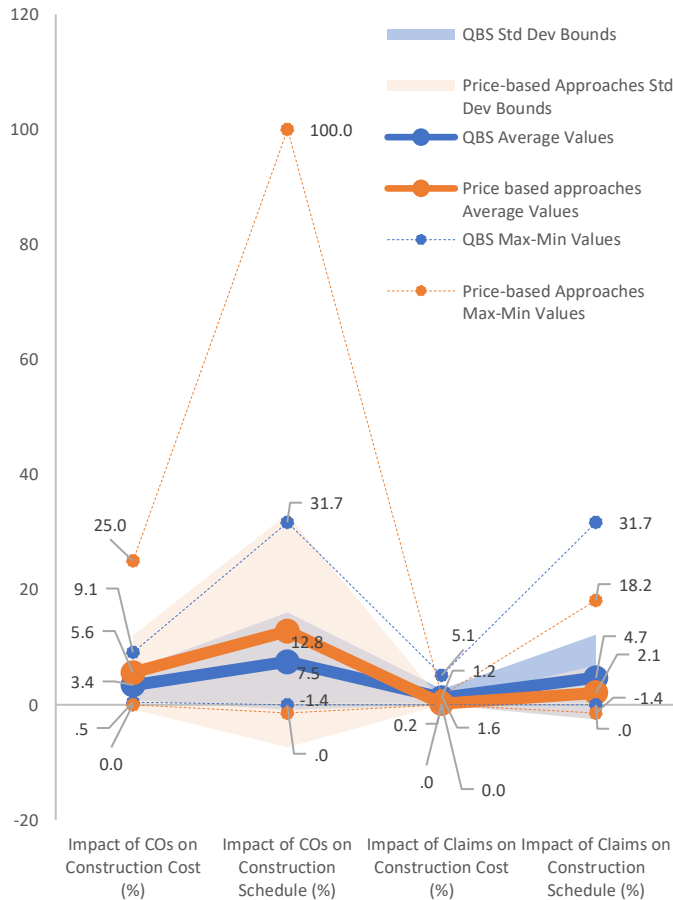
Adjustments to design or construction scopes result in a number of claims, change orders (COs), RFIs, and NCRs to be issued throughout the project. Primary analysis indicated that QBS projects exhibited slightly higher numbers of claims, RFIs, and NCRs, while significantly lower number of COs. Consequently, the impact of COs on cost and schedule in QBS projects were considerably lower than that of price-based methods. Further, other factors could have played a role in these observations, but challenges in collecting additional information limits this analysis.

Impact of COs on Construction Cost: QBS demonstrated resilience towards the impact of COs, exhibiting about 40% less impact comparing with the price-based approach.

**Impact of COs on Construction Schedule:** Similar to the impact on construction cost, QBS had an avg. value of 7.5%, about 40% lower than price-based ones (12.8%). Additionally, sample data of QBS approach demonstrated a smaller variation on impacts of COs.

Impact of Claims on Construction Cost: Both QBS and price-based approach exhibited low impact from claims (1.2% and 0.2% respectively).

Impact of Claims on Construction Schedule: Similar to the impact of claims on construction cost, both QBS and price-based approach demonstrated minimal impact from claims.
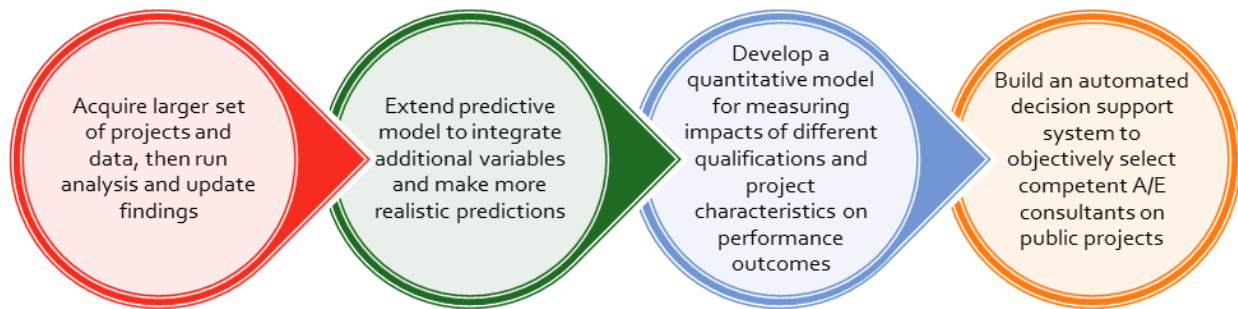
Associations between A/E qualifications and project performance indicators

Correlation analysis and validation through predictive models were performed on the questionnaire results to confirm the results obtained from the preliminary analysis as well as explore the associations between A/E qualifications and project outcomes. Understanding such correlations can help demonstrate how QBS, which solely focuses on A/E qualifications as the determining factors and evaluation criteria instead of price, can impact the performance outcomes of projects. Accordingly, the preliminary findings from correlation tests and predictive models revealed good initial associations between several A/E qualifications (independent impact factors) and key project performance areas (dependent variables), which further strengthens the argument that basing selection decisions on qualifications rather than price can have direct and strong correlations with how a project subsequently performs. These findings are supported by results from different studies conducted in other Canadian regions and the US. The figure below illustrates an example of how certain correlated A/E qualifications can predict performance indicators.
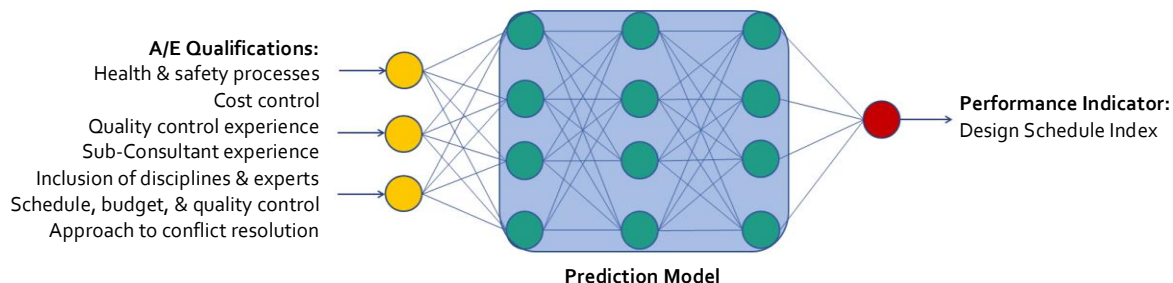
Future Work

While many public owners are slowly shifting from solely depending on price, as in the case of lowest-price bidding approach, to incorporating qualifications into their evaluation criteria at various degrees, such as BVP or QCBS, owners need to exclude price completely as a determining factor. As shown by the preliminary findings and indications of this study and literature, once price is included as a factor, projects tend to exhibit less favorable performance outcomes as compared to QBS-based projects. Therefore, the conversation about owners adopting QBS when soliciting professional consultant services should be ongoing, more widely spread, and welcomed towards potentially delivering value adding and effective public projects. Harnessing the services of competent and highly qualified design firms can leverage the quality and cost-time effectiveness of projects serving the public interest. These recommendations are based on the preliminary findings from analyzing a limited data set in this study. As such, a larger set of projects and additional information is needed to support, generalize, and validate these findings. Accordingly, future work will focus on the following aspects:

Executive Summary
Part 2

Developing a Decision-support System for Objective Consultant Evaluation and Ranking

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The identification and selection of proficient engineering consultants can play a vital role in the success of any project. Non-price criteria are often overlooked when bid price is involved in the evaluation process, where owners give all consultants the same rating for the qualifications-related criteria, and price becomes the deciding factor. The subjectivity associated with the qualitative nature of non-price criteria is one of the owners' main concerns regarding adopting a Qualifications-Based Selection (QBS) approach to procure Architectural and Engineering (A/E) services. To convince owners that implementing QBS is feasible, a decision-support system that all includes all the necessary criteria and is capable of objectively evaluating consultants is essential.

This report explains the findings of a research project conducted to develop an automated decision-support system for the evaluation and ranking of engineering consultants using QBS with minimum subjectivity and bias as well as improved consistency and transparency. This system can be utilized for projects with different needs and requirements. In this regard, 85 Request for Proposals (RFPs) used by public organizations in Alberta to evaluate consultants are analyzed thoroughly to identify all the relevant consultant evaluation criteria, sub-criteria, and criteria weights. An extensive review of the literature is carried out to check the evaluation criteria considered, determine an appropriate approach to measure the qualitative criteria, and select a suitable state-of-the-art decision-making technique for the development of the analytical model.
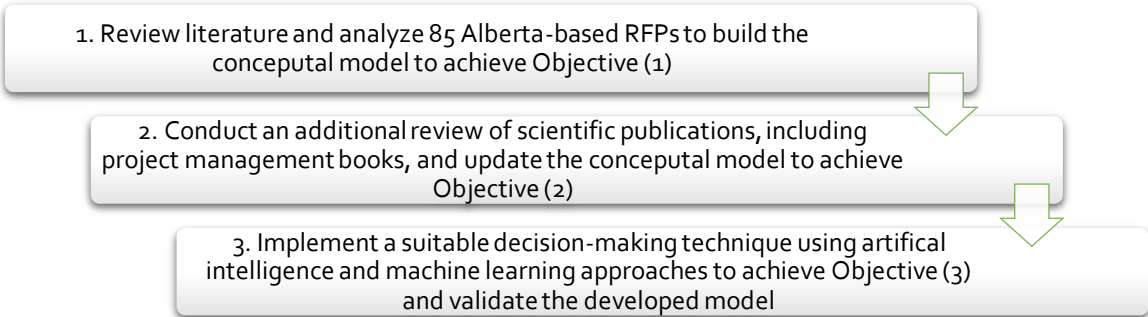
Background

Decision makers are under economic and political pressures to save money[1], and that is why price-based selection is the most prevalent procurement approach employed. However, unlike what clients assume, selecting consultants based on price does not guarantee cost savings because this may impact quality. Also, a higher design cost might translate to lower construction costs, which can be achieved, for example, by selecting a qualified consultant that provides a sustainable, low-impact design. The quality and costs of construction are greatly impacted by the competence, attitudes, and commitment of design consultants[2]. Communities that adopt QBS experience lower long-term costs because QBS prioritizes quality throughout the evaluation and selection process[3]. There is still a need for an analytical consultant selection model that can be used as a reliable tool to assist owners in objectively evaluating engineering consultants. The following deficiencies are identified in the previously developed consultant selection models: the absence of a complete set of all relevant evaluation criteria (e.g., focusing on some factors and ignoring others), and the inherent disadvantages of the decision-making approach, such as subjectivity and lack of transparency.

Objectives & Approach

This study aims at improving the consultant evaluation and selection process in Canada as well as establishing a system for owners to implement QBS with less subjectivity and greater reliability. The specific objectives of this research are the following:

(1) **To identify a standard, comprehensive set of consultant evaluation criteria and sub-criteria, and determine a suitable multi-criteria decision-making approach**
(2) **To establish a proper approach to measure the evaluation criteria, which are of a qualitative nature**
(3) **To develop a computerized analytical model to objectively assist owners in identifying competent consultants with improved consistency, transparency, and fairness**

The study utilizes both academic research and industry practices to achieve the research objectives. This approach comprises three main steps, as presented below.

> 1. Review literature and analyze 85 Alberta-based RFPs to build the conceputal model to achieve Objective (1)

> 2. Conduct an additional review of scientific publications, including project management books, and update the conceptual model to achieve Objective (2)

> 3. Implement a suitable decision-making technique using artifical intelligence and machine learning approaches to achieve Objective (3) and validate the developed model

Decision-support System Development

The analysis of the RFPs helped identify the main criteria groups and their average weights, determine all the evaluation criteria relevant to each criteria group, and discover the major problems in the current industry practices in Alberta. In addition, scientific literature helped establish an approach to objectively measure the criteria and build an analytical model for consultant evaluation and ranking.

Main criteria, sub-criteria & criteria weights from Alberta-based RFPs

Technical Criteria 47%

Project Comprehension and Methodology
(1) Proposal quality, (2) Goals, objectives, and tasks comprehension, (3) Work plan, (4) Communications management, (5) Stakeholder management, (6) Risk management, (7) Safety management, (8) Environmental Management, and (9) Innovation and value-added services

Quality and Project Controls
(10) Quality assurance and control, (11) Dispute/conflict management and resolution approach, (12) Task-based schedule, (13) Schedule control approach, and (14) Cost control approach

Pie chart:
- Project Team Credentials, 28%
- Project Comprehension, Methodology, and Management Systems, 47%
- Firm Credentials, 25%

Distribution of Criteria Weights in the RFPs

Major issues in the RFPs:
1. Absence of a standard set of evaluation criteria
2. Insufficient descriptions of criteria
3. Combination of dissimilar criteria
4. Duplication of evaluation requirements

Managerial and Organizational Criteria 53%

Firm Credentials
(15) Overview of the organization, (16) Approaches to lessons learned and knowledge sharing inside the firm, (17) Three relevant projects the firm has completed in the past five years, and (18) Ability to create long-term relationships with clients

Project Team Credentials
(19) Project leader credentials, (20) Project organizational chart and description of team members, (21) Project team qualifications and experience, and (22) Project team collaborative projects

Pre-evaluation inquires

Pre-evaluation inquiries, shown below, are yes/no questions posed to the decision-maker prior to the evaluation to screen consultants and determine which consulting firms are eligible for the detailed evaluation process. The main idea behind those inquires is that some of the evaluation criteria are regarded inadequate for comparing and contrasting consultants, because if a consultant's submission does not meet the requirements of those questions, no time or effort should be expended on their evaluation as this implies that they are not qualified for the job.
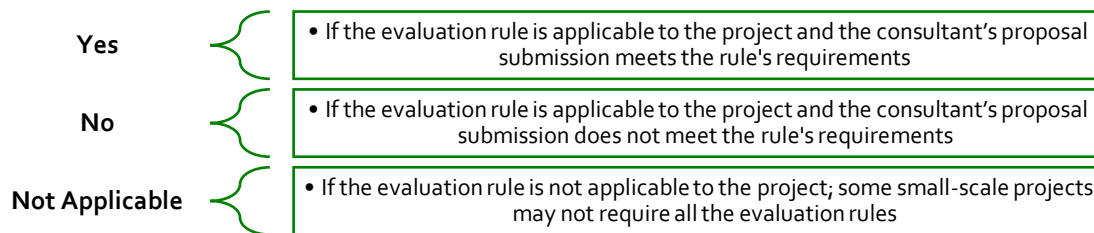
Firm Capacity ⇨	Does the consultant have sufficient resources allocated for this project?
Firm Stability ⇨	Are the past, present, and future financial status of the consultant stable?
Relevant Experience ⇨	Does the consultant have proven experience in similar nature, scope, and complexity projects?
Client-Consultant Relationship ⇨	Is the client-consultant previous working relationship satisfactory?
Referees ⇨	Would the two referees work with the consultant again?
Health and Safety Record ⇨	Is the health and safety record of the consultant on previous projects acceptable?
Claims Record ⇨	Does the consultant have a record of unjustified claims in past projects?
Failed Contract ⇨	Has the consultant failed to complete a contract, had a recent termination of a contract by the client, or had withdrawn from a contract prematurely?

Objective measurement of evaluation criteria

Implementing QBS is still a major concern for owners due to the qualitative nature of evaluation criteria. Evaluation rules are found to be the most suitable approach to measure those criteria, where a set of rules is established from scientific papers, project management books, and the descriptions of criteria and evaluation requirements in the analyzed RFPs. The average number of evaluation rules is about six for each criterion, with relevant requirements that the consultant has to fulfill. Accordingly, decision-maker's judgements will be based on those rules rather than personal opinions, feelings, or assumptions. Each rule is given a specific score based on its relevant importance, with a total of 100 for all the rules forming a single criterion.
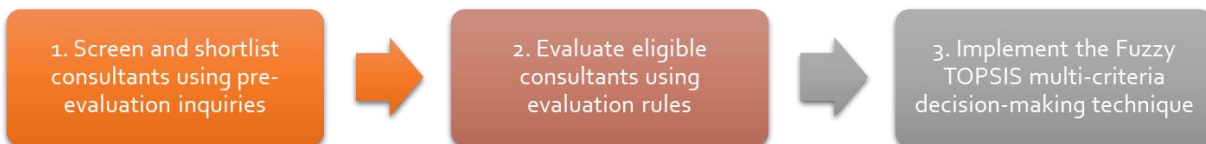
Regarding the communications management criterion, for example, using technology for communication is ignored in the RFPs. The changing nature of construction projects has prompted a shift towards using technology as a main communication method[4], and with the COVID-19 pandemic affecting the entire world for almost two years now, technology has become crucial for communication. Internet-accessible databases can be utilized to convey information across all project stakeholders[5]. Also, major construction-sector clients are increasingly requesting engineering and construction firms to use Building Information Modeling (BIM) because of its benefits[6]. Accordingly, these aspects are considered in this criterion's rules.

The decision-maker is required to check each evaluation rule and has the following three options to choose from:

Yes — • If the evaluation rule is applicable to the project and the consultant's proposal submission meets the rule's requirements

No — • If the evaluation rule is applicable to the project and the consultant's proposal submission does not meet the rule's requirements

Not Applicable — • If the evaluation rule is not applicable to the project; some small-scale projects may not require all the evaluation rules

Analytical consultant evaluation & ranking model

A three-step comprehensive consultant evaluation and ranking process, depicted below, takes place to develop an automated decision-support system. The analytical model is built using Python (PyCharm) programming language, which is widely used for data analysis and machine learning.

1. Screen and shortlist consultants using pre-evaluation inquiries → 2. Evaluate eligible consultants using evaluation rules → 3. Implement the Fuzzy TOPSIS multi-criteria decision-making technique

During Step 1, all consultants are screened using the pre-evaluation yes/no questions. Following that, consultants who have passed the screening phase are evaluated thoroughly in Step 2 using the 22 criteria and their evaluation rules. Based on the decision-maker's responses (yes, no, or not applicable) to the evaluation rules, the overall score of each criterion will be automatically calculated and then translated to a linguistic rating (low, medium, high) for each criterion. In Step 3, the Fuzzy TOPSIS technique is utilized, where fuzzy logic (a subset of artificial intelligence) converts the linguistic performance ratings into numbers for TOPSIS to perform some mathematical computations and rank consultants. Unlike previous implementations of Fuzzy TOPSIS, where the decision-maker often provided an evaluation in the form of a linguistic term, in this research, the linguistic ratings depend on the consultant fulfillment of the evaluation rule requirements, which will reduce subjectivity in the decision-making process.

Application

The screenshots shown below represent a numerical example extracted from the developed computerized decision-support system. The decision-maker is first asked to respond to some questions concerning the project characteristics. The system then recommends criteria weights, with a total of 47% for technical criteria and 53% for managerial and organizational criteria, which are derived from the analysis of the RFPs. The decision-maker also has the choice of entering the desired criteria weights based on the project needs and requirements.

```
Project Characteristics:
Q1. What is the type of the project? infrastructure
Q2. What is the size of the project? (the following are recommended: Small Projects < $75k, $75k <= Medium Projects <= $200k, Large Projects > $200k) medium
Q3. What is the level of complexity of the project? medium
Q4. What is the expected level of environmental, sustainability and green design considerations in the project? low
Q5. What is the expected level of innovation in the project? low
Q6. What is the main project driver? (e.g., schedule, resources) resources


The recommended weights (%) for the Technical Criteria are: [C1=2, C2=4, C3=4, C4=3, C5=2, C6=3, C7=3, C8=3, C9=3, C10=6, C11=2, C12=4, C13=4, C14=4]
NOTE: The total weight of the Technical Criteria should be 47%
Please enter the weights without the % sign
C1. Please enter the weight of the 'Proposal Quality' criterion: 2
C2. Please enter the weight of the 'Goals, Objectives and Tasks Comprehension' criterion: 4
C3. Please enter the weight of the 'Detailed Specific Description of Project Approach' criterion: 4
C4. Please enter the weight of the 'Communication Management (Project Communication Plan)' criterion: 3
C5. Please enter the weight of the 'Stakeholder Management' criterion: 2
C6. Please enter the weight of the 'Risk Management' criterion: 3
C7. Please enter the weight of the 'Safety Management' criterion: 3
C8. Please enter the weight of the 'Environmental Management' criterion: 3
C9. Please enter the weight of the 'Innovation and Value-added Services' criterion: 3
C10. Please enter the weight of the 'Quality Assurance and Quality Control' criterion: 6
C11. Please enter the weight of the 'Dispute/Conflict Management and Resolution Approach' criterion: 2
C12. Please enter the weight of the 'Tasked-based Schedule' criterion: 4
C13. Please enter the weight of the 'Schedule Control Approach' criterion: 4
C14. Please enter the weight of the 'Cost Control Approach' criterion: 4
Note that the total weight entered by the user for the Technical Criteria is: 47.0%


The recommended weights (%) for the Managerial and Organizational Criteria are: [C15=4, C16=4, C17a=5, C17b=5, C17c=5, C18=2, C19=10, C20=5, C21=7, C22=6]
NOTE: The total weight of the Managerial and Organizational Criteria should be 53%
Please enter the weights without the % sign
C15. Please enter the weight of the 'Overview of the Organization' criterion: 4
```

After that, the decision-maker is asked to specify the number and names of the consulting firms that will be screened. The pre-evaluation inquiries phase, which requires yes/no answers, will then start.

```
Please enter the total number of Consultants to be screened prior to evaluation: 5


Please enter the name of each Consultant:
Company AA
Company BB
Company CC
Company DD
Company EE
['Company AA', 'Company BB', 'Company CC', 'Company DD', 'Company EE']


Pre-evaluation of Company AA
1. Does the Consultant have sufficient resources allocated for this project? yes
2. Are the past, present, and future financial status of the Consultant stable? no
FAILED! The Consultant is not eligible for the next evaluation stage


Pre-evaluation of Company BB
1. Does the Consultant have sufficient resources allocated for this project? yes
2. Are the past, present, and future financial status of the Consultant stable? yes
3. Does the Consultant have proven experience in similar nature, scope, and complexity projects? yes
4. Is the Client-Consultant previous working relationship satisfactory? yes
5. Would the two referees work with the Consultant again? yes
6. Is the health and safety record of the Consultant on previous projects acceptable? yes
7. Does the Consultant have a record of unjustified claims in past projects? no
8. Has the Consultant failed to complete a contract, had a recent termination of a contract by the Client, or had withdrawn from a contract prematurely? no
PASSED! The Consultant is eligible for the next evaluation stage
```

Consulting firms that pass the screening process will be the ones eligible for the detailed evaluation phase, where the decision maker is asked to check each criterion's evaluation rules and respond with yes, no, or not applicable based on the proposal requirements and the consultant's submission. During this phase, the qualifications of eligible consultants are evaluated in detail. According to the decision maker's answers to the evaluation rules, the total score of each criterion will be calculated, and low, medium, and high ratings will be generated.

```
Evaluation of Company BB

(1) Evaluation of Technical Criteria - Project Comprehension and Methodology Criteria:

For Criterion #1 - Proposal Quality:
1.1 Complete proposal: yes
1.2 Detailed proposal with all the relevant information: yes
1.3 Clear proposal in terms of work description: yes
1.4 Well-presented proposal: no
The total score for the 'Proposal Quality' criterion is Medium


For Criterion #2 - Goals, Objectives, and Tasks Comprehension:
2.1 Scope of work comprehension: yes
2.2 Detailed goals, objectives, and deliverables: yes
2.3 Roles and responsibilities comprehension: yes
2.4 Inclusion of the consultant's role in construction (e.g., shop drawing review and approval, final walkthroughs, construction inspections): no
2.5 Deep understanding of construction QA/QC: yes
2.6 Design vision - Illustrative project comprehension (e.g., plans, sketches): no
The total score for the 'Goals, Objectives, and Tasks Comprehension' criterion is Medium


For Criterion #3 - Detailed Specific Description of Project Approach (Work Plan):
3.1 Work Plan matches the RFP requirements: yes
3.2 Methodology rationale and constructability of design: yes
3.3 Inclusion of project specific required approaches: yes
3.4 Description of included, excluded and optional services, and those provided by others: yes
3.5 Integration of cross-disciplinary perspectives: yes
3.6 Integration of sub-consultants and/or specialists' services: yes
3.7 Implementation of lean principles (e.g., identify and map value stream, create flow via waste removal, respond to customer pull, and strive for perfection): yes
3.8 Design at each stage fulfills basic legislative requirements, codes, and standards related to safety, accessibility, and community needs: yes
3.9 Clear plan for providing a final product that functions; a product that is effective, efficient, convenient, safe, and easy to operate and maintain: yes
The total score for the 'Detailed Specific Description of Project Approach (Work Plan)' criterion is High
```

Performance ratings are then collected by the Fuzzy TOPSIS model. The user of the system does not see any of the scientific formulas and computations done by the Python model; however, the ranking of consultants is generated by the model in a fraction of a second, from the most qualified to the least qualified consultant, as presented below.

```
OVERALL ranking of Consultants from the highest to the lowest is:
Company BB    0.696
Company EE    0.502
Company DD    0.315



Ranking of Consultants from the highest to the lowest for the Technical Criteria only is:
Company BB    0.576
Company DD    0.475
Company EE    0.348



Ranking of Consultants from the highest to the lowest for the Managerial and Organizational Criteria only is:
Company BB    0.798
Company EE    0.631
Company DD    0.177
```

Advantages of the developed decision-support system

Analyzing all the relevant aspects needed for a thorough consultant evaluation process.

Enhancing the level of innovation and sustainability in construction projects; the future of construction is moving towards being smart and sustainable.

Minimizing subjectivity in consultant evaluation and the need for group decision-making by using evaluation rules to measure the criteria.

Improving transparency and fairness in the decision-making process because the decision-maker does not base their judgments on personal opinions.

Establishing a flexible and adaptable system that can be utilized for different projects; the user can exclude any non-applicable criteria and evaluation rules, and adjust the criteria weights based on the project characteristics.

Providing a breakdown for the ranking of consultants: overall ranking, ranking of technical criteria, and ranking of managerial and organizational criteria

Introducing a reliable system that owners can easily understand and use, and can result in a more robust decision-making process

Future Work

The RFPs under study are used by public owners in Alberta only. Therefore, the dataset can be extended by incorporating RFPs from other Canadian provinces. Also, the developed set of consultant evaluation criteria and evaluation rules can be updated periodically based on market changes.

The developed decision-support system can be made available online and made accessible to owners in order to help them evaluate and select competent consultants. It can also be used to aid in the selection of qualified contractors, where an analysis of the contractor evaluation criteria can be conducted, and adjustments to the model can be made accordingly.