IMPACTS OF PRE-PROJECT INVESTMENT & QUALITY OF DOCUMENTS

ON PROJECT DELIVERY EFFICIENCIES

FINAL REPORT | NOVEMBER 2021

CDAO
Construction & Design Alliance of Ontario

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On behalf of the:

CDAO
Construction & Design Alliance of Ontario

Executive Summary

Significant levels of schedule delay and cost escalation during the construction of major public and private projects are often the reality in Canada.

To assist the industry and project owners to work collaboratively to achieve effective and efficient reductions in schedule delays and cost escalation, a consortium led by the Construction and Design Alliance of Ontario (CDAO) commissioned a comprehensive, three-year study: *Impacts of Pre-Project Investment & Quality of Documents on Project Delivery Efficiencies*.

Concluding in 2021, the study was based on recent and project-specific data, and focused on the relationship between project delivery efficiencies and project owners' investment in upfront pre-planning on design and consulting services.

The CDAO study identified:

- the important role of the project owner's commitment to upfront investment during the pre-project planning and design stages on the quality of design documents – and subsequent construction project performance.
- a direct and positive correlation between the amount of time and investment that owners spent in pre-planning – and the quality of design documents in terms of completeness and suitability of purpose.

According to the Literature Review which helped focus the study and define the survey parameters, devoting optimal time and resources in the pre-planning and design stages of a project is in the owner's best interest; there is a cascading order-of-magnitude impact of unaddressed design issues.

Research has shown that an error that costs $100 to address during pre-planning could cost $1,000 to address during the design phase and $10,000 during construction. Therefore, early discovery of the errors or preventing the errors are essential for project cost efficiency. Many researchers have indicated insufficient design fees, unrealistic time frames and improper pre-project planning have the potential to lead to poor quality of the design/bid documents.

Scope of the Study

The study was initiated by CDAO and supported financially by the Association of Consulting Engineering Companies – Canada, the Association of Consulting Engineering Companies — Ontario, the Association de la Construction du Québec, the Association of Registered Interior Designers of Ontario, the Canadian Construction Association, the Corporation des entrepreneurs généraux du Québec, the Grand Valley Construction Association, the Greater Toronto Sewer and Watermain Contractors Association, the Mechanical Contractors Association of Ontario, the National Trade Contractors Council of Canada, the Ontario Association of Architects, and the Ontario General Contractors Association. Conducted by the Ryerson Institute for Infrastructure Innovation, the study was co-funded by Mitacs, a national funding agency that supports applied research and industry-academia collaboration.

The study included a literature review, online survey and in-person interviews. The nation-wide online survey, distributed in both English and French, featured four different and yet congruent sets of questions to owners, design consultants, general contractors (GC), and subcontractors (Subs). Throughout the report, architects and engineers (A/E) are referenced as the dominant design consultant groups participating in the survey. However, the finding are applicable to all design disciplines.

While varying opinions were expressed among respondents to the online survey, there was consensus that bringing all stakeholders onto the same page regarding the importance and value of an owner's commitment to investment in project pre-planning and design, will assist in finding solutions for the ongoing issues of schedule delays and cost overruns.

A Timely and Important Study

The need to work toward achieving better outcomes in the delivery of public and private projects has important consequences for owners, the design and construction sectors, and the public.

There is an urgent need for public and private clients to make changes to their procurement practices to address a root cause of schedule delays and cost overruns – inadequate investment in pre-project planning by owners in the Request for Proposal (RFP) and design stages.

Currently, there are many funded infrastructure projects in the pipeline and more coming forward; the opportunity is now to create better efficiencies to get the best value and deliver much-needed infrastructure in a way that avoids the unwanted consequences resulting from delays and cost overruns.

Significant Findings

The study confirmed the important role of the owner's investment in upfront pre-project planning and design. According to the study:

- *Owners and stakeholders should spend more time and effort to ensure they adequately scope the project before going to market.* The clarity, completeness, and accuracy of the initial information provided in the Request for Proposal was found to have a strong positive correlation with the frequency of client-initiated scope change and the extent of budget change in the design stage, which will further influence the success of bidding and the extent of schedule delay and cost overruns in the construction stage.
- *There is a need for commitment on the part of owners to allow the time and budget for design reviews, checks, and verifications to be undertaken throughout each phase of the design process.* Design documents that are incomplete, unclear, or conflicting from one page to the next impact the efficient delivery of construction projects.

As ***Figure 23*** from the survey demonstrates, the result of this pre-planning investment by the owner will be significantly improved design document quality, which itself will result in significantly improved project delivery efficiency.

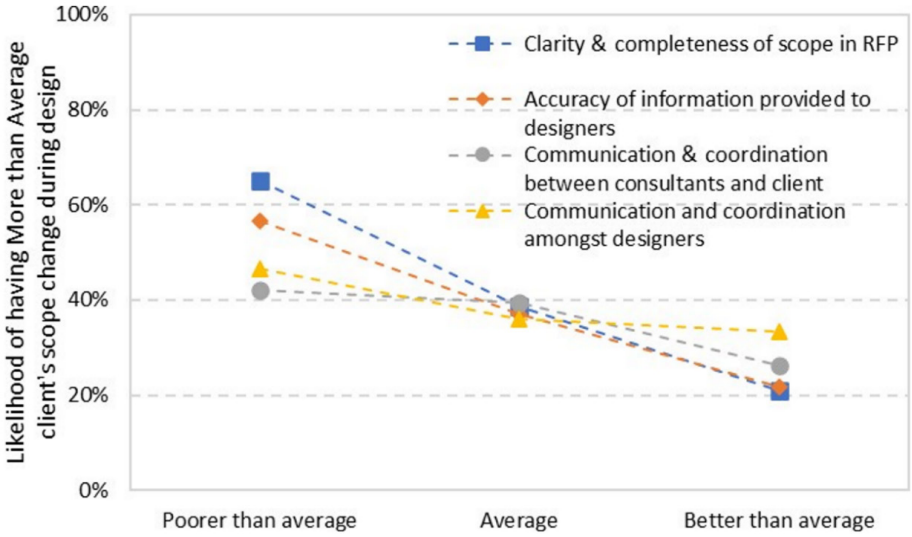

Figure 23. Client-initiated scope change vs. the quality of RFP and CCC among consultants during the design stage

- *The survey confirmed that design document quality issues are rooted in issues of inadequate time provided, inadequate fees, and inadequate information about existing conditions.* These issues frequently result in schedule delays and cost increases during project delivery.

As ***Figure 15*** demonstrates, respondents believe that an owner's investment in the pre-planning stage is key to efficient and timely project delivery.

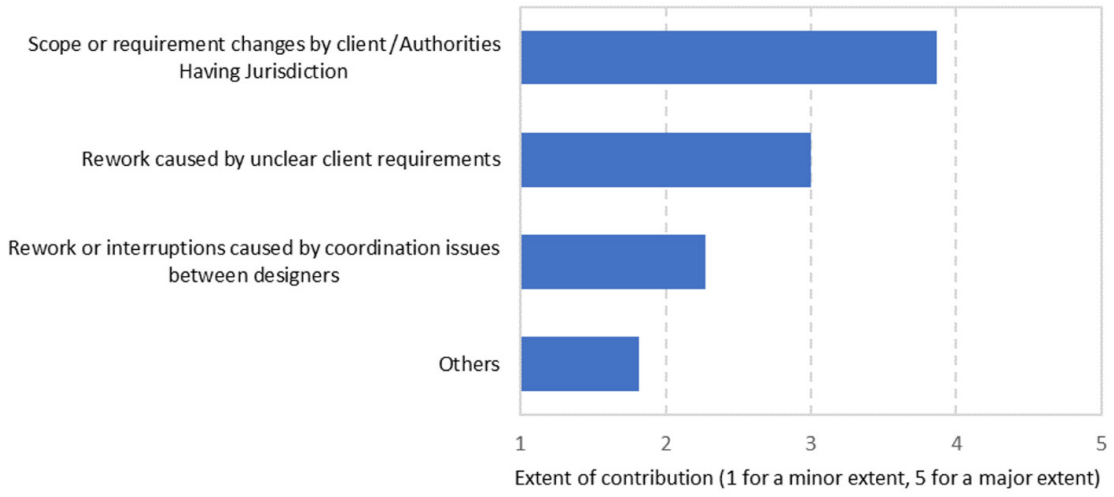

Figure 15. A/E's opinions on factors contributing to design schedule delays

Conclusion

The study demonstrates that significant opportunities exist for better collaboration and communication among owners, designers, general contractors, and subcontractors, which will improve design document quality and construction productivity.

Further, the study results provide all project stakeholders with a basis for discussion about positive change in project delivery for public and private construction projects in Canada.

Acknowledgments

We would like to acknowledge the tremendous support from the individuals and organizations that have guided us throughout this study and nation-wide online survey. Their efforts are greatly appreciated.

First of all, we are indebted to Clive Thurston, who initiated the project, raised funds, and set up a Project Steering Committee (PSC) to provide continuous support for this research project. Without his support, this research project would not have gotten off the ground.

Next, we want to offer our sincerest thanks to the other members of the Project Steering Committee: Bruce Matthews, Sandra Burnell, Sandra Skivsky, Kristi Doyle, and Giovanni Cautillo, who generously shared their insights and contributed their valuable time to review the survey design, promote the survey through their professional channels, and review the report. In addition, Bruce served as the chair of the PSC, and his effective coordination must be acknowledged.

Our next special thanks goes to Revay and Associates Limited for their assistance in translating the survey to French. This helped make the survey a truly national one. In addition, the On-Site Magazine provided a free promotion of the survey through its online platform.

Lastly, we would like to express our gratitude to the following organizations that promoted this online survey:

- Mathematics of Information Technology and Complex Systems (Mitacs)
- Construction Design Alliance of Ontario
- Ontario General Contractors Association
- Ontario Association of Architects
- Association of Consulting Engineering Companies – Ontario
- National Trade Contractors Council of Canada
- Canadian Construction Association
- Grand Valley Construction Association
- Revay and Associates Limited

However, the contents of this report do not necessarily reflect the official views or policies of the above-mentioned organizations or individuals. Any mistakes or errors of the report belong to the authors.

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List of Acronyms

Acronyms	Meaning
A/E	Architects/Engineers
DBB	Design Bid Build
BIM	Building Information Modeling
CCA	Canadian Construction Association
CCC	Cooperation, Coordination and Communication
EPC	Engineering, Procurement and Construction
GC	General Contractor
ICI	Industrial, Commercial, and Institutional buildings
PSC	Project Steering Committee
QoD	Quality of Design Documents
RFI	Request for Information
RFP	Request for Proposal
SHD	Shop Drawings
Subs	Subcontractors

1. Introduction

The construction industry is a major contributor to the nation's economy. It provides the necessary built environment in which we all live, work, and play. Construction projects in Canada, however, have long been facing a recurring challenge related to cost overrun and schedule delay. While this situation is ascribed to many reasons – the quality of documents being a common one – the industry lacks concrete data to pin down the root causes and solutions. To address this issue, a research project was initiated by a consortium of industry associations from the design and construction industry in Ontario and co-funded by Mitacs, a national funding agency that supports applied research and industry-academia collaboration. Ryerson Institute for Infrastructure Innovation was commissioned to take on this study. To ensure the success of the study, a Project Steering Committee (PSC) was formed to guide and support the research team. The PSC consists of experts representing general contractors, subcontractors (or subs), architects, engineers, and other industry perspectives.

Generally, 'construction documents' include tendering instructions, construction agreements, general specifications, special specifications, design drawings, addenda, Request for Information (RFI), change orders, change directives, and so on. However, this study focuses only on the design drawings and technical specifications prepared by architects and engineers before bidding. Therefore, the quality of documents (QoD) in this study refers to the quality of those design documents prepared by the design team, or Architect or Engineer (A/E). The other documents released by A/E after design, such as addenda, RFI, and change orders, are treated as a consequence that may be attributed to poor design documents and many other relevant reasons. Although change orders and change directives have different contractual implications in project administration, the term 'change orders' used in this report may include change directives unless the context requires explicitly distinguishing them.

The goal of this study is to establish solid empirical evidence on the relationship between the quality of design documents and project owners' upfront investment during the pre-project stage, along with key project performance indicators in the project life cycle. The project performance metrics include the frequency of bidding cancellation, construction schedule delay, and construction cost overrun. The results are expected to provide an objective framework for a change in the project delivery policies for public infrastructure. From a neutral, third-party perspective, the study also attempts to provide an opportunity for the design and construction industry to improve communication and trust amongst all project stakeholders.

To achieve this research goal, the study includes three corroborating components:

1. Conduct a nation-wide online survey to collect data and opinions on the current state and trend of the quality of design documents, factors contributing to the quality of documents, and the impacts on project delivery efficiency.
2. Collect factual project data from sample projects to further quantify the impacts.
3. Conduct in-person interviews to obtain best practices and lessons learned from the sample projects.

This report describes the results of the online survey conducted over the summer of 2020. The online survey sought to collect data to answer the following specific questions:

I. What is the current state and recent trend of the quality of design documents (QoD)?

II. What are the contributing factors for the QoD?

III. How and to what extent does the QoD affect project performance?

IV. How can the QoD be improved?

The remainder of the report is structured as follows:

- Section 2 explains the methodology of the survey, including the design and distribution of the survey questions.
- Section 3 presents and discusses the survey results.
- Section 4 concludes the report with major findings and recommendations.
- The Appendix presents some ancillary survey results and analyses.

2. Methodology

2.1. Online Survey Design

It is essential to design survey questions that collect relevant and reliable data that can collectively produce a holistic answer to the research questions that the survey attempts to answer (Fowler 1995). To ensure a reasonable completion rate, the number of survey questions was limited in order for an average respondent to be able to complete them within 15 minutes.

The survey included three sections, and the second section was further divided into four different sets of questions for different stakeholder groups, including the Owner, A/E (also known as Consultant), General Contractor (GC), and Subcontractors (Subs). The details are explained below:

Section I – Background Questions: Four questions were designed to obtain the general background of respondents, including which sector of construction they have worked in, the primary role they are currently playing, and the number of years of working in the construction industry in their current position. The data collected were stored anonymously and used to assess the quality of the response.

Section II – Project-Specific Questions: This was the core part of the survey. A unique feature of this study that separates it from many previous studies was that this survey focuses on collecting more project-specific data rather than general opinions. Therefore, at the beginning of the section, the following survey direction was given:

The questions in this section seek to elicit your experience of the most recent project you have been involved in up to substantial performance/completion. All your answers in this section should be based on this one project. For questions where you are uncertain of the solution, please provide your best estimate.

Questions in this section covered the project background, the state and contributing factors of the QoD, project performance, and recommendations for improving the QoD. Considering respondents' general access to the information required to accurately answer the questions, this section was divided into four groups based on the respondent's current role in the project. Table 1 illustrates the mapping between the survey questions and the target research questions to be addressed. As shown in Table 1, questions related to the current state of the QoD were posed mainly to respondents representing GC and Subs because they are the parties who are directly affected by the QoD and, therefore, more likely to provide an unbiased assessment. On the other hand, questions related to the contributing factors for the QoD were asked of the Owners and A/E because the Owners may affect the application of the potential contributing factors. In contrast, the A/E are the direct recipients of those factors.

Section III – General Opinions: This last and concluding part of the survey included only one question seeking respondents' general opinion on the trend in the quality of design documents over the past 10 years.

To ensure all respondents understood the questions consistently, the survey questions were reviewed and revised several times by the PSC before the final distribution. In the early stage of the project, several key project owners in the Greater Toronto Area were invited to a roundtable workshop discussing their interests and concerns related to this study. Findings from the workshop as well as those from a pilot study of three projects at the beginning of the project were considered in developing the survey questionnaire.

The survey questions and instructions were prepared in both English and French.

Table 1. Question mapping of the online survey questions

Respondent Group	Section I	Section II					Section III
	Participant background	Project background	State of QoD	Contributing factors for QoD	Impact of QoD	Recommendations	Trend of QoD
Owners	Q1-4	Q5-11; Q27		Q12-14	Q15-26	Q28-30	Q31
A/E	Q1-4	Q5-10		Q11-20; Q23	Q21-22	Q24	Q25
GC	Q1-4	Q5-10; Q31	Q21-23		Q11-20; Q24- 30; Q32	Q33	Q34
Subs	Q1-4	Q5-10	Q16-19		Q11-15; Q20-29	Q30	Q31

2.2. Implementation of the Online Survey

2.2.1. Target Participants

The target participants of the survey were practitioners and professionals in the design and construction industry, including Owners, A/E, GC, and Subs, as well as other relevant consultants that are closely working in the industry. To avoid selection bias, stratified and random sampling were used in this survey. As explained in the preceding subsection, respondents from different stakeholder groups were labeled (and thus stratified) and provided with different sets of questions. For each group or stratum, the respondents may be further stratified into different subgroups based on the projects' size and delivery model. Within each group or subgroup, random sampling was applied.

The online survey links (both English and French versions) were distributed through participating associations and major public owners to the target population across Canada to achieve random sampling. To eliminate multiple attempts by one person, the survey allows only one response per browser. If someone were to try to take the survey again using the same browser, they would have received a message that they had already taken the survey.

2.2.2. Implementation

The English version of the survey was transferred to SurveyMonkey and made available online on May 12, 2020. The French version went live on June 29, 2020. The survey links were distributed along with a cover letter and a brief project overview to the potential respondents through the industrial associations and organizations across Canada. The survey in both languages was closed on September 3, 2020.

3. Results and Discussions

The survey attracted a total of 757 respondents. Amongst them, 442 responses were deemed usable for data analysis purposes. These include 357 complete responses and 85 responses that skipped only the last few questions related to recommendations on improving the QoD. The remaining respondents left the survey too early to provide meaningful data. About 30% of the participants exited after Section I (Background), indicating that they realized they were not ready to complete the project-specific questions. The self-screening effect of the project-specific questions ensured the quality of the complete responses received. The subsequent result analysis is based on the 442 valid responses unless stated otherwise

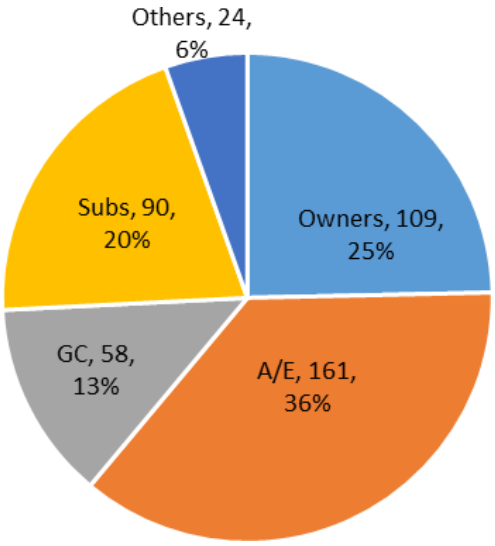

Figure 1. Number and percentage of responses by stakeholder groups

Figure 1 shows the distribution of the valid responses by stakeholder groups. While the distribution is not perfectly uniform, each of the four major stakeholder groups (i.e., Owner, A/E, GC and Subs) has a good representation of their views in the survey. Further analyses of the participants' working experience, current role in jobs, construction sectors they are working in, and the underlying projects for the survey were performed, and the details can be found in the Appendix. It is confirmed that the survey respondents were a good representative sample of professionals from different industry sectors and professional roles, and almost all underlying projects were recently completed projects. More importantly, 75% of the survey participants were senior professionals with over 15 years of working experience in the construction industry, and 85% of the underlying projects were completed in 2019 and 2020. These confirm the significance and currency of the survey results.

3.1. Current State of the QoD

The most interesting question of all is how the practitioners view the current state of the quality of design documents. Document quality, in general, can be characterized by its completeness, clarity, and accuracy. However, all these characteristics are relatively subjective and hard to measure. Besides, design documents of a project often contain many components, each developed by A/E professionals of a different discipline (e.g., architecture, civil, structural, mechanical, electrical). Moreover, due to the anchoring effect – a cognitive bias commonly recognized in psychology, a respondent tends to give biased assessments based on their extraordinarily unpleasant or extraordinarily pleasant experience with a particular piece of document. Therefore, we only asked the general contractors and subcontractors who use the design documents to evaluate the quality of design documents (QoD).

Considering all these factors, five questions were designed to probe the following attributes of the QoD, respectively, with the target participants in the parentheses:

1. (Subs) document completeness, i.e., the degree of completeness of the design documents as a percentage;
2. (GCs) document consistency, i.e., the level of coordination or consistency of design drawings and technical specifications across various design disciplines;
3. (Subs) the quality of drawings and specifications provided for Subs for preparation of their shop drawings (SHD), or adequacy for SHD;
4. (GC & Subs) the errors and omissions observed in design drawings or technical specifications;
5. (GC & Subs) the quality of technical specifications, on a scale of 1 (for excellent) to 5 (for very poor), for the following four components of technical specifications:
   - Provisions in the general requirements (Division 1)
   - General specifications
   - Product specifications
   - Execution specifications (specified standard of workmanship)

For Questions 2-5, the respondents were asked to evaluate the attributes relative to other projects with similar type, size and complexity. Results of the five questions are presented below.

Figure 2 shows a histogram derived from the Subs respondents regarding the completeness of design documents. The horizontal axis represents the percentage of completeness ranging from 0% to 100% in a 10% interval. While the mode (i.e., most likely response) is 80% completeness, the average value is only 66.3% or two-thirds completeness. Only about 5% of the respondents claim that the documents are fully complete. In other words, 95% of subcontractor respondents would say that they had not received a complete set of design documents in those projects they experienced.

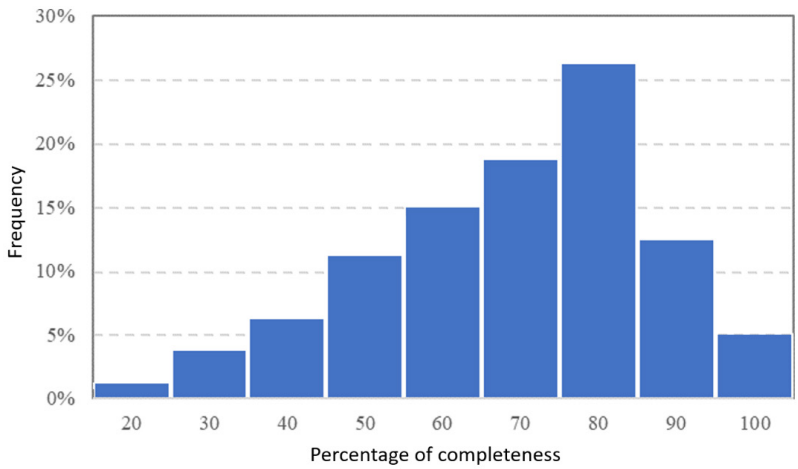

Figure 2. Subs' assessment on the degree of document completeness

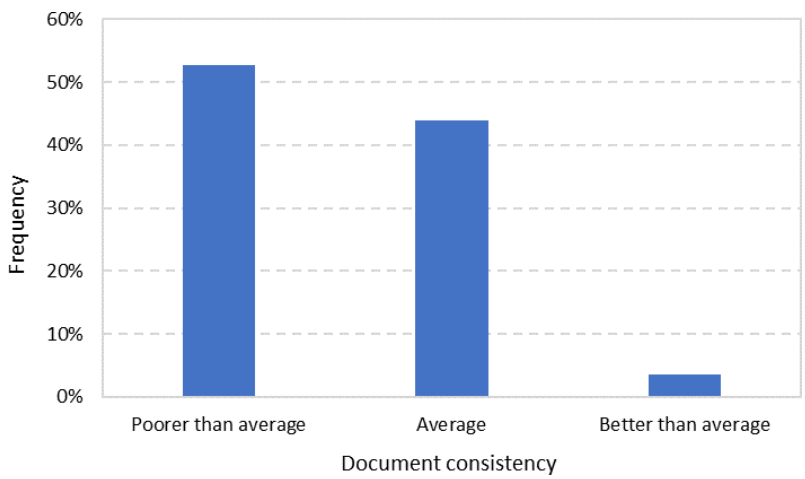

Figure 3. GC's assessment on document consistency

When asked to compare the level of document consistency across various disciplines with other projects with similar type, size and complexity, over 50% of the GC respondents reported the level of document consistency was poorer than similar projects, and less than 5% of the respondents felt it was getting better (Figure 3). This indicates that the satisfaction of the general contractors with document consistency was very low. Note that the 'Average' in Figure 3 should be understood as being similar to 'other projects with similar type, size and complexity.' Therefore, one should not interpret Figure 3 as a biased result for the unbalanced percentages between 'Poorer' and 'Better'. The 'other projects with similar type, size and complexity' that the respondents were asked to benchmark against were apparently those they had experienced before. Therefore, the result shown in Figure 3 demonstrates a gap between the present project and an 'average' project *in the past*.

Hence, the result indirectly reveals a worsening trend of the level of document consistency. Note that many questions in the survey were asked in this way, and thus, the results must be interpreted this way as well.

Figure 4 summarizes Subs respondents' answers on the document adequacy for SHD, i.e., the quality of the drawings and specifications they received to prepare shop drawings. Very similar to the GC's high-level assessment on the document consistency above, the Subs' responses on the document adequacy for SHD are also pessimistic: Nearly 40% think their quality is poorer and only 8% feel the quality is better than average, i.e., than on a typical project in the past.

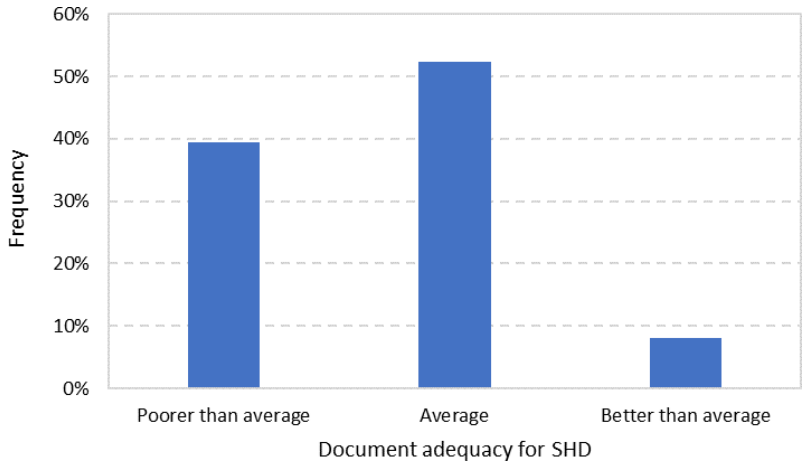

Figure 4. Subs' assessment on document adequacy for SHD

Since both Figure 2 and Figure 4 were results from the Subs' responses, a correlation analysis can be performed between the two responses of every Subs respondent. The results are presented in Figure 5, in which the y-axis represents the average degree of document completeness corresponding to the categorization of document adequacy for SHD represented in the x-axis. The result demonstrates a clear positive correlation between the two metrics. As the document adequacy for SHD moves from 'poorer than average' to 'better than average', the average document completeness increases from about 60% to 86%. This correlation analysis confirms the consistency of responses across different questions.

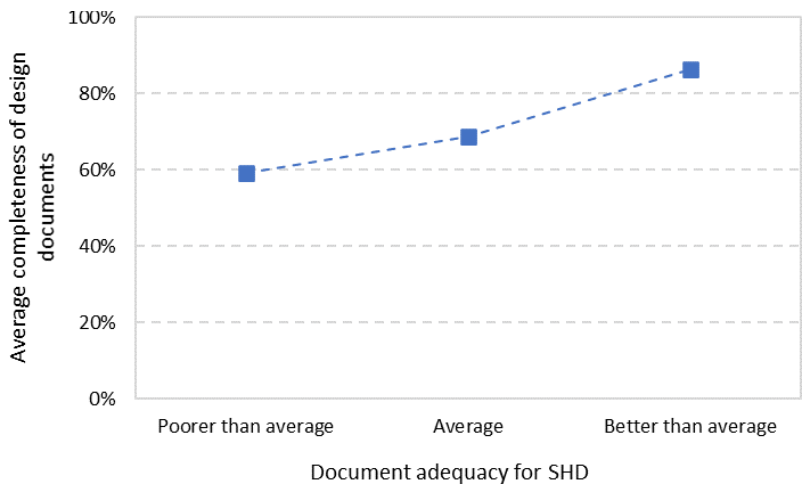

Figure 5. Correlation between document adequacy for SHD and document completeness

Asked to compare the Errors and Omissions existing in construction drawings with those in technical specifications, 76% of the GC and 64% of the Subs respondents claimed that construction drawings have more errors and omissions than technical specifications (Figure 6). Only 12% of the GC and 21% of the Subs respondents expressed the opposite opinion. Still, 12% of general contractors and 15% of subcontractors are not decisive, which may be interpreted as believing both parts of the documents have similar quality.

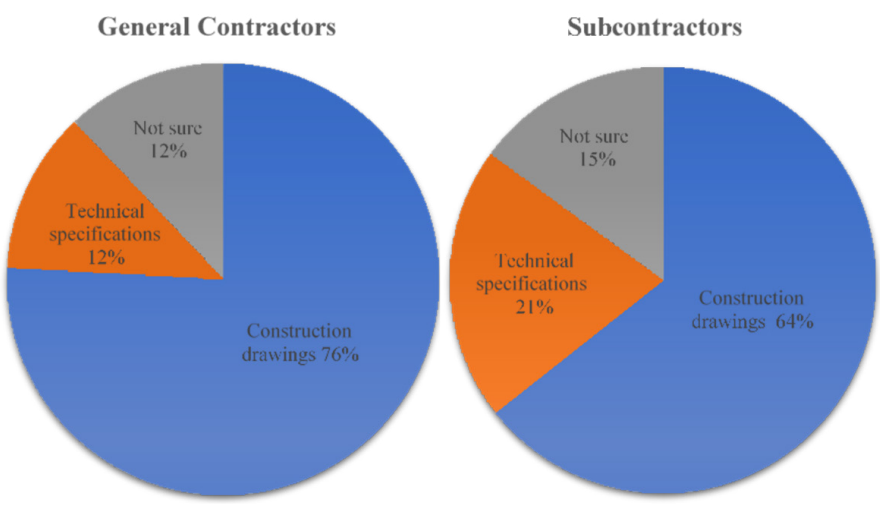

Figure 6. Errors and Omissions: construction drawings vs. technical specifications

The next question was related to the quality of different components of technical specifications. Figure 7 shows the results of this question aggregated from GC and Subs respondents. About 65-70% of the respondents feel the quality of all four components of the technical specifications is of acceptable or better quality. This echoes the finding presented in Figure 6 that technical specifications are more satisfactory than design drawings. Also, Figure 7 shows an interesting trend that the execution and product specifications are more flawed than the general requirements and specifications.

Figure 7. The quality of technical specifications

3.2. Trend of the QoD

As explained in Section 2.1, the survey was concluded with a final question asking all participants their opinion about the trend of the QoD over the past 10 years.

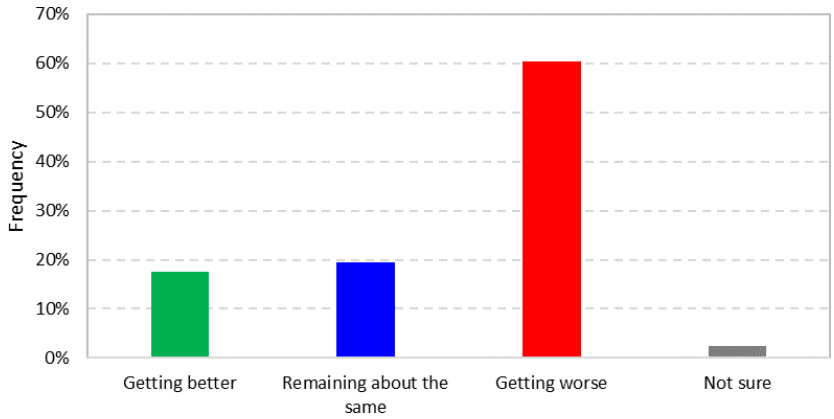

Figure 8. The overall trend of the QoD over the past 10 years

Figure 8 summarizes the responses to the trend in the QoD based on all respondents. While about 18% of the respondents claim that the quality is getting better over the past 10 years, 60% of the respondents believe the quality is deteriorating, and 20% consider that the quality remains the same, which can be understood as the same 'poor' if we trust the response shown in Figure 2.

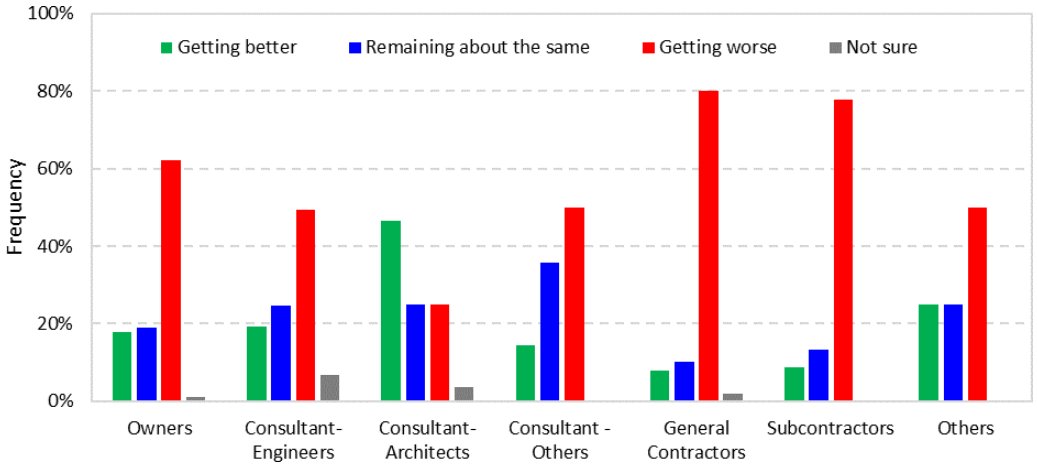

Figure 9. The QoD trends by respondents representing different groups

However, Architects do not seem to agree with this assessment. Figure 9 shows a detailed distribution of the responses categorized by the respondents' professions. About 80% of the GCs and Subs responding to the survey indicated that the QoD is getting worse over the past 10 years. This proportion drops to about 60% for Owners and 50% for Engineering and Other Consultants. For the Architect group, however, 50% of the respondents claimed that the QoD is being improved, and only one-quarter of them admitted that the quality is getting worse. Why there is such a gap in perception is worth further discussion.

Further analyses were performed on the trend of the QoD based on respondents' working experience, industry sector, and geographical region. Fairly consistent observations were made. The details are included in the Appendix.

3.3. Factors Contributing to the QoD

To understand the factors that would affect the QoD, we designed several questions for the Owner and A/E participants. The questions focused on the following potential factors, categorized by the affected stakeholders:

- **Owner**
  - The clarity and completeness of the project scope described in the Request for Proposal (RFP)
  - The accuracy of the information provided to the designer during the design stage
  - The client's scope change during the design stage
  - The budget change as an indirect indicator of the quality of pre-project planning

- **A/E or Consultant**
  - Consultant's satisfaction on the time frame provided by the contract
  - Consultant's satisfaction with the consultation fee
  - The amount of work done by junior staff
- **Both Owner and A/E**
  - How the design contract is obtained, i.e., the contracting method
  - How the design contract is priced, i.e., the pricing method
  - Communication and coordination between the clients and designers, and amongst design consultants

Different questions were designed and asked to the proper group(s) of respondents. The results are shown below.

3.3.1. Owner's Contribution

To explore the contributing factors from the Owner's side to the QoD, A/E respondents were asked to assess the quality of the RFP provided by the client in terms of clarity, completeness, and accuracy. The evaluation results are shown in Figure 10. Asked to compare with projects in the context of similar dollar value, type, and complexity, 50-60% of the A/E respondents rated the clarity, completeness, and accuracy of the project scope and other information provided to the designers during the design stage as 'Average'. However, the difference between the percentages of 'Better than Average' and that of 'Poorer than Average' for clarity and completeness of project scope is greater than the difference shown in the accuracy of information.

In terms of the number of client-initiated scope changes, 36% of the A/E respondents claimed the changes were 'More than Average,' and only 13% rated 'Fewer than Average.' Considering that the responses were based on comparisons with projects completed in the past, Figure 10 seems to suggest that the perceived clarity and completeness of the project scope described in the RFP is improving. In contrast, Figure 11 indicates that the actual number of client-initiated scope changes is getting worse.

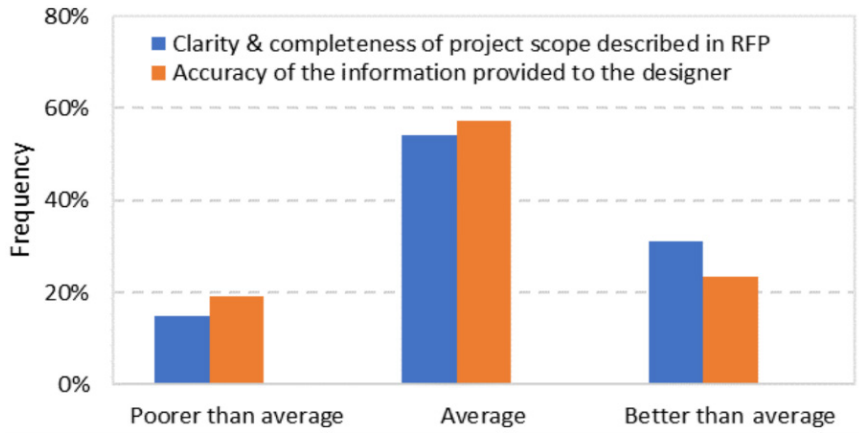

Figure 10. A/E's evaluation on the clarity, completeness, and accuracy of information provided by clients

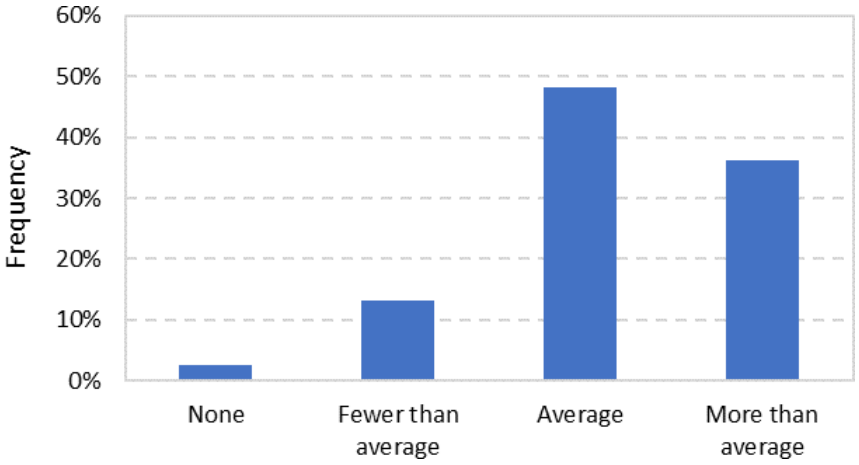

Figure 11. A/E's evaluation on client-initiated scope change during design

In addition to the client-initiated scope changes, another objective indicator for the quality of pre- project planning is the budget change in the design, which refers to the difference between the approved budget in the RFP and the budget estimate before the issuance of bid documents. In general, the budget change is affected by many reasons, some of which are not within the control of owners (e.g., inaccurate budget estimates and material cost escalation). However, it is expected that high-quality pre-project planning would lead to a more precise and complete description of project scope and functional and technical requirements, which would result in a smaller budget change in the design stage. Therefore, the budget change in the design stage is used in the study as an imperfect proxy of the quality of upfront planning.

Figure 12 shows the distribution of budget change in the design stage. The result was derived from the response of the Owner respondents, who are the only group having access to this information. While 20% of the Owner respondents were experiencing no budget change in their most recent completed projects, about 68% witnessed varying degrees of budget increase, and 12% reported a budget decrease. The average budget increase is estimated to be approximately 15%.

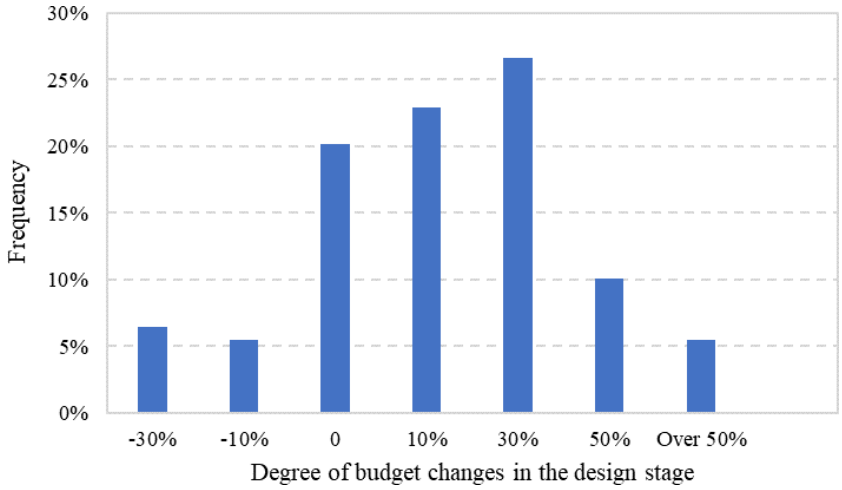

Figure 12. Owner's assessment on the degree of budget changes during the design stage

It would be interesting to correlate the degree of budget change with the preceding three factors (i.e., clarity and completeness of project scope, accuracy of information, and frequency of client-initiated scope change). However, as mentioned above, the budget change information was obtained from the Owner respondents, and the other three questions were asked to the A/E respondents. Therefore, the survey data do not support a direct correlation analysis. Nevertheless, the comparison between the client-initiated scope change (Figure 11) and the budget change (Figure 12) reveals at least an indirect positive correlation relationship. That is, as the number of client-initiated scope changes increases, the budget change tends to increase as well.

3.3.2. A/E's Contribution

Design time, design fee, and the work performed by junior design staff are the major factors considered in the survey that are deemed to affect the A/E's performance in design.

To determine if and how design time given to an A/E would affect the QoD, the A/E respondents were asked to report the duration of design work, whether they thought the design time frame was reasonable, and whether the design was completed on time. Figure 13 shows that over 60% of the respondents believed that the contractual design time frames were reasonable, and yet 27% responded with insufficient time. These proportions were consistent and corroborative to the percentages of projects that were completed on time or with delay shown in Figure 14. A detailed examination of the data shows that the Consultant respondents tend to rate the design time frame as 'longer than needed' when the design duration was longer than 70 months or six years.

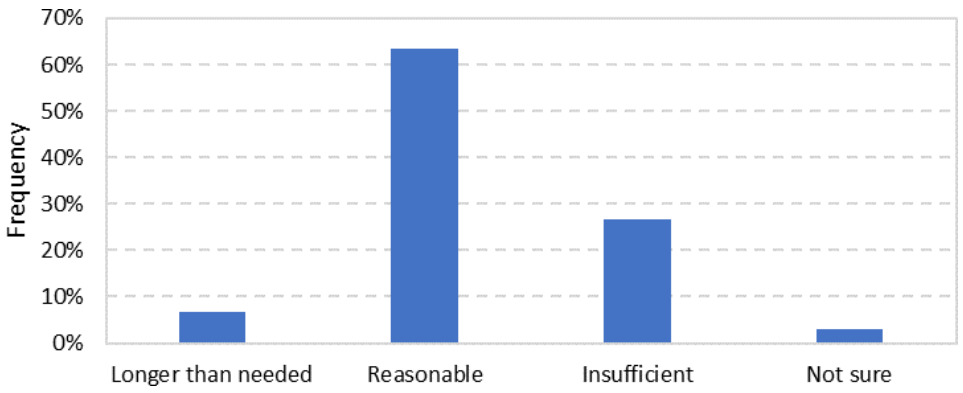

Figure 13. A/E's evaluation of the design time frame

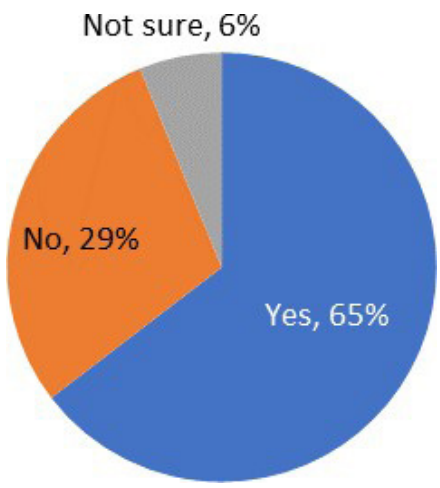

Figure 14. A/E's response of whether design work is completed on time

To further explore the reasons for insufficient design time and for design work that was not completed on time, the Consultant respondents were asked to rate the degree of contribution of the following pre-selected list of potential factors that contributed to design delay, with 1 for minor contribution, and 5 for significant contribution:

- Scope or requirement changes by client/Authorities Having Jurisdiction.
- Rework caused by unclear client requirements.
- Rework or interruptions caused by coordination issues between designers.

Figure 15 shows the average score of the three factors of design schedule delay. Among the three factors, the scope or requirement changes are ranked the highest, with the coordination issues-induced rework ranked the lowest. The survey question also allowed the respondents to identify other factors they believe to be more critical in their projects. The result includes optimistic initial deadlines, funding issues, projects poorly defined, trades strikes, coordination issues instigated by client facility groups after the design was complete, adversarial working relationships with contractors, lack of clear stakeholders/decision-makers, and weather.

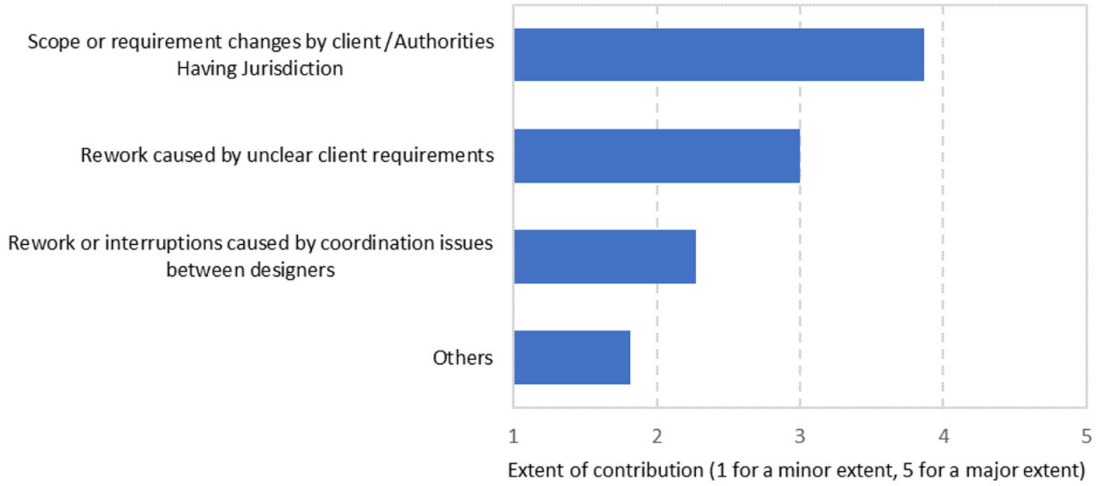

Figure 15. A/E's opinions on factors contributing to design schedule delays

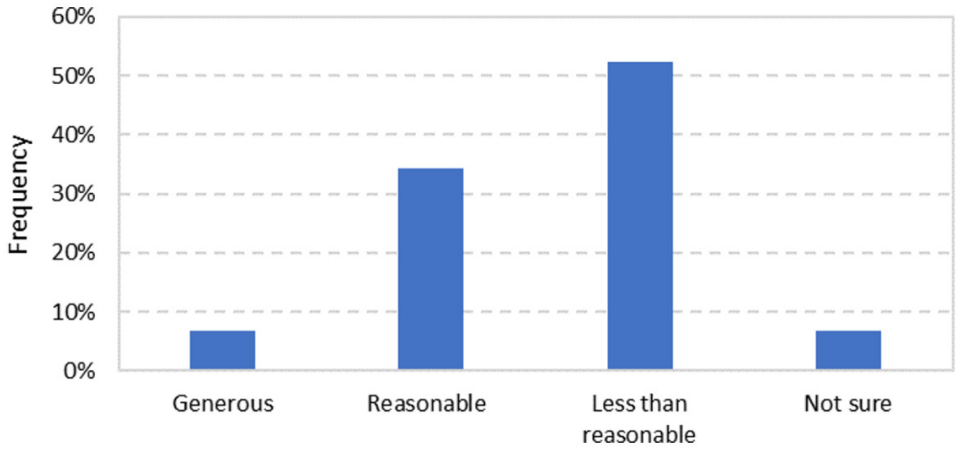

Figure 16. A/E's satisfaction with design fee

As for design fees, two questions were designed. One asks the A/E respondents whether they feel the design fee given to the project was less than reasonable, reasonable, or generous, whereas the other question asks whether they feel the given design fee was adequate to produce a quality design document. The two questions sound very similar, but there is a subtle difference. The difference helps us identify if there exists any discrepancy between the reality and the general expectation of the industry on the quality of documents.

Figure 16 shows that 52% of the A/E respondents thought the design fees were less than reasonable, whereas only 7% felt the design fee was generous. However, when asked whether the design fees were adequate to produce quality design documents, 58% of A/E respondents agreed that the design fees were sufficient and only 33% said otherwise (Figure 17). These slightly conflicting results seem to reveal a general sentiment of 'you get what you pay for' within the architecture and consulting business.

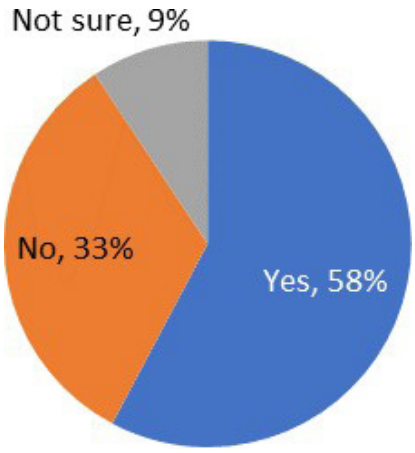

Figure 17. A/E's response on adequacy of the design fee to produce quality design documents

The extent of junior staff involvement in a design project may affect the QoD. Figure 18 shows that more than half of the A/E respondents answered that less than 25% of work was accomplished by junior staff who had fewer than five years of working experience in this field. Still, about 15% of A/E respondents responded that junior staff completed more than 50% of work.

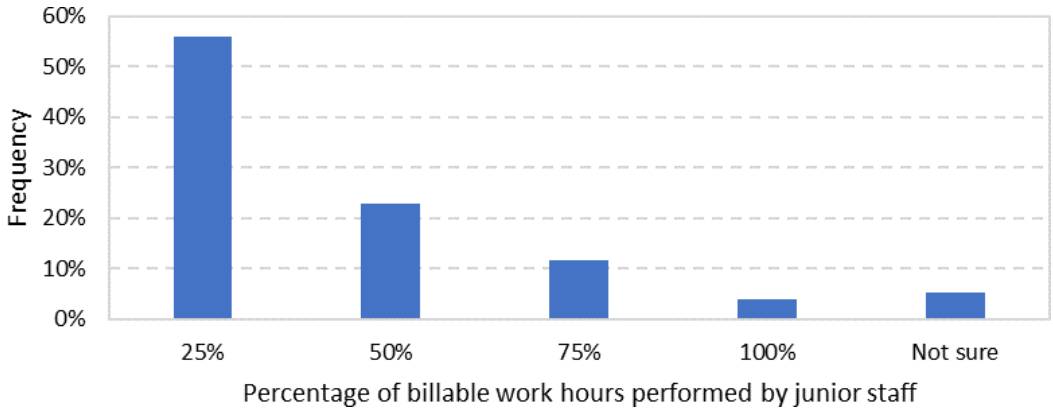

Figure 18. Percentage of billable work hours performed by junior staff

3.3.3. Factors Related to Both Owner and A/E

The preceding subsection presents the perceptions of A/E respondents on design schedule and design fee as well as the average actual performance of the design projects in terms of cost and schedule. To understand how market forces might have shaped the schedule and cost pressures toward design firms, questions were designed to probe how the design firms obtained a design contract (i.e., the contracting model) and which pricing model was adopted. In addition, two questions were asked to A/E respondents to rate the coordination and communication between the clients and design consultants, and the coordination amongst different design consultants.

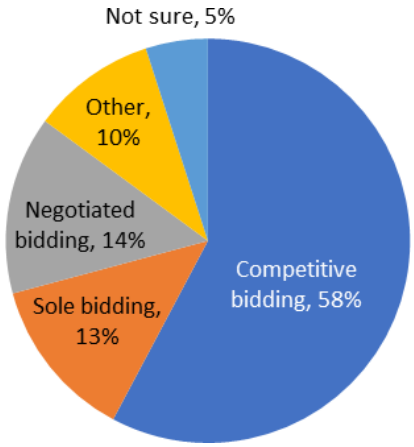

Figure 19. Contracting methods of design service projects

Figure 19 indicates that most design contracts are entered through competitive bidding. Figure 20 reveals that a fixed-price contract is the dominant pricing method currently being used in the Canadian construction industry.

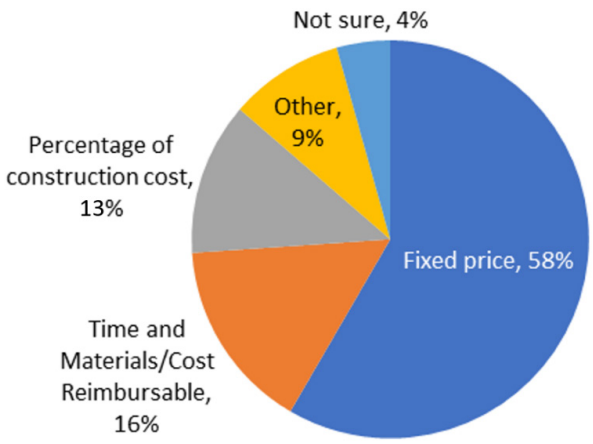

Figure 20. Pricing models of design service contracts

Collectively, cooperation, coordination, and communication (CCC) is another important factor that influences the quality of design. These include the CCC between design consultants and the client's consultants, as well as the CCC among different consultants within the design team.

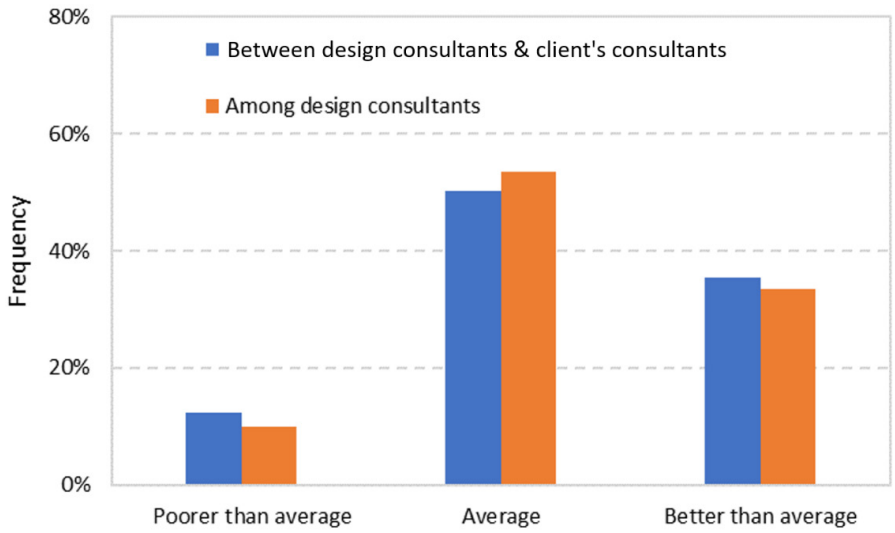

Figure 21. A/E's evaluation on the quality of CCC among consultants

A/E respondents were asked to evaluate the CCC between the client's consultants and design consultants, and the CCC amongst different design consultants within a design team. They were specifically asked to compare the CCC in the underlying project with other projects with similar types, size and complexity in the past. The responses are shown in Figure 21. The histograms of the two types of CCC do not show significant difference. Around 35% of the respondents claimed 'Better than Average' communication and coordination and only about 10% claimed 'Poorer than Average.' This result indicates an improvement of the CCC between the design consultants and client's consultants, and within the design team.

3.3.4. Discussions

The preceding results show the current state of the quality of RFPs in terms of the clarity and completeness of project scope and the accuracy of information provided in the RFPs, the contracting and pricing methods of design contracts, design time frame and design fees, and cooperation, coordination and communication (CCC) among consultants. But how would these factors affect the quality of documents (QoD)?

To answer this question, Figure 22 depicts an influence diagram starting from the owner's pre-project planning to the quality of design documents. The influence diagram includes the major factors considered in the survey. When applicable, either a green upward arrow or a red downward arrow is added beside every factor to represent its overall favourable or unfavourable state or change, depending on how the question was asked. For example, more respondents rated the clarity, completeness, and accuracy of the information described in the RFP, and the cooperation, coordination and communication (CCC) among the consultants as 'better than average' than 'poorer than average', whereas the rating for the owner-initiated scope change was biased toward 'more than average'. These conflicting results seem to suggest that the clarity and completeness of project scope described in the RFP may not be a good predictor for the number of client-initiated scope changes. Is this true? The following analyses try to shed some light on this.

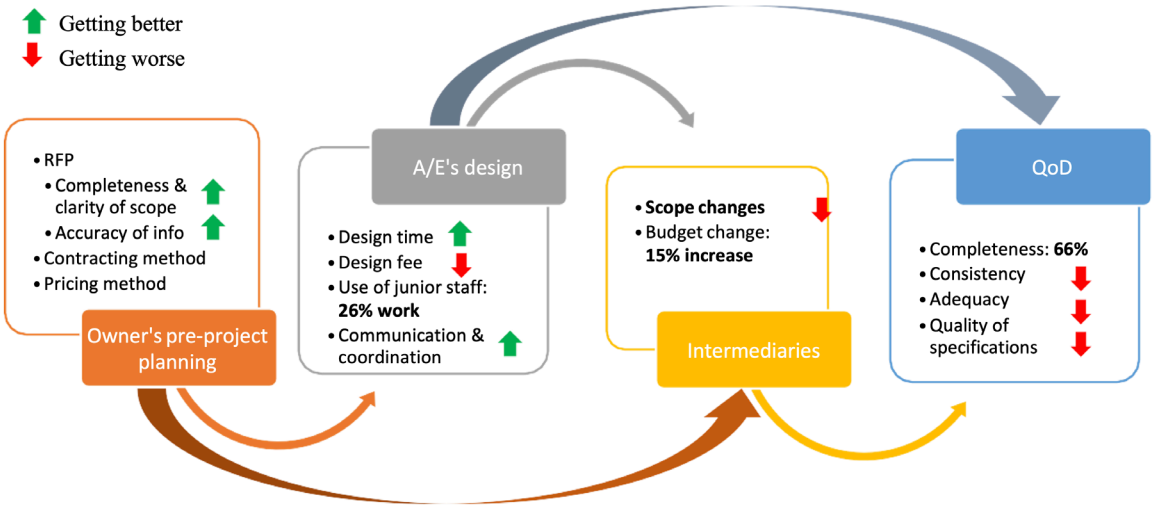

Figure 22. Influence diagram between the Owner's pre-project planning and the QoD

First of all, Figure 23 shows clearly that both the quality of the RFP and the CCC among consultants positively affect the client-initiated scope changes. In the figure, the x-axis represents respondents' ratings of 1) the clarity and completeness of the project scope described in the RFP, 2) the accuracy of the information provided to designers, 3) the CCC between design consultants and the client's consultants, and 4) the CCC among design consultants during the design stage. The first two measure the quality of the RFP, and the last two measure the quality of CCC. The y-axis is the likelihood of having 'more than average' client-initiated scope changes during the design stage. It is clear that all four factors have positive effects on scope changes. As the quality of the RFP improves, the client-initiated scope changes reduce and the CCC improves.

This analysis provides an interesting case in that the traditional cross-sectional analysis may not be reliable. By comparing the state of the quality of the RFP and the state of client-initiated scope changes, the traditional cross-sectional analysis would claim that these two have no correlation as one is getting better and the other getting worse. But our longitudinal analysis allows within-project comparison, which reduces drastically many unnecessary noises in the cross-sectional comparison.

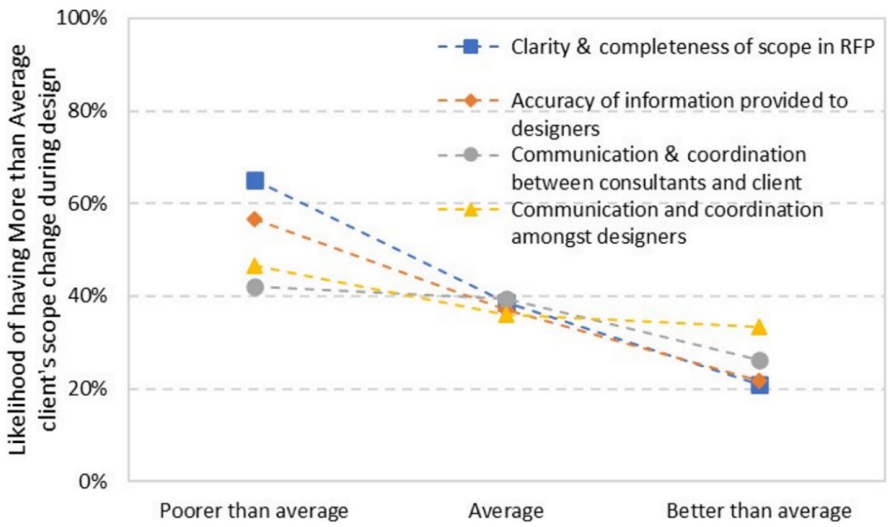

Figure 23. Client-initiated scope change vs. the quality of RFP and CCC among consultants during the design stage

Therefore, it would be highly desirable to perform a similar longitudinal analysis to identify the major factors for the QoD metrics presented in Subsection 3.1. Unfortunately, this is impossible because as explained before, the QoD metrics were evaluated by, and could be relatively objectively evaluated only by the GC and Subs respondents, whereas the questions of the contributing factors were posed to the Owner and A/E respondents. Since those respondents did not participate in the same project, this kind of direct correlation is impossible. This discrepancy can be addressed through interviews and detailed project case studies.

Before this online survey, we studied three projects in detail from the same public owner as a pilot study. All the project managers from the three parties (owners, consultants, and contractors) were interviewed. Among the three projects, two of them happened to be managed by the same project manager from the owner side. For the two projects, one was completed with a cost decrease of 2%, and another with a 16% increase. The main reason for the cost increase, according to the project manager, was the scope change and poor quality of the pre-project planning, because the project with decreased cost had a conceptual design while the other didn't. The project manager strongly recommended having a conceptual design with a more accurate budget in the RFP stage. Interestingly, the third project with less than 1% cost increase actually did not have a conceptual design. However, the owner provided a detailed asset condition assessment report and a thorough environmental assessment as well as an accurate initial budget furnished by an engineering consultant.

Therefore, pre-project planning is a multi-faceted task. As the World War II leader and US President Dwight D. Eisenhower nicely put it, "Plans are useless, but planning is everything." The quality of the pre-project planning is tested and vindicated by the certainty of the scope of work exhibits in the subsequent design and construction activities. As brownfield projects are becoming a greater proportion of the current construction industry, investigation of existing conditions seems to be more paramount in the upfront planning stage. If existing condition investigation is deferred to the design stage or even the pre-construction stage, excessive scope changes are inevitable. This, along with other vague statements about functional and technical specifications in the RFP, creates a lot of uncertainties for the design team. When this is further aggravated with the compressing design time frame and low-fee-based selection of designers, poor design documents seem to be inevitable.

3.4. Impact of the QoD on Project Performance

The survey included questions to probe the effects of the QoD on project performance in terms of number and size of modifications, bidding efficiency, construction schedule performance, construction cost performance, and construction productivity. In the following, the impacts of the QoD on each of the project performance metrics are discussed separately. In each subsection, the states of the performance metrics gauged directly from the review respondents are presented at first, followed by a correlation analysis to determine the impact of the QoD metrics on the specific performance metric.

3.4.1. Design Modifications and RFIs

In this survey, modifications refer to addenda during bidding, and change orders and change directives during construction. In addition, Requests for Information (RFIs) during bidding and construction stages are also discussed together in the category of modifications. For simplicity of presentation, we use change orders to include both change orders and change directives, even though these two terms have completely different contractual implications in contract administration.

Figure 24 shows the aggregated responses of GCs and Subs on the number of addenda, RFIs, and change orders. Compared with projects of similar dollar value, type, and complexity in the past, the relative number of addenda during the bidding stage does not show much change. However, more than 50% of the respondents categorized the numbers of RFIs and change orders during the construction stage as 'More than Average,' suggesting that the QoD is causing even more RFIs and change orders or directives than before.

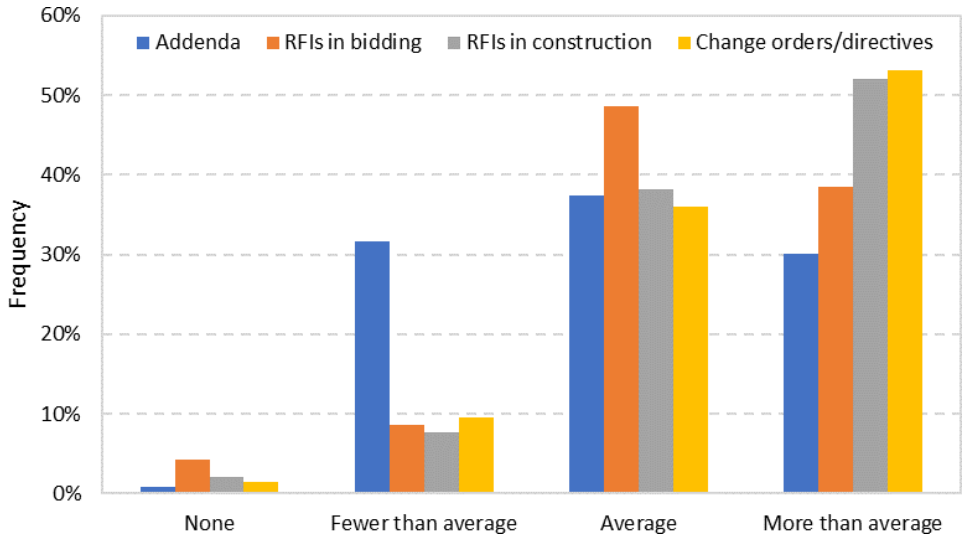

Figure 24. GC's and Subs' response about the number of modifications comparing with similar projects

To investigate the impact of the QoD on the frequency of modifications during bidding and construction, we plot the frequency of having 'More than Average' modifications against 1) document consistency across various design disciplines, and 2) document adequacy for shop drawings. Both graphs in Figure 25 show a clear declining trend, except for the number of RFIs in construction and the number of change orders when the level of coordination is 'Better than Average', but that is primarily because of the small sample size (only two) for the 'Better than Average' category.

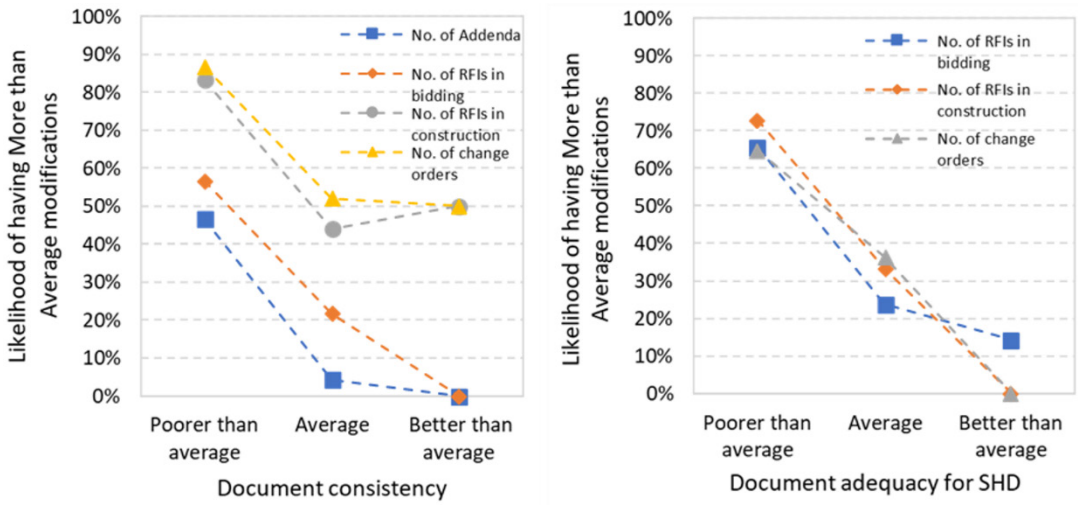

Figure 25. Impact of a) document consistency and b) document adequacy for SHD on design modifications

3.4.2. Bidding

First of all, the overall state of bidding performance in the industry needs to be understood. Based on the responses of Owners and GCs, Figure 26 shows that 43% of the surveyed projects experienced bid cancellation or extension. Figure 27 indicates the top three reasons for bid cancellation or extension are project scope changes, incomplete bid documents, and late issuance of addenda.

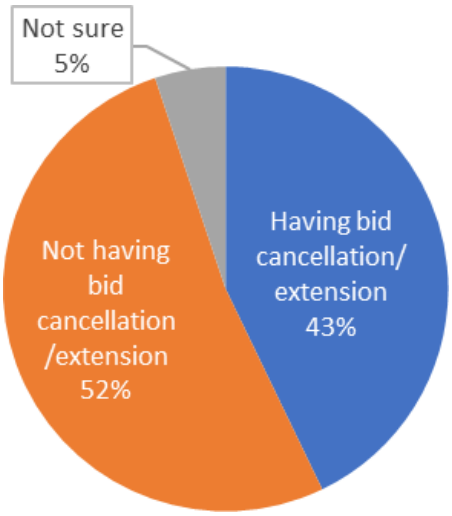

Figure 26. Projects experiencing bid cancellation or extension (Owners and GCs)

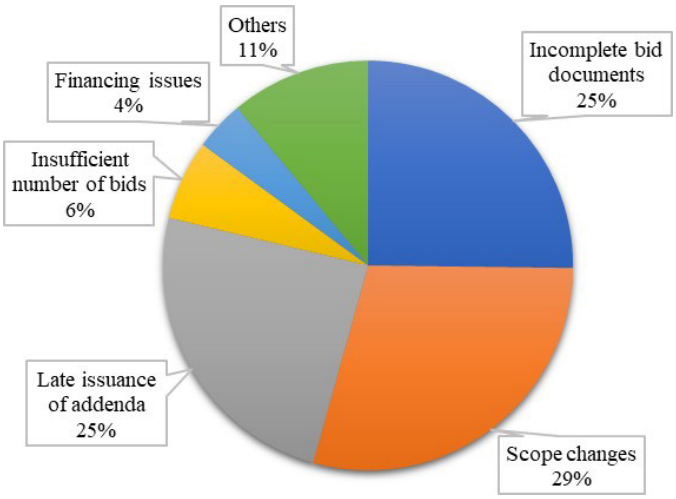

Figure 27. Reasons for bid cancellations or extensions (Owners and GCs)

A further correlation analysis is performed to investigate the relationship between the likelihood of bid cancellation or extension and the GC's evaluation of document consistency across various design disciplines. As Figure 28 shows, when the level of document consistency deteriorates from 'Average' to 'Poorer than Average,' the likelihood of bid cancellation or extension increases from 38% to 62%. On the other hand, when the document consistency is improved from average to better than average, the likelihood of bid cancellation or extension surprisingly increases to 100%. This anomaly is caused by the small sample size (only two samples) for the 'Better than Average' category, and therefore, should not be trusted.

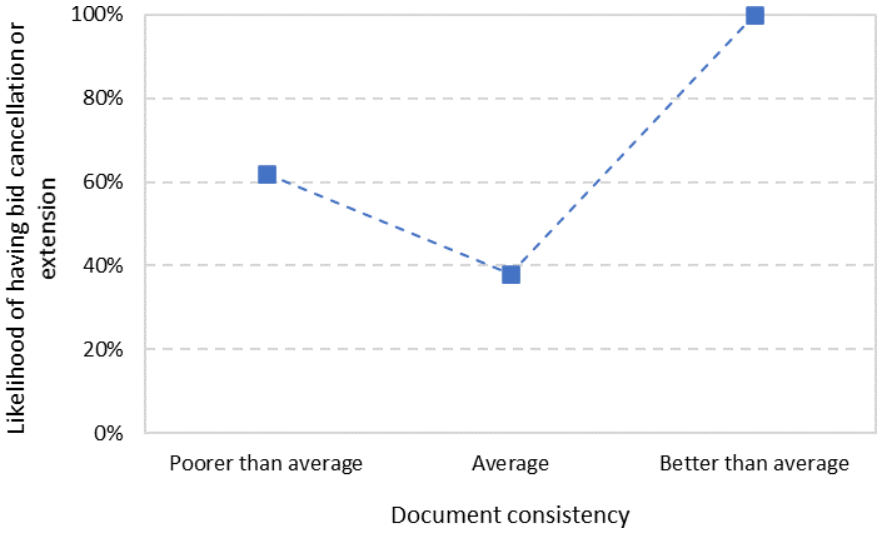

Figure 28. Impact of document consistency on bid cancellation or extension (GC)

Relating the extent of addenda and RFIs to the likelihood of bid cancellation or extension, a more sophisticated trend analysis can be performed, with the results shown in Figure 29. Similar trends are observed for the number of addenda and the number of RFIs: the more addenda and RFIs are issued, the more likely the bid will be cancelled or extended. Similarly, the size of addenda also has a positive correlation with the potential of bid cancellation or extension. Overall, when the number or size of addenda, or the number of RFIs moves from 'Average' to 'Fewer than Average', the likelihood of bid cancellation or extension can drop from the average level of 52% by about a half to the level of 25% to 30%. Besides, the contractors' level of satisfaction with the design team's response to RFIs also affects bidding success. When the answers are satisfactory, the likelihood of bid cancellation or extension is shown to reduce by almost a half compared to the situations with average or unsatisfactory responses. Still, the trend along the RFI satisfactory from 'Neutral' to 'Unsatisfied' is counter-intuitive, because the data points are slim and therefore, should not be trusted.

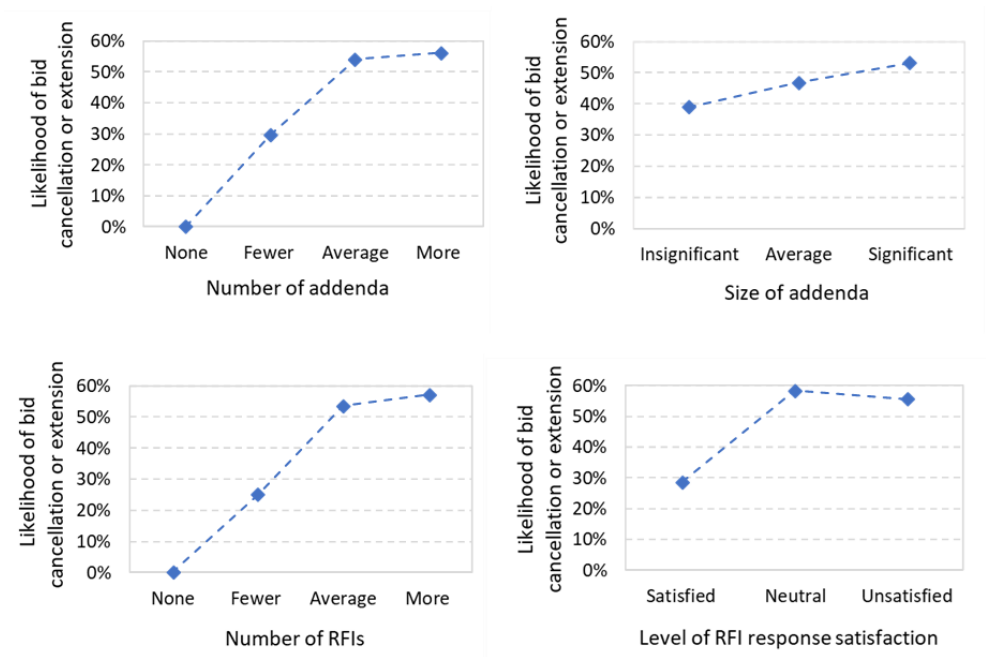

Figure 29. Impacts of addenda and RFIs on bid cancellation or extension (GC)

3.4.3. Construction Schedule Performance

Regarding the construction schedule performance, the Owner, GC and Subs respondents were first asked whether the project was delivered on time, behind schedule, or ahead of schedule, and then followed with a question about the exact extent if it was not delivered on time.

Figure 30 shows the overall distribution of construction schedule performance regarding whether the project is completed on time, ahead of schedule, or behind schedule. According to the Owner respondents, 63% of the surveyed projects were completed behind schedule. This percentage varies from 59% for GC respondents to 72% for Subs respondents.

The statistical distribution of the construction schedule delay in the percentage of the initially planned schedule in the construction contract is shown in Figure 31. One may note that the relative frequencies of zero delay in Figure 31 are higher than the relative frequencies of 'on-time' delivery. This is because of some missing data – some survey participants reported that the project was delivered behind schedule, but did not provide either the planned construction duration or the exact amount of schedule delay. The overall average schedule delay is estimated as 36% of the planned schedule, although the estimates of the three categories of respondents differ slightly as shown in Table 2. This estimate is very close to the result obtained by Zhang, Chen, and Yuan (2020) for large public infrastructure projects.

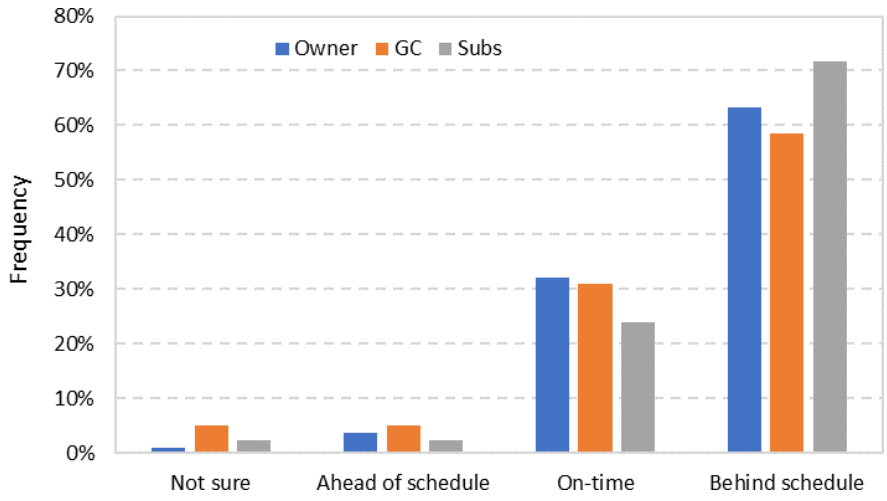

Figure 30. Likelihood of involving construction schedule delay

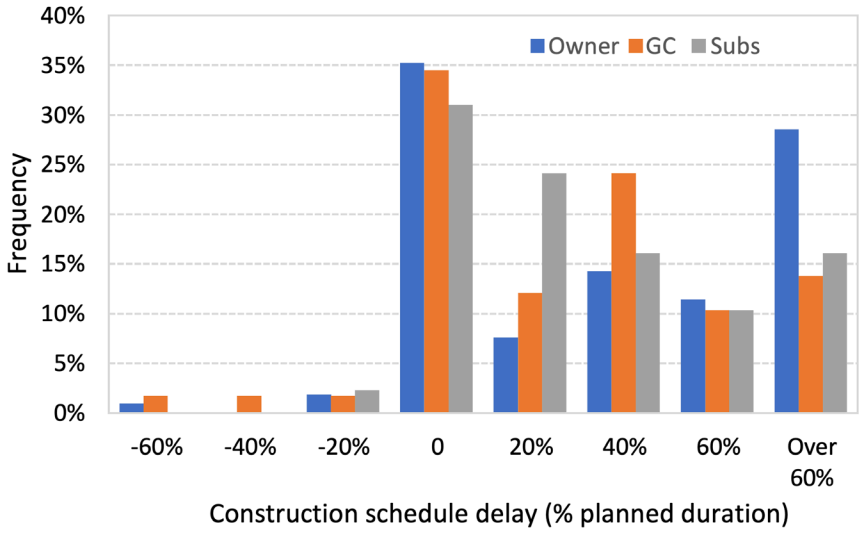

Figure 31. Distribution of the extent of construction schedule delays

Table 2. Average schedule delays (unit: % planned construction duration)

Respondents	Owner	GC	Subs	Overall
Average	41%	26%	38%	36%

A further question was asked to the Owner, GC, and Subs groups to rate the degree of contribution of a pre-selected list of major influencing factors for schedule delay, 1 for minor contribution, and 5 for significant contribution. Respondents were also allowed to input other factors that they consider more important. The average score of each factor is calculated. The results are shown in Figure 32, with the top graph for the Owner and GC respondents, and the bottom graph for the Subs respondents. On average, design issues are rated the highest in all three groups

Figure 32. Factors contributing to construction schedule delays (Top: Owners and GC; bottom: Subs)

In addition to the direct questionnaire, correlation analyses were performed to examine the impacts of various QoD-related metrics on the construction schedule performance (Figure 33). As the document consistency deteriorates from 'Average' to 'Poorer than Average', the average schedule delay increases from about 10% planned duration to 38%. By contrast, as the document adequacy for SHD deteriorates from 'Average' to 'Poorer than Average', the average schedule delay increases from about 25% planned duration to 58%. In relative terms, it seems that the document consistency plays a more important role than the adequacy for SHD does. This is understandable because the document consistency measures the QoD at a macro level while the document adequacy for SHD does at a micro level. Once again, since there are only two samples behind the values of 'Better than Average', the trend from 'Average' to 'Better than Average' is not trustable.

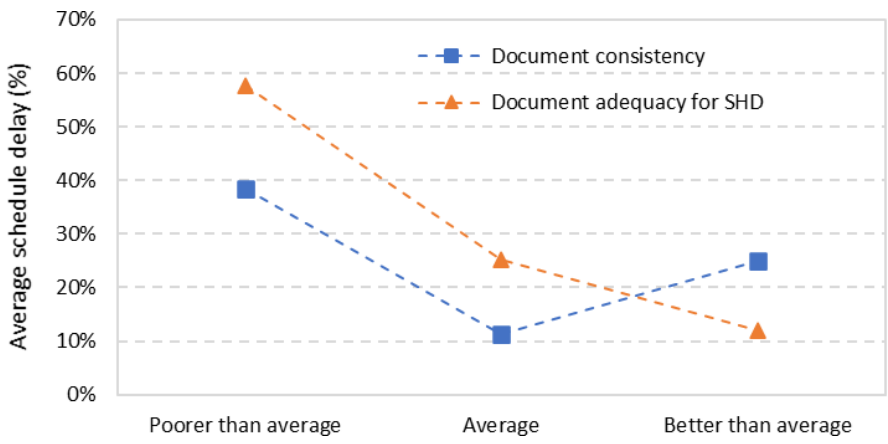

Figure 33. Impact of the QoD on average construction schedule delay (GC)

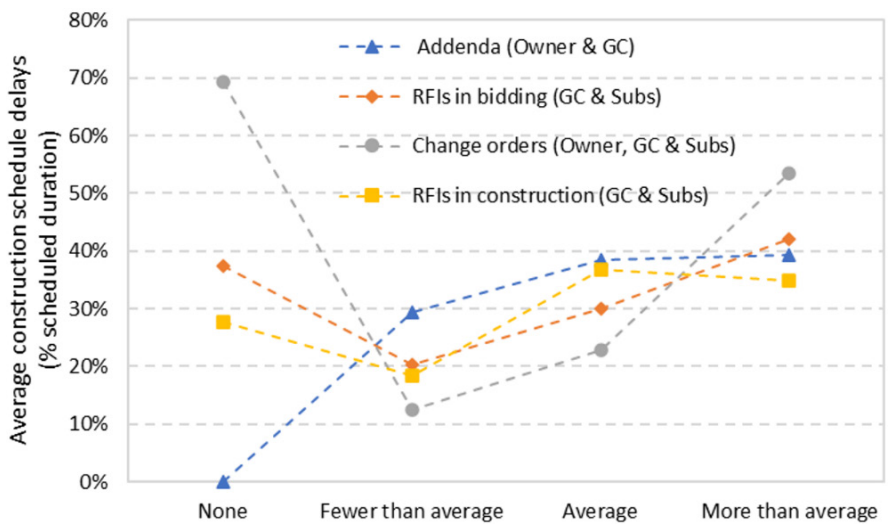

Figure 34. Impact of design modifications on construction schedule performance

Next, the correlation between design modifications and the average construction schedule delay was studied. As shown in Figure 34, as the number of addenda, RFIs, or change orders increases, the average construction schedule delay also increases in general, subject to some statistical variation between 'None' and 'Fewer than Average' due to the small sample size in the 'None' group.

3.4.4. Construction Cost Performance

The investigation for construction cost performance is very similar to that of the construction schedule. First of all, as shown in Figure 35, 72% to 92% of the respondents stated that their projects suffered from a cost overrun. In terms of the extent of cost overruns, the distribution of the three respondent groups as shown in Figure 36 vary slightly. Overall, when cost overruns occur, 80-90% of the projects suffer from a cost overrun within 30%. Still, about 3% of projects may have cost overruns greater than 50% of the original contractual value.

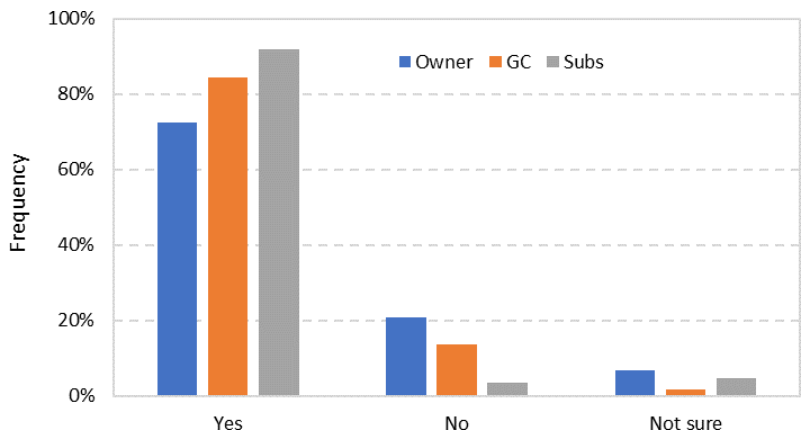

Figure 35. Likelihood of cost overruns in the construction stage

With a small variation among the Owner, GC and Subs respondents, the overall average construction cost overrun is estimated to be 22% of the original contract value, as shown in Table 3.

Table 3. Average cost overruns in construction (unit: % original construction contract value)

Respondents	Owner	GC	Subs	Overall
Average	20%	24%	24%	22%

Similar to the study for construction schedule delay presented previously, the survey respondents were asked to identify the key influencing factors for construction cost overruns as well. Figure 37 shows that design issues are rated with the highest average score across all three respondent groups, indicating that overall, design issues are perceived by the industry as the most significant contributor.

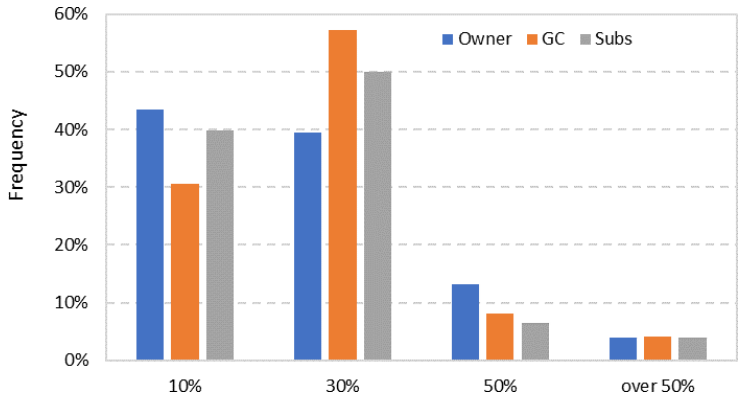

Figure 36. The extent of cost overruns in the construction stage

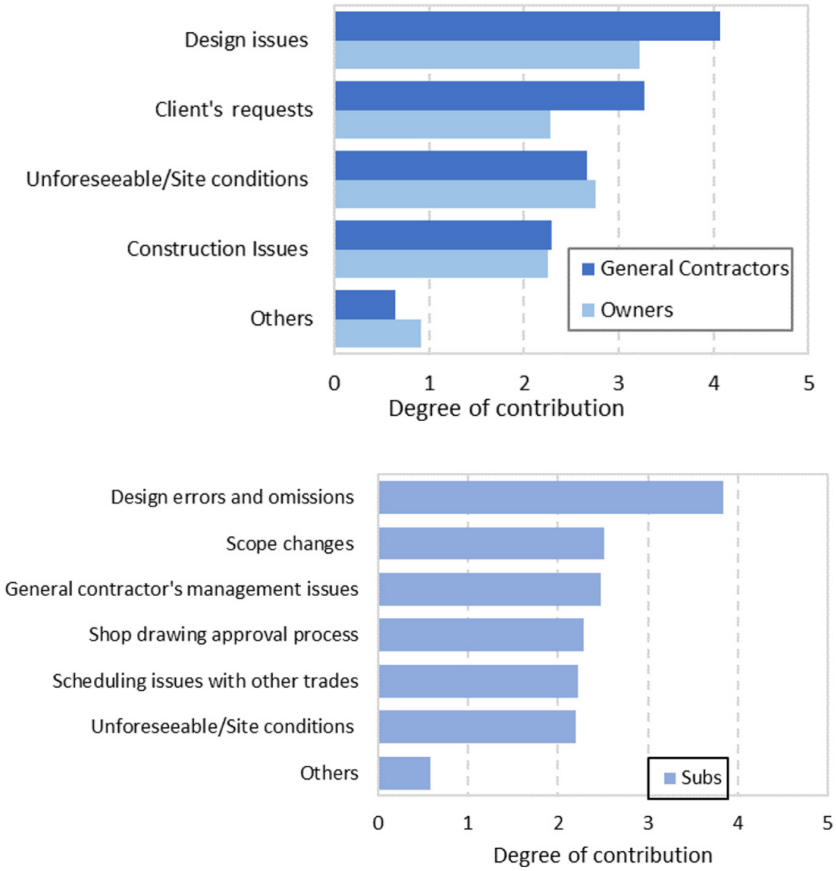

Figure 37. Factors contributing to construction cost increase (Top: Owners & GCs; bottom: Subs)

In the following graph, a similar approach is taken to determine the impact of the QoD-related indicators on the construction cost performance, as it was done for construction schedule performance above. First, Figure 38 shows how document consistency and document adequacy for SHD affect the average cost overruns. Similar to the observation for schedule performance, document consistency exerts a greater influence on the cost overruns as well. As the document consistency deteriorates, the average cost increase changes from 0 at 'Better than Average', to 19% at 'Average', and then to 29% at 'Poorer than Average'. The document adequacy for SHD seems to be a much less sensitive predictor for cost overruns as the average overrun increases from 15% almost linearly to 27%.

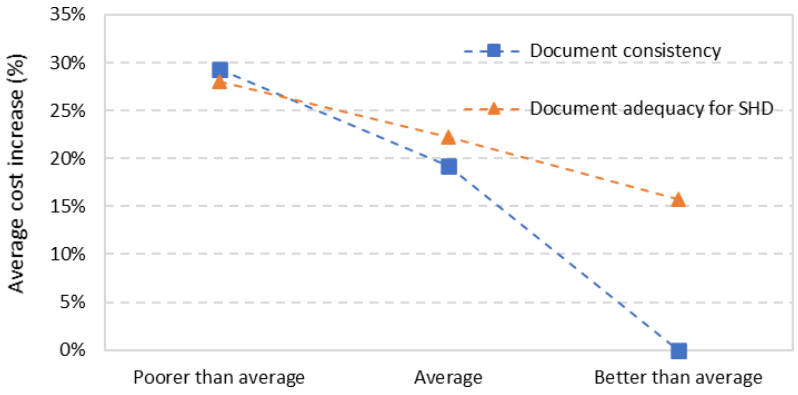

Figure 38. Impact of the QoD on average construction schedule delay (GC)

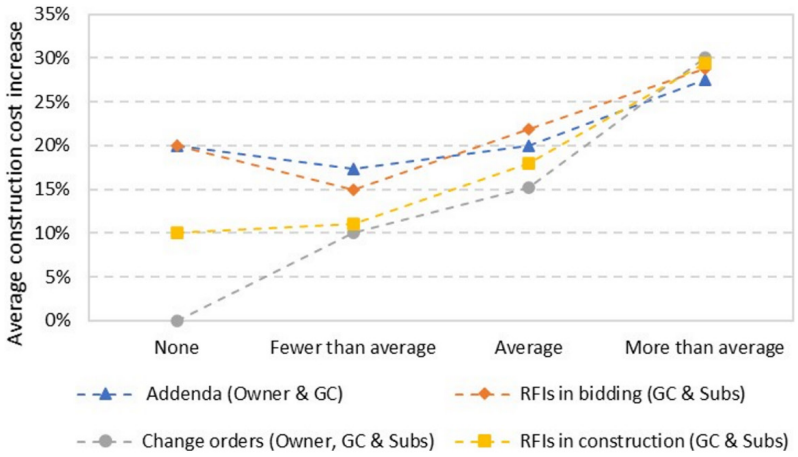

Figure 39. Impact of design modifications on construction cost performance

The relationships between design modifications and the average cost overruns are displayed in Figure 39. It is clear that except for some statistical variation due to the small sample size (under six samples) in the 'None' category, clear and consistent positive correlations are obtained between the relative number of design modifications and the extent of cost overruns. In addition, among the four types of modifications, change order seems to be the most sensitive predictor for the average cost overruns.

3.4.5. Efficiency of the Use of Resources

Productivity in general is defined as the ratio of output per input. As for construction productivity, a commonly used measure is the labour productivity, which is defined as the units of work placed or produced per man-hour. In economic models, a commonly used definition for total factor productivity is the total output per input of labour, materials, equipment, energy, and capital (Shehata and El-Gohary 2011). This study defines the construction productivity as the efficiency in the use of resources (time, money, and materials) for the intended purpose during construction. Figure 40 shows that, in comparison with other projects of similar dollar value, type and complexity in the past, 45% of GC respondents and 49% of Subs respondents stated that inefficient use of resources caused by design issues was 'Higher than Average.' Only 8% to 15% of respondents rated it as 'Lower than Average' for their projects. This indicates that inefficient use of resources caused by design issues is a significant problem for the current construction industry.

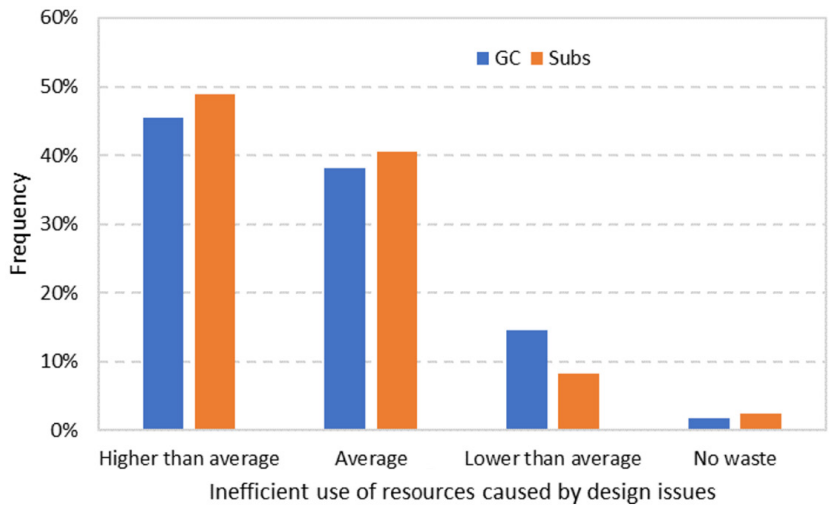

Figure 40. Inefficient use of resources caused by design issues (GC & Subs)

Does the QoD affect the efficiency of resources? To answer this question, Figure 41 plots the likelihood of having 'Higher than Average' inefficient use of resources against document consistency and document adequacy for SHD. Clearly, as document consistency and adequacy for SHD improves, the likelihood of inefficient use of resources declines steadily from about 70% to 0%.

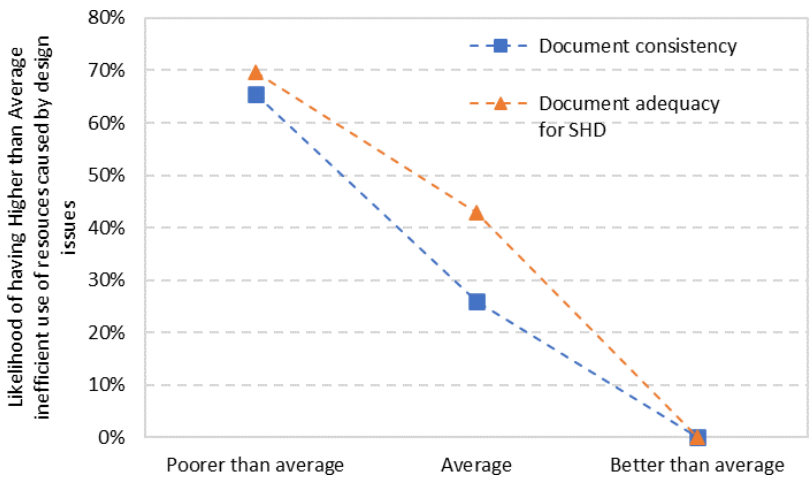

Figure 41. Impact of QoD on inefficient use of resources

Regarding the impact of design modifications during bidding and construction, Figure 42 shows an overall increasing trend for addenda and change orders or directives. The trend for the RFIs in bidding and RFIs in construction shows some nonmonotonicity, which can only be explained by statistical error.

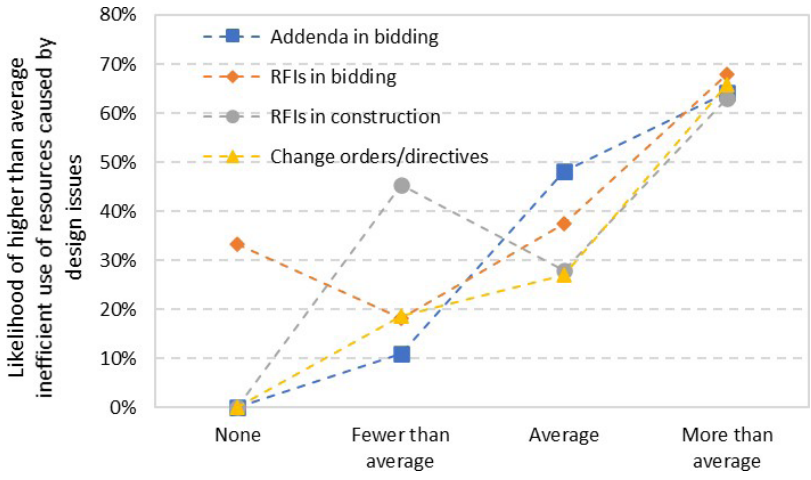

Figure 42. Impact of design modifications on inefficient use of resources

3.4.6. Discussions

This subsection focuses on the investigation of the states of various project performance metrics for the bidding and construction stages, and the impacts of the QoD on these metrics. For the bidding stage, the primary performance measure used is the likelihood of bid cancellation or extension.

Although the consequences of bid cancellation and the consequences of bid extension are not the same, the survey took a coarse-grained approach and treated both as undesirable events in bidding. In addition, the survey also took addenda and RFIs in bidding as two intermediaries that would directly affect the potential of bid cancellation or extension. The survey found a concerningly high likelihood (43%) of bid cancellation or extension. This means that for every seven tenders, three will be either extended or cancelled. In addition, the correlation analysis found that the document consistency can significantly affect the success of the bid. As the document consistency deteriorates from 'Average' to 'Poorer than Average', the likelihood of bid cancellation or extension increases from 38% to 62%. Similar trends were found for the relationships between the two intermediaries and the likelihood of bid failure. Moreover, the correlation analyses have also confirmed that the QoD has a negative impact on the number and extent of addenda and RFIs in bidding. A snapshot of the impact chain from the QoD to the bidding performance is illustrated in Figure 43.

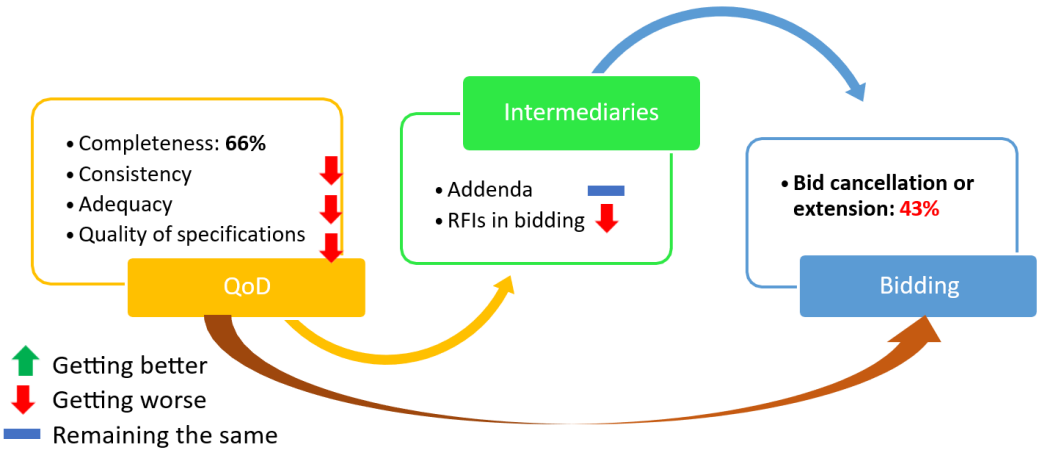

Figure 43. Influence diagram from the QoD to bidding performance

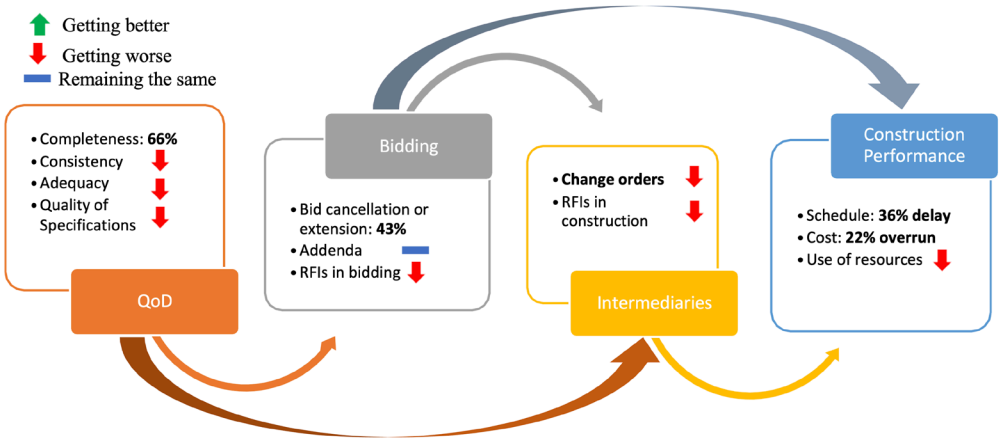

Figure 44. Influence diagram from the QoD to construction project performance

As for the construction project performance during the construction stage, the study took schedule, cost, and use of resources as the three key performance measures. In addition, change orders and RFIs in construction were taken as the intermediaries that connect the QoD and project performance. The influence diagram is shown in Figure 44.

The study found that currently a typical construction project may suffer from a schedule delay of 36% of planned duration and a cost overrun of 22% of contractual value. Compared with past similar projects, 45% to 49% of current projects are wasting more resources in terms of time, money, and materials due to design issues.

The correlation analyses confirmed that the document consistency and adequacy both have a negative effect on all three project performance indicators. As the document consistency (adequacy for SHD) deteriorates from 'Average' to 'Poorer than Average', the average schedule delay increases by about 3.8 (2.3) times, the average cost overrun increases by about 1.5 (1.2) times, and the likelihood of having 'Higher than Average' waste of resources increases by about 2.5 (1.7) times. These results all suggest that the document consistency across various design disciplines plays a more important role than the document adequacy for SHD, which was also corroborated with the findings of the direct survey questions. In addition, positive correlation relations have been observed between the frequency of design modifications (i.e., addenda and RFIs in bidding, and change orders and RFIs in construction) and the three key performance indicators.

3.5. The Impact of Pre-Project Planning Efforts on Construction Performance

Section 3.3. presents the results for how the quality of the owner's pre-project planning would affect the QoD. Section 3.4. presents more results on how the QoD or QoD-related documents would affect construction project performance. This section offers additional analyses of some possible 'nonlinear' effects that have not been covered in the preceding sections. These include the relationships between 1) the owner's construction contingency and construction cost overrun, 2) the budget change in design and construction performance, and 3) client-initiated scope change and extra service time spent by the A/E during construction.

3.5.1. Relation between Owner's Construction Contingency and Cost Overrun

In a construction project, the owner and the contractors often determine and set aside their own construction contingencies. While contractor contingencies are often built into their bid estimates, the owner's contingency is reserved for additional 'unknown' or 'unpredictable' work. An estimate of the commonly used contingency size would help us further understand the implication of the cost overruns observed above.

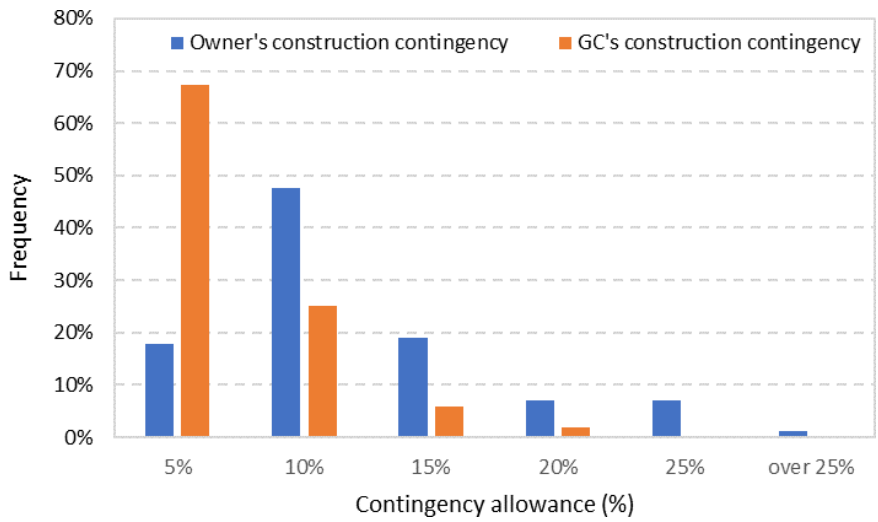

Figure 45. Owner's and GC's construction contingency

Figure 45 confirms the general view that owners usually take a greater contingency size than GCs do. According to the survey, 66% of owners only allowed less than 10% construction contingency, which is only half of the actual average cost increase in their budget. By contrast, 67% of GCs only set less than 5% construction contingency for the risk they carried, which is only one-fifth of the total average cost overruns reported by the GC respondents. It must be recognized that the GC's construction contingency is only for the risks that the GC assumes (e.g., rework caused by the contractor's mistake). It does not include the owner's scope change.

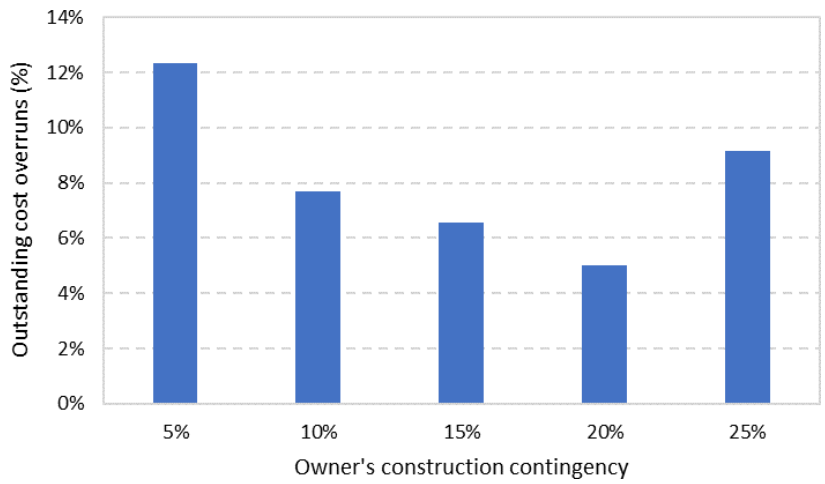

Figure 46. The difference between the average construction cost overruns and the Owner's construction contingency

The outstanding or net cost overrun is defined by the raw cost overrun minus the owner's construction contingency. When the net cost overrun is positive, it means that the cost overrun is not fully covered by the owner's contingency. Figure 46 plots the outstanding cost overruns versus the owner's construction contingency.

Overall, the contingency size does not reflect the associated risks; in other words, the owners have consistently underestimated the cost risks in construction. The trend shown in the figure is interesting: the higher an owner's construction contingency, the smaller the outstanding cost overruns are until the contingency is greater than 20%, where the trend is contaminated by the statistical noise due to the small sample size.

The gap between the construction cost increase and the owner's construction contingency indicates that owners underestimated the cost-related construction risks. Owners are recommended to improve their risk management.

3.5.2. Impact of Budget Change on Project Performance

In this subsection, the degree of budget change during the design development is used as another proxy to measure the quality of the owner's pre-project planning. It is assumed that zero budget change signifies a better quality of pre-project planning. In contrast, either a budget cut or creep would suggest that something had been missed during the planning stage, and must be addressed in the design stage, causing budget change. Note that this part of the analysis was based solely on the survey results provided by the Owner group of respondents (109 responses). They were the only entity having access to the budget information. The potential impact considered here includes the incidences of bidding cancellation or extension, having a 'More than Average' number of addenda, having a 'More than Average' number of change orders/directives, construction schedule delays, and construction cost overruns, as well as the average extent of construction cost overruns.

Figure 47 shows the correlation between the budget change during the design stage and the likelihoods or incidences of bidding cancellation or extension, of having a 'More than Average' number of addenda, and of having a 'More than Average' number of change orders/directives. A distinct V-shape can be observed from the curves except for the change orders/directives due to the small sample variation at the 'Budget Decrease' category (refer to Figure 12). Therefore, the budget change (no matter an increase or decrease) would impact the number of addenda and bid efficiency. In other words, it has a negative impact on the design and bidding. On the other hand, the budget increase seems to have an even worse effect than the budget decrease.

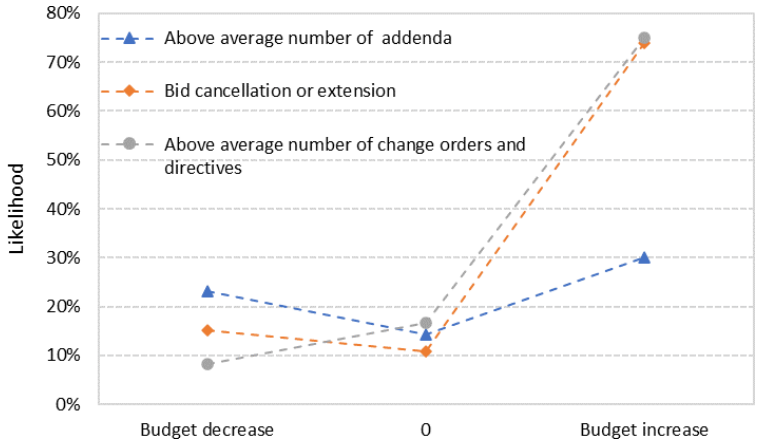

Figure 47. The impact of budget change in design on design modifications

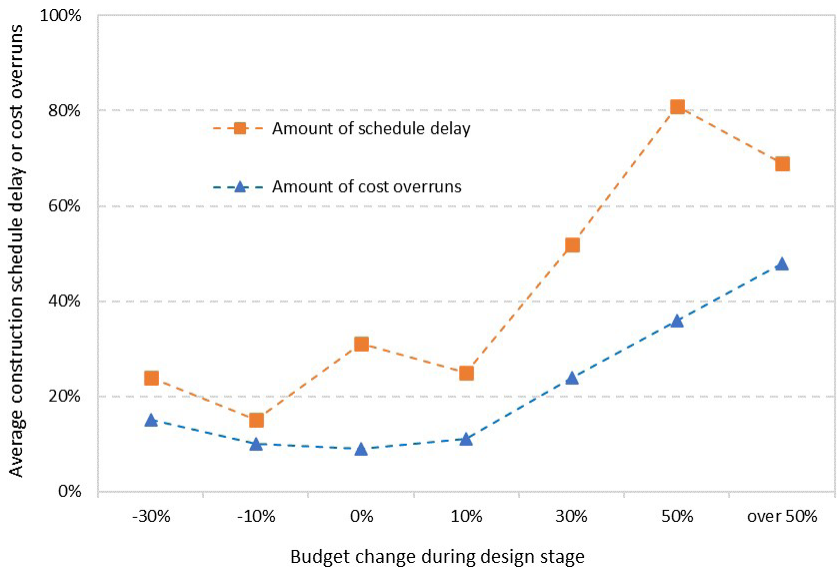

Figure 48. Correlation between budget change during the design stage and the schedule delay and cost overruns in the construction stage

Figure 48 shows the correlation between the budget change and the average schedule delay as well as the average cost overruns. Interestingly, the average cost overruns curve is similar but in a U-shape. As for the average schedule delay, more statistical variations are observed between the budget decrease (negative) groups and no budget change (0) group due to the much smaller sample size; nevertheless, the increasing trend in the budget increase side is clear and consistent. This U-shape reveals an interesting phenomenon. On the one hand, a budget increase in the design stage does not eliminate or decrease the potential of further cost increase in the construction as one may wish, which shows that the danger of poor pre-project planning is far reaching as it can creep into not only the design stage, but also the construction stage. On the other hand, a budget decrease in design seems to invite a 'compensation' in construction so that the final project cost gets close to the original budget the owner set. Both sides highlight the importance of pre-project planning.

3.5.3. Impact on Extra Service Hours Spent by Consultants during Construction Stage

This subsection deals with the relationship between the level of owner-initiated scope change during the design stage and the consultant's extra service hours during the construction stage. For this reason, we need to understand the overall status of extra service hours that consultants spent during construction at first. A survey question was asked to consultants regarding whether they spent more hours during the construction stage than initially planned in their fee proposal, and if yes, this was followed by two additional questions probing the extent of and reasons for the extra hours.

Figure 49 shows that 69% of the A/E respondents spent more service hours than originally planned. On average, the consultants need to take 30% more service hours than initially planned. The extra time spent during construction can be considered as one of the reasons that the majority of consultants (52%) claim the design fee paid is less than reasonable. It might also explain why most designers think the design fee is less than reasonable but adequate to produce quality design documents.

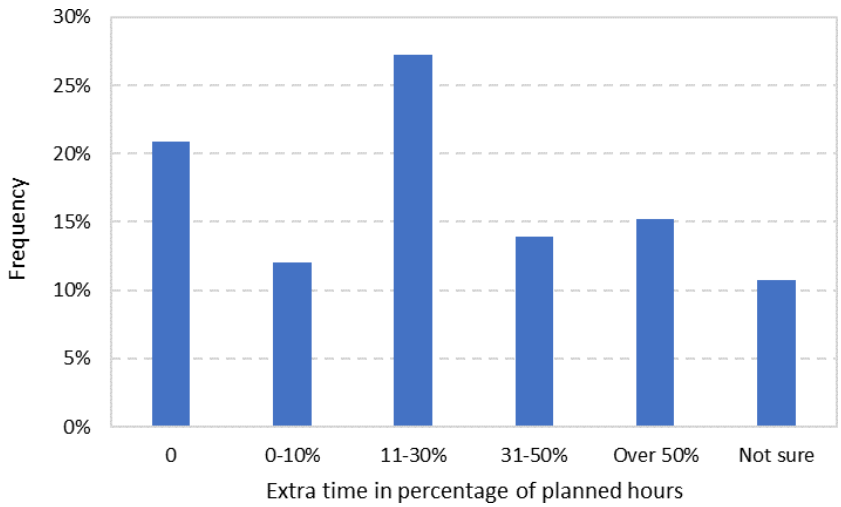

Figure 49. The extent of extra time consultants spent during construction

The A/E respondents were asked to rate a few potential reasons for the unplanned service time. The results are shown in Figure 50 in decreasing order of the respondent rate. The top three causes are 1) construction issues beyond the consultant's control, 2) the scope change during construction, and 3) requests for information. Therefore, the uncertain existing conditions and scope change during construction influence not only the GC's project performance but also the consultant's service time. The excessive time spent on handling requests for information shows that there possibly is an issue with design errors and omissions in the current design documents in general. While the first two causes can be improved by an owner's investment in pre-project planning and design, the RFIs can be reduced through better design services.

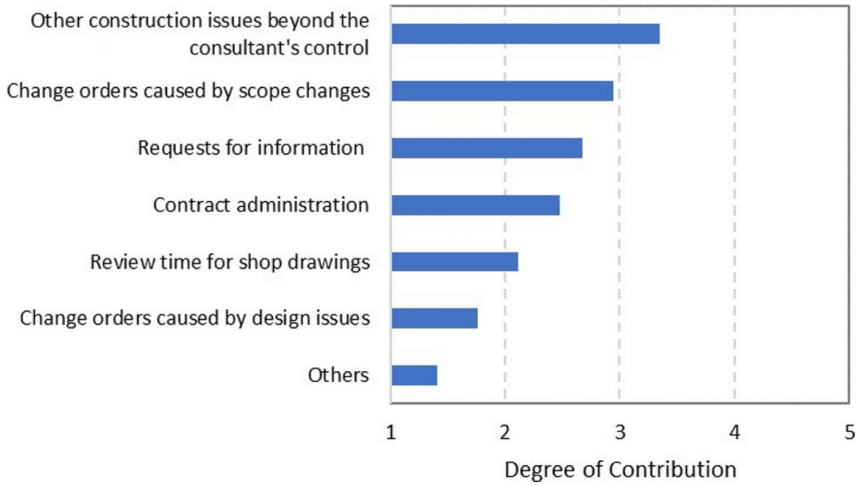

Figure 50. A/E's ratings on the potential factors for extra service time spent during construction

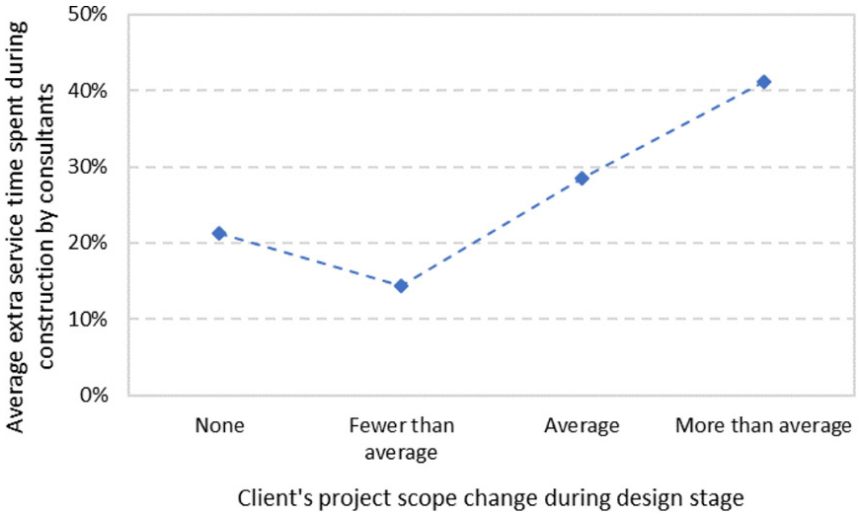

Figure 51. Relation between client-initiated scope change in the design stage and extra service time spent by consultant during construction

To benchmark against the direct and yet relatively subjective rating, a further correlation analysis was performed between the client's scope change in design stage and the consultant's extra service time spent in the construction stage. As shown in Figure 51, at an average level of scope change, the extra service time is around 30% of the originally planned time. When there is a more than average scope change during the design stage, consultants will spend about 40% of extra service time, on average, during construction. Again, the variation at the 'None' category might result from the small sample size of four samples.

3.6. Recommendations

The third and last part of the survey included three questions, asking respondents to identify and rank three recommendations from a pre-selected list of potential recommendations, which were gleaned from our previous literature review and pilot project study. The three questions were related to how to improve pre-project planning (Figure 52), the quality of design documents (Figure 53), and construction productivity (Figure 54), respectively. The Owner group was asked to answer all three questions, whereas the A/E group answered the QoD question, and the GC and Subs group answered the construction productivity question. All figures are presented in decreasing order on the percentage of the first recommendations. Still, the breakdown of the percentage of response for all three recommendations is also given in an accumulative manner.

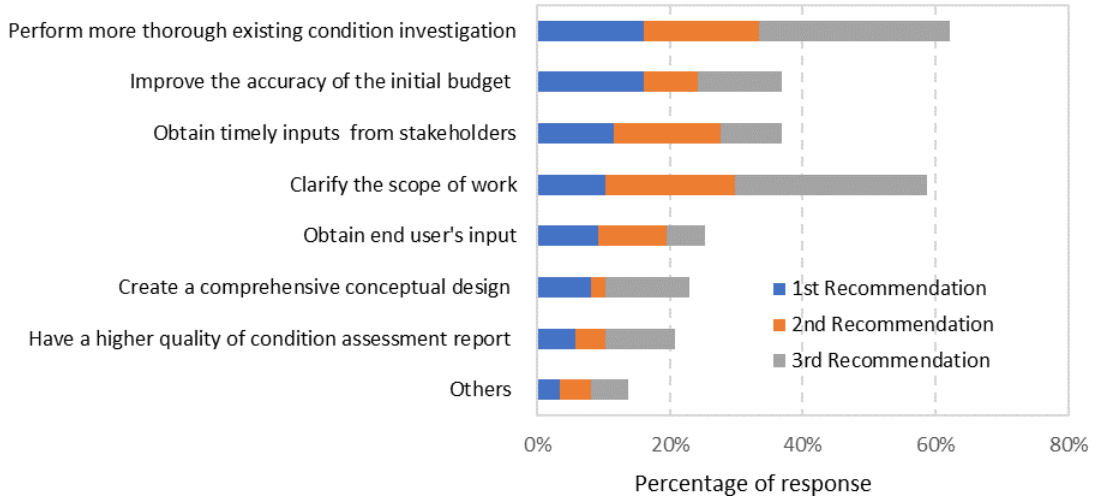

Figure 52. Recommendations for improving pre-project planning by Owner respondents

Figure 52 shows that the first recommendation varies significantly regarding the pre-project planning, with the most significant response rate ('perform more thorough existing condition investigation') lower than 20%. However, about 60% of Owner respondents agreed that the existing condition and scope of work are important issues. The next two recommendations worth highlighting are the accuracy of initial budget estimation and timely inputs from stakeholders in the planning stage.

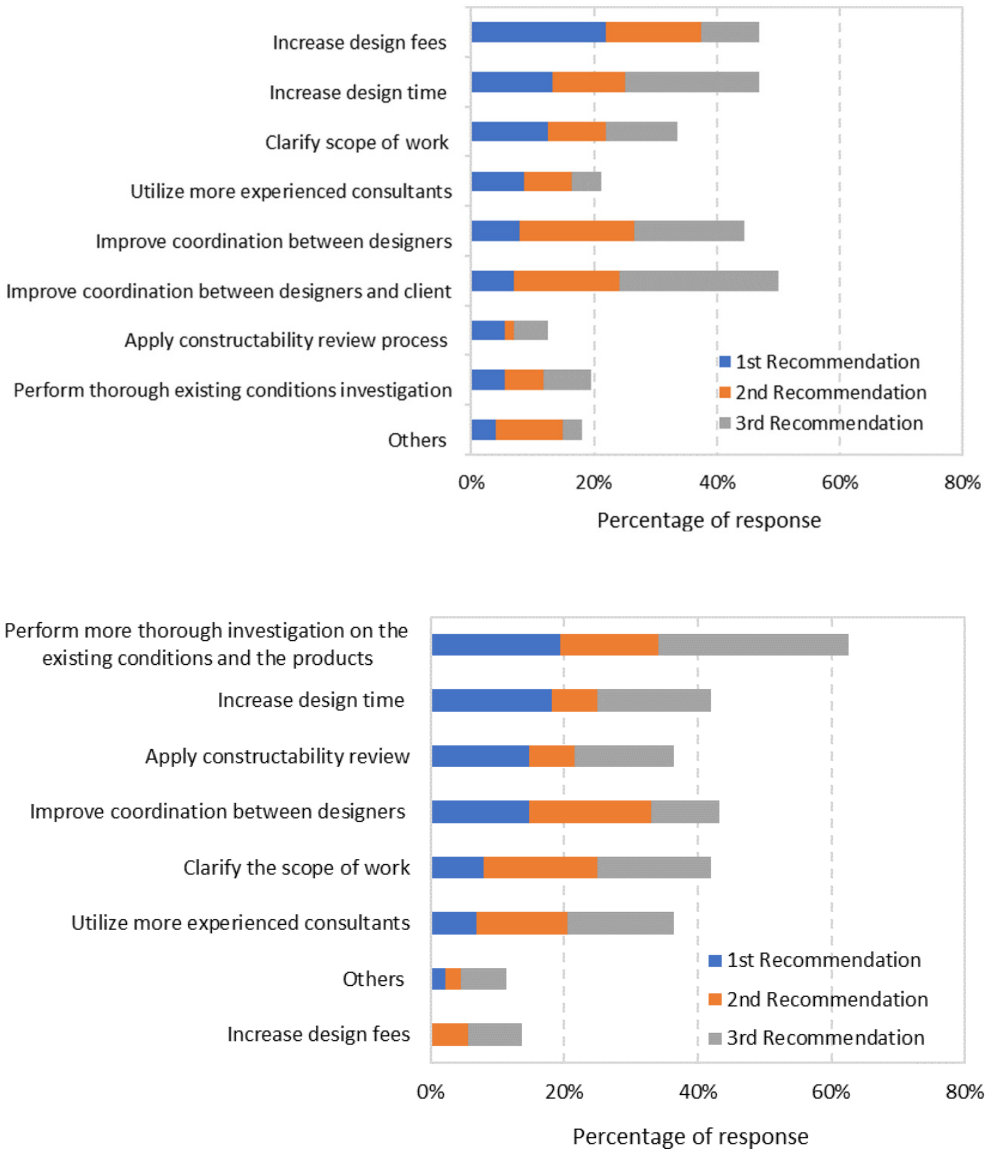

Figure 53. Recommendations for improving the QoD by A/E (top) and Owner (bottom) respondents

Both the Owner and A/E groups were asked for input on how to improve the QoD. Figure 53 shows the results for the two groups separately. At the top, the A/E respondents asked for higher design fees, longer design duration, and improved coordination and communication within a design team and between the design team and clients. By contrast, the Owner respondents ranked the highest for the recommendation 'perform more thorough investigation on the existing conditions and products to be used,' followed by 'increase design time', and 'improve coordination and communication' within a design team and between the design team and clients.

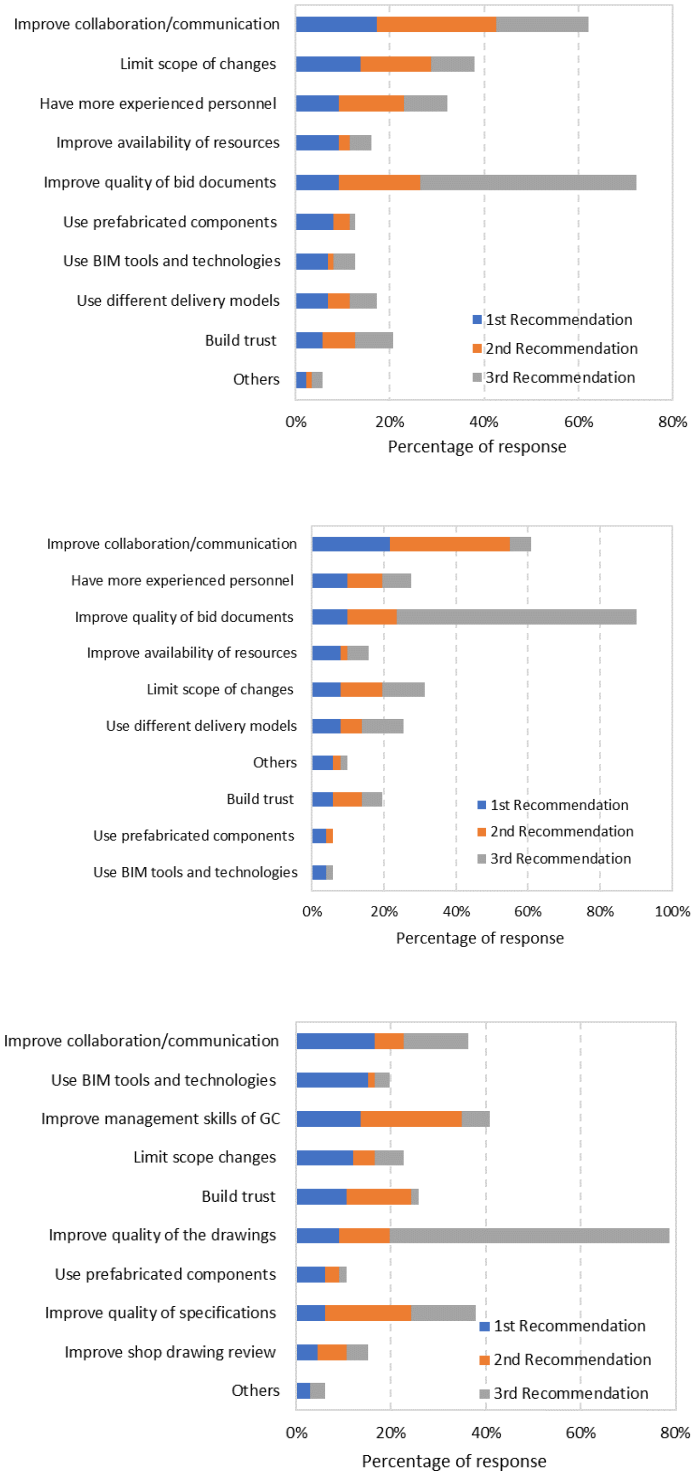

Figure 54. Recommendations for improving construction productivity by Owners (top), GCs (middle), and Subs (bottom)

Finally, the question was asked to the Owner, GC, and Subs groups about how to improve construction productivity. For this question, the opinions seem to vary more widely, as shown in Figure 54. In addition, Table 4 provides a concise summary of the top three recommendations with the highest percentage of response. Overall, improving collaboration and communication, quality of bid/design documents, construction management skills, and limiting scope change are common recommendations that most respondents agree with. It is interesting that although about 16% of Subs respondents ranked BIM tools as the first recommendation, the overall percentage of responses for this recommendation is less than 20%, far below the nearly 80% response recommending 'improving quality of the drawings.'

Table 4. Summary of recommendations for improving construction productivity

Owners	General Contractors	Subcontractors
1. Improve collaboration and communication between stakeholders	1. Improve collaboration and communication between stakeholders	1. Improve the quality of the design drawings and technical specifications
2. Improve the quality of bid/ design documents	2. Improve the quality of bid/ design documents	2. Improve collaboration and communication between stakeholders
3. Limit the number of scope changes	3. Limit the number of scope changes	3. Improve the management skills of the general contractors

4. Conclusions

The online survey results have painted a challenging picture of the present state of the design and construction industry across Canada in terms of project delivery efficiency. About 43% of the projects surveyed suffered from bid cancellation or extension, 59-72% of the projects suffered from a various degree of construction schedule delay, with the average schedule delay reaching 36% of the planned duration (or 5.43 months), and 79-92% of the projects suffered from construction cost overruns, with an average increase of 22% of the contract value. In addition, 45-49% of the projects had a 'Higher than Average' waste in the use of time, money, and materials in construction due to various reasons.

As for the quality of design documents, the average document completeness was estimated to be only 66.3%, with only 5% of the projects having a fully complete set of design documents before they would be passed to a subcontractor. Over 50% of the GC respondents rated document consistency across various design disciplines, and nearly 40% of the Subs respondents rated document adequacy for shop drawings, as 'poorer than average' than projects with similar type, size and complexity, whereas the percentages of projects being rated 'better than average' were only 3% and 8% for document consistency and document adequacy for shop drawings, respectively.

In addition, the survey indicated that the quality of design documents has been getting worse over the last 10 years. A significant difference was observed between Architect respondents and other respondent groups in the view of the QoD trend over the past decade. Close to a half of the Architect respondents believed that the QoD was getting better, and only 25% thought it was getting worse. By contrast, about 50-80% (or 63% on average) of the other respondents believed the QoD was deteriorating. This apparent discrepancy reveals the complexity of the QoD. Trade bias is probably too quick and simple an explanation. Expectations of different stakeholders on the completeness, clarity, accuracy, and consistency of the design documents are different. They must be understood in the given design fees and time frame and the owner's pre-project planning quality. Bringing all the stakeholders to the same page regarding the quality requirements of the design documents will undoubtedly help.

Although the study does not conclude that the quality of design documents is the primary cause of the above-mentioned construction project performance issues, which was never the purpose of the study in the first place, the study does find strong correlation between the QoD and the construction project performance indicators, as well as many intermediaries including addenda, RFIs, change orders and directives, and extra service times spent by A/Es during construction.

The study has also confirmed the important role of the owner's upfront investment in pre-project planning. The clarity, completeness, and accuracy of the information provided in the RFP were found to have a strong positive correlation with the frequency of client-initiated scope changes and the extent of budget change in the design stage, which further influence the success of bidding and the extent of schedule delay and cost overruns in the construction stage. In the future, project owners should increase their upfront investment to enhance the certainty of project scope. In this regard, a conceptual design does not necessarily provide the full solution. As brownfield projects are making up a greater proportion of the current construction industry, investments on the investigation of existing conditions and environmental impact assessments seem to be more paramount in the upfront planning stage.

Regarding the contributing factors to the QoD and recommendations for improving the QoD, the Owner and the A/E respondents expressed somewhat different views. The A/E respondents suggested higher design fees and longer design duration, whereas the Owner respondents believed that the existing condition investigation should be improved. Survey results indicated that 69% of the consultants spent, on average, 30% more service time than originally planned during the construction. This supports the quality issue with design documents and may also explain the consultants' satisfaction with the design fees.

According to the survey results, the areas that need to be improved in pre-project planning include: the existing condition investigation, clarity of the scope of work, and the accuracy of the initial budget. To improve construction productivity, respondents from the Owners, GCs, and Subs groups have a nearly converging view: improving the QoD, improving collaboration and communication, and limiting scope change are the top three recommendations.

An important contribution of the study is the novel use of the project-specific survey method. Using the survey data, detailed correlation analyses were performed and the impact chain starting from the quality of RFP through the various intermediaries and the QoD to the project performance are established and shown in Figure 55. The figure offers a quick snapshot of the current status of the quality of pre-project planning, the quality of design documents, and the overall project performance, as well as a number of intermediaries related to the quality of design documents. Although the quantification of the effects in each in relation in the whole impact map requires more data, the study has demonstrated the opportunities for future research in this area.

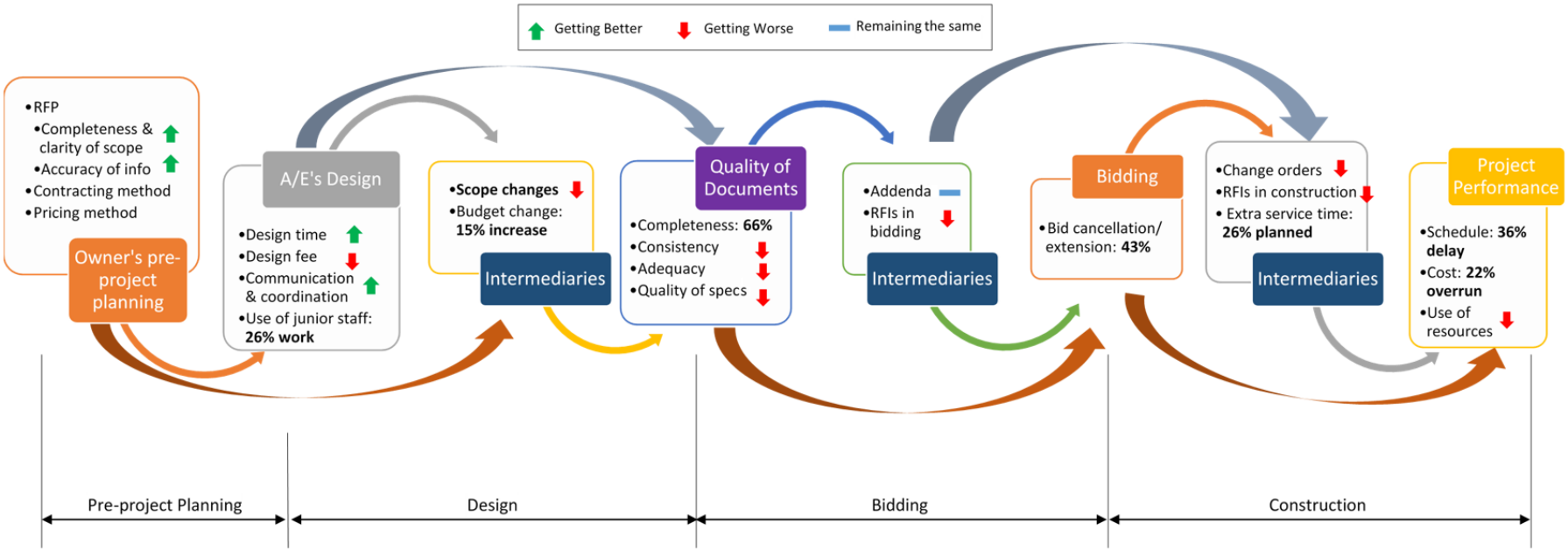

Figure 55. Summary of the influence diagram from pre-project planning through the quality of design documents to construction project performance

Appendix - Additional Survey Results

This appendix contains results of the other questions and correlational analyses derived from the online survey. They provide additional evidence that collectively support the major conclusions of the study.

A.1 Participant Background

To assess the quality of response, the survey started with three questions to obtain respondents' background in terms of their working experience in the design and construction industry, the subsector of the industry in which they work, and the major role they are currently playing.

A person with fewer than five years of experience is considered a junior professional, whereas one with more than 15 years of working experience can be viewed as an expert. According to Figure 56, 75% of the respondents in this survey are experts, and less than 5% are at the junior level. Again, it indicates a positive sign of the quality of the survey.

Figure 56. Distribution of respondents by working experience in the construction industry

The respondents of the survey well represent the subsectors of the construction industry. As shown in Figure 57, 39% of the participants have working experience in the Industrial, Commercial, and Institutional (ICI) construction sector. The rest are almost equally distributed among the residential building, transportation and transit, heavy industrial construction, and municipal utilities/civil sectors.

The respondents of the survey well represent different professions, too. As shown in Figure 58, 38% of the respondents are A/E, of which 7% are architects, 27% are engineering consultants, and 4% are other consultants. Owners account for 26% of the respondents, and GCs and Subs account for the remaining 36%.

Overall, it can be concluded that the participants of the survey are a good representative sample of the professionals in the design and construction industry.

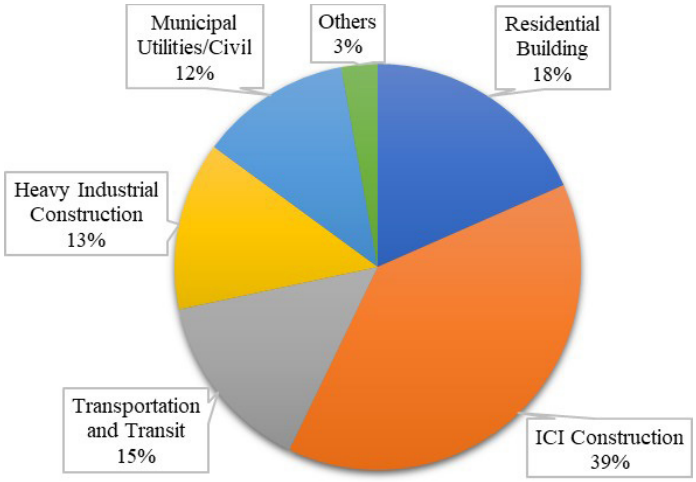

Figure 57. Distribution of the industry sector in which participants have experience

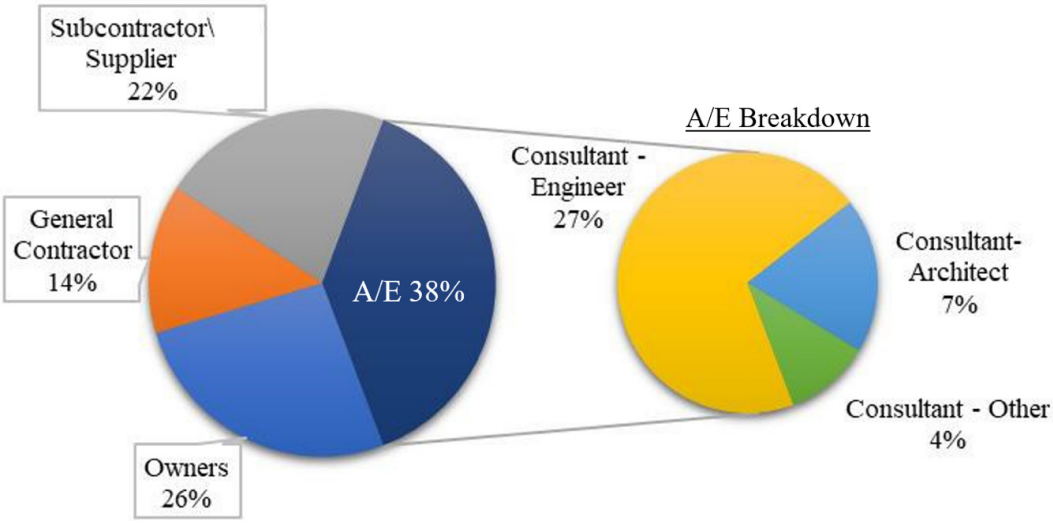

Figure 58. Distribution of the participants by their role in the projects

A.2 Project Background

A salient feature of this survey that differs from previous similar studies is the project-specific questions. Instead of asking for general opinions, the central part of the survey seeks to elicit participants' experience of *the most recent project in which they have been involved in up to substantial performance/completion*. Their answers are expected to be based on that one project. Therefore, it is crucial to understand the projects' background in the respondents' minds on which their answers are based. The project background includes the year of project completion, industry sector, project size, and geographical locations.

It is expected that all underlying projects were completed within the past five years, and the later, the better. Figure 59 shows that a vast majority of the projects were completed in the past two years, and only 13 out of the total 442 projects (about 3%) were completed before 2015. Figure 60 presents the breakdown of the surveyed projects by industry sector. The distribution is similar to the participants' analysis shown in Figure 57, except that the ICI projects take an even higher proportion (59%). This represents the reality of public infrastructure.

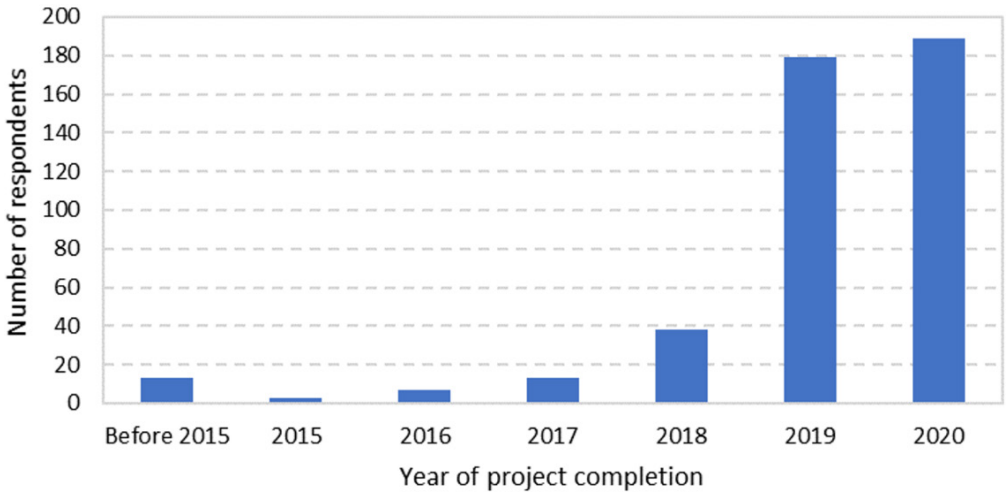

Figure 59. Distribution of the surveyed construction projects by completion year

In this survey, projects are defined as a small project if the value of the construction contract was less than $5 million, as a large project if the value was greater than $25 million, and as a medium project if the value was in between. Figure 61 plots the distribution of the project size for participants representing Owners and GCs. For both participant groups, 81% of the participants responded to the survey based on a small or medium project. It reflects the reality of the construction industry; that is, there are much fewer large-size projects than small to medium projects.

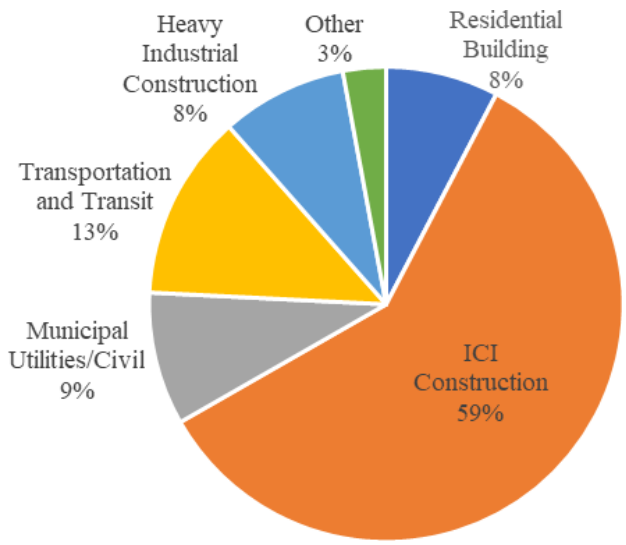

Figure 60. Breakdown of the surveyed construction projects by sector

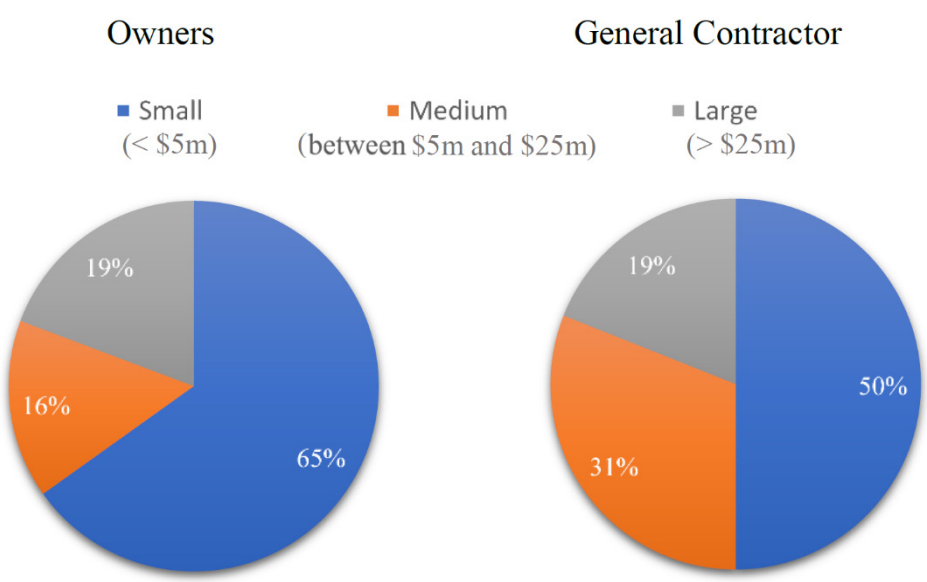

Figure 61. Breakdown of the surveyed construction projects by project size

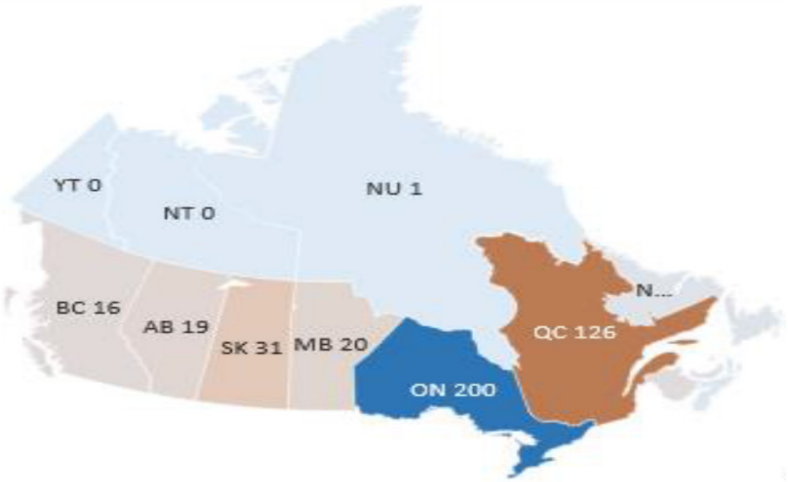

Figure 62. Distribution of the surveyed construction projects by geographical location

Figure 62 indicates the geographical distribution of the projects in the survey. As shown, they are mainly from the provinces of Ontario and Quebec since the survey participants are mostly from these two provinces.

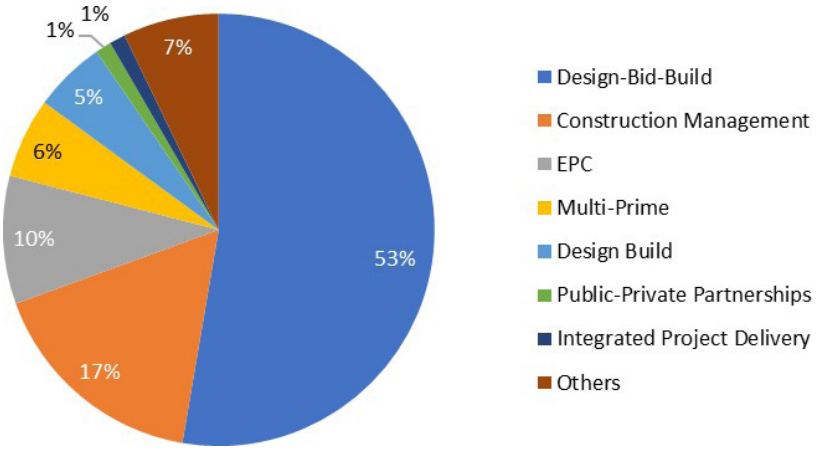

Figure 63. Distribution of the projects by project delivery method

According to the responses from Owner and GC participants, Figure 63 shows that the dominant delivery method in the current Canadian construction industry is still the traditional Design-Bid-Build (DBB) method, followed by Construction Management and Engineering, Procurement and Construction (EPC).

To conclude this section of the report, the results above have confirmed that the surveyed construction projects are good representative samples of construction projects in central Canada.

A.3 Trend of the QoD

Figure 64 reveals that junior professionals have a more optimistic view toward the quality trend than senior professionals. Figure 65 presents the more severe quality of design document issues in the ICI and municipal utilities/civil sectors than residential building and transportation/transit sectors.

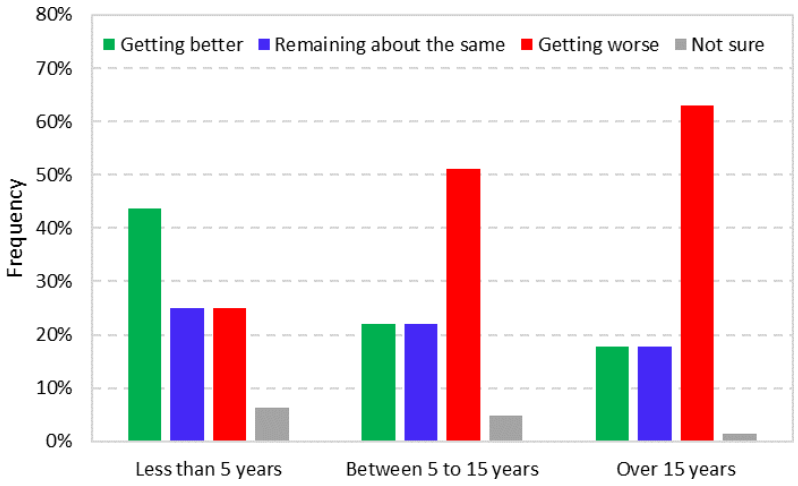

Figure 64. The QoD trends by respondents with different working experiences

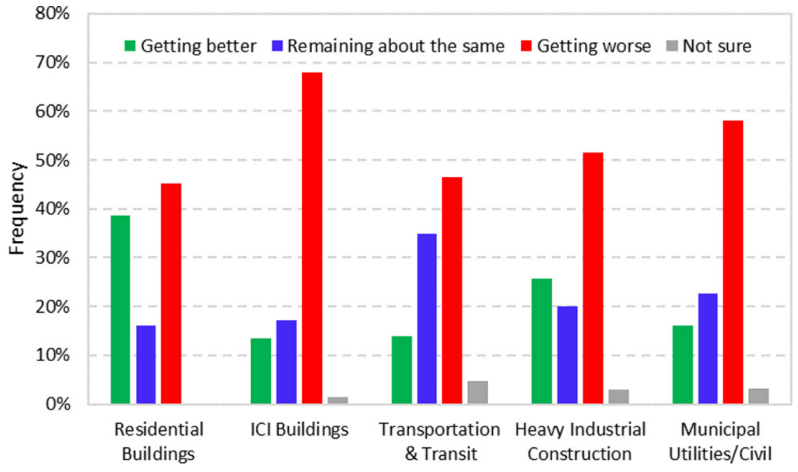

Figure 65. The QoD trends in different construction sectors

Quebec data shows a worse trend in the quality of design documents than Ontario (Figure 66).

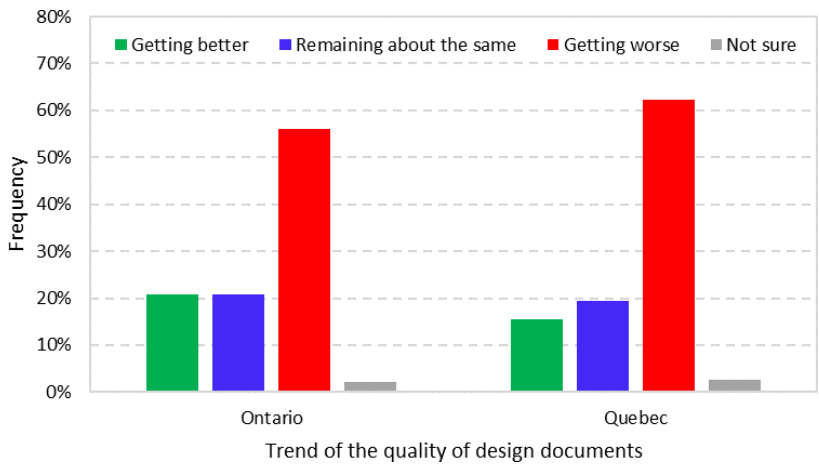

Figure 66. Comparison of the QoD trends in Ontario and Quebec

A.4 Use of Junior Design Staff and Satisfaction on Design Fee

Further analysis of A/E's satisfaction on design fee focused on the design projects where more than 51% of the work was performed by junior staff. Despite the small sample size (only 24 samples), Figure 67 reveals an obvious increase in the satisfaction of design fee in comparison with Figure 16. Considering both the 'generous' and 'reasonable' categories, the satisfaction rate is 30% higher than that obtained from all A/E responses.

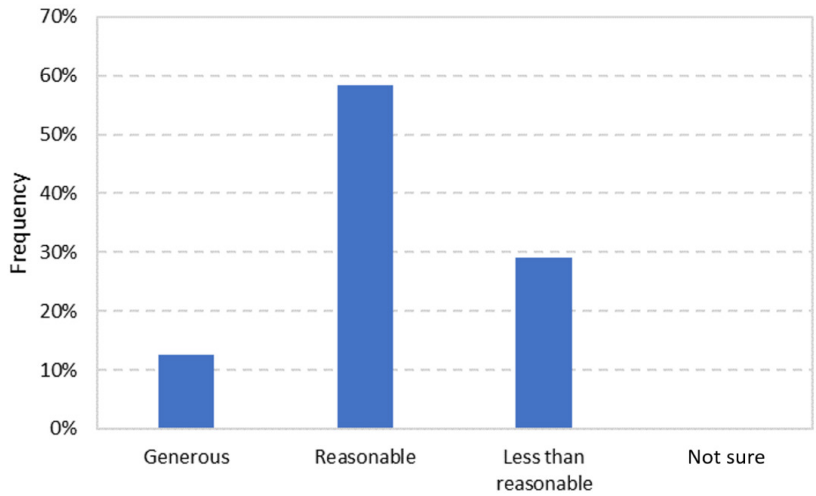

Figure 67. A/E's satisfaction on design fee with design documents mainly completed by junior staff

A.5 Design Duration

The design time spent on the surveyed projects spans from two to 108 months, with a median of 14 months (Figure 68). This result matches the finding presented in Figure 61 about the size of the underlying projects in the survey (fewer large projects and more small projects).

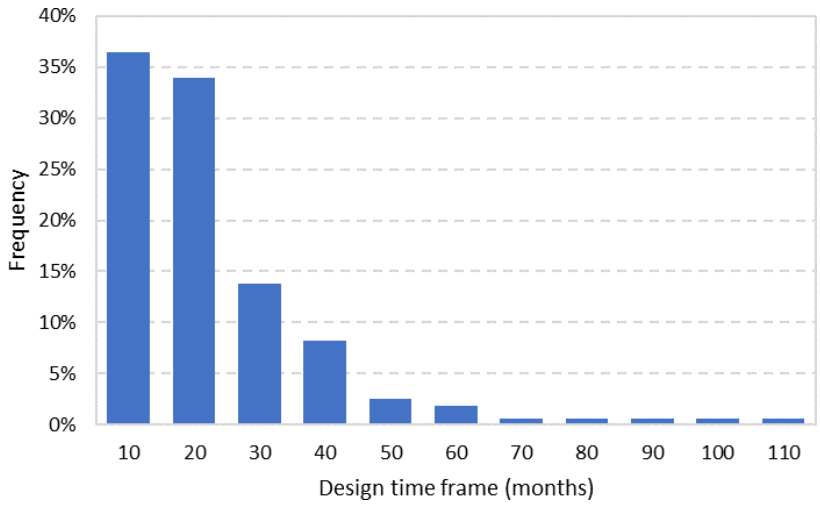

Figure 68. Distribution of the duration of design work

A.6 Communication and Coordination Between Consultants

Two similar analyses are performed to show the correlation between CCC among consultants and A/E's evaluation on design time and design fee. Figure 69 shows the result for the CCC between the design consultants and client's consultants, and Figure 70 for the CCC among the various consultants within the design firm. Both figures depict a strong correlation between the CCC and the design time and fee as perceived by the consultants. These results corroborate the direct survey results presented in Figure 15, in which communications and coordination were also listed as one of the most important factors influencing schedule delay in the delivery of design documents.

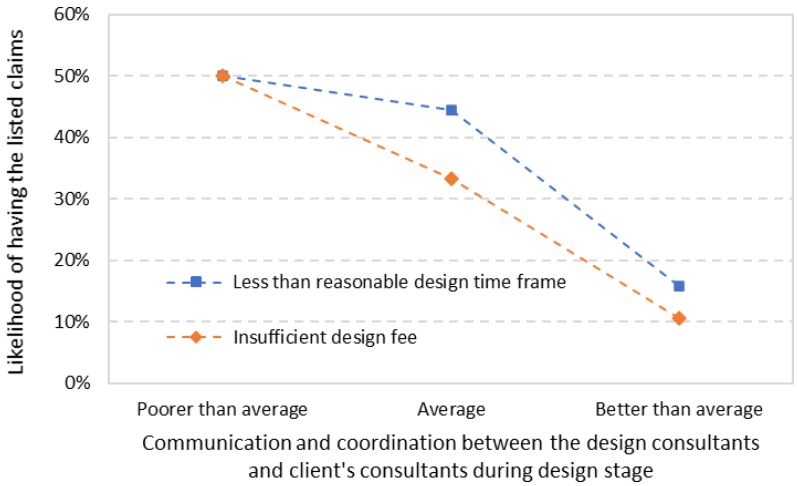

Figure 69. Influence of the CCC between the design consultants and client's consultants on the design time and design fee perceived by consultants

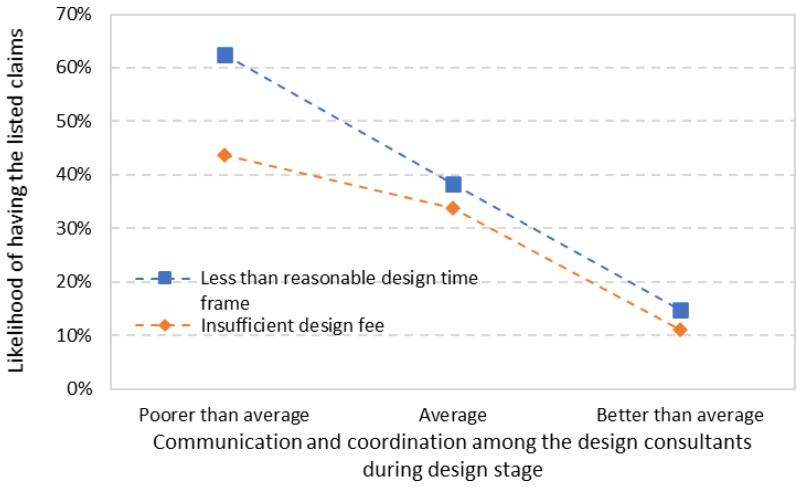

Figure 70. Influence of CCC among the design consultants on the design time and design fee perceived by consultants

A.7 Impact of Design Contracts on Design Time and Fees

The impact of the contracting method on consultant's satisfaction of the design time frame and design fees provided thereto are shown in Figure 71 and Figure 72, respectively. In comparison with the other two contracting methods, the competitive bidding creates higher pressures for the design firms in both time and cost. Similar analyses are performed for the impact of the pricing method on consultant'ssatisfaction of the design time frame (Figure 73) and design fees (Figure 74). Without surprise, the fixed- price model creates a negative impact on the consultants' satisfaction of time and money.

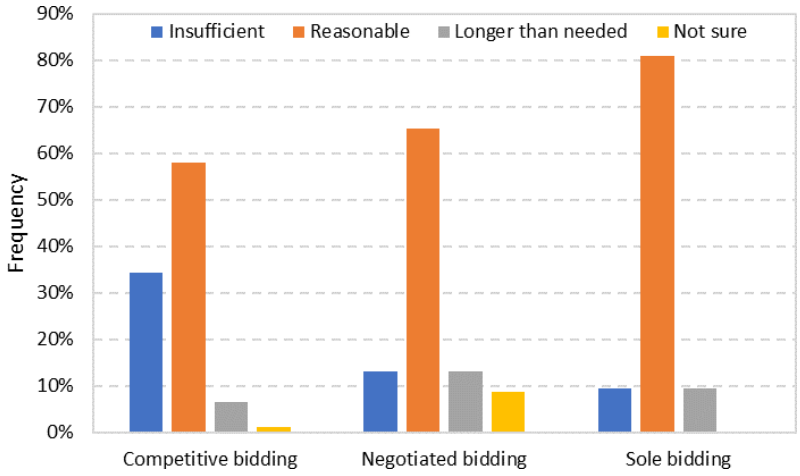

Figure 71. Comparison of A/E's satisfaction on design time frame by contracting method

Figure 72. Comparison of A/E's satisfaction on design fee by contracting method

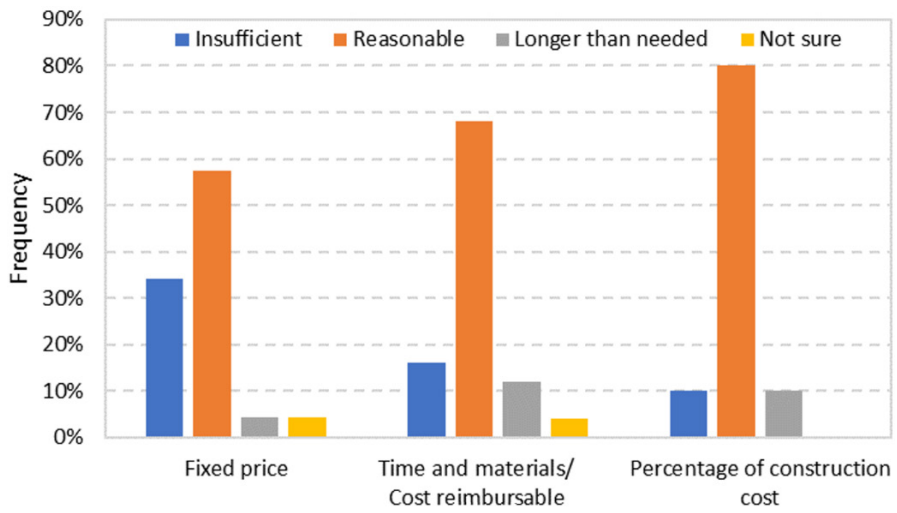

Figure 73. Comparison of A/E's satisfaction on design time frame by pricing method

Figure 74. Comparison of A/E's satisfaction on design fee by pricing method

References

Akampurira, Emmanuel, and Abimbola Windapo. 2019. 'Key Quality Attributes of Design Documentation: South African Perspective.' Journal of Engineering, Design and Technology 17 (2): 362–82.

CCA. (2016). Quality of Documents Workshops – A report from the CCA standard practice committee. Canadian Construction Association. Retrieved January 15, 2021, from https://www.cca-acc.com/wp-content/uploads/2016/11/QofDReport.pdf.

CCA. (2018). Towards Perfect Project. Association De la Construction du Québec. Accessed July 1, 2019. http://www.cca-acc.com/wp-content/uploads/2018/08/TowardsPerfectProject.pdf.

COAA. (2009) The Alberta Report - COAA Major Projects Benchmarking Summary. Accessed January 31, 2021. https://www.coaa.ab.ca/COAA-Library/COP-BEN-RES-01-2009-v1%20The%20Alberta%20Report%20-%20COAA%20Major%20Projects%20Benchmarking%20Summary.pdf.

Cochran, W.G. (1977). Sampling techniques (3rd ed.). New York: John Wiley & Sons.

Fowler, F. J. (1995). Improving Survey Questions: Design and Evaluation (Applied Social Research Methods) (1st ed.). Sage Publications, Inc.

Jarkas, Abdulaziz M. 2014. 'Factors Impacting Design Documents Quality of Construction Projects.' International Journal of Design Engineering 5 (4): 323–43.

Lopez, R., Love, P. E. D., Edwards, D. J., & Davis, P. R. (2010). Design error classification, causation, and prevention in construction engineering. Journal of Performance of Constructed Facilities, 24(4), 399–408.

Oyedele, L. (2003) 'Design factors influencing quality of building projects in Nigeria: consultants' perception', Australasian Journal of Construction Economics and Building, Vol. 3, No. 2, 25–32.

Revay. (2010). The Pitfalls of Incomplete Contract Documents. Revay and Associates Limited. Accessed June 29, 2019. https://www.revay.com/wp-content/uploads/2020/10/v29no1en.pdf.

Shehata, M. and El-Gohary, K. (2011). Towards improving construction labor productivity and projects' performance. https://www.researchgate.net/publication/271563611_Towards_improving_construction_labor_productivity_and_projects'_performance.

Tilley, P., Wyatt, A. and Mohamed, S. (1997). 'Indicators of design and documentation deficiency,' Proceedings of the Fifth Annual Conference of the International Group for Lean Construction. ISO (2005). Quality Management Systems-Fundamentals and Vocabulary (ISO 9000: 2005), International Standards Organisation.

Tilley, P., McFallan, S. and Sinclair, R. (2002) 'Improving design and documentation quality,' in Measurement and Management of Architectural Value in Performance-Based Building, Proceedings of the CIB W60/W96, Joint Conference on Performance Concept in Building and Architectural Management, Hong Kong, 6–8 May 2002, CIB Publication No. 283, pp.361–377, Rotterdam.

Zhang, Jing, Fangjian Chen, and X. X. Yuan. 2020. "Comparison of cost and schedule performance of large public projects under P3 and traditional delivery models: a Canadian study." *Construction Management and Economics* no. 38 (8):739-755. doi: 10.1080/01446193.2019.1645344.

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