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Increasing engagement with the supply chain to improve the performance of power sector projects

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Increasing engagement with the supply chain to improve the performance of power sector projects

by

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Dedication

A mamá y a papá;

a mi hermana Paula, la mejor que me podría haber tocado;

a mi increible familia en Argentina, especialmente a mi tío Jorge;

a mis amigos y amigas,

and to all the amazing people I met in Austin, that enriched this experience and made my time at grad school a wonderful adventure.

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Abstract

Increasing engagement with the supply chain to improve the performance of power sector projects

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Global and complex supply chains are the norms on capital projects, particularly in the power sector, and better integration of the supply chain is an opportunity to improve project cost, schedule, quality, and safety. In that context, this research wants to identify opportunities that can improve the engagement with the supply chain in power projects and understand the potential of those opportunities to improve the project performance.

Based on the review of existent literature and twelve open-ended phone interviews with industry experts representing different stakeholders, eleven opportunities were identified. Opportunities varied from framework agreement with suppliers and modularization to improvements in supplier's contracts and early design freeze.

In order to determine the relationship between the opportunities and project performance, a survey was designed, and 30 responses were collected and analyzed. According to the respondents, all opportunities are viable for consideration and have potential to improve project performance, but early involvement of stakeholders, use of

standard designs across projects, and better integration of suppliers in Advanced Work Packaging ranked in the top.

Overall, the present work provides recommendations that mainly owners and contractors in the power sector can consider in order to improve the engagement with their suppliers. Companies should choose the opportunities that are better for them to implement based on their current involvement with the supply chain, their objectives, and their resources.

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Chapter 1: Introduction

RESEARCH MOTIVATION

Global and complex supply chains are the norms on capital projects, particularly in the power sector. Industrial projects involve the management of hundreds of engineered components such as pipe spools, pumps, structural steel components as well as highly sophisticated equipment that came from suppliers around the world.

Also, increasing levels of project scope are performed by various aspects of the supply chain, which increase its complexity. This includes, for example, off-site prefabrication, modularization, and standardization of components. This complexity leads to a condition of poor visibility of materials status, increased risk, and diminished ability to take timely decisions.

Materials deliveries on projects that miss site need dates are a common occurrence on many projects, while companies are involved mostly in arm's length and short-term relationships, missing opportunities to collaborate to better respond to dynamic and unpredictable changes.

At the industry level, cost overruns, schedule delays, and contractual claims are common on construction projects.

In that context, better integration of the supply chain may bring opportunities to improve project cost, schedule, quality, and safety. Specifically, early and better collaboration and information sharing among stakeholders, as well as the integration of supplier production planning and site planning can allow more timely materials deliveries and adjustment of production schedules for mutual benefit, cost reductions, and improved forecasting ability.

While there is academic research about supply chain engagement at several areas of the construction industry, the Power, Infrastructure, and Utility (PUI) Committee of the Construction Industry Institute proposed to investigate supply chain engagement for power projects in particular. The committee members considered that it might be possible to decrease risk and improve performance on multiple metrics with the improved engagement of suppliers and decided to explore opportunities to achieve this in order to generate recommendations for practitioners in the sector that, if implemented, can improve project performance.

RESEARCH OBJECTIVES

The purpose of this research is to identify and evaluate opportunities for an increase in the engagement with the supply chain in power projects, that can be translated into an improvement in the performance of those projects.

Specific objectives:

a) Identify areas of opportunities that can improve the engagement with the supply chain of projects in the power sector.
b) Understand the potential of the identified opportunities to improve the performance of projects in the power sector.

STRUCTURE OF THE THESIS

There are seven chapters in this thesis, reflecting the evolution of the research approach. The first chapter introduces the research motivation and general and specific objectives. The second chapter presents the research methodology, and chapter 3 introduces the literature review.Chapters 4 to 6 present the process and results from expert interviews and survey. Chapter 4 reports exempts from the interviews categorized in areas,

while Chapter 5 presents the final list of opportunities for improvement of the engagement with the supply chain, built by the research team from the literature and experts' comments. Chapter 6 presents the survey results. Finally, Chapter 7 reports conclusions, academic and practice contributions, and recommendations for future research.

Chapter 2: Research Methodology

This chapter presents an overview of the methodology used in this research project and the specific research methods implemented in each phase. Figure 1 illustrates the general organization of the research approach.

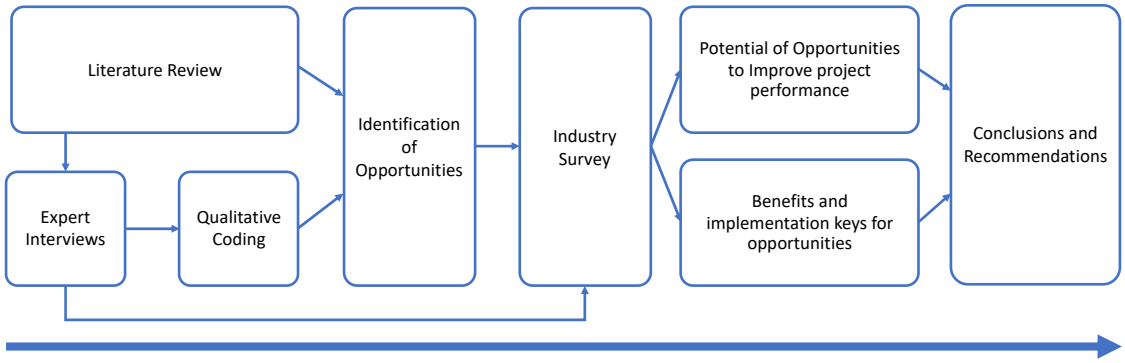


Figure 1 - Research Methodology

Literature Review and Expert Interviews

The initial stage of this research consisted of a combination of literature review and expert interviews. Based on the objectives of the research, an initial literature review was performed, which defined discussion topics for the interviews. From opinions collected during the interviews, new literature topics were identified and reviewed, that were also used to generate new discussion points during the interviews. Figure 2 illustrates this process.

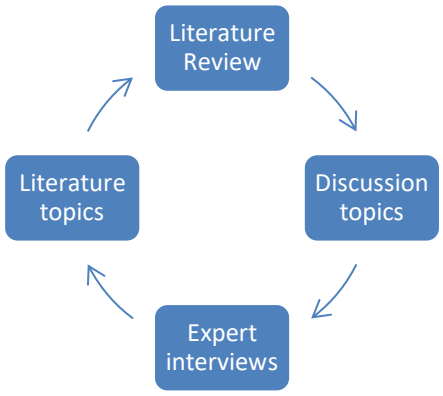


Figure 2 - Literature Review and Expert Interviews

The objective of the literature review was to develop an overview of the existing research in the supply chain management and supply chain engagement areas. The method followed was to search journals with key words related to those areas and identify and analyze those articles connected to the research objectives. Chapter 3 presents the most important points of the literature review. A questionnaire guide for the interviews was prepared based on those relevant points.

Semi-structured interviews were used to collect data from experts. According to Qu and Dumay (2011), this method allows the interviewer to pursue in-depth information around a topic, and that was what the research team wanted. In order to organize and direct the conversation with experts to the specific topics and issues the researchers wanted to cover, a questionnaire guide was prepared. The questionnaire included broad themes. Interviews were both by phone and in person.

Phone interviews with industry experts were conducted to ask about the problems they were facing with power projects, their causes and potential solutions, and to investigate their opinions about some opportunities for improvements identified during the literature review. Experts from different companies within the power sector were

interviewed, including suppliers, contractors, engineers, and owners. Some experts were interviewed more than one time to ask for clarifications.

Two extended expert interviews about projects executed by a utility company were conducted. Each case study involved a three-hour discussion session where several participants from the owner company, contractor, supplier and engineer shared their opinions about the project's performance, issues encountered and solved, and lessons learned.

The sample of expert interviews was build using purposive sampling and chain referral sampling. Initial experts were identified based on their previous collaboration in CII research terms and their roles in the organizations, as they were asked to refer other people who could potentially participate in the study. Interviews were held until the research team considered that new data would not bring additional insights to the research objectives.

QUALITATIVE CODING

The chosen method for the analysis of the information collected during interview was thematic analysis, also called qualitative coding. According to Braun and Clarke (2006) thematic analysis is a method used for identifying, analyzing, and reporting patterns (themes or codes) within the data, and that can produce an insightful analysis that answers particular research questions. A code or pattern is a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocate attribute for a portion of language-based or visual data (Saldana, 2009). The research team reviewed interview transcriptions to identify important themes and patterns, and an initial coding was performed, which was then refined as codes were grouped into categories. Chapter 4

presents the output of the qualitative coding, including categories and key excerpts from interviews.

IDENTIFICATION OF OPPORTUNITIES

Based on the literature review and qualitative coding conducted, the researchers analyzed each of the codes and literature areas and, based on their similarity, combined categories into opportunities. Chapter 5 presents this process, a definition of each opportunity, and states questions that were generated during the identification process.

INDUSTRY SURVEY

A survey was designed in order to investigate the potential to improve project performance of the identified opportunities, as well as to obtain insight into the questions generated during the interviews and identification process. Groves et al. (2004) defined a survey as "a systematic method for gathering information from (a sample of) entities for the purpose of constructing quantitative descriptors of the attributes of the large population of which the entities are members". Also, according to Lavrakas (2008) , a survey can be considered a special type of interview where the questionnaire is administered in a standardized fashion, this is, in the same way to all the respondents, with the purpose of collecting data about one or more specific topics. Therefore, the survey methodology allowed the research team to get information from a large sample of individuals relatively quickly.

There are two types of questions that can be included in a survey: Close-ended questions where a list of fixed responses are included for each question so the respondents can choose and Open-Ended questions where responders are asked to answer each question

in their own words. The designed survey included mostly close-ended questions and a small number of open-ended questions.

The survey included three categories of close-ended questions:

1) The first category consisted of questions to identify the characteristics of the company the person responding to the survey belong to, as well as his/her professional experience.

2) The second type of question inquired about the potential that the identified opportunities had to improve project performance.

3) If the respondent thought that any opportunity was promising, follow up questions about those opportunities were asked for more insight.

The survey was tested before it was sent in the following ways:

1) Some specific questions were tested by asking a small sample of respondents to think aloud when they were selecting between the different choices, to analyze if the question was understood in the way the researchers wanted;

2) Feedback from experts was asked for specific questions;

3)The final version of the survey was tested on a small sample of the target population to identify issues that may arise during the survey period.

The survey was administered using the software Qualtrics and distributed by sending the link via email. It was initially sent to the participants of the Power, Infrastructure and Utilities committee of the Construction Industry Institute. The participants of this committee are industry practitioners that work for companies that have projects in the mentioned sectors. They were asked to distribute the survey within their companies, and also to send the survey to other colleges.

ANALYSIS OF SURVEY RESULTS

Survey responses were collected for one month and analyzed by the research team. Preliminary results are reported in Chapter 6.

Note: Survey results are preliminary, and the survey will remain open to collect more responses for future analysis.

Chapter 3: Literature Review

This chapter presents the main points of the performed literature review. As mentioned in the methodology chapter, the literature review was conducted both before and during the interview phase, as more topics were reviewed as industry experts mentioned them as challenges or opportunities.

It consists of the review of a set of areas or topics related to supply engagement. The areas were initially chosen following the PUI committee ideas about supply chain engagement and expanded by the research team as a deeper understanding of the research objectives was achieved. The areas reviewed are:

a. Construction contracts
b. Early involvement of stakeholders
c. Coordination of owner furnished equipment
d. Framework agreements, partnership, and corporate alignment
e. Aspects related to contracts: Integrated Project Delivery (IPD), use of incentives and penalty clauses, and contract language.
f. Material tracking
g. Building Information Modeling
h. Modularization
i. Standardization
j. Early design freeze
k. Advanced Work Packaging

A. CONSTRUCTION CONTRACTS

This section presents three aspects related to construction contracts: It starts with a summary of collaborative contracting, continues with an overview of incentive contracting,

and finishes with a description of the legal jargon of many construction contracts that represents a common issue that prevents collaboration and information sharing.

Collaborative contracting

Hayford (2018) states that the construction industry has suffered from reduced productivity and inefficiency for decades, and one of the reasons is the lack of alignments of incentives between project owners and the other project participants. According to the author, it was from a desire to overcome this misalignment that the concept "Collaborative contracting" was born. The expression embraces a broad and flexible range of approaches to managing the relationships among project participants based on the recognition that there can be a mutual benefit in a more collaborative and cooperative relationship between them. The features that collaborative contracts may incorporate can range from: a) contractual commitments to co-operate and act in 'good faith'; b) early warning mechanisms, designed to alert other participants to emerging issues; c) early involvement of the main-contractor and key specialist sub-contractors in the design process; d) governance arrangements that facilitate collective problem solving and decision making; e) payment arrangements that financially motivate each participant to act in a manner that is best for the project, rather than best for the participant; f) the agreement of each participant to waive its right to sue any other participant for mistakes, breach of negligence by another participant.

Collaborative contracts take different forms from partnering to the recently popular Integrated Project Delivery. According to the American Institute of Architects (AIA) (2007), Integrated Project Delivery is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the

owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction.

IPD and collaborative approach can, according to Stencil and Powell (2018), eliminate waste in project design, improve the productivity of the job site, increase the value project of the project, improve construction methods, allow for more innovative ways to perform on-site work, and help to save money.

The authors also mentioned the following challenges when trying to implement IPD on projects: Unwillingness to move from traditional project delivery methods, lack of understanding of how IPD/Collaborative contracting works, difficulty in selecting compensation and incentive structures, lack of trust between stakeholders, and difficulty in selecting partners among others.

Incentive contracting

According to Hasan and Jha (2015), the objective of the inclusion of incentive/disincentive provisions in contracts is to align contractor motivation with the owner's objective so that project performance can be improved. According to the authors, these type of provisions takes advantage of the fact that contractors in general want to increase their profit, and incentives allows them to do it if they perform better.

In terms of the type of incentives to include, On Cheung et al. (2018) indicate that incentives are often gauged by performance in terms of cost, time and quality: Cost incentives, schedule incentives and performance or technical incentives. The authors also state that incentives can also be non-financial, such as the possibility of awarding future work. Meng and Gallagher (2012) suggest that incentives and disincentives should not be disconnected. They should be use togheter to have a more positive effect on project performance and. They also suggested that multiple incentives may help to achieve an

overall improvement of project performance while a single incentive may be more effective in a particular performance area.

It is interesting to analyze the effect that incentive schemes might have on project performance. In that sense, the literature presents two different perspectives that appear to be inconsistent. On the one hand, according to Meng and Gallagher (2012), the use of incentives is a way to aligne stakeholders objectives and to direct efforts to enhance teams' performance in executing the project and finally leads to better project performance. On the other hand, Merrow (2011) analyzed the performance of industrial megaprojects under different types of contracts and concluded that the success rate of projects that used an incentive scheme was significantly lower than those projects where these mechanisms were not used. Suprapto et al. (2016), clarifies these contradictory views by stating that incentives have a positive effect on relational attitudes that are reflected on enhanced team working quality, and as a consequence, they are indirectly associated with better project performance. However, by analyzing a sample of 113 capital projects, the authors found that incentive-based contracts, have a negative direct effect on project performance. When they considered both the indirect and the direct effects of contractual incentives, they cancel each other leading to a non-significant cumulative effect on project performance.

Contract language

Two common concerns of industry professionals about construction contracts are the lack of clarity and the encouragement of adversarial relationships. The lack of clarity in the language prevents the contract to be easily understood by the project team members, and frequently, there is a misalighment of interest between the parties: Instead of focusing on achie ing the specific projects objectives, parties tend to be motivated by their own interests.

For example, Bunni (1990) commented on traditional contracts: "Originally, these documents were drafted in precise, legal language which would remain unequivocal even when subjected to detailed and hostile scrutiny by astute legal minds. However, as revisions were incorporated, the language became more and more complicated and inscrutable". The same author conducted a study that revelated that 86% of the sentences in the International Federation of Consulting Engineers (FIDIC) suite of contracts could be understood by only 4% of the population, equivalent to those with an IQ of 130 or more.

There have been several efforts worldwide to create standard contracts with plain language, and multiple organizations have published contract templates that can be used by the construction industry for different applications. The International Federation of Consulting Engineers (FIDIC), The American Institute of Architects, and The Engineers Joint Contract Documents Committee are some examples of organizations that create standard documents. However, one example of contracts that were created to solve some of the issues of traditional contracts is the "New Engineering Contract" (NEC). It consists of a family of contracts that are written in plain language and designed to stimulate good management (2018). The first edition was published in 1994, and updated multiple times, with the latest release in 2017. Wright and Fergusson (2009) analyzed the performance of the NEC Engineering and Construction Contract with a case study and concluded that compared with a traditional form of contract, NEC delivers expected business benefits in terms of project management, contract clarity and contract relationships and provides a forward-looking proactive environment to manage project time and costs.

B. EARLY INVOLVEMENT OF STAKEHOLDERS

For the past half century, the most used project delivery system in the United States has been design-bid-build (DBB), to the extent that this method is also referred to as the

traditional method (Moynihan & Harsh, 2016). In this project delivery approach, design is followed by the construction phase, and the owner has separate contracts with the designer, constructor, and supplier. Generally, construction starts when the design is complete, and procurement begins with construction (Construction Industry Institute, 2003). According to Moynihan (2016), the contractor's knowledge of constructability and what works in the field can be a valuable resource to have on the front end of a project; however, because of the sequential nature of the DBB method, the contractor has minimal input during the design phase. Also, according to Northey (2018), suppliers are involved so clients can get budget pricing for the conceptual and design phase, and they are pulled in at the end of the bidding process to provide accurate pricing, with no other involvement. In that context, the involvement of these stakeholders early can be beneficial for the project.

The following sections expand on the concepts of early supplier and contractor involvement, reporting the benefits that these stakeholders can bring to projects if they are involved early.

Early contractor involvement

Although construction knowledge and experience are recognized as essential design inputs, its impact on design is limited by the designer's lack of construction experience and partial understanding of construction requirements (Arditi, Elhassan, & Toklu, 2002). Also, as mentioned before, in the DBB project delivery system, contractors are generay chosen by a competitive bidding when the design is almost complete; thus, their input in design is limited.

In that context, CII defined constructability as "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives" (Construction Industry Institute, 1986). CII postulated

that maximum benefits occur when individuals with construction knowledge and experience become involved in the early stages of a project. As a measure of the benefits of constructability and the importance of the timing, the task force that developed the constructability definition analyzed four cases that implemented constructability early in the project. For one of them, 73% of the constructability savings had been obtained by the time approximately 20% of engineering was complete. 91% percent of the savings had been accrued by the time 50% t of engineering was complete. Also, the most significant savings originated from construction input addressing issues such as construction methods, sequencing, and procurement strategies.

According to CII, having construction input brings the following benefits:

1. First, when compared to designers and owners, contractors have a higher level of construction expertise because of their specialized training, in-depth knowledge of construction materials, methods, and local practice. Beyond the general constructability guidance, contractors are in the best position to provide project and contractor-specific information on the availability and limitations of resources in terms of cost, performance, access, and site conditions to support design.
2. Second, contractors are ultimately responsible for the actual construction operations. Contractors' inputs to design have a direct impact on their construction performance. The interaction between a contractor and a designer throughout the design process will also further improve their collaboration during construction.
3. Third, by engaging a contractor up front, the contractor can make inputs continuously during the initial design stage, which has the best opportunity to influence project cost. This arrangement also gives contractors adequate time for a better quality of construction planning.

The majority of literature identifies benefits of early contractor involvement, and even though there are no major disadvantages, there are several challenges associated with it. Sødal et al. (2014) identified the following challenges:

1. Contractor's focus on schedule and cost can reduce innovation.
2. Conflicting interests between designers and contractors: Since the contractor will tend to have a substantial cost and design focus while the designer may not.
3. Suppression of designer interests
4. Involving subcontractors: If the general contractor is subcontracting most of the work, it will have few inputs on the constructability of the scope carried out by subcontractors.
5. Establish trust and mutual respect for the collaboration to work: Personal relations between key personnel can influence and determine whether it is a success or not.

Early supplier involvement

Early supplier involvement (ESI) is a concept used in manufacturing and has been defined by Bidault et al. (1998) as a form of vertical cooperation where manufacturers involve suppliers at an early stage in the product development/innovation process, generally at the level of concept and design. Early supplier involvement can be seen as a means to integrate suppliers' capabilities in the customer's supply chain and operations, in order to take advantage of the suppliers' technological expertise in design and manufacturing (Dowlatshahi, 1998).

According to Zsidisin and Smith (2005), ESI has both benefits and drawbacks. The authors identified the reduction of product development cycle times, improvement of product quality, utilization of supplier technology expertise and management of cost as the main benefits. On the other hand, the drawbacks include increasing product and

development costs, improper sequencing of tasks, incorrect level of supplier involvement, organizational resistance and selection of incapable suppliers.

Northey (2018) mentioned benefits of early supplier involvement specifically for the construction industry: a) Alternative designs, by having the opportunity to discuss specific product designs that meet precise specifications from the get-go instead of waiting until bid time; b) Creative solutions, because suppliers can give a different perspective that can lead to innovation; c) Labor savings since suppliers can offer already assembled solutions; d) Simplified project logistics, and e) Value and loyalty, since suppliers involved early make a time and financial commitment that can lead to a long-term business relationship.

Also, early supplier involvement can help to keep the project on schedule: For long lead time items, early ordering is key to maintaining the construction schedule, and engineering activities for these items must be completed at the earliest possible dates so that this equipment can be ordered as early as possible (Construction Industry Institute, 2011). Involving suppliers early can help to complete these activities sooner.

With early involvement of suppliers, it may be possible for contractors and owners to implement and get advantage of the innovation that the suppliers can produce. This is because suppliers are usually in a better position than other stakeholders to maintain R&D programs and develop new solutions (Blayse & Manley, 2004), since they function in a more steady market than other parties, and therefore, they are regarded as a key source of innovation.

C. COORDINATION AROUND OWNER FURNISHED EQUIPMENT

Definition

According to Ibbs et al. (1987), Owner-furnished Equipment (OFE) procurement is a contract administration technique utilized on many construction projects to save costs and time. In this type of contract, the supplier sells the equipment directly to the project owner, who provides it to the contractor for the installation. Owners generally use this type of procurement strategy in order to obtain costs savings (by the elimination of the contractor's markup) and schedule savings (since they are usually able to purchase equipment early in the project timeline, where the contractor is not even selected, which is specially relevant for long lead items).

Advantages and disadvantages

Talal Abi-Karam (2005) pointed out seven advantages and six disadvantages of the use of OFE. These advantages and disadvantages are:

Advantages:

1) Cost savings due to sales tax exemption status.
2) Elimination of the contractor's markups on equipment prices.
3) Reduction of the overall construction schedule due to the phasing of activities.
4) Owners exercise control over the selection, procurement, start-up, and testing.
5) Selection of equipment that meets the owner's specific needs.
6) Matching OFE with existing inventory for better operation and maintenance.
7) Owner's ability to control operating performance.

Disadvantages:

1) Increase the need for owner's coordination and supervision
2) Require additional coordination with the general construction contract

3) Increase liability and property insurance due to OFE storage
4) Increase warranty risks
5) Require additional design, engineering and coordination time
6) Increase construction management costs and consultant's fees

After studying 55 projects using OFE purchasing in various corners of the United States, Ibbs et al. (1987) identified that the actual cost savings of using direct procurement averaged 6.4% of the OFE product's cost. Moreover, these observed that those projects were estimated to have been completed about 3.7 months earlier with OFE contracting, and that product-related specification disputes were drastically reduced. The authors' study also concluded that the extra administration costs that direct purchasing demands, though highly project-specific and variable, are in some cases outweighed by the savings.

Additional coordination needed

When OFE strategy is implemented, supplier-owner-contractor coordination will require additional effort to ensure timely delivery of equipment, storage, and efficient installation (Abi-Karam, 2005). In order to avoid delays, owners must have an active role and detect and control the variables, such as shop drawings reviews and approvals, that can produce a schedule slippage. In that context, Ibbs et al. (1987) commented that the it is important to have one person responsible of handling all OFE-related issues is one of the most important components of successful OFE contracting and that also leads to fewer start-up problems.

Ibbs also found that the preparation of construction and product delivery schedules are indicated to provide noteworthy benefits since it was positively correlated with improved deliverability. Talal Abi-Karam mentioned that an OFE supplied by a vendor might be on the critical path of the construction contract. As a result, failure to supply an

OFE in a timely fashion will result in slippage of the construction contract end date and will subject the owner to delay claims and extended overhead claims by those who were affected. In order to avoid these claims, close monitoring and visibility into the statys of the order is critical.

Both authors agree that the start-up and testing phase is a significant source of risks. Since the contractor is generally responsible for installing the OFE, and the supplier is in charge of testing, roles and responsibilities be muddled during this stage. However, contractually, the contractor has no control over the vendor due to the lack of privity of contract. Typically, the start-up and testing activity precede substantial completion and closeout of the projects, and it triggers the release or retainage. If the supplier is not able to commission the equipment, the contractor cannot declare substantion completion, and it will be exposed to liquidated damages and other consequences.

D. FRAMEWORK AGREEMENTS, PARTNERSHIP, AND STRATEGIC ALIGNMENT

The following sections will present the definition and main characteristics of framework agreements and a comparison with other forms of relationship contracting, as well as the advantages and disadvantages of its use.

Definition of terms

The construction industry has adopted in the last few decades different procurement models in order to increase collaboration between stakeholders. Partnering, alliancing, and strategic alliances are some models that can be seen under the orbit of relationship contracting. This last term has been defined by the Australian Constructors Association (1999) as a process to establish and manage the relationships between the parties that aims

to remove all barriers, encourage maximum contribution and allow all parties to achieve success.

The Construction Industry Institute (1996) defined partnering in the following way: A long term commitment between two or more organizations to achieve specific business objectives by maximizing the effectiveness of each participant's resources. This requires changing traditional relationships to a shared culture without regard to organizational boundaries. The relationship is based on trust, dedication to common goals, and an understanding of each other's expectations and values. Walker et al. (2002) mentioned that there is no partnering contract as such; instead, an agreed partnering charter forms the basis of a working agreement that is intended to shape a non-adversarial culture to promote win-win working relationships between partners.

On the other hand, MacDonald (2019) defined alliance contracting as an arrangement where parties agree to work cooperatively and to share risk and reward, measured against the performance indicators. The parties work as a single integrated team to deliver a specific project under a contractual framework where their commercial interests are aligned with actual project objectives. For this author, alliancing involves a formal contract in which the parties undertake to act in the best interests of the project, and this is a key difference from partnering where the undertaking to act in such a manner is purely voluntary.

For the same author, a strategic alliance is one in which an agreement or contract has been reached between a client and contractor and consultant to undertake projects of similar nature over an extended period, usually a number of years. Strategic alliances can be delivered under a framework agreement.

The Official Journal of the European Union (European Parliament, 2004) defines a framework agreement as an agreement between one or more contracting authorities and

one or more economic operators, the purpose of which is to establish the terms governing contracts to be awarded during a given period, in particular with regard to price, and where appropriate, the quality envisaged.

All of these terms significantly differ from the concept of arm's length type relationship, which refers to the traditional approach of customer companies negotiating conditions as favorable as possible solely with their interest in mind and thereby keeping the supplier at arm's length (Jonsson, 2008). This style uses a short-term angle in the aspect of customer companies using the lowest price perspective rather than that of total cost and delivery quality. The focus on the lowest price often generates parallel suppliers bidding for a single item, which generally leads to less contact between the supplier and the customer than using a single source supplier. Jonsson states three characteristics of this traditional approach: a) Customer and supplier have a competitive relationship to each other; b) It is a win/lose game for both parties; c) Each party tries to reduce the opposing party's position of power.

Framework agreements characteristics

According to Gur et al. (2017), framework agreements are anticipated arrangements for the delivery of good and services over a certain period. For the authors, a typical framework agreement is composed of two stages: In the auction stage, an auction-type mechanism takes place to select one supplier as the framework agreement winner for a given product or service. Then, in the buying stage, the supplier should deliver the products under the conditions stipulated, during the duration of the agreement.

A key aim of a framework arrangement should be to establish a pricing structure; however, this does not mean that actual prices should be fixed but rather that there should be a mechanism that will be applied to equipment pricing during the period of the

framework. It should also be possible to establish the scope and types of goods/ services that will need to be called-off (CIPS, 2018).

Framework arrangements can provide many benefits to the buying organization including (CIPS, 2018):

1. Flexibility to determine the specific requirement at the call-off order stage.
2. Saving time at a critical stage in a project, as the buyer can firm up the requirement at the appropriate time and simply call-off rather than having to go through competitive bidding that could cause unnecessary delays to a project.
3. Leverage economies of scale through aggregation.
4. Avoids duplication: one buyer goes out to the marketplace on behalf of all the other buyers in the organization (mainly for public procurement).
5. Avoids re-work, as framework agreements/contracts can be used to remove the need for requisitions and approval processes (as the risk has already been managed) - however some organizations prefer to use the full acquisition procedure, even for call-off orders.
6. It is a suitable method of conducting business in an organization that has devolved budgets - by putting arrangements in place and then empowering end-users to order from them.
7. It is an appropriate method for use by consortia that set up arrangements on behalf of a number of organizations as it provides leverage through economies of scale while maintaining the independence of the buying organizations.
8. Enables eProcurement by putting the suppliers' offerings under the framework arrangement on the eProcurement system for buyers to use

9. Can be used as a method of variety control/standardization as appropriate by offering buyers only the choice of products within a category of spend which are provided for under the framework arrangements in place.

Corporate Alignment

Each organization has different levels, and each level has own objectives and intensions. It is interesting to analize the need of alignment of the different levels within a company and between clients and customers, that are needed to ensure successful collaboration.In that context, Nikinosheri and Staxang (2016) conducted a case study about a contractor-supplier relationship in the construction industry. One of their findings was the difference of opinion in the organizations, both internally and externally that prevented collaboration: On one hand, the strategic level at the supplier want to increase the services provided to customers and to be involved in the design phase to contribute with material and logistics solutions. On the other hand, the operational level at the supplier company consider that the contemporary mode of operation is satisfying, which is focus on delivering products. This corporate misalignment, according to the authors, can have negative consequences for the supplier since it affects the strategy of increasing sales of services.

For the contractor, the situation is the opposite: The operational level is interested in the services provided by the supplier because it will benefit them; however, the strategic level focus on price and does not consider services as a priority.

Figure 3 illustrates the misalignment between the operational level in both organizations and the strategic level. The vision of the strategic level at the supplier company is more aligned with the need and attitude at the operational level of the contractor

company, and the approach of the strategic level at the contractor company is aligned with the approach of the operational level at the supplier company.

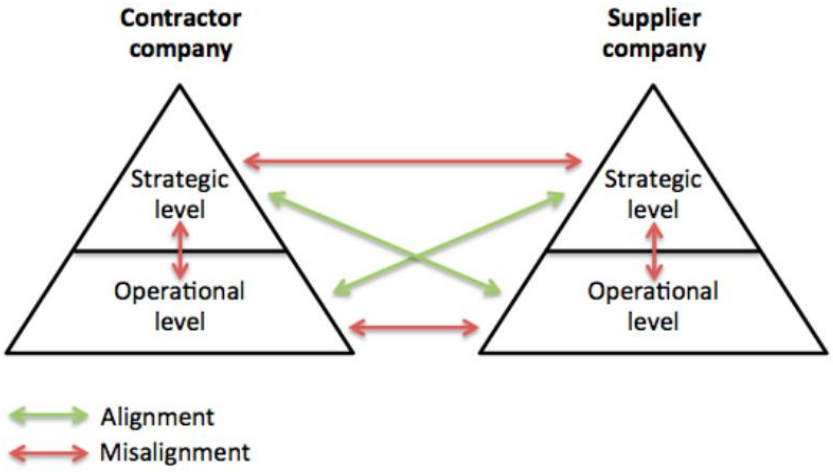


Figure 3 – Alignment and Misalignment between strategic and operational levels of contractor and supplier

In an ideal scenario, to create a collaborative and mutually beneficial relationship, the alignment should exist internally and externally as in Figure 4.

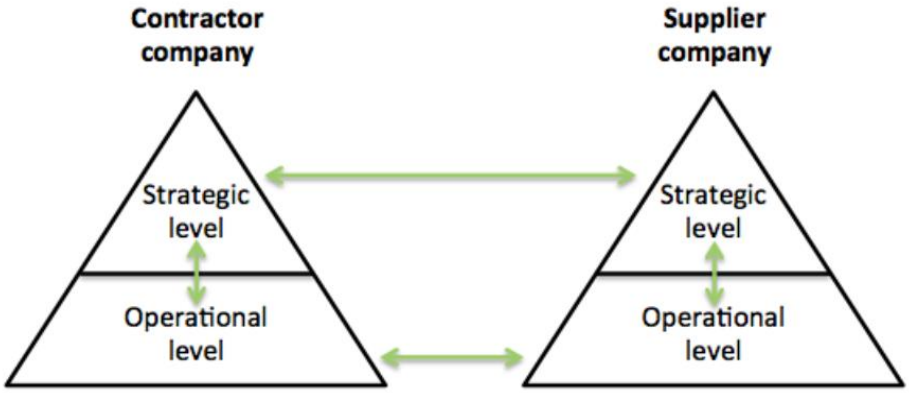


Figure 4 – Ideal alignment scenario

E. IMPLEMENTATION OF AUTOMATED MATERIALS IDENTIFICATION, LOCATING AND TRACKING TECHNOLOGY

Automated Materials Identification, Locating, and Tracking Technologies (AMILTT) such as RFID (Radio Frequency Identification), barcodes, GPS, mobile user interface devices, the internet and so forth are used to assist materials management processes by improving materials and information flow across the supply chain and on the construction site (Wood & Alvarez, 2005). On industrial projects, such as power plants, the management of engineered components on large laydown yards over long periods makes automated materials tracking desirable (Grau, Caldas, Hass, Goodrum, & Gong, 2009).

Different authors have investigated the impact of the implementation of AMILTT on the performance of construction projects in multiple metrics. The following paragraphs summarize their findings:

In terms of productivity, Grau et al. (2009) conducted a field trial on a large project site to compare a traditional tracking procedure with an automated approach to track structural steel components, in terms of labor productivity, and they observed an improvement in steel erection productivity by 4.2%.

In terms of cost savings, Demiralp et al. (2012) observed that the use of RDIF allowed a reduction in the number of missing elements, a reduction in the number of incorrectly delivered materials, and a reduction in the duration of some activities that resulted in decreased labor costs.

In terms of time, RDIF combined with other digital technologies such as tablets scanners and GPD can map the location of materials and avoid having crews wasting time trying to locate materials in the laydown yards (Harvey, 2016). Also, AMILTT technology can also be used for updating the schedule: for example, Gajamani and Varghese (2007)

developed a system based on the use of RFID to automatically collect data, identify the installed components of a structure, update the schedule based on the identified components and present the as-built progress status.

The advantages of material tracking technology have also been studied by O'Brien et al. (2017). The authors conducted case studies of capital projects that have utilized technologies and process for materials management operations in the supply chain and onsite processes and reported the main findings in terms of benefits and challenges of the implementation of the mentioned technologies. Among the benefits, the authors mentioned:

1. Efficient material transactions: Increased efficiency in the material receiving, locating and issuing times, as well as confidence regarding material availability during material transactions. Reduction in material loss, rework, misplacement, unnecessary searching and error reporting.
2. Improved visibility: Enhanced visibility by providing near real-time status and location information of materials.
3. Digitized information sharing: The AMILTT system can streamline some processes such as data entry, generation of packaging lists/shipments/material releases, and reporting and monitoring, with its ability to generate electronic data, share information across multiple stakeholders, and provide accessibility at multiple locations via a common platform.
4. Productive meetings: The improved access to information due to the AMILTT technology can help stakeholders to have productive meetings, making the focus of those meetings the issues and not the reliability of the data.
5. Improved safety: Improved safety of the job site by reducing the exposure of the crew to a hazardous work environment.

On the other hand, some of the challenges that O'Brien et al. (2017) identified are:

1. Changes: Minor changes can affect the materials management function.
2. Data integration: The integration of the AMILTT system with the different legacy systems can be time-consuming and require coordination and communication between the technology solution providers and the company IT teams.
3. Organization and Sociological: There can be a reluctance among upper management (mainly because of the implementation costs) or hesitance of crews in the field to embrace the technology (due to resistance to change and lack of experience with technology).
4. Technology and Process: Hardware, software and process-related issues and glitches can affect the performance of this technology.

F. BUILDING INFORMATION MODELING

Construction projects are becoming much more complex and challenging to manage (Chan, Scott, & Chan, 2004), and, as a way to cope with this complexity, information and communication technology has been evolving at a fast pace. One significant development during the last decade is the proliferation of Building Information Modeling. According to the American Institute of Architects (NBIMS, 2004), a Building Information Model is "a digital representation of the physical and functional characteristics of a facility."

BIM Dimensions

Even though initially the term BIM referred to the 3-dimensional models, there are also other dimensions that can be identified. 3D models can be combined with a schedule or time-related information to create a 4D CAD model, generating a simulation that allows

a step-by-step visualization of the construction process (Schneider, 2013). When a 4D model is linked with cost information, a 5D model is created; quantities can be obtained from the model in an automated process that is called model-based quantity take-off (that takes less time and is more accurate than manual take-offs), and those quantities can be combined with cost data to generate automatic cost estimates (Schneider, 2013). The sixth BIM dimension refers to sustainability, and finally, the seventh dimension is known as the Facility Management dimension (Dallasega, et al., 2015).

BIM applications in construction

The BIM project execution planning guide (2010) identifies twenty-five BIM uses. Those uses were recognized through interviews with industry experts, case studies, and literature review. The uses are: Existing conditions modeling, cost estimation, phase planning, programming, site analysis, design reviews, design authoring, energy analysis, structural analysis, lightning analysis, mechanical analysis, other engineering analysis, LEED evaluation, code validation, 3D coordination, site utilization planning, construction system design, digital fabrication, 3D control and planning, record model, maintenance and scheduling, building system analysis, asset management space management/tracking and disaster planning.

BIM maturity levels

BIM is a process aiming to involve stakeholders in a systemized information flow for optimal collaboration. However, in the progression of the industry from separate to collaborative working, milestones or levels can be identified. These levels are part of the Bew-Richards BIM Maturity Mode and, according to Adams (2019), represent:

1. Level 0 BIM: Level 0 effectively means no collaboration. 2D CAD drafting is used, and distribution is via paper or electronic prints, or a mixture of both.
2. Level 1 BIM: This typically comprises a mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation. There is no collaboration between different disciplines – each publishes and maintains its data.
3. Level 2 BIM: This is distinguished by collaborative working – all parties use their 3D CAD models, but not necessarily working on a single, shared model. Design information is shared through a common file format, which enables any organization to be able to combine that data with their own in order to make a federated BIM model and to carry out interrogative checks on it. This is the method of working that has been set as a minimum target by the UK government for all work on public-sector work by 2016.
4. Level 3 BIM: This level represents full collaboration between all disciplines by using a single shared project model which is held in a centralized repository. All parties can access and modify that same model, and the benefit is that it removes the final layer of risk for conflicting information. This is known as 'Open BIM.' The different levels can be seen in Figure 5.

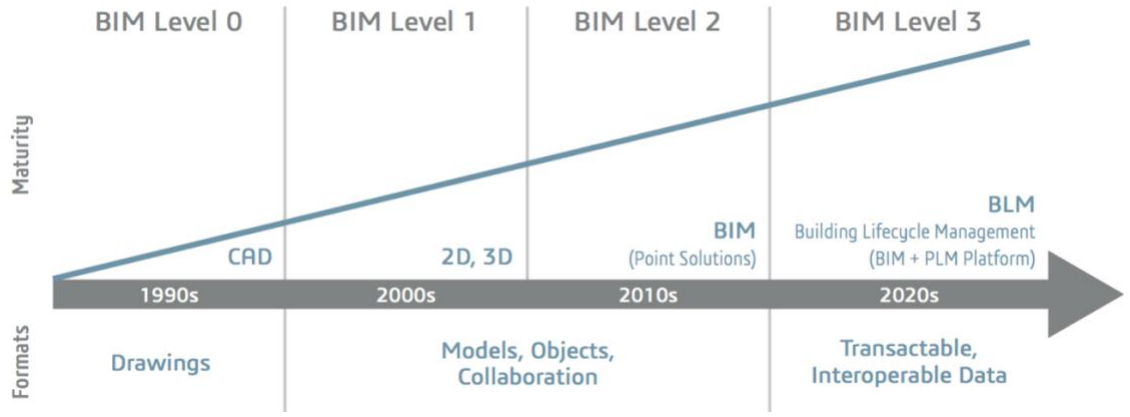


Figure 5 - BIM Maturity levels – Source: TMD Studio

G. MODULARIZATION

The following sections present the concept of modularization, an overview of its advantages and disadvantages, and a review of the application of modularization in construction in general, and in industrial and power projects in particular.

Definition of modularization

According to Choi (2014), the technique of exporting a portion of site-based work to a fabrication or module assembly shop is commonly referred to as modularization, and has the potential to increase construction efficiency and productivity. According to the author, since its introduction, the value and benefits of modularization have been widely recognized, which includes lower capital costs, better scheduled performance, higher productivity, improvements in quality, increased safety performance, reduced waste, and better environmental performance.

Modularization is defined by Haas et al. (2000) as the preconstruction of a complete system away from the job site that is then transported to the site. The modules are large and possibly may need to be broken down into several small pieces for transport. A module, according to Tatum et al. (1987), is a major sector of a plat resulting from series of remote

assembly of operations and may include portions of many systems, usually the largest transportable unit or component of a facility.

Advantages of Modularization

This section addresses the main benefits of modularization according to existing literature. It is a list of the principal and more relevant positive aspects, and not a comprehensive report of all the constructive impacts that the use of this approach may involve for a project:

A) Improved Project Schedule: Reduced construction schedule and elimination of weather delays are the two main reasons why modular projects have better schedule performance. The construction of the modules can occur simultaneously with the on-site work, so projects can be completed sooner than traditional construction. Furthermore, most of the construction is completed inside a factory, which mitigates the risk of weather delays. As a consequence, the facilities are ready to operate sooner, allowing for a faster return of investment. As an example, a survey from McGraw Hill Construction (2011) shows that 66% respondents (contractors of residential projects) indicated that prefabrication/modularization processes can have a positive effect on schedule performance, with 35% of those respondents indicating that it can reduce the project schedule by four weeks or more. Figure 6 shows a representation of the time saving of a modular project compared with a stick-built approach.

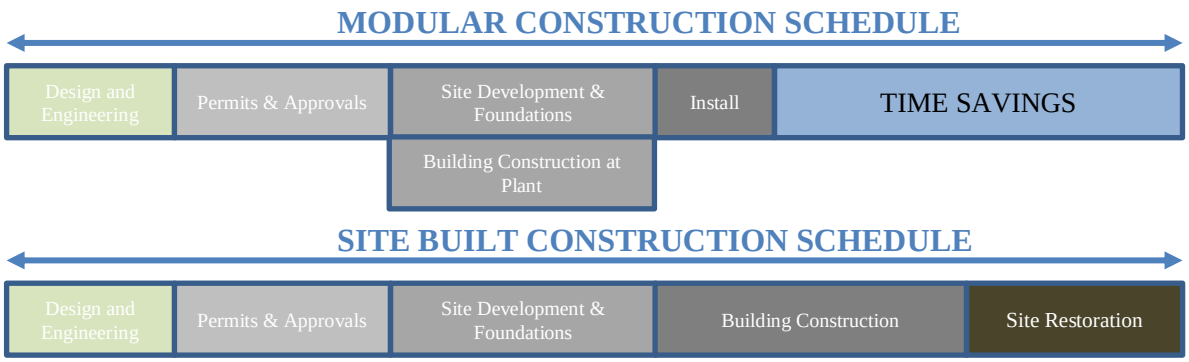


Figure 6 - Timeline comparison between modularization and site-built construction – Source: Modular Building Institue

B) Reduced Cost and Budgets: The cost benefits of using modularization is one of the main drivers for its implementation. Some cost savings are: Reduction of onsite labor and accommodation, as well as staff budget, fewer materials delivery, reduced cost of transporting workers, among others. Labor rates in fabrication shops are also typically lower than on-site construction. According to Rogan et al. (2000), modularizing could lower costs by about 15%.

C) Site Safety: If modularization is extensively implemented in projects, work is shifted to controlled environments, which result in an improvement in quality mainly because of reduced exposure to inclement weather, extremely high or low temperatures, hazardous operations, and elevated fabrication activities.

D) Quality: With better and controlled indoor work environment, increased availability of a skilled labor force, increased quality control and increased module testing, an improvement in quality can be achieved with a modular approach.

E) Productivity improvements: Productivity is improved since there are less site disruptions and wet trades, and because weather effects are minimized (Gibb & Isack,

2003). As a consequence, productivity can be improved. As an example, contractors working in a prison loose a significant amount of time ingressing and egressing from the site due to security checks. A reduction of field work will lead to less on-site personeel and cost savings for security. In the case of airports, road and rail projects, site access and working space are often restricted, and pre-assembly is seen to bring additional benefits.

F) Achieve green construction: The factory-controlled process generates less waste and creates fewer site disturbances (Modular Building Institute, 2018). With a modular approach, there is less site disturbance as on-site traffic is greatly minimized from workers, equipment, and suppliers. Also, when building in a factory, waste is eliminated by recycling materials, controlling inventory and protecting building materials, as well as reduced air and water pollution, dust and noise, and overall energy costs.

G) Reduced Site-based Permits: Modularization influences the types and number of permits needed, since there are less dangerous or hazardous operations such as working at high heighs or welding. Also, as work can begin in the shops while permits are still not ready, the effect of a lengthy permitting process is minimized. (Choi, 2014).

Disadvantages of Modularization

Owners usually consider and evaluate modularization benefits and challenges to determine is this approach is the best option for executing a project. Primary challenges or disadvantages are: High initial investment, coordination challenges, and engineering design, procurement and logistic barriers:

A) High initial investment: According to Choi (2014)**,** in order to design modules on time, and to satisfy quality and safety standards, companies need to invest more, sooner. Also, the cost of transportation also rises with the use of bigger cranes and ships. However, as mentioned in the previous section, the overall cost of the project can be reduced. Figure

7 shows a conceptual comparison between modular projects and stick build projects in terms of fixed and variable cost, where the high initial fixed cost is incurred early:

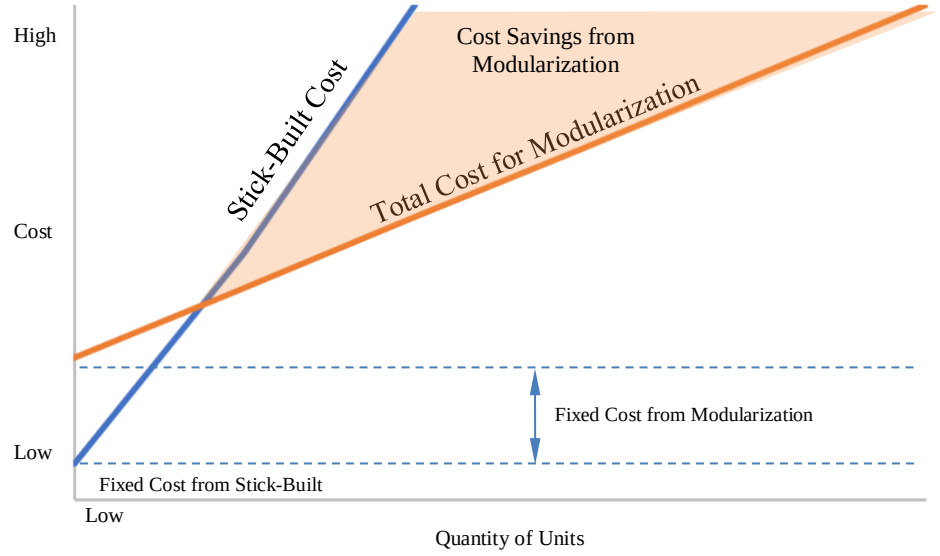


Figure 7 - Conceptual comparison between the cost of modular construction and stick-built construction

B) Coordination challenges: Because many activities are performed in parallel rather than in series as in conventional construction, more extensive coordination between stakeholders is needed. Design, fabrication, inspection, transportation, handling and erection activities should be carefully planned to avoid expensive rework and to meet owner requirements. This is translated into the need of more people, resources, and effort allocated to coordination activities.

C) Engineering Design Barrier: Early scope definition and freezing is important, which involves correct timing of critical decisions because there is a "window of opportunity" that should be considered (Choi, 2014).

D) Procurement barrier: The universe of providers of components via prefabrication/modularization is relatively small compared to the universe of providers of other kinds of components (McGraw-Hill Construction, 2011). This limited range of sourcing options is seen as a constraint and a risk factor.

E) Logistics barrier: Logistical challenges such as the shipping of the modules (need for careful shipping sequence and availability of storage space), availability of heavy lift cranes (Cranes having 5000 tons of capacity or more are an unlikely development for example (Youdale, 2009)), and transport restrictions (length, width, height and gross weight) limit the extent of modularization in a project and may discourage stakeholders to build bigger modules on projects.

Modularization across the industry

McGraw-Hill Construction (2011) examined, through an Internet survey, the level of modularization in different sectors. The five sectors using modularization in over 40% of projects are healthcare, higher education (dormitories and school projects), manufacturing, low-rise office buildings, and public works. On the other hand, the construction of renewable energy plants and the petrochemical sector use lower levels of modularization.

O'Connor et al. (2015) commented that a high level of modularization is found among industry sectors and projects that possess the following characteristics: (1) located in areas with a limited craft workforce, extreme site environments, extreme climatic conditions, a workforce with low productivity, highly congested areas or in environmentally sensitive areas (3) with urgent completion schedule targets; (4) projects with extreme demands for quality, which can be more readily met with shop fabrication: (5) located in regions with long permitting cycles; (6) operations-sensitive projects that

require avoiding hot work in or near operating units; (7) ready access to high-quality fabrication yards, and (8) projects with technical/contract requirements.

Modularization in the industrial sector

Even though the potential benefits of modularization are well known, according to Haas et al. (2000) the extent of modularization in the industrial sector had grown little as of 2000. O'Connor et at. (2016) identified needed changes or adaptation in conventional project work process to increase the level of modularization for industrial projects. The authors developed a list of critical success factors (CSF) and identified enablers that can accomplish the associated CFS. The CFS identified are: Module Envelope Limitations, Alignment on Drivers, Owner's Planning Resources & Processes, Timely Design Freeze, Early Completion Recognition, Preliminary Module Definition, Owner- Furnished/Long Lead Equipment Specification, Cost Savings Recognition, Contractor Leadership, Contractor Experience , Module Fabricator Capability, Investment in Studies, Heavy Lift/Site Transport Capabilities, Vendor Involvement, Operations and Maintenance (O&M) Provisions, Transport Infrastructure, Owner Delay Avoidance, Data for Optimization, Continuity through Project Phases, Management of Execution Risks, and Transport Delay Avoidance

Modularization in the power sector

Both O'Connor et al. (2015) and McGraw-Hill Construction (2011) stated that low levels of modularization are found in renewable energy plants and power plants. However, in the power sector, there have been some efforts from suppliers to increase the level of modularization. For example, General Electric offers a significant number of the elements of the Power Island of power plants (main pipe rack, vessel, cooling water, ejector) as

modules to facilitate installation (General Electric, 2019). Also, Eaton (2016) developed a modular design for an electrical substation that is assembled, integrated and tested in a factory environment, and that presents some advantages such as reduced costs and footprint, increased transportability, environmental benefits, and more flexibility.

Also, there has been research about the benefits of modularization in power plants: Gotlieb et al. (2001) compared two different designs for a 300MW coal-fired installation: a modular design and a stick-build design**.** The most significant difference between the two designs is the full use of modular or skid-mounted mechanical and electrical equipment. The authors presented the differences between the two concepts in term of design, schedule, and cost.

In terms of design, some of the advantages that the authors identified of the modular approach are: better access for equipment maintenance and inspection, smaller structure due to lighter loads, reduction in wiring, among others.

In terms of the construction schedule, the following conclusions were reported: the modularized power plant, from the start of engineering and design through completion of plant start-up, will require 34 months for completion. The stick-built power plant that would require 43 months for completion, which means that modularizing represents a nine months reduction in the total project duration. The bulk of the time savings comes from four significant items: Use of pre-fabricated and pre-tested modules that only require installation, final piping and electrical hookup; Reduced amount of field labor associated with assembly and construction; Reduced time required for plant start-up since the modules will have been shop-tested prior to shipment; and displacement of 40 percent of the stick-built field manhours, which can be expended more efficiently in a shop environment than in the field.

Finally, the authors reported that cost savings could be expected. These are a result of the displaced stick-built field hours, improved efficiency of 15% and a bare wage rate at 20% less than the field labor rate. Also, equipment rental, small tools, expendable supplies and temporary facilities for the stick-built portion of the plant are significantly reduced due to the lower amount of field labor expended and the shorter overall duration in the field for both direct construction and plant start-up. Moreover, construction staff costs savings, which are due to the overall shorter duration in the field for construction and plant start-up, and savings associated with modularization of the piping, electrical, buildings and structures were identified. The two offsets to the above savings are increased home office and engineering costs due to the modular design and increased structural costs for the modules and module logistics and transportation costs.

H. STANDARDIZATION

This section covers the concept of standardization by stating its definition, the current level of standardization in capital projects and its advantages and disadvantages. The last section covers the concept of combining standardization with modularization.

Definitions

Standardization can be defined in many ways: CII defines standardization as the attempt to design elements of a facility consistently in such a way to promote repetition, increase productivity and reduce field errors (Construction Industry Institute, Constructability Implementation Guide, 2016). Also, Karim and Nekoufar (2011) define standardization of a project as to all activity to make a large-scale project as identical as to other similar projects by means of standardization of design, reducing output variability, strategic planning, standardization of procurement and construction.

Standardization in the industry

O'Connor et al. (2013) analyzed the current levels of standardization of various sub-sectors of the capital projects industry. According to the authors, higher levels of design standardization are often found among industry sectors and projects that possess the following characteristics: a) Dominant OEM- and equipment-driven project, such as a gas turbine power generation projects, integrated gasification combined cycle projects, fluidized bed combustion projects, and high temperature gas-cooled reactor projects; b) Facilities that involve a large number of repetitive units, such as low-sulfur gasoline refinery units, hotels, prisons, university dormitories, franchise restaurants, fuel stations, and retail stores; c) Shipbuilding industry. On the other hand, according to the authors lower levels of plant design standardization are often found among industry sectors and projects that possess the following characteristics: a) Projects involving a new or immature manufacturing process/technology that is likely to continue to change; b) Brownfield projects with highly variable existing conditions and complex interfaces between new and existing facilities; c) Projects requiring high levels of fuel type- or feedstock-driven customization, such as refineries; d) Projects with highly variable, uncontrollable site locations that may involve wide variations in such aspects as seismic conditions or ambient working temperatures; e) Manufacturing markets with very tight profit margins that cannot accept the performance tradeoffs often required with standardization; f) Organizations with very short-term investment timeframes and less tolerance for slow investment payback (which may result from the expense of developing the standard design), g) Markets with highly variable clients, that fail to coalesce into a uniform group with shared objectives and predictable needs.

Disadvantages and benefits from Design Standardization

O'Connor et al. (2013) identified ten advantages and three disadvantages of the implementation of standardization and assessed and ranked the relative significance of their impact.

Advantages:

1) Design only once and reuse multiple times
2) Design and procure in advance/respond to schedule needs
3) Accelerated, parallel engineering for site adaptation
4) Learning curve benefits in fabrication
5) Procurement discounts from volume or early commitment
6) Construction materials management cost savings
7) Learning curve benefits in module installation/site construction
8) Learning curve benefits in commissioning/startup (planning & execution)
9) Learning curve benefits in operations and maintenance (given clients with multiple plants)
10) O&M Materials management cost savings

Disadvantages:

1) Cost of assessing the market and establishing the scope
2) Cost of establishing the design standard
3) Sacrificed benefits from conventional customization

Standardization with Modularization

Considering the advantages and disadvantages listed for the use in modularization and standardization in infrastructure projects, this section has the objective of commenting on the combination of both.

O'Connor et al. (2013) stated that the concept of combining design standardization and modularization is not new to the construction industry or other industries. This combination is an opportunity that can combine the benefits from both strategies. The authors explained that one could standardize plant designs with no modularization, and one can modularize plants with no design standardization. When both are accomplished on a project, however, additive benefits result, and in some cases, certain benefits are amplified.

The authors identified two approaches to combine design standardization with modularization: formulation of a modular, standardized plant, and the creation of a standard module.

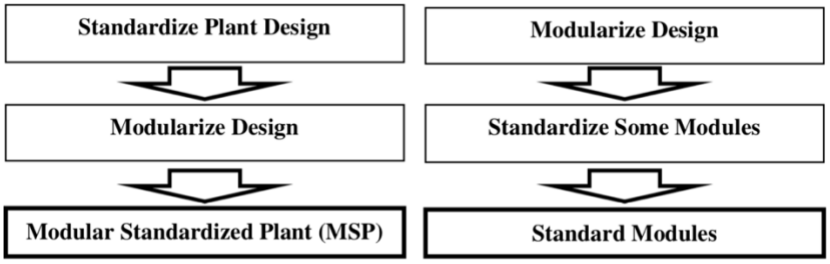


Figure 8 - Approaches for combining standardization with modularization

When plant design standardization is applied at a business-unit level, it is often referred to as a corporate reference plant strategy. Subsequent modularization of a standard design can then result in a modular standardized (reference) plant (MSP). A modular reference plant incorporates all the benefits of both design standardization and modularization, which, taken together, can be sizeable. Alternatively, when design standardization is applied as part of a more significant modularization effort, standard modules or standard submodules result. In this case, not all project modules are of a standard design, and the entire plant is not the result of a business-unit-level design

standardization effort. Many, though not necessarily all, of the benefits from standardization can result from this approach. Figure 8 illustrates the differences between these two approaches.

The authors depicted the costs and benefits of implementing standardization and modularization from the perspective of fixed and variable costs, at the conceptual level. Figure 9 illustrates that the costs and savings from modularization (light blue area) or modularization and standardization (dark green area) may be highly influenced by fixed costs (line-height) and variable costs (line slope).

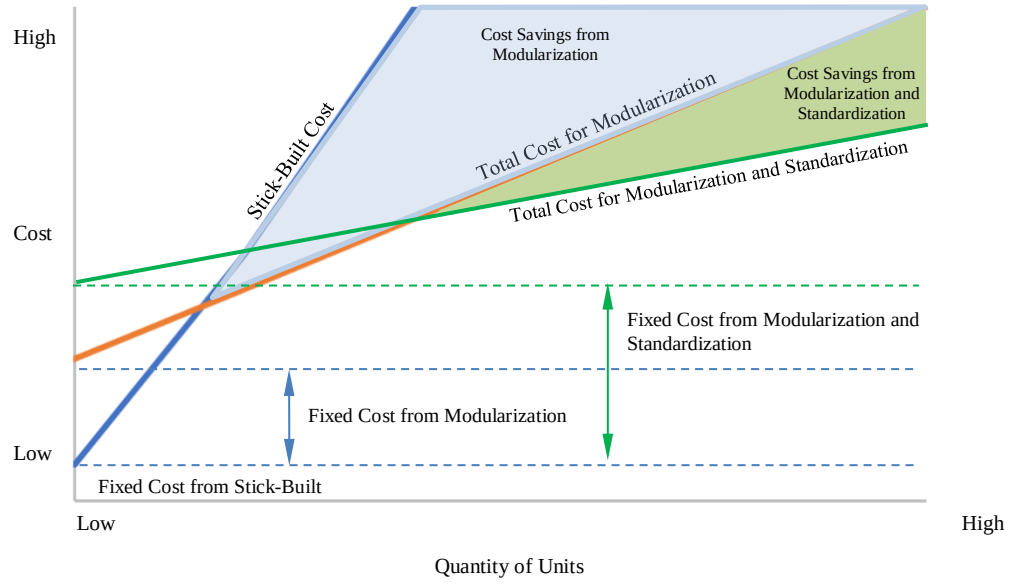


Figure 9 - Cost savings from Modularization and Standardization

I. EARLY DESIGN FREEZE

Definitions

CII (1995) defines change as any event which results in a modification of the original scope, execution time or cost of work. Changes cause performance disruptions especially on time and cost. Even though many factors can cause changes in construction

projects, one of the most influential factors is design change (Gde Agung Yana, Rusdhi, & Wibowo, 2015). Buratti et al. (1992) studied the causes of changes in industrial construction projects and concluded that design deviations average 78% of the total number of deviations, 79% of the total deviation costs and 9.5% of the total project cost.

In that context, Design Freeze (DF) is a method that is used during the design development stage of any project to mitigate the risks associated with change by controlling changes and forcing the completion of design stages on time (Hemal, Waidyasekara, & Ekanayake, 2017). The term refers to one certain point in the project timeline, at the end of the detailed design phase, at which the final set of the technical drawings is signed off and released to production or construction.

Some benefits of design freeze have been reported by Eger et al. (2005) for the manufacturing industry: When the design is frozen, the product can be manufactured. Also, when key parameters are frozen, dependent design can be finalized. In construction, for example, design freeze allows ordering of long lead time items and minimization for costly changes. Finally, according to Choi (2014), one of the key critical success actors for the success of the implementation of modularization in industrial projects is the timely design freeze: Owners and contractors should be disciplined to implement timely staged design freezes so that modularization can proceeds as planned.

Importance of early freeze

Figure 10 graphically demonstrates the relationship between ‘scope for change’ and the ‘cost of change’ during different stages of the project:

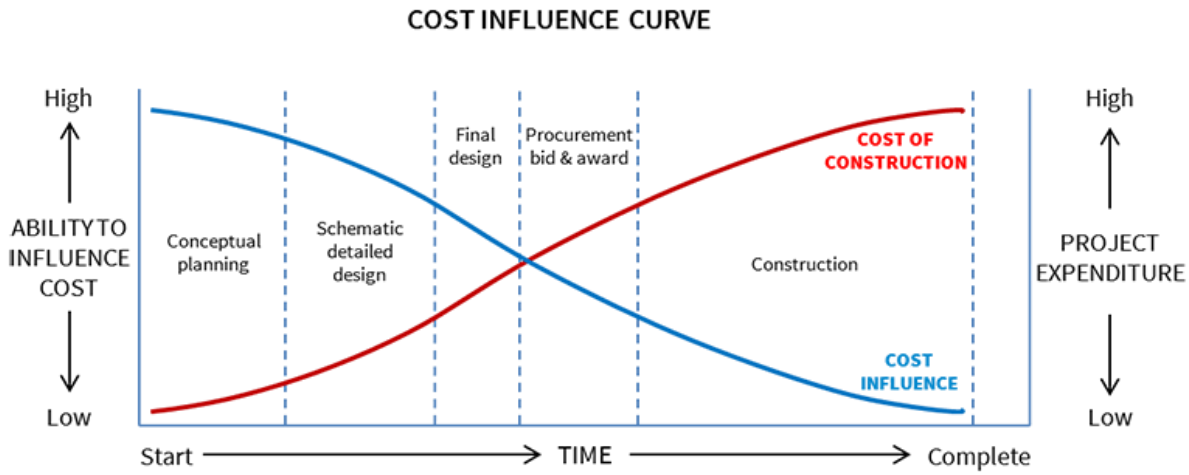


Figure 10 - Cost influence curve

According to Barrie and Paulson (1991) in the early phases of a project, i.e., the expenditures are small compared to the total project cost. Typically, engineering and design fees account for approximately 10% of the total cost. Similarly, capital costs invested by the time construction is completed often are a small fraction of the operational and maintenance costs associated with a project's complete life cycle. However, even when expenditures during the early phases of a project are small, decisions and commitments made during that period have a greater influence on what later expenditures will be. On the first day, management has a 100% level of influence in determining future expenditures, but as engineering and design continue, decisions become more detailed, but the implications are no less significant. As these decisions evolve and commitments are made, the remaining level of influence on the costs of the project drops off precipitously. As a consequence, it is evident that changes will have a greater cost impact the later they are implemented into the design. If there is a point in time where no more changes are accepted (i.e., design freeze), and if this point is as early as possible in the project development process, savings can be obtained.

J. ADVANCED WORK PACKAGING

Definitions

Construction projects generally consist of a set of numerous resources and components that should be connected and assembled to create the final product. This creates numerous interfaces and increases the need for coordination of the stakeholders involved in the process. The basis for effective interface planning and management is breaking the construction process into manageable work packages. The Project Management Institute (PMI) recommends using work breakdown structures (WBS) to divide a project into pieces so they can be managed easily (PMI, 2004) and defines Work Package as a deliverable at the lowest level of the WBS.

In that context, CII (2013) defines Advanced Work Packaging as the overall process flow of all the detailed work packages (Construction Work Packages (CWPs), Engineering Work Packages (EWPs), and Installation Work Packages (IWPs)), where:

a. Engineering Work Package (EWP): An EWP is an engineering and procurement deliverable that is used to create CWPs. The EWP should be aligned with the construction sequence and priorities.
b. Construction Work Package (CWP): A CWP defines a logical and manageable division of the work within the construction scope. CWPs are aligned with the project execution plan and the Work Breakdown Structure.
c. Installation Work Package (IWP): An IWP is a deliverable that enables a construction work crew to perform a work in a safe, predictable, measurable, and efficient manner.

In general terms, CII (2013) identified productivity and predictability of project performance as the two main benefits that the implementation of advance work packaging can bring to projects.

Benefits of Advanced Work Packaging

CII (2013) identified, through case studies and expert interviews, benefits that are associated with AWP. Those benefits are:

a. Improved Project Party Alignment and Collaboration
b. Project Data Stored in One Location and Site Paperwork Reduced
c. Issues Identified During Planning – Increased Quality and Reduced Rework
d. Improved Project Predictability – Cost and Schedule
e. Improved Safety Awareness and Performance
f. Drives Planning and Accountability
g. Supervisors Spend More Time Supervising
h. Decreased Supervisor and Craft Turnover
i. Improved Labor Productivity
j. Increased Reporting Accuracy
k. Enhanced Turnover
l. Improved Client Satisfaction

SUMMARY OF LITERATURE REVIEW

The literature review conducted covered different topics related to capital projects that can be grouped into the following categories:

1. Strategies to improve collaboration and information sharing, since for a better engagement of the supply chain, working toward the same goal and exchanging data

are vital factors. The strategies reviewed are: Framework agreements, partnership, and alliances, Early involvement of stakeholders, Coordination of owner furnished equipment and Construction contracts.

2. Technology that can be implemented to improve project performance: Material Tracking and Building Information Modeling.
3. Industry trends and strategies that were successfully applied in other sectors and may involve advantages for power projects: Standardization and Modularization.
4. Other areas such as Early Design Freeze and Advanced Work Packaging.

Chapter 4: Expert Interviews

This chapter presents the results from the conducted expert interviews with owners, contractors, suppliers, and engineers working in power projects.

QUESTIONNAIRE

As mentioned in previous sections, the literature review and industry experts' interviews were conducted at the same time and based on the interviewed comments the literature review was successively expanded. This is why the questionnaire guide changed and was completed as this process was developed. The main questions asked to the experts were:

1. What are some of the frictional aspects that usually arise during the execution of power projects that if solved can improve supply chain engagement and project performance?
2. What are potential improvements and innovations that can better engage supply chain stakeholders?
3. For projects or experiences with innovative/extensive/beyond the norm approaches for: Modularization, Standardization, improvements in contracts, early involvement of stakeholders, Owner Furnished Equipment, framework agreements, material tracking technology, BIM and AWP:
    a. What was different in the execution of this project compared to standard approaches or other projects?
    b. What were the main drivers?
    c. What were the main benefits?
    d. What were the challenges encountered?

e. What would be possible to do in order to support a more frequent or common implementation of this innovative approach?

EXPERTS INTERVIEWED

For confidentiality purposes, the name and company of the expert's interviewed were removed from the text. However, the following table presents the company and the area they experts interviewed work for:

Table 1 - Expert interviews

EXPERT	TYPE OF COMPANY	Area
EXPERT 1	Owner - Investor	Operations
EXPERT 2	Supplier – Bulk materials	Management
EXPERT 3	Supplier – Prefabricated materials	Management
EXPERT 4	Contractor - EPC	Operations
EXPERT 5	Contractor - EPC	Procurement
EXPERT 6	Owner - Utility	Procurement
EXPERT 7	Contractor – Construction Management	Operations
EXPERT 8	Supplier – Bulk materials	Supply chain

Also, two extended expert interviews were conducted, with multiple participants from the following companies:

Table 2 - Extended expert interviews

COMPANY	TYPE
OWNER	Utility company
CONTRACTOR	Electrical contractor
SUPPLIER	Engineered equipment supplier
ENGINEER	Engineer

When presenting the results from the extended interviews, companies are used to represent the experts.

INTERVIEW CODING

As mentioned in Chapter 2, coding was used to analyze the information collected into the interviews. Interview transcriptions were reviewed to identify important themes and patterns, and initial coding was performed. After the initial coding was finalized, the codes were organized into categories by grouping similar ones. The following categories were identified:

Table 3 - Identified categories from expert interviews

1. Framework agreements/Partnership/Alliance Contracting	2. Early O&M input in the design
3. Use of BIM to support design, procurement and construction and sharing of models	4. Material tracking technology
5. Visibility into supplier production schedule	6. Modularization
7. Visibility into the contractor construction schedule	8. Adaption of advance work packaging
9. Visibility into contractor procurement schedule	10. Incentives/Liquidated damages
11. Provisions to include Field technical support	12. Early Design Freeze
13. Use of standard designs	14. Integrated project delivery
15. Coordination around owner purchased equipment	16. Standard contracts/Language
17. Better estimating/Control of quantity growth	18. Early involvement of stakeholders
19. Develop standards around testing and commissioning	20. Factory testing
21. Strategy of multiple owners co-investing in the same place	22. Automation technology/Robotic welding

The following chart shows the association between the expert interviewed and the categories:

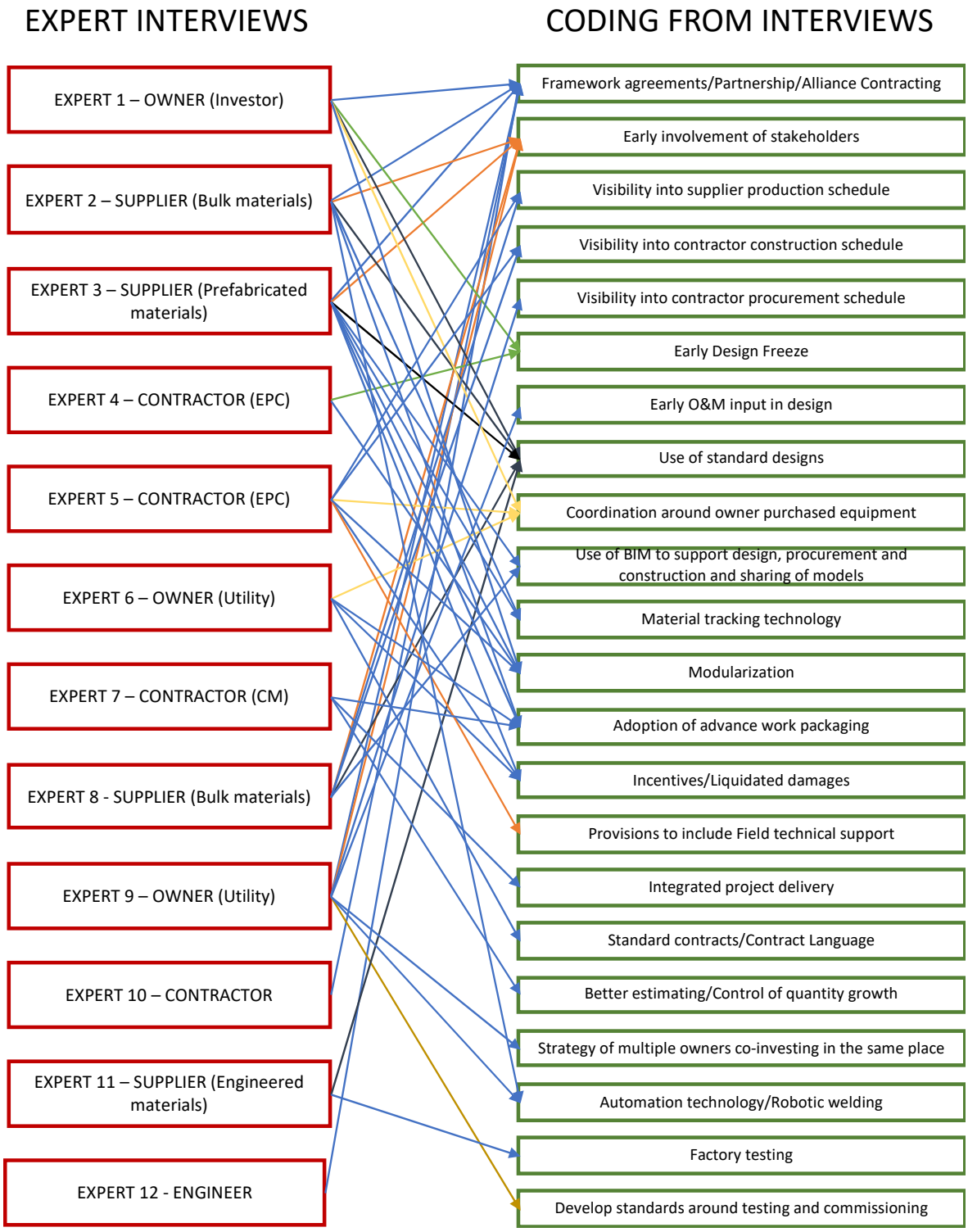


Figure 11 - Association expert interviews - coding categories

RELEVANT ASPECTS FROM EXPERT INTERVIEWS

The following sections present the key points collected in each interview associated with the above categories.

Expert 1: Owner – Investor

Framework agreements/ Partnership / Alliance Contracting	"Framework agreements can drive down costs because of volume purchasing, life cycle efficiency, and less inventory. However, it is key to select the partner wisely in order to avoid cost escalation."
Early design freeze	"I see that early design freeze is an opportunity for advancement in power projects. It is essential to lock the scope and design as quickly as possible."
Use of standard designs	"The main challenge to come up with a complete standard design is the change in the footprints. The benefits include cost reduction, speed of execution and improved quality."
Coordination around owner furnished equipment	"We do not usually buy the equipment since we have a small team. By transferring the responsibility to the contractor, we are reducing the risk, but at the same time spending more money, since we are not saving the contractor markup."
Modularization	"I participated in a project where some natural gas compressing facilities were built using modularization, and others using a stick build approach. The non-modularized facilities took three times on-site at ended up with a higher cost than the modularized facilities."

Expert 2: Supplier – Bulk Materials

Framework agreements/ Partnership / Alliance Contracting	"One of the challenges with framework agreements is to negotiate the right price escalation. Owners want to know the rates, particularly labor rates, one or two years in advance, and that is a challenge since there are not labor indexes for the business."
Early involvement of stakeholders	"Early involvement of suppliers involves advantages because the supplier can influence the strategy about cost. We can assist the owner with the purchase process or implement a different technology. Early involvement of suppliers can lead to lower costs for the project in the long term."
Use of standard designs	"Every company has its standards, and there is not a global standardization in the industry. Moving forward in that direction will be beneficial since we would be able to build for inventory and can we would get advantage of periods of low demand and use the existing structure of labor to produce those standards components and have good delivery schedules for future orders."
Adoption of Advance Work Packaging	"Although AWP can increase field productivity, for suppliers its use demands time and planning effort. However, AWP can bring advantages: if its use of AWP involves more planning from our customers and fewer priority changes, it would be beneficial for us".
Material tracking technology	"At some point, RFID is going to be a great technology to use broadly, but for pipe spools (round and heavy) the handling often produces the loss of the barcodes, so we are not using it yet. However, we do use barcode tracking of the spool sheets on the shops, so we can know how the spools are progressing through the shops."
Automation Technology/Robotic Welding	"An ideal scenario would be to identify or to achieve a simplified welding process that is independent of the skills of the welders."

Expert 3: Supplier – Prefabricated Materials

Framework agreements/ Partnership / Alliance Contracting	"Most EPCs we work with have a strategy of looking for the lowest price in terms of unit rates instead of choosing one partner and a tendency not to share information about the need dates with the suppliers. In an agreement scenario, the EPC would share the actual need dates, which will allow us to plan production and men hours accordingly. Also, in an agreement to work together across multiple projects, we can offer more accurate pricing because we have more information, and as a consequence, the uncertainties and the risks are reduced."
Early involvement of stakeholders	"Early involvement helps to avoid change orders and conflicts. The estimation of the cost of not being involved early in the project is difficult, but the effect that this has on our production planning and in the clients or work we may go after is significant."
Use of standard designs	"We believe that all stakeholders are pushing standards in the industry. We have an experience with an EPC firm, where we meet once a year to discuss the standards around connections, and potential cost and schedule savings."
Liquidated damages	"As the customers are usually responsible for most of the changes, a claim about liquidated damages is difficult to win for them. All of this can only create an adversarial relationship with the client instead of a collective or team approach."
Adoption of Advance Work Packaging	"The division of the engineering in packages is not efficient from our point of view, because similar components are divided into different packages, received and sequenced in different moments."
Modularization	"Usually, module yards are not large, so they need the steel just in time, which is a challenge. Also, we noticed that with modules, the quality and detail of the drawings we receive is usually higher than in other projects."
Material tracking technology	"There is much discussion about RFID as a technology that can increase efficiency. Right now, I think it is more beneficial for the field than for the fabrication shops."
Use of BIM to support design, procurement, and construction and sharing of BIM models	"Although it has been a growth in the use of 3D programs in the last decade, the number of models we receive is limited and, in some cases, not detailed enough for fabrication. A potential saving time strategy will be to work on the 3D model instead of using the drawings: Send the model back and forward with modifications until its complete and ready for fabrication."

Expert 4: Contractor-EPC

Early design freeze	"When the design is between 60% and 90% complete, it should be frozen. Typically, if you try to freeze the design earlier than 60%, and you do not have construction input, you are going to run into construction issues. However, if you do not lock it down, the design is going to start changing based on personal preferences." "The difficult I had run into when I tried to freeze the design early is that the construction crews are not normally involved in much of the upfront conversations. Also, the people that are going to operate the final product very rarely have made the input that they wanted or needed at the beginning of the design process."
Modularization	"There are two main reasons why modularization is used: The first is a cost perspective (lower labor rates available in places such as Indonesia or Thailand). In this case, you need to be sure that there is no reduction in quality or safety, and the transportation costs are reasonable. The second reason is site congestion and availability of workforce. In power plants, as they are not necessarily close to the coast, the transportation (by trucks) limits the size of the modules."

Expert 5: Contractor-EPC

Coordination around owner furnished equipment	"In our projects, the owner typically buys the most critical equipment (because they may have long term agreements with suppliers for example), and this often produces conflicts because the owner may have negotiated the contract with provisions we may not agree."
Liquidated damages	“If they are used, they should be measurable, reasonable, and include incentives associated with the achievement of certain targets."
Field technical support	“Contracts should include provisions to be sure that the contractor involves the right resources to provide adequate field support to face field changes. Contractors need to have enough field engineers to make the response time in case of a problem as short as possible. A collaborative team between the owner and the contractor in the field is key to ensure prompt resolution of problems.”
Visibility into the supplier production schedule	“The challenge is to match the delivery sequence with the construction sequence. While suppliers want to manufacture elements in a way to improve their shop efficiency (which may not be consistent with the construction sequence in the field) contractors in some cases want to have the equipment weeks or month in advance, to have a buffer in case of potential issues with the equipment production or delivery. Having visibility into both schedules can help in that sense."
Visibility into the construction schedule	

Expert 6: Owner - Utility

Coordination around owner furnished equipment	"We divided the project into several similar units, and we used different approaches for each one. For the first unit, we used an EPC strategy, but after realizing some commercial possibilities by buying the equipment, we decided to buy critical and highly engineering equipment for the rest of the units."
Liquidated damages	"Liquidated damages may produce unwanted behavior and relationships. One of the keys to project success is to have good relations between stakeholders, and this is a challenge when liquidated damages are in place. A negotiation of long-term agreements is particularly difficult when liquidated damages are included."
Standard contracts/contract language	"It is a problem when the EPC try to add their set of terms and conditions, to the provisions we normally use, because handling those two sets is difficult, especially when they are discrepancies. The use of standard contracts can save much time up front."

Expert 7: Construction Manager

Adoption of Advanced work Packaging	"The industry has been experiencing low field productivity over the last years, which is the reason behind some contractors leaving the fixed price combined cycle power plant sector. With the use of Advance Work Packaging, some improvements in the time spent in direct work can be achieved."
Better estimating/Control of quantity growth	"Some major organizations are thinking about not building fixed price combined cycle power plants anymore since they cannot be competitive. One of the reasons for this is quantity growth from the initial estimates. For example, even though a major contractor has the policy of performing three different estimates with three different groups of people, quantities ended up being much higher than originally expected. This is as a result of the lack of certainty in the design at the moment of executing the estimate. Locking the scope of work earlier may contribute to solving this issue."
Integrated project delivery	"The use of IPD can help to increase productivity, reduce changes and allow projects to finish on time and budget."

Expert 8: Supplier – Bulk Materials

Early involvement of stakeholders	“The better the information we can get from our clients, the more efficient our production can be. Early involvement is a way to get better information earlier”.
Use of standard designs	"The use of standard designs across the industry has the potential to decrease the cost of the product we supply since it will mean more volume. Also, it will improve our forecasting ability, which can impact our lead times. Moreover, there is a possible reduction in our O&M costs with the use of standard designs, since the number of products and production line are likely to decrease."
Visibility into the supplier production schedule	"Better visibility into the overall project plan and the overall project schedule can improve our engagement with clients. A truly integrated project schedule, if shared, can help us to plan better. Also, we are frequently asked about our production schedule, but we usually do not share this information because it involves confidentiality agreements with our sub-suppliers."
Visibility into the construction schedule	

Expert 9: Owner – Utility – Part I

Framework agreements/ Partnership / Alliance Contracting	"One of the best opportunities for cost containment and improvements in quality that we see is to move toward alliance agreements in those markets where we have experience. Using the same supplier across multiple projects will help us to have consistency and achieve savings in spare parts thanks to a reduction of inventory.*"*
Early involvement of stakeholders	"Ensuring early engagement of EPC firms in the project development phase is key to be sure that the project is as lucrative and competitive as possible. The EPC firm can help in the selection of the right technology as well because these firms are in contact with the technology daily. Even though competitive bidding is beneficial, in partnering agreements, EPC, contractors and suppliers can be involved early on and bring their experience and inputs with them."
Develop standards around testing and commissioning	"Our testing group has significant experience but no standards or clear procedures of how to do the testing and commissioning of substations. Those technicians will eventually leave the company, so when we faced the construction of multiple substations simultaneously, we decided to delegate the testing activities to a contractor, who found the following challenges: First, since we did not have standards, it was hard to communicate our requirements and to get a good estimate. After the first substation was tested, the contractor understood what we wanted, and re-estimated the job, resulting in a much higher price.*"*
Use of standard designs	*"*We decided to standardize the design of the substations of our network, creating three different designs according to the characteristics of the equipment and working conditions. We have used the design multiple times, and this has allowed us to be more efficient in the following ways: Reduce time and cost in the procurement of the equipment (since one supplier was used for all the substations), reduce time and costs in the construction (by the use of the same contractor, which was able to offer a volume discount and became more efficient with subsequent projects), as well as to apply lessons learned from one project to other. Finally, there are also advantages in the operation, since having the same type of equipment allowed operation and maintenance people to perform their tasks faster.*"*

Expert 9: Owner -Utility – Part II

Early O&M input in the design	“At the end of the day, it is better for a design to be reviewed by the largest possible number of people, and to have everyone aligned with it, but this is always a challenge. During benchmarking trips, we bring people from the O&M group on board, so they can bring their perspective and potentially drive innovation. One of the biggest challenges to capture the maintenance expertise of O&M experts into the design is the communication of abstract drawings and models to them."
Strategy of multiple owners co-investing in the same space	"We built an electrical substation in the distribution network. We went until subtransmitions voltages (40kv), and there was another organization installing equipment for higher voltages in the same space. We owned the property, and we allowed the other organization to build their necessary equipment there. The coordination of design and construction was a challenge, but without planning, both organizations hired the same engineering company and the same contractor to work with. The result was a perfect integration between the equipment and good communication and project performance."
Visibility into the contractor’s procurement schedule	"We want to know what the contractor is buying at all times. Visibility into the procurement plan is key to be sure that the milestones are going to be met. Also, our inputs into the procurement schedule can be beneficial for the project.”
Adoption of Advanced Work Packaging	"We decided to implement AWP on two projects: The renovation of the headquarters office, and an environmental compliance program in four of our power plants. We brought contractors on board in both projects, we made them implement this concept, and we obtained a great result. For example, the environmental compliance project finished on time, with excellent safety records (below the national average or the industry), and with an increase in field productivity."
Automation technology/Robotic Welding	“In the protection and control area is where the most cutting-edge technology lies in the energy distribution sector. Right now, we are in the process of implementing a new automation standard, based on a concept called Network Protection and Control. The objective is to gather more information about how the substations are working and to make the different parts of the protection system to exchange data. This also reduces the number of wires and saves cost from that perspective.”

Expert 10: Contractor

Framework agreements/ Partnership / Alliance Contracting	“One of the concerns that they realize owners have regarding framework agreement is the fact that the contractor, not competing with others, will increase prices. This should not be a concern, because we have a lot to gain in maintaining the relation going. We do not want to jeopardize a relation that keeps us working."

Expert 11: Supplier (Engineered materials)

Factory testing	"Traditionally, for some electrical equipment like transformers, the manufacturer will ship the equipment to the customer, who will test and measure the performance metrics on site. However, one of the changes that some suppliers have implemented is to test before shipping, which produced significant cost savings for suppliers.”
Use of standard designs	“In the utility space, there are almost no standards. Some utilities have made some standardizations efforts, but most have not. It would be much more convenient if we have standard designs, for example, for some of the equipment for electrical substations. For transformers or switchgear boxes, the lead times for a new design is 40 weeks, while for an existent design, it can be only 26 weeks. Even the testing and commissioning activities are easier with a standard design because companies can get advantage of the lessons learned in previous projects.” Even a standard design that can last 18 months would be useful and help to save money, engineering time, and achieve economies of scale. Those savings can be shared with the clients”.

Expert 12: Engineer

Framework agreements/ Partnership / Alliance Contracting	“Framework agreements are becoming more popular, and when markups and rates for time and materials are agreed upon, some advantages can be achieved, such as time savings, improved quality, ability to react faster, better availability, and a better price for the clients since the profit margins can be lower if the work is guaranteed”

Chapter 5: Opportunity identification

Based on the main categories identified during the coding of expert interviews, and the main ideas obtained from the literature review, the research team identified a list of potential opportunities that can increase the engagement of suppliers in power projects.

The first section of this chapter presents an overview of the identification process, and then a section where each opportunity is defined is included. Finally, at the end of each section, some questions that emerged during the process are reported. These questions represent areas where more information would be interesting to understand the potential of the opportunities to improve project performance.

OPPORTUNITY IDENTIFICATION AND DEFINITION

Based on the expert interviews and literature review conducted, the researchers analyzed each of the codes and literature areas and, based on their similarity, combined categories into opportunities. Some of the areas and codes were grouped into the "Other opportunities" categories, and a section is included at the end of this chapter explaining this reasoning. Figure 12 shows the combination of areas into the eleven opportunities identified.

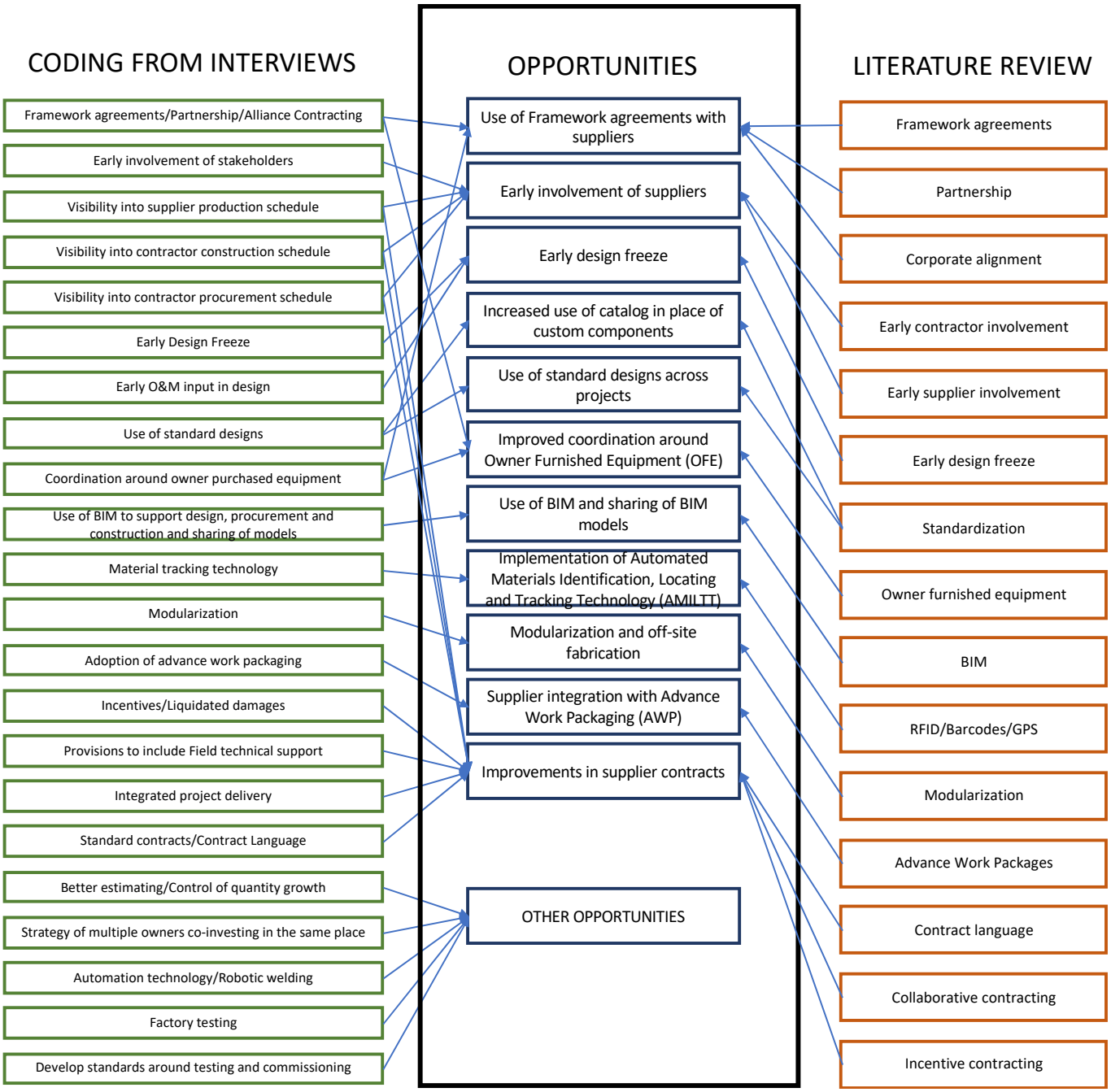


Figure 12 - Identified opportunities

1. **Use of Framework agreements with suppliers**

Definition: Use of long-term agreements with suppliers instead of competitive bidding as a procurement strategy for equipment and products. The framework should establish the terms and conditions that apply to any order placed during a given period of time.

This opportunity combines the Framework agreements/Partnership/Alliance contracting, and some aspects of Coordination around owner furnished equipment categories from the expert interviews and the Framework agreements, partnerships and corporate alignment section from the literature review.

The opportunity only refers to framework agreements and no to other types of relationship contracting, since it suggests an arrangement over an extended period, and not project specific, to set up the terms governing contracts to be granted throughout a particular period of time , in particular about price.

Moreover, while framework agreements can exist between any stakeholder (Owner-Contractor, Owner-Supplier, Owner-Engineer, Contractor-Supplier, Contractor-Engineer, and Engineer-Supplier), as the focus of this research is the supply chain, this opportunity only refers to the agreements where suppliers are involved. It is worth notice that, in the case of a framework agreement between an owner and a supplier, where a contractor has to install equipment bought by the owner, additional efforts are needed to avoid coordination problems.

Questions from opportunity identification

The following questions arose during the expert interviews and literature review:

a. What are the benefits of the use of framework agreements with suppliers?

b. One supplier commented: *"The better the information we can get from our clients, the more efficient our production can be*." In that context, can framework agreements increase trust and information sharing between the stakeholders involved in the agreement?

2. Early involvement of suppliers

Definition: Engage key suppliers early in the project timeline (i.e., project planning or early design). Early engagement allows clients to get timely suppliers input that can influence the project strategy, and it helps suppliers to improve their forecasting ability, among other benefits. This opportunity also involves giving suppliers the chance to make suggestions and recommendations concerning equipment choice and specifications that can add value to the project.

This opportunity combines the following categories from expert interviews: Early involvement of stakeholders, Visibility into the supplier's production schedule, Visibility into the contractor's construction schedule and Visibility into constructor's procurement schedule. Owners, engineers, and contractors interviewed have stated that having visibility into the supplier's production schedule will be advantageous to have certainty into the delivery date. Also, suppliers have stated that more visibility into the project schedule can help them improve their planning to know precisely when their products are needed. Finally, one of the owners mentioned that having visibility into the constructor procurement schedule can benefit the project since they can give their input to the contractor procurement process. It is clear from the expert comments that improved visibility in the mentioned schedules can better engage benefit all stakeholders. In that context, a supplier mentioned: "Early involvement in projects usually allows us to build a

better relationship with our clients, and information exchange about need dates and schedule is often better when that is achieved."

Early involvement of suppliers and early involvement of contractors were two areas included in the literature review. However, while the early involvement of all stakeholders yields many benefits such as lower likelihood of developing poor designs, improved construction operations, higher customer satisfaction, and more creative solutions (Aki Aapaoja, Harri Haapasalo, & Pia Söderström, 2013), the scope of this research is limited to the supply chain, and therefore the research team has narrowed this opportunity to include only early involvement for suppliers. Its benefits have been commented in Chapter 3 – Literature review.

Questions from opportunity identification

The following questions arose during the expert interviews and literature review:

a. What are the benefits of early supplier involvement?
b. When are different types of suppliers typically first involved, and when would be optimal to have them involved in projects?
    a. Considering the following comment *"Early involvement of suppliers encompasses advantages because the supplier can influence the strategy about cost by advising during the development phase of the project"*; Where is the value in those recommendations? How frequent are those recommendations implemented? What is the involvement that suppliers are willing to have during early stages without the owner's commitment?
c. A contractor mentioned: *"Prescription of suppliers by owners limits our flexibility. If we are allowed to choose our suppliers and subcontractors, 10%*

of savings can be achieved for the project". In this context, what are the time and cost savings that a project can achieve if contractors have more flexibility in supplier selection?

d. *"An issue we are dealing right now is the quality of the information we received from clients when requesting a quotation or placing an order. For example, without clear need dates, it is hard to estimate a price, or even to determine if we have availability to provide what is requested".* From this comment, it is clear that the quality of the information suppliers receive is important: How clear and specific are the Requests for Quotation (RFQs) and Purchase Orders (POs) that suppliers receive from clients? How important is it to improve these documents?

3. Early Design Freeze

Definition: Completion and client's final approval of the design (i.e., design substantially complete - no significant modifications are accepted) as early as possible in the project development timeline to avoid costly changes.

Questions from opportunity identification

The following questions arose during the expert interviews and literature review:

a. What are the benefits of early supplier involvement?

b. Considering this comment from a contractor: *"The difficulty I had run into when I tried to freeze the design early is that the construction crews are not normally involved in much of the upfront conversations.*", what other issues arise when trying to accomplish an early design freeze?

c. How important is the supplier's involvement in early design freeze? What is the supplier's role in early design freeze?

4. Standardization

From the expert interviews and literature review, the research team found that the concept of standardization in power projects can refer to:

1. Use of catalog (standard) in place of custom components in a particular project (e.g., use of a catalog switchgear box in one substation design instead of a custom switchgear box).
2. Use of standard designs for components across the industry (e.g., use of the same transformer by all utilities across the U.S.)
3. Use of standard designs for components across projects from the same owner (e.g., use of the same transformer in all substations owned by the same utility.)
4. Use of a standard total project design (e.g., the construction of multiple power plants with the same design)
5. Use of a standard total project design across the industry (e.g., using one power plant standard design across the industry)

While the use of industry standards for equipment or project designs may help companies to achieve increased efficiency and time and cost savings, this concept is out of the scope of this research since it represents a broader effort needed by the industry, and it is not project/company specific. Therefore, points 2 and 5 are not considered opportunities for this research.

From a supply chain and project/company perspective, stakeholders can benefit from points 1, 3 and 4, and the opportunities associated with those points are:

a. Increased use of catalog in place of custom components

Definition: Broader use of standards (catalog) components as opposed to unique/custom products as a way to increase efficiency (e.g., reduced costs for suppliers and improved lead times for clients).

Questions from opportunity identification

The following questions arose during the expert interviews and literature review:

a. What are the benefits that increased use of catalog components can bring to projects?
b. How many projects can replace custom components by catalog designs with no detriment to performance?

b. Use of standard designs across projects

Definition: Extensive use of a design at several sites. This includes the use of standard designs for components across projects from the same owner (e.g., use of the same transformer in all substations owned by the same utility), and the use of a standard total project design (e.g., the construction of multiple power plants with the same design)

Questions from opportunity identification

The following questions arose during the expert interviews and literature review:

a. What are the benefits of the use of standard designs across projects?
b. What are the success factors for the use of standard designs across projects?

5. Improved coordination around Owner Furnished Equipment (OFE)

Definition: Better communication and information sharing between contractor-owner, owner-supplier, and supplier-contractor when the owner buys major pieces of

equipment from suppliers that the contractor has to install. The purpose of the improved coordination is to avoid issues (i.e., delays, rework, claims) during procurement, shipping, storage, installation or commissioning.

This opportunity includes the Coordination around owner furnished equipment and Framework agreements/Partnership/Alliance contracting categories from the expert interviews. The reason of the inclusion of the second category is that in case of a framework agreement Owner-Supplier, the contractor will receive the equipment directly from the owner, and it may not have any contractual relationship with the supplier, which increases the need of coordination to be sure that all equipment transactions, installation, and commissioning are carried out without issues.

Questions from opportunity identification

The following questions arose during the expert interviews and literature review:

a. A contractor mentioned: "OFE *often produces conflicts because the owner may have negotiated the contract with provisions we may not agree."* In this context, how often is the supplier-contractor coordination a challenge when the owner buys the major pieces of equipment? What are the issues that commonly arise?
b. How can supplier-contractor coordination be improved?

6. Use of BIM and sharing of BIM models

Definition: Implementation of Building Information Modeling to generate 3D virtual parametric models of projects and/or components that contains relevant data needed to support engineering, procurement, fabrication, and construction. This opportunity also includes timely sharing of BIM models (project models to the suppliers, and supplier equipment models to other stakeholders) so they can be used to increase

efficiency. The models should have a level of development compatible with the use that the stakeholder needs the model for.

Questions from opportunity identification

The following questions arose during the expert interviews and literature review:

a. What are the benefits that BIM can bring to projects in terms of supply chain engagement?
b. Considering the following comment from a supplier: "*The number of models we receive is limited and, in some cases, not detailed enough for fabrication."* Are BIM models being shared between stakeholders? What are the characteristics of the models that are shared (LOD, quality, usefulness)? How easy is to use the shared models?

7. Implementation of Automated Materials Identification, Locating and Tracking Technology (AMILTT)

Definition: Implementation of automated materials identification, location and tracking technology (e.g., RFID, barcodes, GPS, mobile user interface devices) as an integrated approach to materials management and information flow in the supply chain of capital construction projects.

Questions from opportunity identification

The following question arose during the expert interviews and literature review:

a. What is the value of AMILTT for power projects?

8. Modularization and off-site fabrication

Definition: Sending out a portion of site-based work to a fabrication or module shop to improve the efficiency and productivity of the construction industry by lowering

capital cost, improving schedule performance, quality and safety. Particularly, better integration of suppliers in the modularization/off-site fabrication process can increase its value, since several of the factors critical for the success of this approach (early alignment of drivers, early design freeze, module fabricator capability, vendor involvement) are related with suppliers.

Questions from opportunity identification

The following question arose during the expert interviews and literature review:

a. Can modularization and off-site fabrication be improved with more integration of suppliers into the process?

9. Supplier integration with Advanced Work Packaging (AWP)

Definition: Advance Work Packaging is built around organizing every material, engineering and non-engineering deliverable around the path of construction. Deeper integration of suppliers into this process can improve the sequencing, scheduling, and coordination of those deliverables, increasing the benefits of AWP in terms of costs, schedule, quality, and safety.

Questions from opportunity identification

The following question arose during the expert interviews and literature review:

a. What benefits can be achieved with more integration of suppliers into the AWP process?

10. Improvements in supplier contracts (collaborative contracting/IPD/incentives clauses in contracts/ plain English)

c. Collaborative contracting/Integrated Project Delivery (IPD)

Definition: Use of collaborative contracting as an approach to managing the relationship between suppliers and clients, instead of conventional procurement and project delivery methods, to improve the alignment of interest and encourage collaboration. Particularly, the use of Integrated Project Delivery (IPD) can harness the talents and insights of all stakeholders to improve project results.

This section includes the collaborative contracting area of the literature review. According to Hayford (2018), the concept "Collaborative contracting" was born from a desire to overcome this misalignment of interests between parties involved in the delivery of construction projects.

The following categories from expert interviews are also contemplated in this section: Integrated project delivery (IPD), provisions to include technical field support, visibility into the supplier's production schedule, visibility into the contractor's construction schedule and visibility into constructor's procurement schedule. IPD as a collaborative contracting approach brings benefits such a reduced cost and improved schedule performance (Stencil & Powell, 2018). Also, as mentioned early, increased collaboration can increase trust and information sharing about need dates and schedule.

d. Use of incentive clauses

Definition: Inclusion of balanced and well-studied incentive/penalty clauses in contracts to increase the motivation of stakeholders to achieve a performance that meets the client's objectives and obtain benefits by shared savings and bonuses.

This section includes the Incentive contracting area of the literature review and the Incentive/Liquidated damages category from expert interviews. As mentioned in the literature review, both incentive and penalty clauses, if well formulated, are associated with better project performance since they have a positive effect on relational attitudes that are reflected on enhanced teamworking quality (Suprapto, Bakker, Mooi, & Hertogh, 2016).

e. Contracts written in plain English

Definition: Use of clear and straightforward language instead of legal jargon in supplier contracts to improve understanding. Contracts should also have a particular focus on collaboration between the parties under the agreement and facilitate and encourage good management practices.

This section comprises the contract language area of the literature review (that comments that contract language has become more and more complicated and inscrutable with time) and the standard contracts/contract language section of the expert interviews.

Questions from opportunity identification

The following questions arose during the expert interviews and literature review:

a. How do stakeholders evaluate supplier contracts?
b. How can supplier contracts be improved?

11. Other opportunities

Five of the categories identified from the expert interviews were not included in the opportunities listed above. Those categories are:

1. Better estimating/control of quantity growth: Quantity growth during execution, considering that it is not due to approved changes, it can be the result of having an inaccurate initial estimate. On the other hand, quantity growth during design can be

the result of a lack of early design freeze or by changes initiated by the owner. In both cases, this concept is related to other of opportunities listed above, and it is not included as a separate opportunity to improve the engagement with the supply chain.

2. Early Operation and Maintenance input in design: While the early involvement of Operation and Maintenance experts in the design is relevant, this opportunity is not related with supply chain involvement and therefore not considered into the list of opportunities. However, this concept is related to the Early Design Freeze opportunity, since "O&M input is as important as construction input when freezing the design, to be sure the people that are going to operate the facility is comfortable with, for example, where access points are located, and no changes or adaptations have to be done in the field."
3. The strategy of multiple owners co-investing in the same place: This opportunity derived from one example where a utility organization achieved some benefits. Due to the uniqueness of the example, it is not included in the final list of opportunities.
4. Automation technology/Robotic welding: These refers to opportunities identified by experts to improve the efficiency of their operations and are not included in the final list of opportunities since are not related to supply chain engagement.
5. Factory testing: This opportunity refers to the testing of transformers in the supplier's shops before shipping to customers to identify and solve issues early and achieve cost savings. Since this opportunity was only mentioned for one type of equipment and one supplier, and it is not related to supply chain engagement, it is not included in the list of opportunities.
6. Develop standards around testing and commissioning: This opportunity is associated with the creation of well-documented standards within a company to

perform activities during substations testing and commissioning. As is not directly related to supply chain involvement, it is not included in the list of opportunities.

OPPORTUNITY IMPLEMENTATION

Some of the opportunities identified can be applied to any project a company is executing, while the implementation of others demands a corporate effort. Figure 13 shows this difference. The use of standard designs across projects needs the decision of an organization to execute projects in a specific way and may also involve an investment in creating a standard design that would be utilized multiple times. Framework agreements with suppliers is another corporate strategy to procure products for the same supplier over a period that most likely involve more than one project. On the contrary, the rest of the strategies can be implemented by any project manager looking for ways to better engage suppliers in projects.

Opportunities / Challenges	CORPORATE STRATEGY	PROJECT STRATEGY
Use of standard designs across projects	✓	
Early involvement of suppliers		✓
Supplier integration with Advanced Work Packaging (AWP)		✓
Modularization and off-site fabrication		✓
Improvements in supplier contracts (Collaborative contracting/IPD/incentives/plain English)		✓
Use of BIM and sharing of BIM models		✓
Early design freeze		✓
Use of framework agreements with suppliers	✓	
Improved coordination around owner furnished equipment (OFE)		✓
Implementation of Automated Materials Identification, Locating and Tracking Technology (AMILTT)		✓
Increased use of catalog in place of custom components		✓

Figure 13 - Opportunity implementation

Chapter 6: Survey and analysis

The research team developed a survey to investigate the potential of the identified opportunities to improve project performance and to gain a better understanding of those opportunities. The questions that arose during the opportunity identification were used as the basis of the survey, that can be found in the Appendix. It was conducted using Qualtrics tool (www.qualtrics.com) and received 30 responses. Of the 30 respondents, 28 completed the survey. The survey was distributed among professionals working in the power industry.

RESPONDENTS DEMOGRAPHICS

Figure 14 shows the breakdown of the 30 respondents by stakeholder category. This figure demonstrates ample representation of owner and contractors, but limited participation of suppliers and designers/engineers. The low number of suppliers and engineers is explained by the fact that the survey was distributed primarily among CII members, which are mainly owners and contractors.

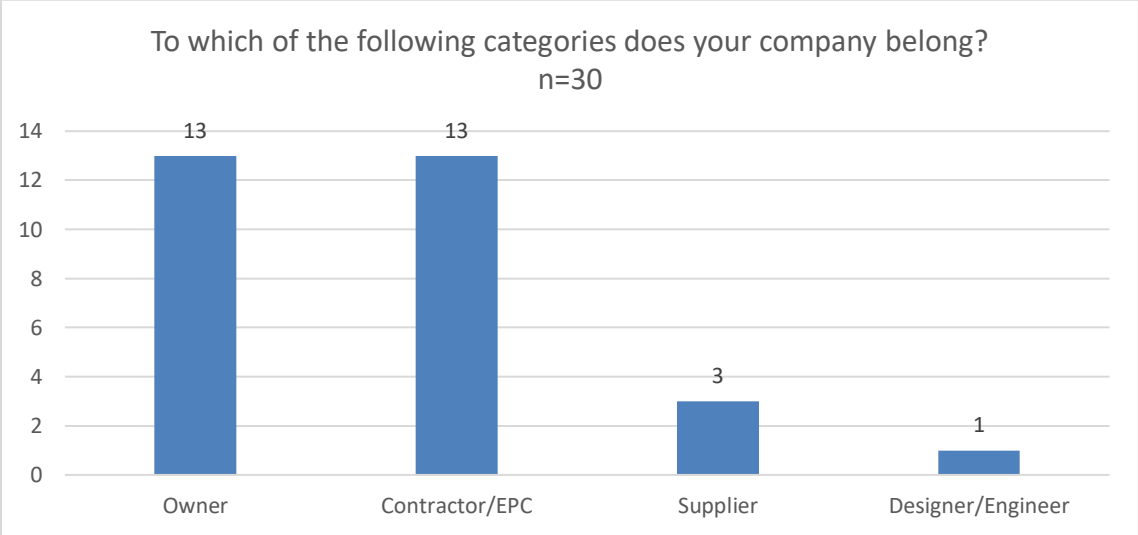


Figure 14 - To which of the following categories does your company belong?

Figure 15, Figure 16 and Figure 17 show the breakdown of the different categories of stakeholders. Figure 15 demonstrates ample representation of utility organization over investing companies (developers, execution, operation, or a combination of those mentioned above). Figure 16 illustrates the breakdown of the different categories of contractors. EPC firms and general contractors are the two groups with more representation, with no responses from specialty contractors, or subcontractors. This is consistent with the fact that are mostly EPC firms and general contractors who assume supply chain management responsibilities. Finally, Figure 17 shows the categories of suppliers who responded to the survey.

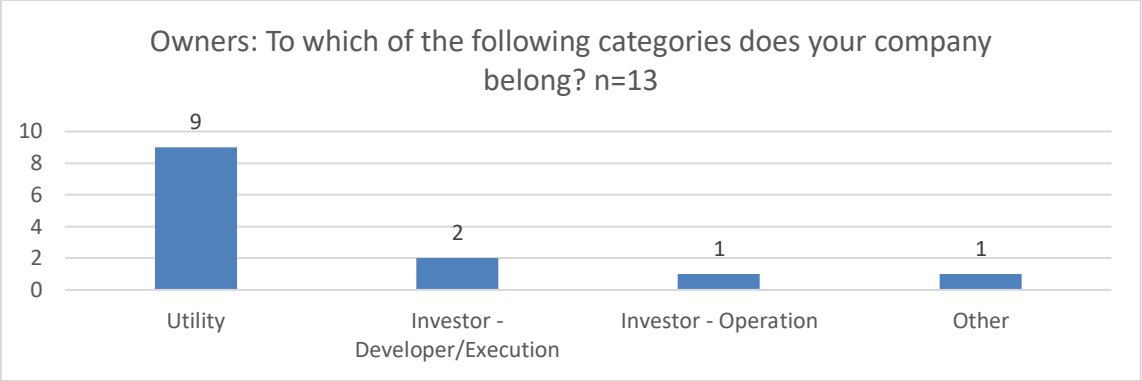


Figure 15 - Owners: To which of the following categories does your company belong?

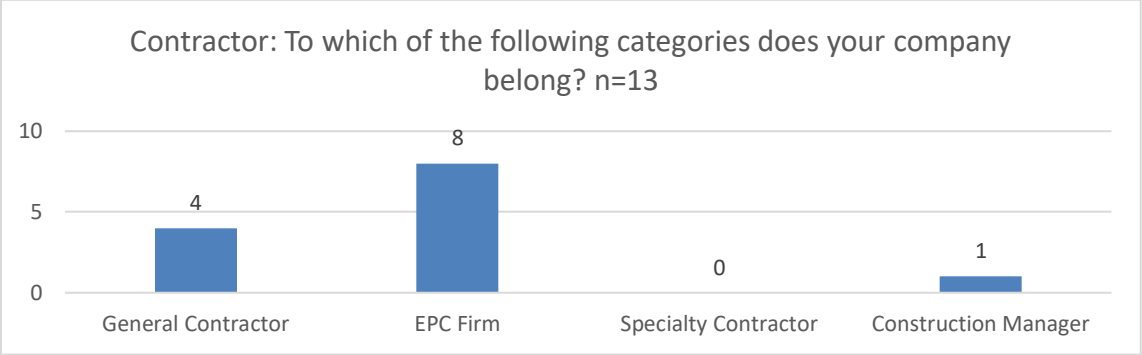


Figure 16 - Contractor: To which of the following categories does your company belong?

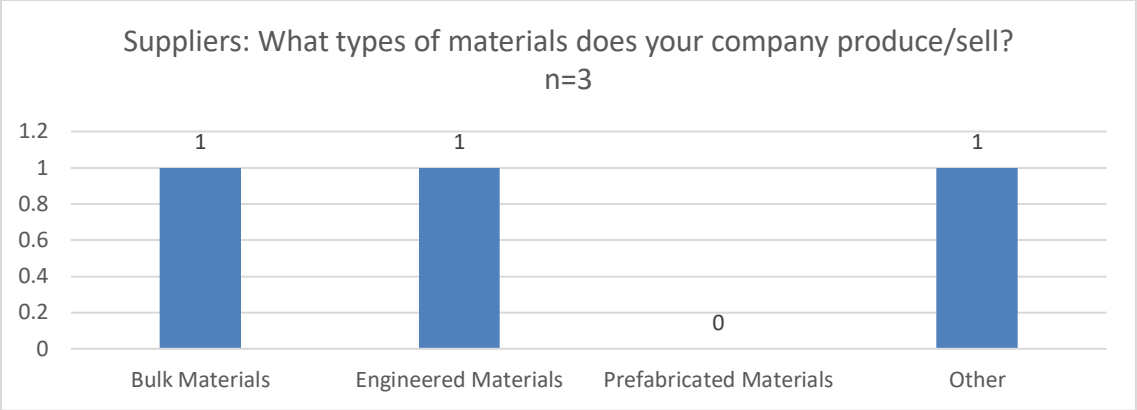


Figure 17 - Suppliers: What types of materials does your company produce/sell?

Respondents also reported other demographic information: The mean, minimum, and maximum years of professional experience were 26.43, 8 and 45, respectively. The mean, minimum, and maximum years of experience in design, construction, and facility management were 22.21, 5 and 42, respectively:

Field	Min	Max	Mean	Standard Deviation	Variance	Responses
4	8.00	45.00	26.43	10.90	118.85	30

Figure 18 – Years of professional experience

Field	Min	Max	Mean	Standard Deviation	Variance	Responses
4	5.00	42.00	22.21	11.02	121.41	29

Figure 19 – Years of experience in design, construction or facilities management

CHALLENGES IN POWER PROJECTS

The respondents were asked about the challenges they identify in power projects. This question was included since the research team wanted the respondents to have in mind several dimensions of project performance, and not only cost and schedule. Results are shown in Figure 20.

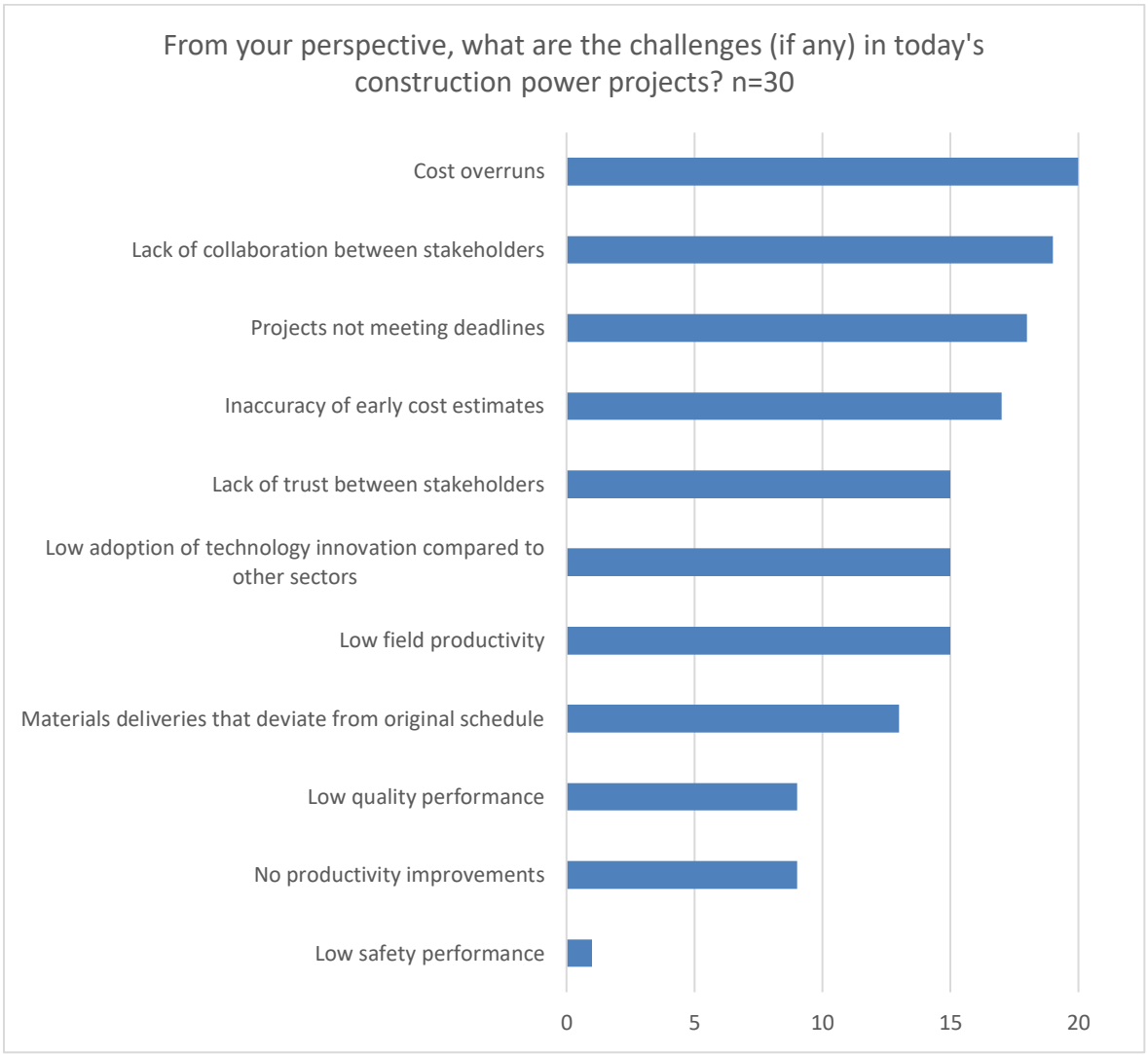


Figure 20 - Challenges in power projects

Cost overruns was the most selected option, which is consistent with the fact that construction projects have a consistently poor record in finishing within budget (Aljohani, Ahiaga-Dagbui, & Moore, 2017). This is also related to the factor ranked in fourth place, inaccuracy of early cost estimates, since quantity growth during design and execution leads to increases in cost.

Lack of collaboration between stakeholders was the second-ranked challenge in power projects. This coincides with opinions collected during expert interviews, where it was mentioned that suppliers chosen by competitive bidding and contractor contracts that include penalties and incentives clauses make it difficult to create of trust, information sharing and collaboration among stakeholders.

Finally, projects not meeting deadlines is the third-ranked challenge, which is consisted with the fact that worldwide, the average big construction project takes 20% longer to complete than it is planned initially (Soto, 2019).

OPPORTUNITIES AND PROJECT PERFORMANCE

Survey respondents were asked to rate the potential of the opportunities to improve project performance (identified by the research team and reported in Chapter 5) on the following scale: High potential, moderate potential, low potential, no potential, detrimental to performance, and do not know. Figure 21 presents the results for all respondents (n=30).

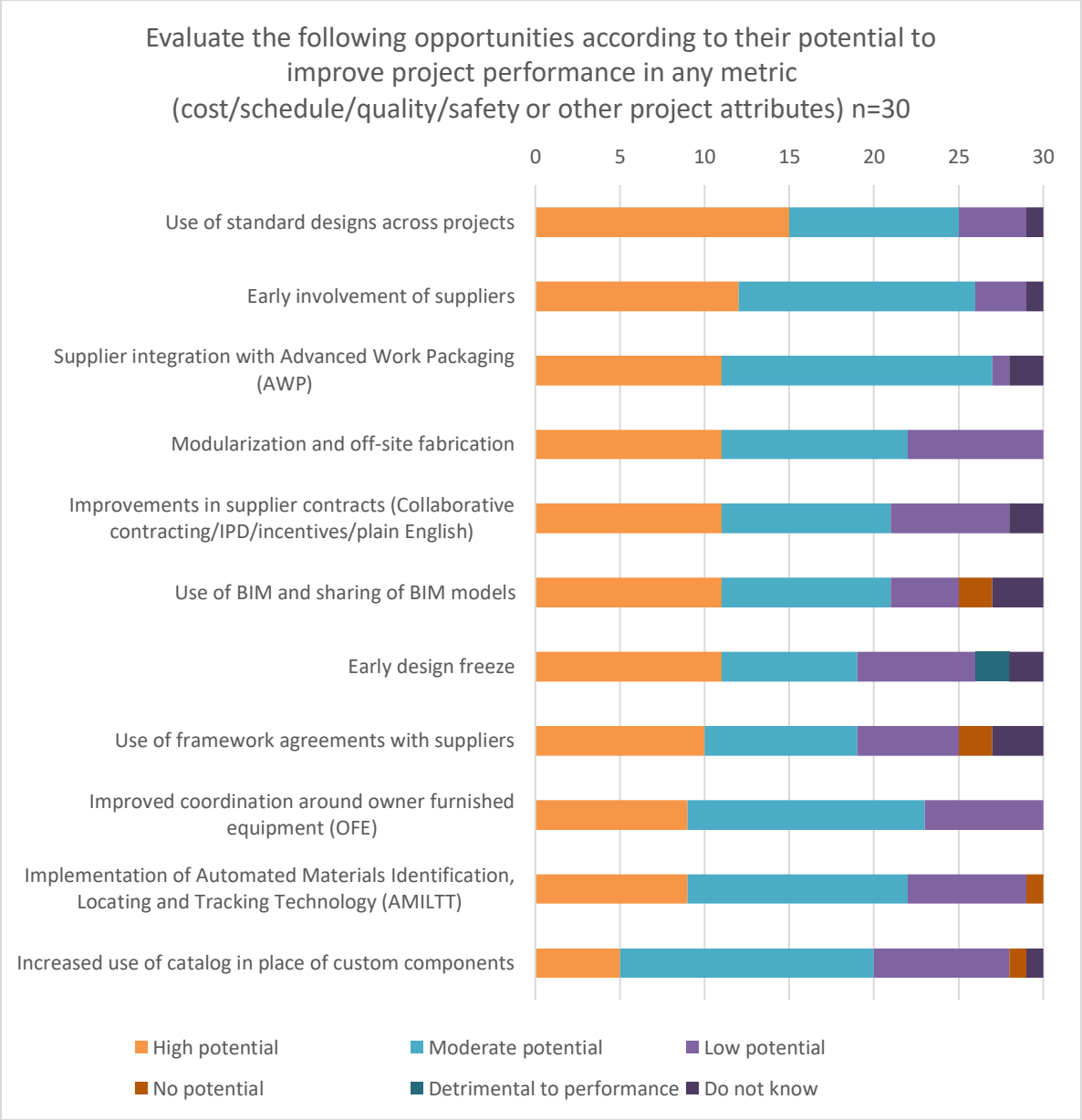


Figure 21 – Opportunities to improve project performance – All respondents

To simplify the analysis, the research team combined the high and moderate potential into one category, and the low and no potential into another. The results are presented in

Figure 22.

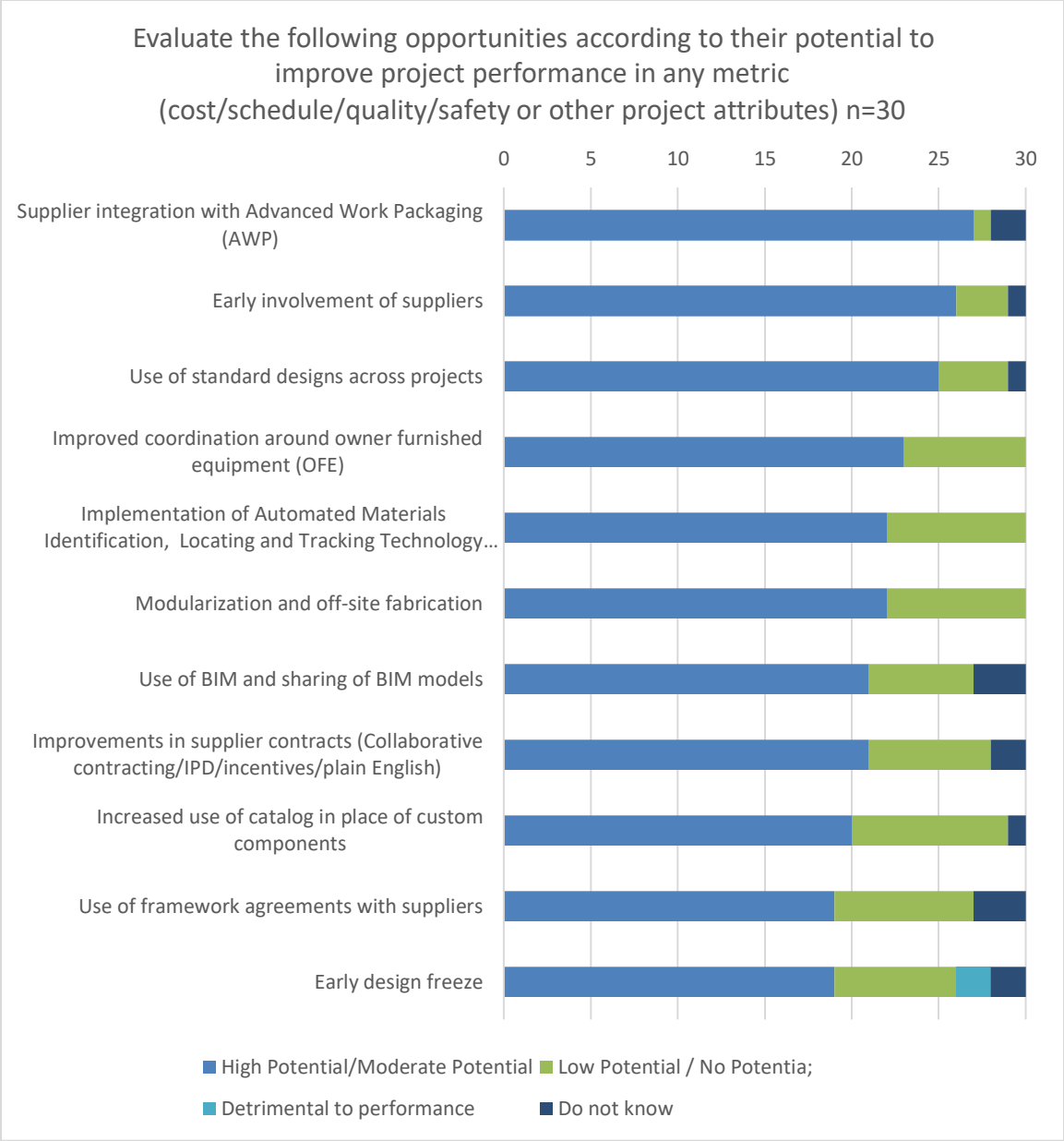


Figure 22 - Opportunities to improve project performance – All respondents – Combined categories

Figure 22 shows that the majority of the respondents (65% or higher) indicated that all options have a moderate or high potential to improve project performance. None of the

opportunities stands out as the most relevant one since even for Early Design Freeze, 19 respondents chose high or moderate potential. Therefore, all the opportunities are viable for consideration when trying to improve project performance by increasing the engagement of the supply chain stakeholders.

Considering all stakeholders, supplier integration of advance work packaging, early involvement of suppliers, and use of standard design across projects are at the top of the list (with more than 80% of the 30 responses). For the research team, this can be explained by the fact that those opportunities can impact project performance in multiple metrics (This topic is expanded in the following sections).

Comparison of contractor and owner responses

The results in Figure 21 were also broken out by stakeholders, and the differences between owners and contractors are reported in Figure 23. Since there was one response from a designer/engineer and three from suppliers, the analysis of those responses is included in the Appendix. Percentages are calculated considering 13 responses from contractors and 13 from owners.

It can be seen that early design freeze ranked in the first place for contractors, and in the last place for owners. This is: 69.25% of the contractors said that early design freeze has high potential to improve project performance, while only 7.69% of the owners indicated the same. One possible explanation for this finding is that freezing the design early would translate into fewer changes and potentially more accurate estimates that can benefit contractors to finish the project within the planned and bided budget and cost, but for owners, freezing the design too early may reduce the flexibility they wanted to keep, and may also imply not having enough construction or operation and maintenance input, that would turn into higher costs once the project is finished.

A similar case represents the opportunity supplier integration with Advanced Work Packaging: 53.85% of the contractors indicated that this opportunity has high potential to improve project performance, while only 15.78% of the owners specified the same. This may be because contractors have more direct contact with suppliers than owners, so they are more likely to see where things are breaking down.

Figure 23 – Potential of opportunities – Comparison Contractor and Owner

The opposite is true for the opportunities about modularization and off-site fabrication, and improvements in supplier contracts. They were ranked first and second for owners, but seventh and ninth for contractors. Some possible reasons for this are:

1. Modularization and off-site fabrication: Since modularization is a strategy that should be contemplated at early stages of the projects, the owner is the one who usually considers it.
2. Improvements in supplier contracts: Owners are generally more interested in contracts than contractors since they are the way they execute projects. Whereas for contractors, they work under a set of terms and conditions, and will probably transfer those to subcontractors and suppliers.

Improved coordination around owner furnished equipment (OFE) is ranked higher for contractors than for owners, which can be explained by the fact that for OFE is the contractor the stakeholder that usually encounters challenges since it does not have a contractual relationship with the supplier.

AMILTT ranked higher for contractors than for owners, which makes sense since they are often the stakeholder responsible for materials movement in the supply chain.

Interestingly, early involvement of suppliers is ranked second overall, but it is eight for contractors and fifth for owners. This is because it ranked first for suppliers, which is consistent with one of the comments collected during experts' interviews, where one supplier mentioned that he could influence the project strategy if it is involved early. Similar is the case of the opportunity about standard designs across projects: It is ranked first overall since in addition to the owners and contractors, the engineer and two of the suppliers indicated that it has high potential to improve project performance.

OPPORTUNITIES WITH HIGHER POTENTIAL

Those who indicated that any of the opportunities had high or moderate potential to improve project performance were asked more questions related to the opportunities. The following sections present the analysis of the questions mentioned above and are presented based on the ranking of Figure 22.

Use of standard designs across projects

The use of standard design across projects has been indicated to have a high potential to improve project performance. It ranked third in the high/moderate potential combined ranking, and first in the high potential ranking.

Respondents were then asked about the potential of the use of standard designs across projects to improve several metrics of project performance in the following scale: High potential, moderate potential, low potential, no potential, and do not know. For this analysis, some of the categories have been combined, and the results are shown in Figure 24.

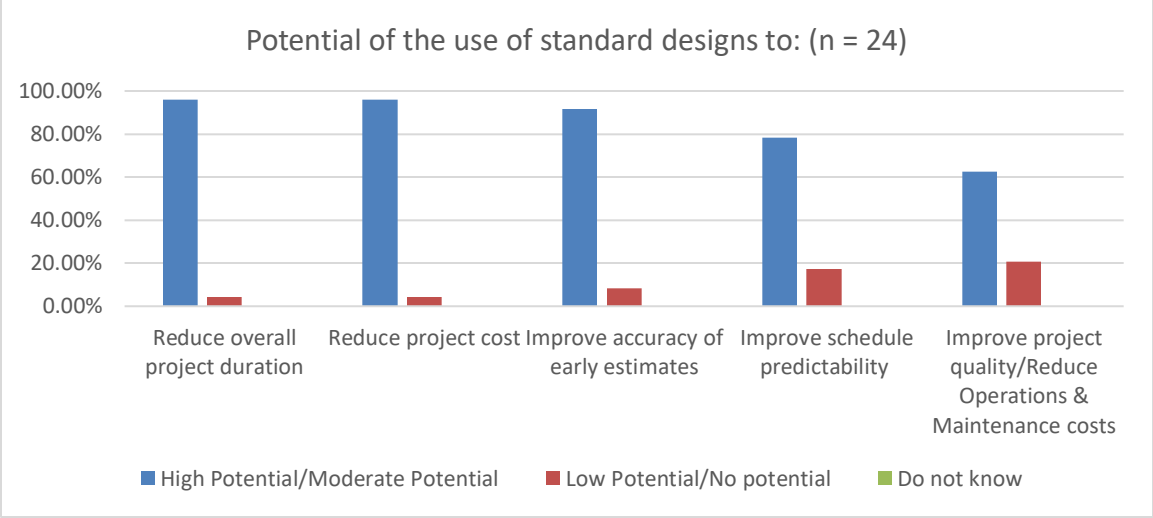


Figure 24 - Potential of use of standard designs to improve project performance

It can be seen that all options have a high potential to improve project performance. Moreover, almost all respondents (more than 95%) specified that project cost and schedule could be reduced by using standard designs across projects. As stated in the literature review, using the same standard reduces design time since most of the design effort has been done for previous projects, reduces construction time since construction crews are familiar with the task to perform, and it also reduces commissioning and start-up time for the same reason. All of these time savings are translated into cost savings due to the reduction of working hours and overhead costs. Also, if standard components are bought for more than one project, economies of scale can be achieved.

One of the contractors interviewed mentioned that some EPC firms were deciding not to perform fixed price combined cycle power plants because of the quantity growth that led to cost overruns in past experiences and prevents them for being competitive. The use of standard designs can help to solve this issue since it can also improve the accuracy of early estimates.

The next question that was asked to those who indicated that the use of standard designs across projects had the potential to increase project performance was related to the success factors needed for this purpose. From the expert interviews, four success factors were identified, and survey respondents were asked about the importance of those factors. Results are shown in Figure 25.

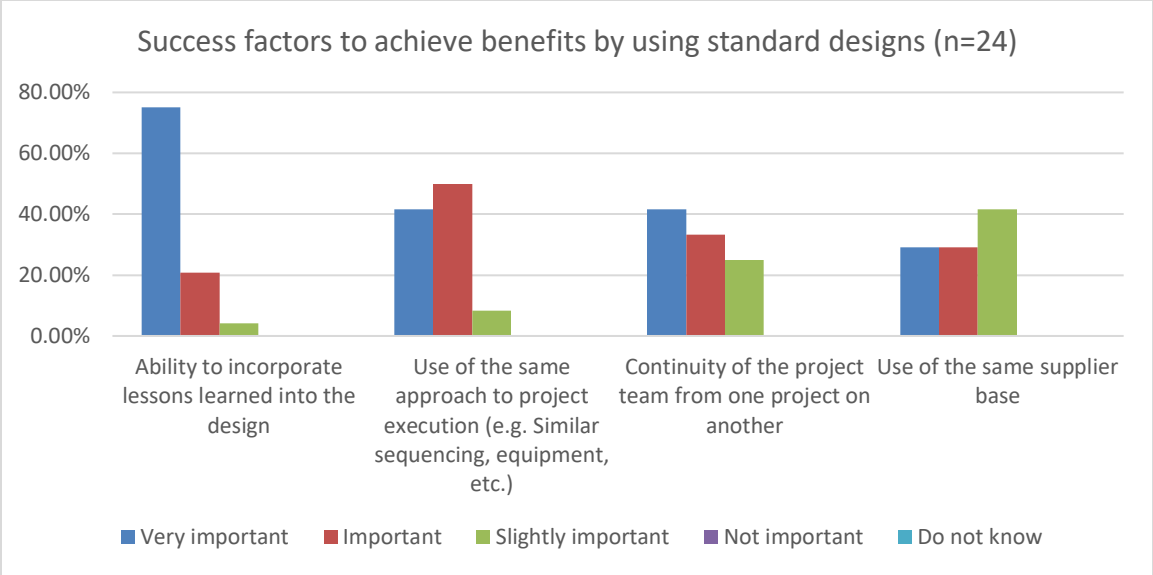


Figure 25 - Success factors to achieve benefits by using standard designs

The incorporation of lessons learned from one project into another is one of the most important considerations to ensure the success of this opportunity. This is consistent with what was identified in the literature review: Learning from one project and applying those lessons in other can lead to time savings. The other factors, use of the same approach to project execution and continuity of the project team from one project to another, have been identified as relevant as well.

Early involvement of suppliers

Early involvement of suppliers has been identified as an opportunity that both clients and suppliers can benefit from. The research team asked owners, contractors and engineers when they usually see suppliers first involved, and when would be optimal to have them involved (i.e., more impact on project success). Results are shown in Figure 26 and Figure 27. Suppliers have been divided into four categories following CII (2011) suppliers' classification: Suppliers of major engineered materials/equipment, suppliers of

minor engineered materials/equipment, suppliers of bulk materials, and suppliers of prefabricated materials.

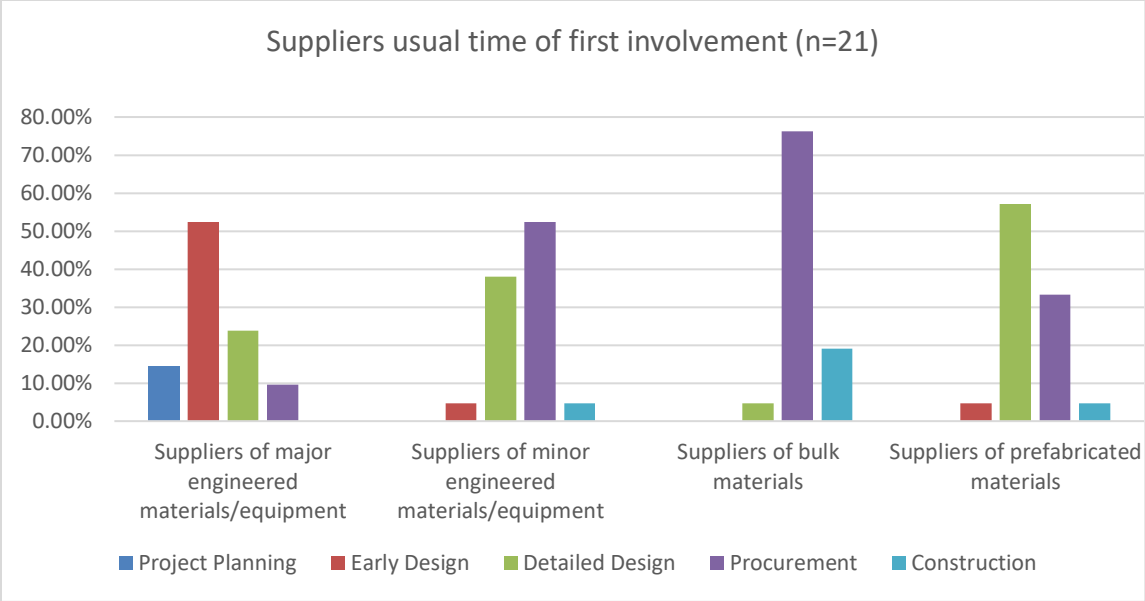


Figure 26 – Suppliers usual time of first involvement

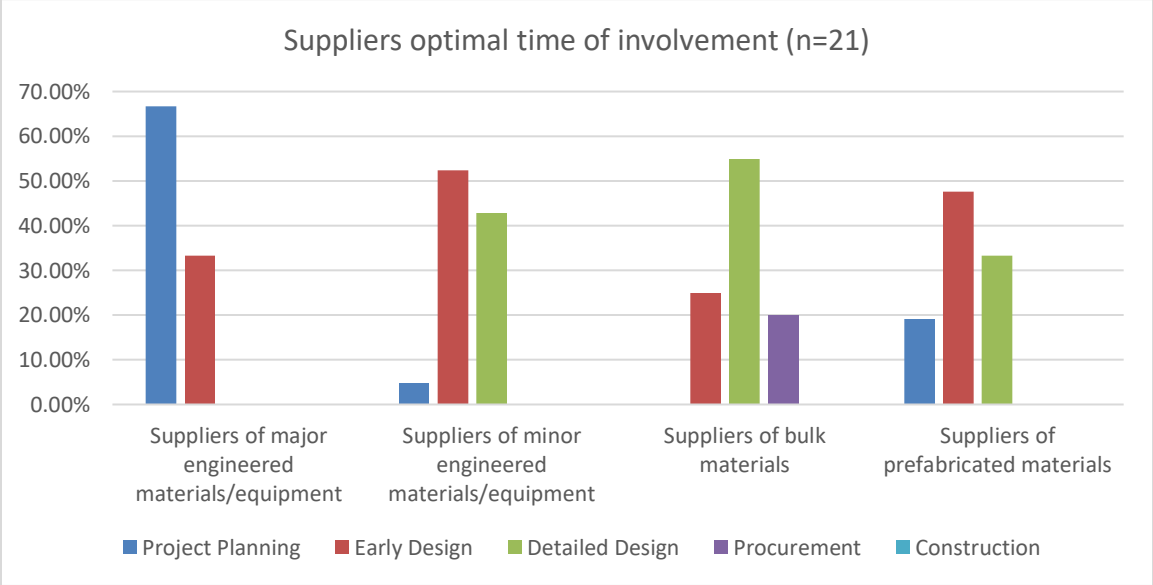


Figure 27 – Suppliers first time of involvement

The graphs show a shift to the right in all categories, indicating that stakeholders believe that earlier involvement of all types of suppliers is needed for better project performance. The following table summarizes the most chosen response for each category:

Table 4 - Usual vs. Optimal time of suppliers' involvement

	Suppliers of major engineered materials/equipment	**Suppliers of minor engineered materials/equipment**	**Suppliers of bulk materials**	**Suppliers of prefabricated materials**
Usual time of first involvement	Early design	Procurement	Procurement	Detailed design
Optimal time of involvement	Project planning	Early design	Detailed design	Early design

As can be seen, the optimal time for suppliers of major engineered equipment to be involved is project planning. There are two reasons why this is important: First because major engineered equipment usually consists of long lead times items that should be ordered in advance to avoid project delays. Second, most engineering decisions are made based on the selection of these components, and suppliers input during the selection of major parts is key. For the rest of the suppliers, the optimal time of involvement is during the design (early or detailed), which makes sense since this stage is when decisions about materials/equipment are made, and suppliers can provide useful information to support those decisions.

It is also interesting to analyze what are the benefits that early involvement of suppliers can bring to projects. Two questions about this (one for suppliers and one for clients) were included in the survey, and the results are displayed in Figure 28 and Figure 29.

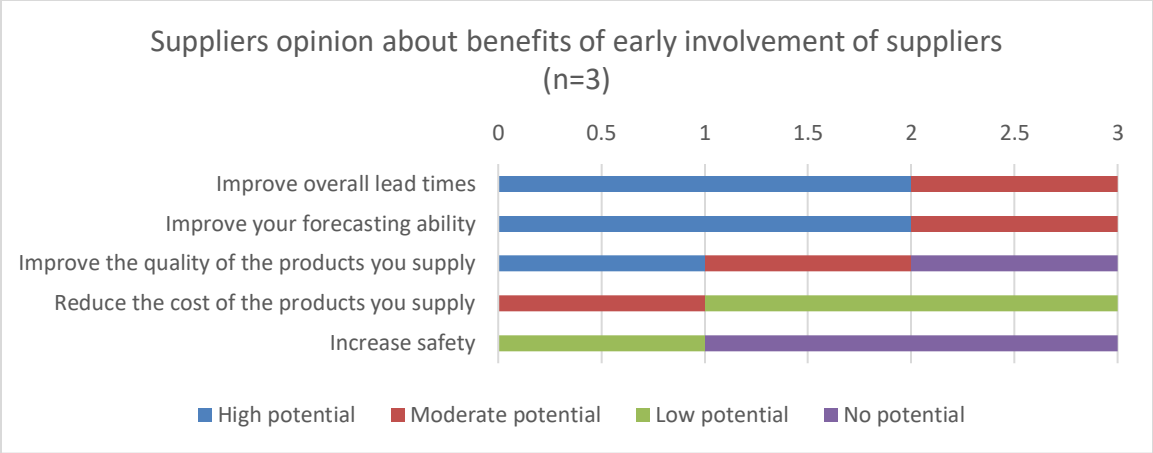


Figure 28 - Suppliers opinion about the benefits of early involvement of suppliers

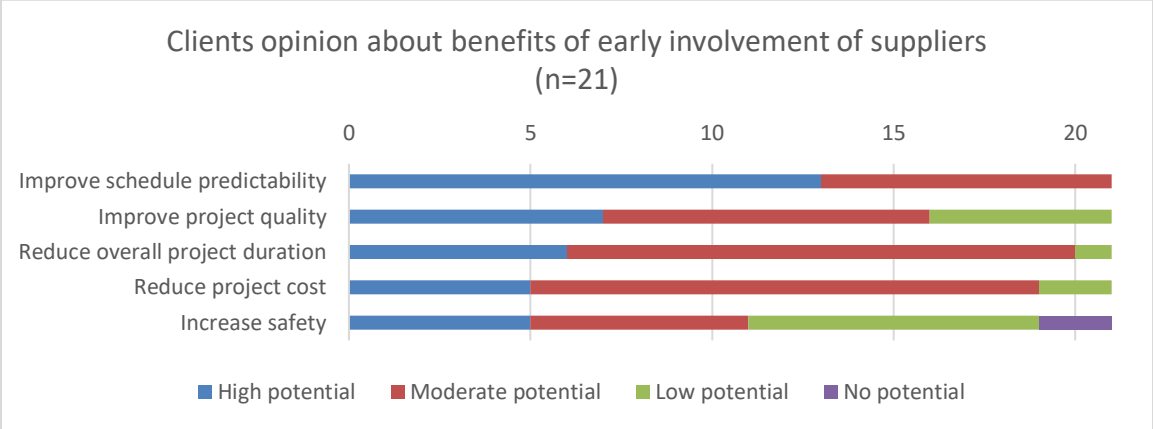


Figure 29 - Clients opinion about the benefits of early involvement of suppliers

Schedule benefits were ranked high for suppliers and clients. Clients mentioned that better schedule predictability could be achieved with early involvement of suppliers. One explanation for this is that more certainty about equipment delivery dates will be available at the moment of creating the schedule, and therefore, it will be more predictable. Also, early involvement can help suppliers to improve their lead times since they will know in advance the materials/equipment needed and they will be able to plan production

accordingly. With more information about equipment specifications and need dates, they will also be able to improve their forecasting ability.

Surprisingly, cost has ranked 4th for both suppliers and clients. Only one supplier mentioned that early involvement has moderate potential for reducing the cost of the products he supplies, and a low number of clients indicated that early involvement of suppliers has high potential to reduce project cost. This contradicts some of the opinions collected during expert interviews where suppliers mentioned that they could influence the strategy about cost if they are involved early.

As found in the literature, suppliers are a source of innovation in the construction industry, since they operate in a more stable market than contractors and owners. Their innovations are translated into recommendations about equipment choice and specifications. A question asking about the value of those recommendations was included in the survey, and the results are presented in Figure 30. Similar to the results obtained for the benefits of early involvement, predictability of lead times and lead times are the two principal values identified.

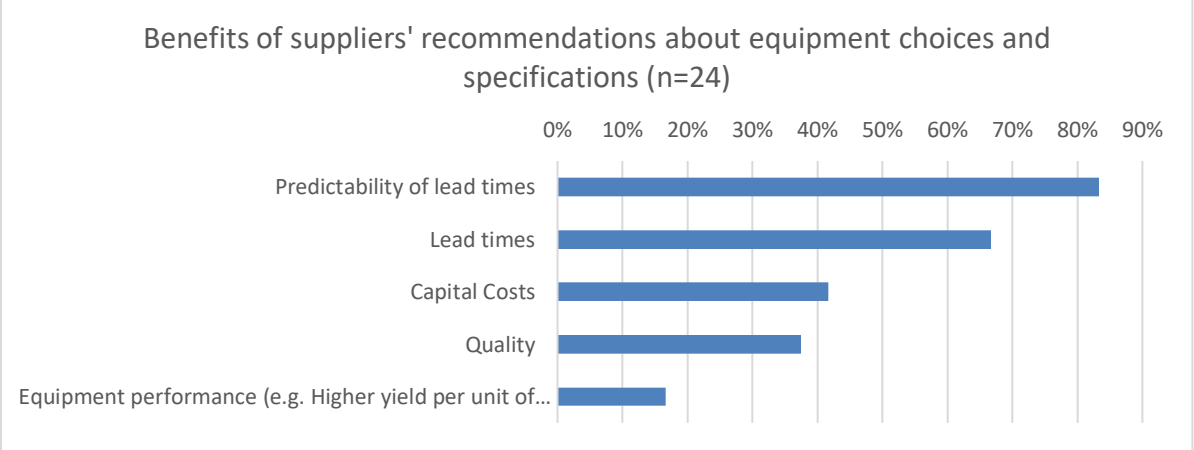


Figure 30 - Benefits of suppliers' recommendations about equipment choices and specifications

Suppliers were asked about how often are they asked to make recommendations and how often are those recommendations implemented. Since only 3 suppliers' opinions were collected, it is not possible to generalize their answers, but it is possible to present preliminary results: Suppliers are asked to provide recommendations in a low number of projects (<40%), however, most of those projects implemented the recommendations (61% to 80%).

During one of the extended interviews, one contractor mentioned that it is frequent for owners to be prescriptive with the suppliers that they use for projects, instead of giving a list of specifications and let them choose suppliers. Based on this comment, contractors were asked about the project cost and schedule savings that it would be possible to achieve if owners were less prescriptive in supplier selection. Results are presented in Figure 31 and Figure 32.

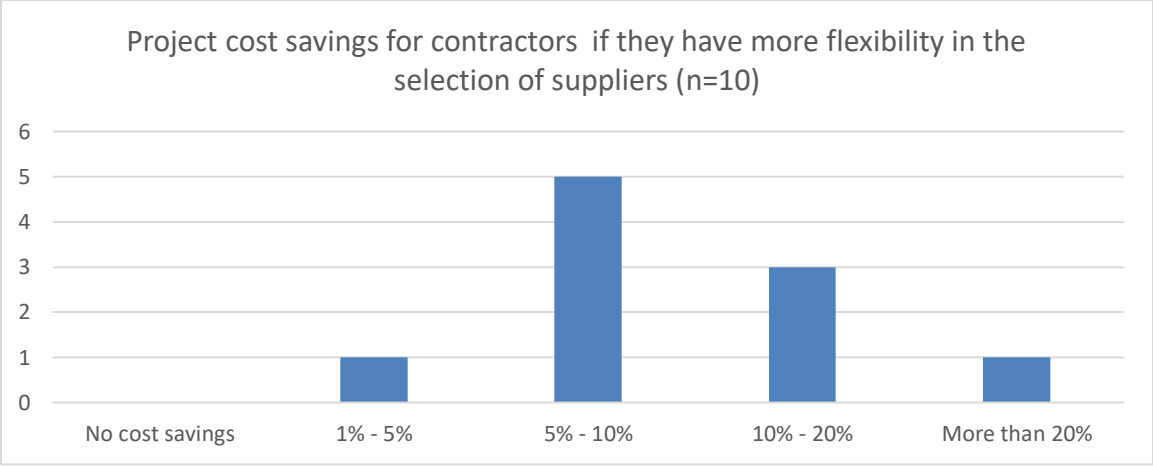


Figure 31 - Project cost savings for contractors if they have more flexibility in the selection of suppliers

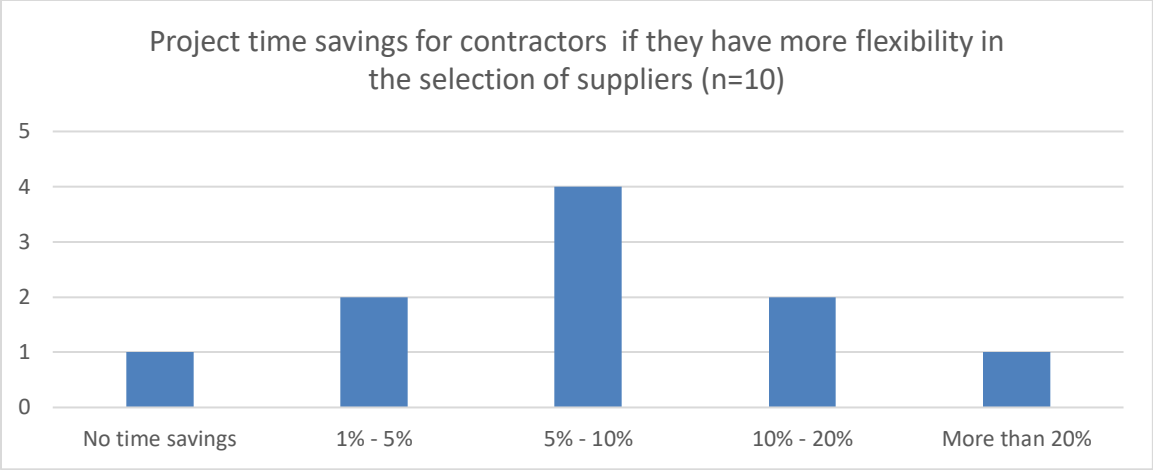


Figure 32 - Project time savings for contractors if they have more flexibility in the selection of suppliers

Significant project cost savings and schedule cost savings can be expected according to these results. This suggests that contractors believe that they can be more effective in finding competitive suppliers than owners, without sacrificing quality or specifications. However, even if delegating supplier selection can be an option for owners to achieve project-specific savings, there are some reasons why they would like to keep this task, such as framework agreements they already have with suppliers, willingness to have consistency across projects or willingness to reduce inventory of spare parts, that would benefit the owner company beyond one project.

Finally, considering this comment collected during expert interviews: "*An issue we are dealing with right now is the quality of the information we received from clients when requesting a quotation or placing an order. For example, without clear need dates, it is hard to estimate a price, or even to determine if we have availability to provide what is requested",* two questions were included in the survey for suppliers and clients:

a. How would you evaluate Request for Quotation (RFQs)? (Figure 33)
b. How would you evaluate Purchase Orders (POs)? (Figure 34)

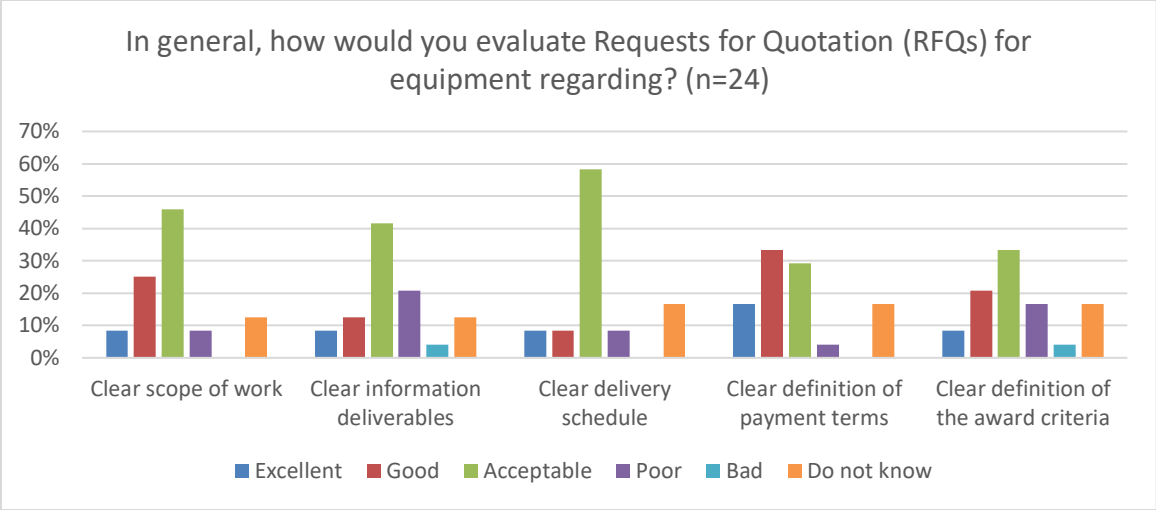


Figure 33 - How would you evaluate Request for Quotation (RFQs)?

In terms of RFQs, the payment terms category is reported to be mostly excellent or good. For the rest of the categories, the most chosen option is "acceptable", which indicates that even if the quality of most of these aspects is enough to satisfy the stakeholders, there is still room for improvements. Finally, a common concern expressed by clients and suppliers during the expert interviews was the lack of certainty about delivery dates, which is consistent with the graph above that shows that the clarity of the delivery schedule is one of the weakest aspects of RFQs. As mentioned before in this section, one of the main benefits of early supplier involvement is schedule predictability so that this opportunity can address the mentioned issue with request for quotations.

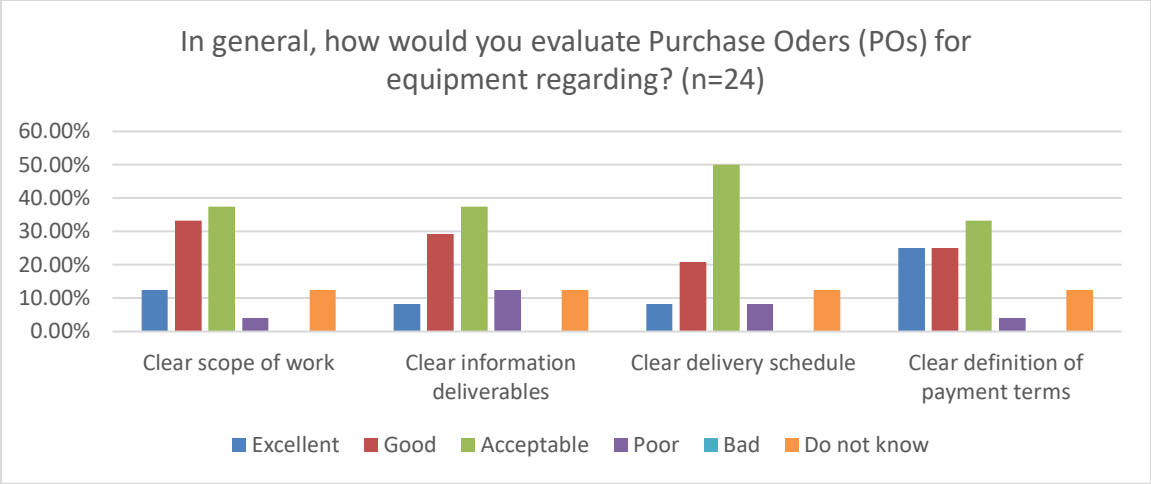


Figure 34 - How would you evaluate Purchase Orders (POs)?

Regarding purchase orders, the analysis is similar to RFQs: Payment terms are mostly good or excellent, and the other items are acceptable. However, there is an improvement of the perceived quality of the scope of work, information deliverables and delivery schedule from RFQs (Figure 33). This was expected since, at the moment of issuing a purchase order, customer and client have already interacted and agreed on these aspects.

Supplier integration with Advanced Work Packaging (AWP)

Respondents were asked about the characteristics of project performance that can be improved with more integration of suppliers into Advanced Work Packaging. Figure 35 presents the result. It can be seen that schedule predictability and productivity ranked first and second. This is consistent with what CII (2013) reported as being significant benefits of AWP: Productivity and predictability of project performance. Therefore, it can be assumed that more integration of suppliers into AWP can leverage the benefits of this process.

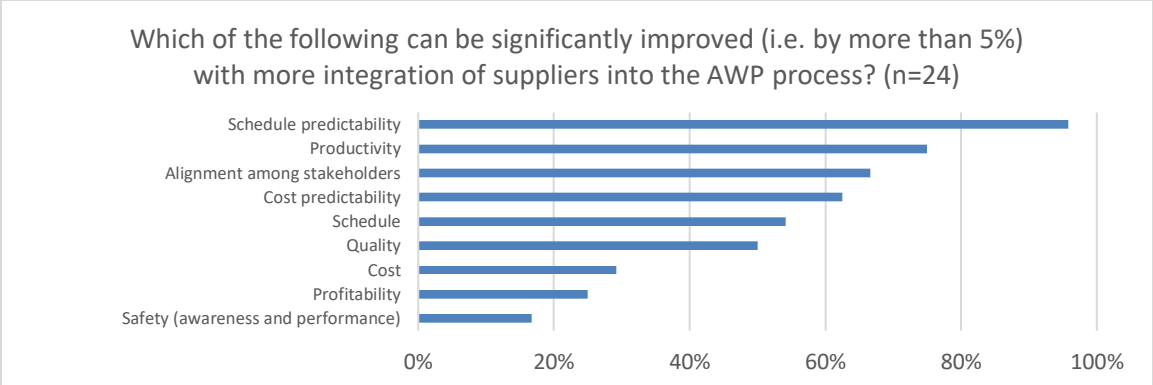


Figure 35 – Benefits of supplier's integration into AWP

Almost all respondents chose schedule predictability as a benefit. One explanation for this is that with more integration of suppliers, more information about the progress of procurement and need dates will be available for the project team, and those can also be adapted to changes into the project schedule.

A more specific question about the benefits of increased supplier integration into AWP was included, and the results are shown in Figure 36.

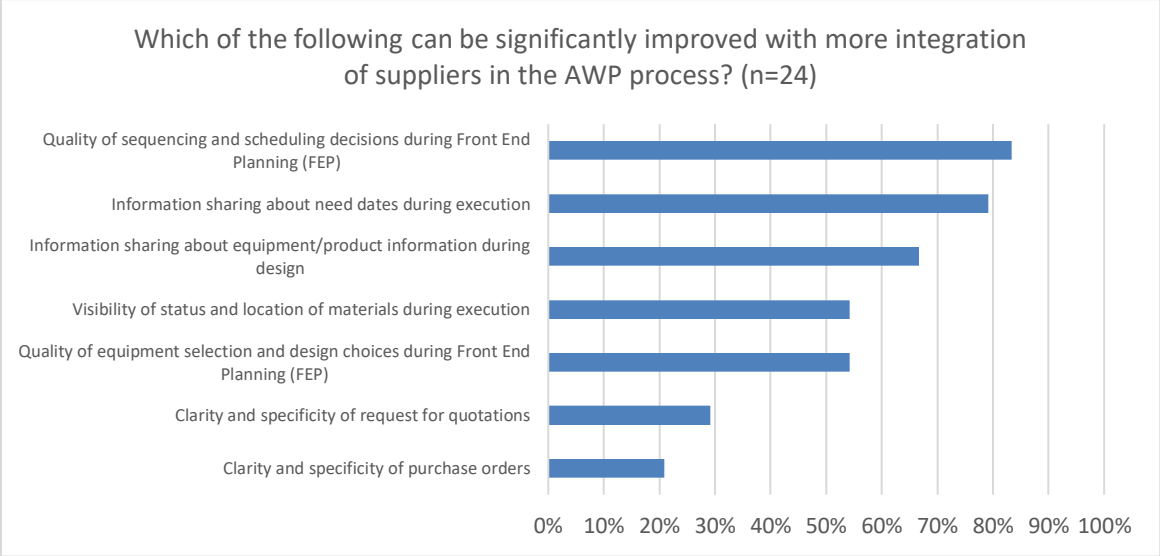


Figure 36 – Specific benefits of more integration of suppliers into AWP

The two main specific benefits are related to schedule predictability: More integration of suppliers can increase the quality of the sequencing and scheduling decisions during Front End Planning (FEP) and can increase information sharing about need dates during execution. This means that suppliers input into AWP can have schedule impact both before and during construction.

Also, it is evident from Figure 36 that this opportunity can increase the quality and quantity of the information shared, not only about the schedule but also about specifications, which is a major concern reported by multiple experts as stated in Chapter 4.

In summary, it can be seen that this opportunity can influence schedule, cost, productivity, and alignment (as more than two-thirds of the respondents chose these options). This multidisciplinary impact explains why this opportunity is ranked first in Figure 22.

Modularization and off-site fabrication

Interestingly, modularization and off-site fabrication were not ranked in the top options overall, but it is the first option for owners.

In order to obtain more insight from those who considered this opportunity has potential to improve project performance, the following question was included in the survey: Which of the following can be significantly improved (i.e., by more than 5%) with more integration of suppliers into modularization and off-site fabrication processes? The results are illustrated in Figure 37. The reason to include this question was that vendor involvement had been reported by CII (2016) as one of the critical success factors of modularization. According to the CII report, OEMs and technology partners need to be

integrated into the modularization solution process in order to maximize related beneficial opportunities.

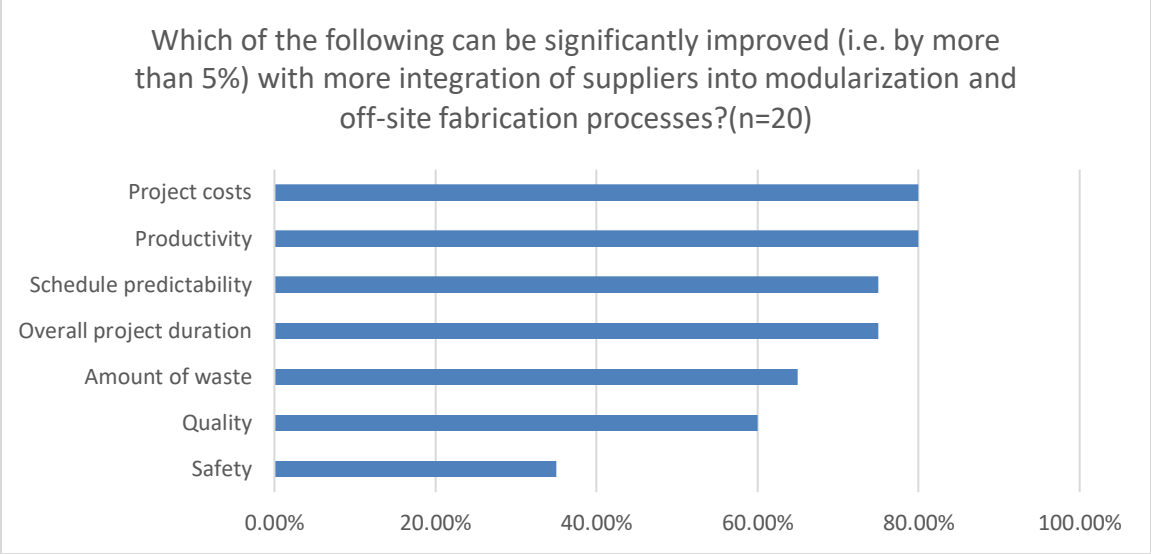


Figure 37 – Benefits of more integration of suppliers into modularization

Project costs and productivity were chosen by 80% of the respondents, which, as noted in the literature review, are two of the main advantages of modularization of projects. Therefore, more integration of suppliers into the modularization plan will enhance the benefits of building with this approach. A reason that can explain why the supplier's involvement in modularization can improve project costs is that they would be able to create an optimal design for the modular approach, which can reduce installation cost and changes. Designs will be better integrated with modular solutions.

One of the suppliers interviewed mentioned that delivering materials to modularization shops is not different than delivering to the job site since in both places there are not large storage areas. If suppliers have more integration with the overall modularization plan, deliveries can be better coordinated, and storage and handling costs can be reduced.

As mentioned by Choi (2014), procurement is a barrier in modularization in the sense that since modules are made in parallel, and the fabrication is done earlier than in stickbuild construction, materials and big pieces of equipments should be secured in advance, and the different partires must advance the delivery schedule of those materials. With more involvement of suppliers, the coordination of these deliveries to the modularization shops can be improved, as well as the visibility into the status and location of materials and into the delivery dates, which is consistent with Figure 37 where schedule related benefits ranked third and fourth.

Safety ranked in the last place, with less than 40% of the respondents choosing that option, which can be explained by the fact that most of the activities involving safety risks are done in the module shops, and suppliers just deliver materials and equipment there. Therefore, more involvement of suppliers will not necessarily lead to safety improvements.

Improvements in supplier contracts

During expert interviews, it was clear that stakeholders were not completely satisfied with some provisions included in contracts with suppliers since they claimed they generate issues such as legal disputes and lack of collaboration. In order to assess the degree of satisfaction, respondents were asked to evaluate contracts considering eight dimensions: Clarity of scope of work, clarity of deliverables definition, delivery schedule, payments terms, dispute resolution mechanism, balance of responsibility, and ease of understanding. Results are presented in Figure 38.

The results suggest that most of the aspects can be improved since "average" was the most chosen response for six of the seven categories. Only “clarity of payment terms” appears to be excellent or good, which is consistent with Figure 33 and Figure 34, where

for purchase orders and requests for quotation, payments terms were indicated to be well defined.

Definition of deliverables and a detailed delivery schedule are the two areas that appear to have the least degree of satisfaction among respondents. This was expected since the quality of the information deliverables, and the lack of certainty about delivery dates were common concerns of the experts interviewed during the first steps of this research.

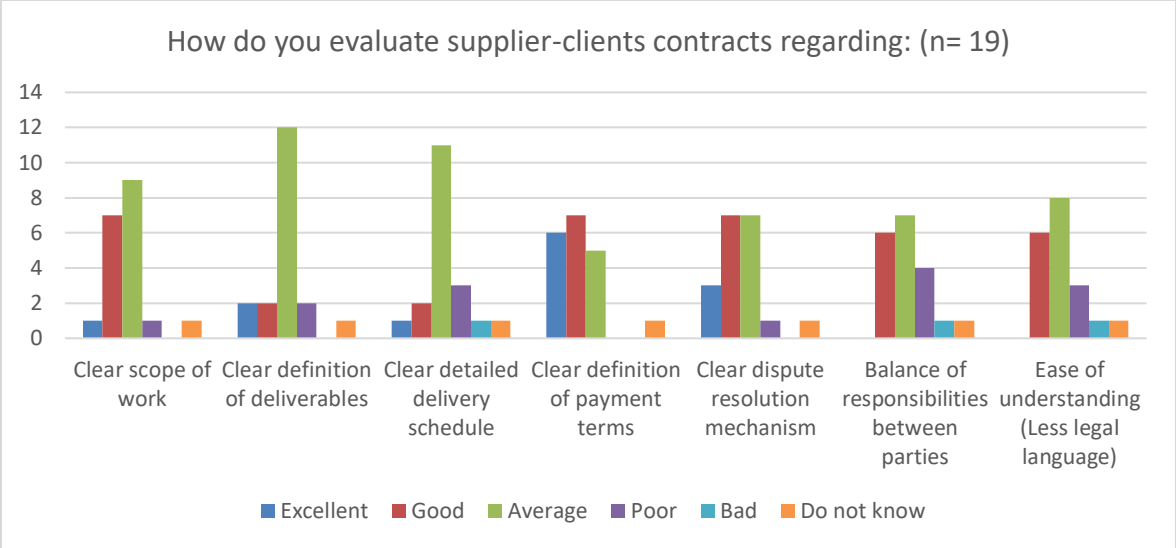


Figure 38 – Evaluation of supplier client's contracts

Given the evaluation presented in Figure 38, the research team considers that contracts with suppliers is an area where improvements are necessary. To determine what can be done to improve the contractual relationship with suppliers, the opinion of the respondents about the potential of some opportunities around contracts to improve project performance was asked. Four opportunities were evaluated: Use of Integrated Project Delivery (IPD), inclusion of penalty and incentive clauses, and contracts written in plain English to facilitate understanding. Results can be seen in Figure 39.

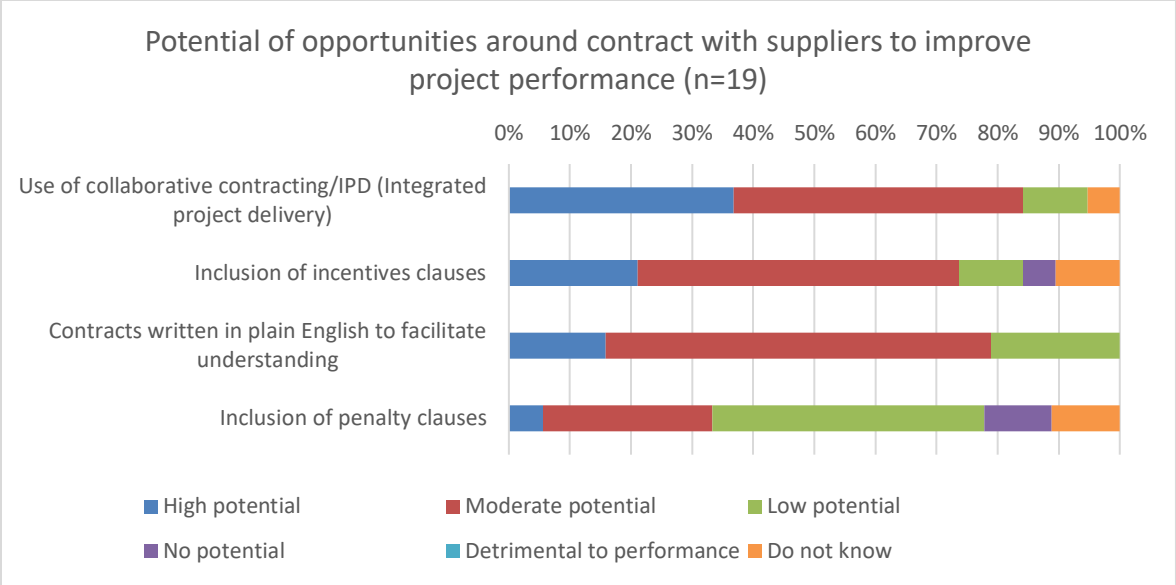


Figure 39 - Potential of opportunities around contracts with suppliers to improve project performance

Respondents indicated that all opportunities except the inclusion of penalty clauses have high or moderate potential to improve project performance. This was expected for IPD since it has been implemented successfully in other sectors (such as healthcare), and its principles of collaboration and integration address some of the main stakeholders' concerns. Therefore, the research team expected that experts would consider IPD as an opportunity to increase project performance.

The research team considered that moving from dense, overlength and full of legal jargon contracts to simple, well-structured plain-language documents would facilitate its understanding by project members and its negotiation. However, the number of respondents that consider that it has the potential to improve project performance was lower than expected.

Lastly, for incentives and penalty clauses, the results were expected: There is a general agreement that incentives are beneficial, and penalties are not. This is consistent with expert's opinions that mentioned that penalties create an adversarial behavior that damages the relationship client-suppliers, but it is in contradiction with Suprapto et al. (2016) that indicated that they have a non-significant cumulative effect on project performance. However, it is worth notice that according to what was reported in the literature review, in order to be successful, incentives should be balanced with penalties and both should be well formulated. Finally, the research team found surprising that no one said that penalty clauses are detrimental to performance.

Use of BIM and sharing of BIM models

A question about benefits of BIM was included in the survey, and the results from 19 respondents are shown in Figure 40.

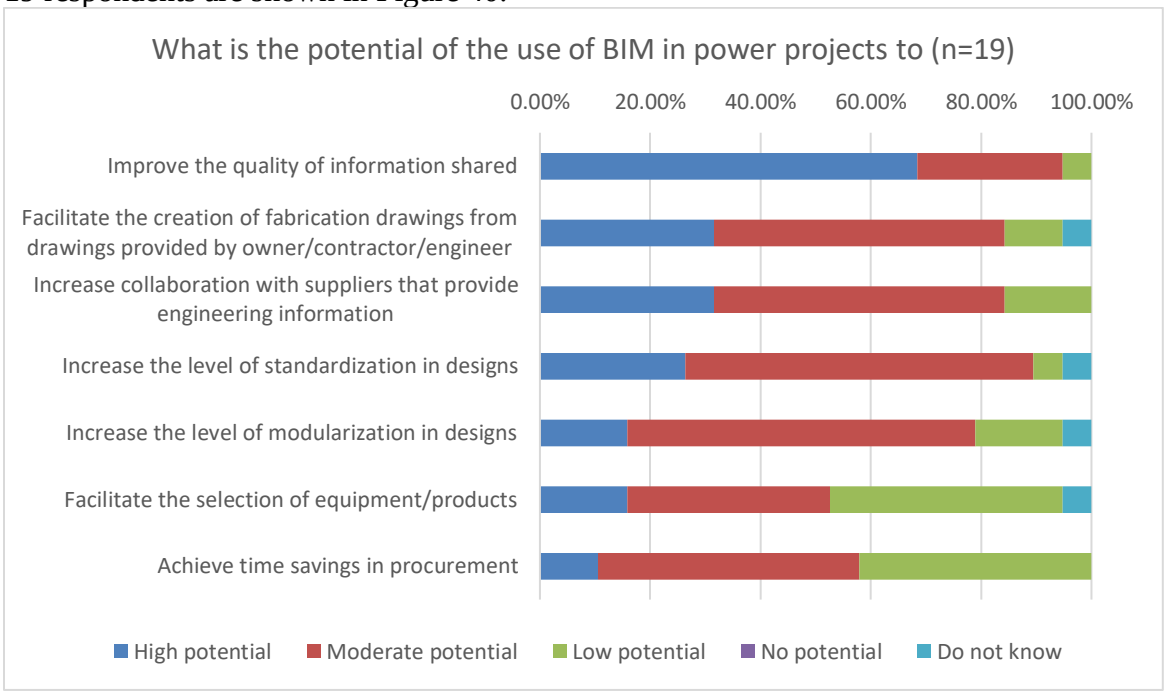


Figure 40 – Use of BIM in power projects

The most significant benefit, according to the respondents, is the improvement of the quality of the information shared, by using 3D federated models instead of 2D drawings and specifications for communication, which also increase collaboration with the party that is sharing the model. A high number of respondents indicated that the use of BIM could increase the level of standardization and modularization in designs, which is consistent with the McGraw Hill report on prefabrication and modularization (McGraw-Hill Construction, 2011).

It is interesting to analyze if models built by one stakeholder are shared with others so that they can add value at multiple phases of the project, or, on the contrary, are kept by those who built it. In that sense, owners were asked about the level of satisfaction they had with the models that they receive. Results are presented in Figure 41.

Figure 41 – Owner satisfaction with shared models

Similarly, owners were asked how easy or difficult was to use those models once the project is finished. Results are shown in Figure 42.

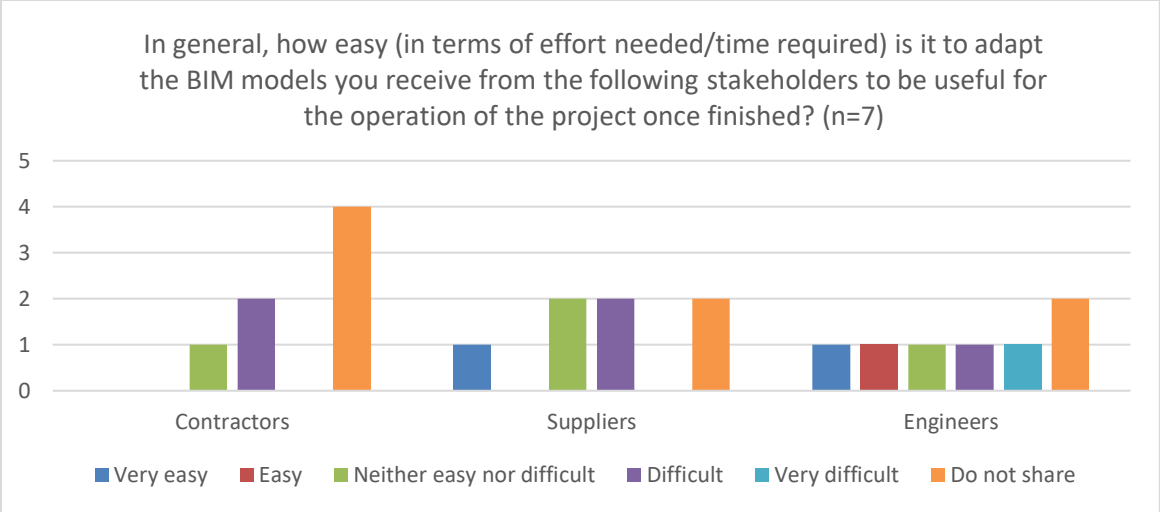


Figure 42 – Effort needed to adjust shared models (owners)

These two charts suggest that:

a. Contractors: They mostly do not share models with owners, and when the models are shared, the quality is usually not enough for owners to use or are difficult to adapt. This may be because requirements for BIM use are not specified in the contract, and contractors only create models to be used during construction. According to the BIM Implementation Guide (2010), when creating a model, it is necessary to think about the future uses that the model would have. Therefore, contractors should have in mind the uses that owners will do of the model when they are developing it.
b. For suppliers and engineers, it is clear that there is still room for more sharing and quality improvements on models.

The same two questions were asked to contractors, and results are shown in Figure 43 and Figure 44.

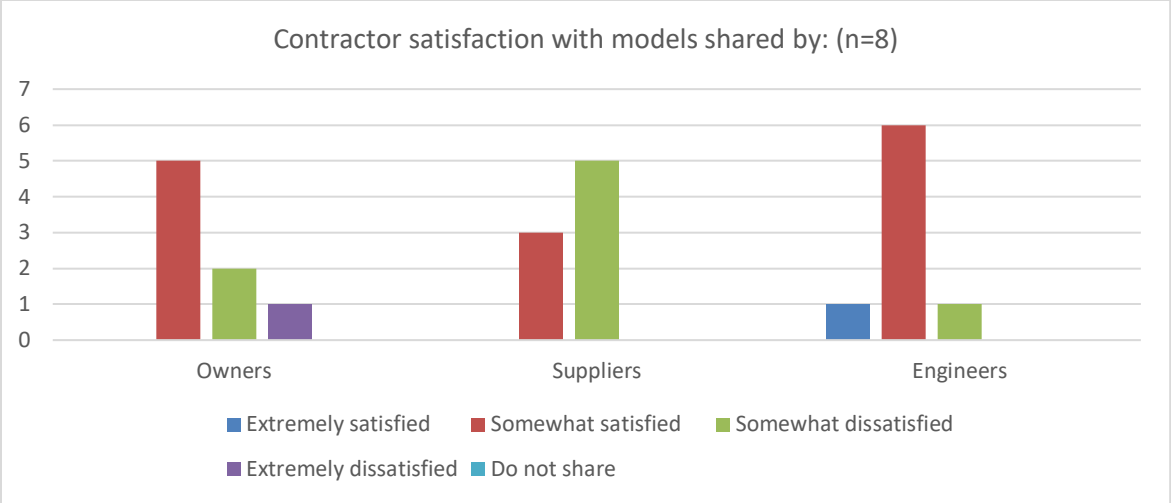


Figure 43 – Contractor satisfaction with shared models

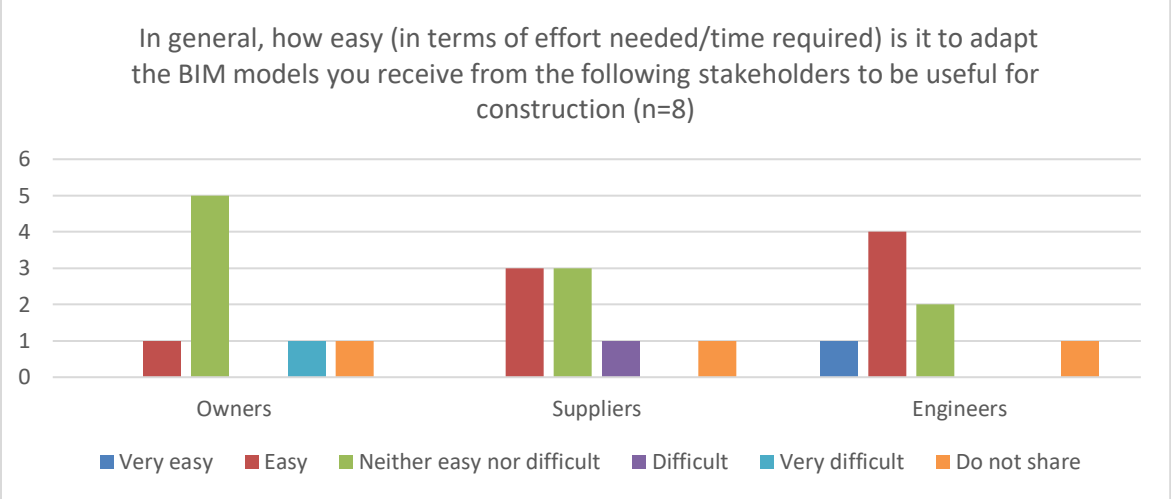


Figure 44 - Effort needed to adjust shared models (contractors)

The first chart suggests that contractors are mostly satisfied with models shared by owners and engineers but dissatisfied with models shared by suppliers. This was expected since it was heard in multiple expert interviews that the use of BIM by suppliers was limited and that the models shared were of a low level of detail.

The second chart suggests that models from engineers are easy to use in construction, but more work is required to adapt models generated by owners and suppliers.

Some suppliers' specific questions were included around BIM and sharing of BIM models. However, given the low number of supplier's answers, no relevant conclusions could be obtained.

Early design freeze

Even though early design freeze can reduce the number of changes that would ultimately impact project cost and schedule, it is not easy to achieve. Respondents were asked about the challenges that arise when trying to accomplish an early design freeze, and results are shown in Figure 45.

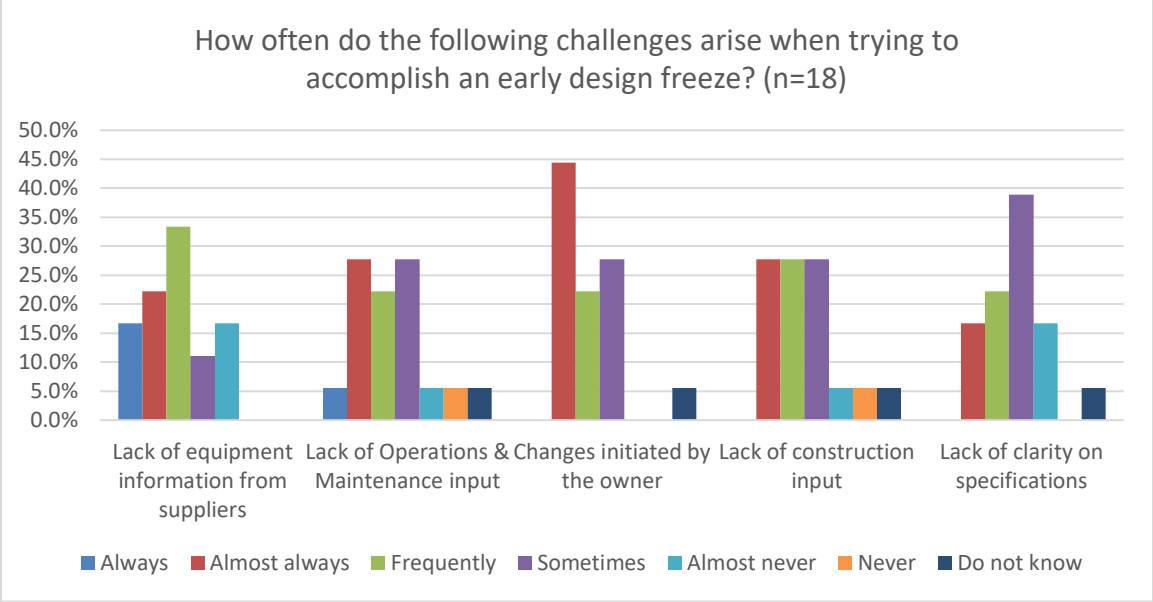


Figure 45 - Challenges that arise when trying to accomplish an early design freeze

The chart above suggests that all of these issues arise relatively frequently when trying to accomplish an early design freeze. The results were expected in the case of lack

of operations and maintenance input, and lack of construction input since contractors and O&M personnel are stakeholders usually not involved during early stages of the design. It was interesting to see that lack of equipment information from suppliers is a challenge that arises always or almost always for most respondents. This suggests that involving suppliers early when trying to freeze the design is an opportunity to explore. Finally, changes initiated by the owners were indicated to be a significant challenge, which was expected since owners generally want to keep flexibility to make changes into the design.

Results in Figure 45 were broken out by stakeholders since there was a significant difference in the ranking of this opportunity (Figure 46 and Figure 47).

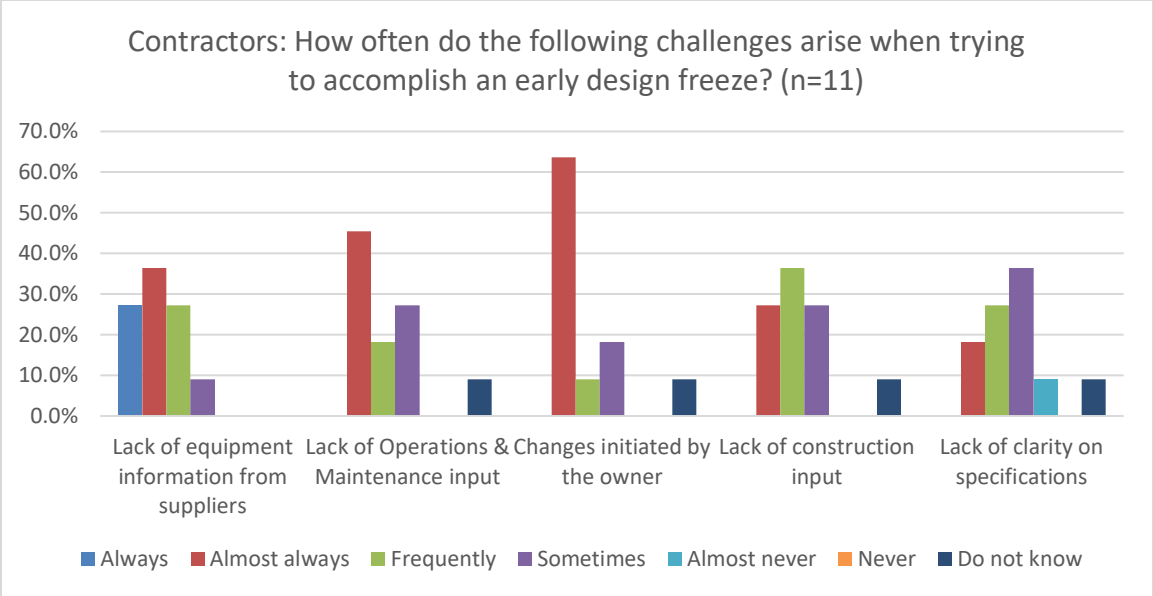


Figure 46 - Early design freeze challenges for contractors

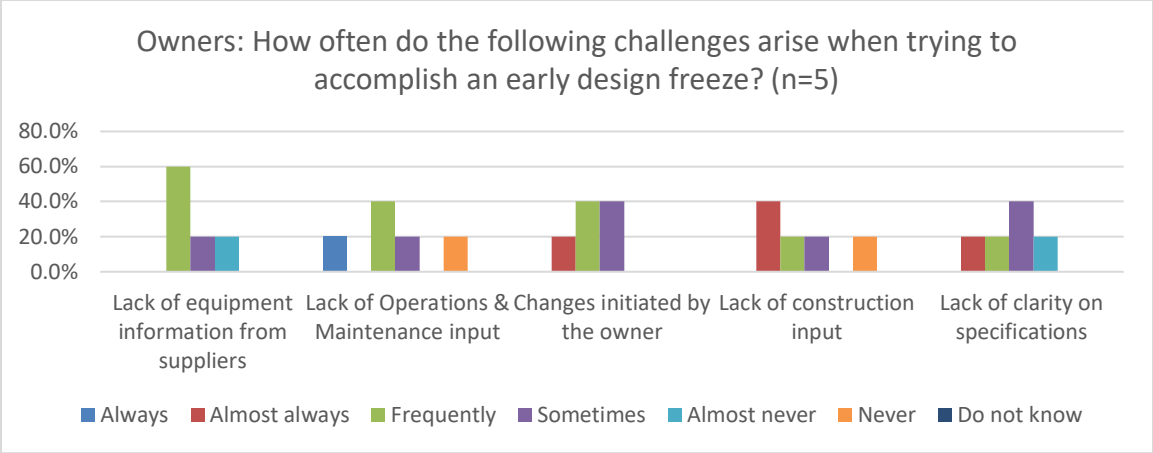


Figure 47 - Early design freeze challenges for owners

Both stakeholders indicated that lack of equipment information from suppliers is a common challenge. Furthermore, contractors selected changes initiated by the owners as the most significant barrier to accomplishing an early design freeze, while owners mostly chose lack of construction, operation, and maintenance input.

Respondents were also asked about the benefits of design freeze. Results are shown in Figure 48:

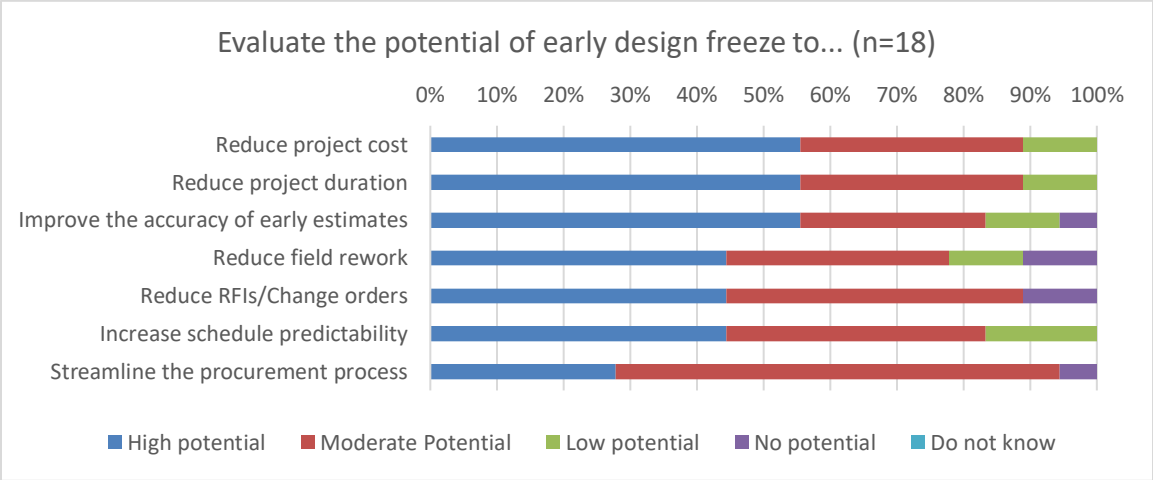


Figure 48 - Benefits of early design freeze

As it can be seen in the figure above, design freeze has potential to achieve most of the listed benefits since all options were chosen by most than two-thirds of the respondents. Notably, early design freeze has been reported to have high potential to reduce two of the most important aspects of project performance: Cost and schedule.

Surprisingly, even though one of the main benefits of early design freeze is the reduction of changes by forcing the completion of design at early stages of the project, the options "reduce field rework" and "Reduce RFIs'/Change orders" were not ranked in the first places.

Since the focus of this research is supply chain involvement, respondents were asked about suppliers' involvement and early design freeze. The first question was about the importance of early involvement, and results are shown in Figure 49.

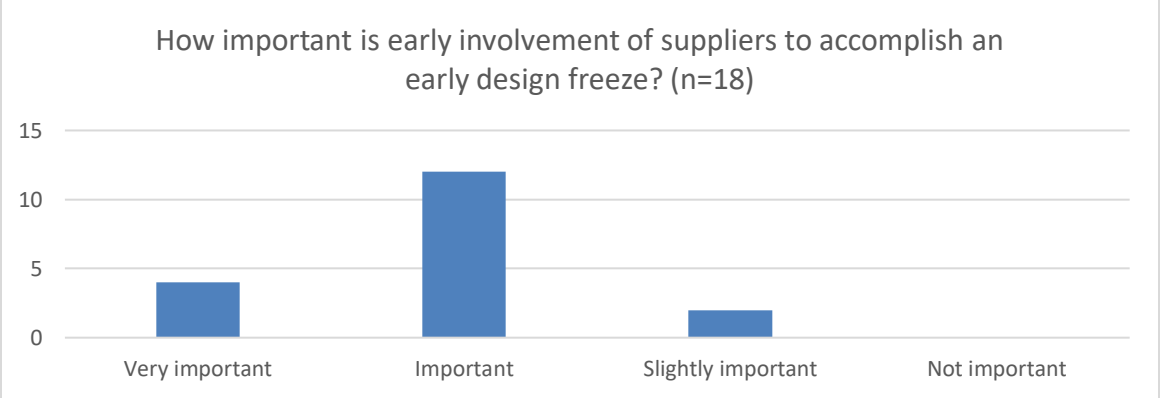


Figure 49 - Importance of supplier's involvement in early design freeze

All respondents indicated that early involvement of suppliers was relevant to achieve an early design freeze, with most responses in the very important and important categories. If this information is analyzed together with the results showed in Figure 45, where it was indicated that lack of equipment information from suppliers was a common

challenge to freeze the design at early stages of the projects, it is safe to conclude that projects should increase the involvement of suppliers at early stages of the project.

The second question was about specific tasks that suppliers can do to help the project to achieve an early design freeze:

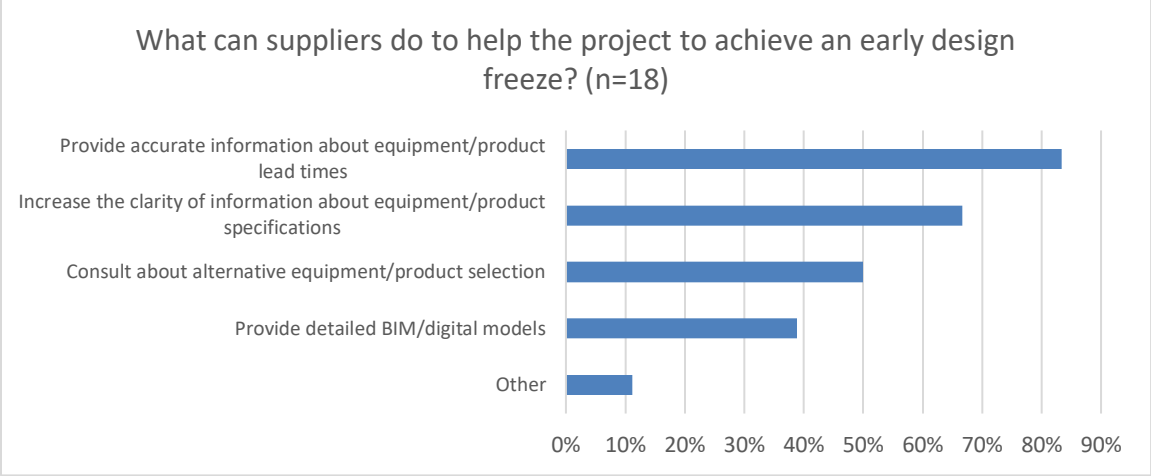


Figure 50 - Supplier's role in early design freeze

It can be seen that it is necessary for suppliers to provide accurate and precise information about lead times and specifications, which is consistent with Figure 45, and it makes sense since lead times affect equipment selection decisions, especially for long lead items, and when selected, information and specifications are required to complete and ultimately freeze the design. This is: With not enough information with suppliers, design cannot be frozen.

Use of framework agreements with suppliers

Stakeholders were asked about the benefits of having framework agreements with suppliers. There was one question for engineers and contractors, and another for suppliers and owners:

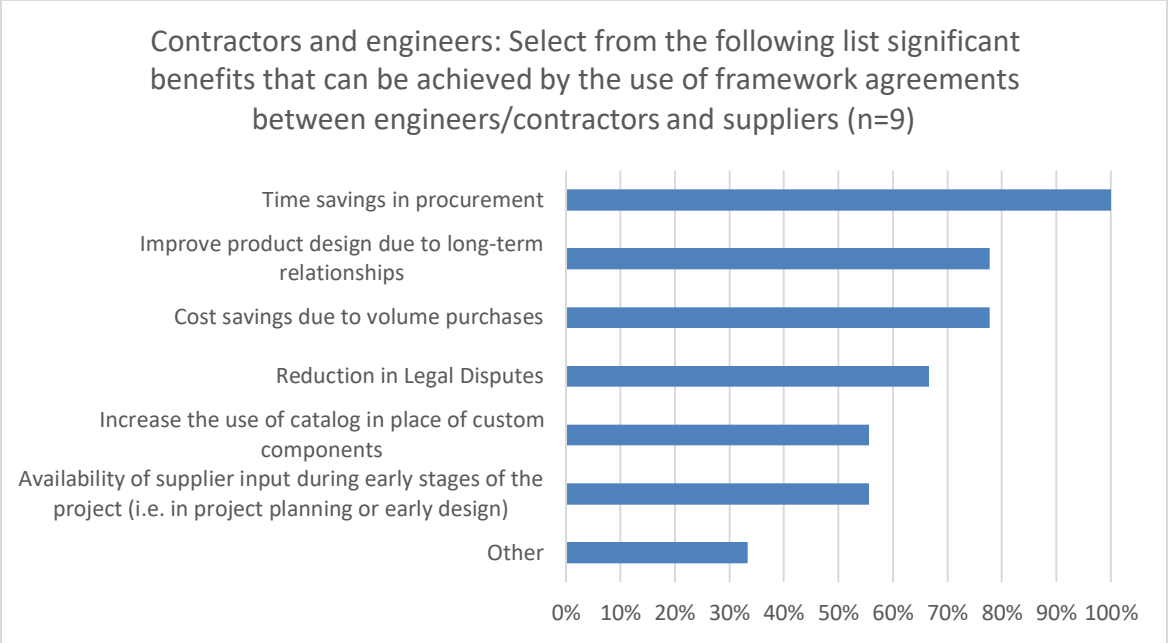


Figure 51 - Contractors and engineers' opinions about benefits of framework agreements with suppliers

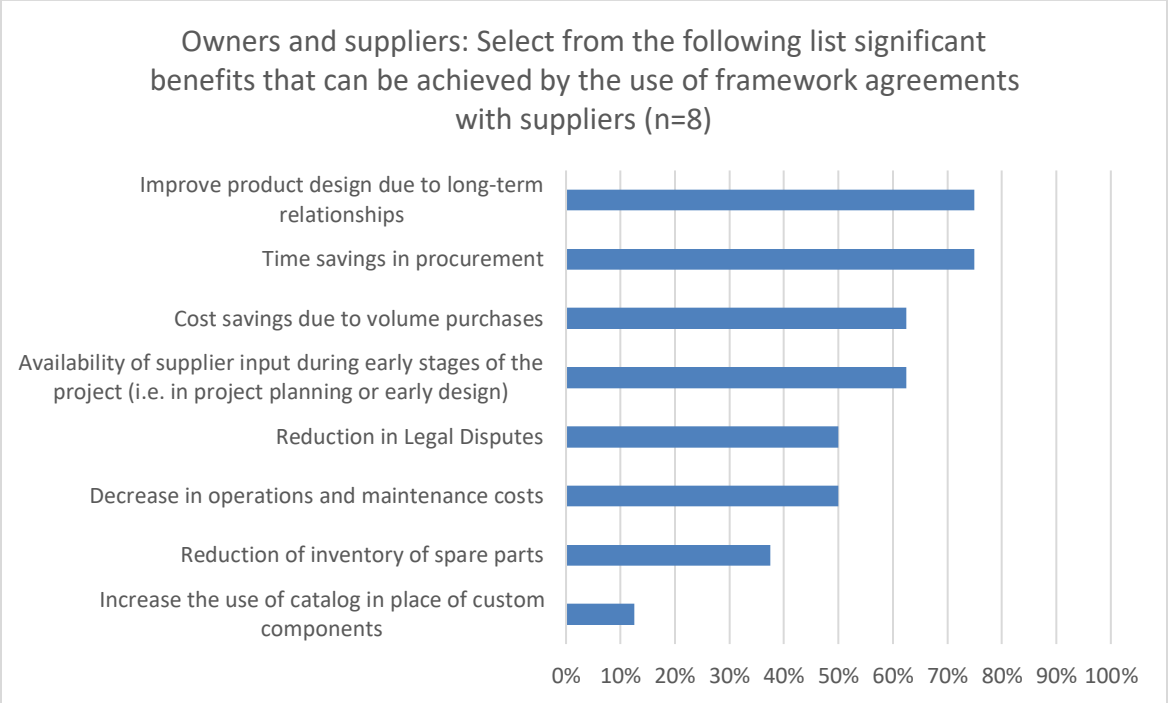


Figure 52 - Owners' opinions about benefits of framework agreements with suppliers

Interestingly, cost savings due to volume purchases was not ranked first. The research team expected cost benefits due to economies of scales to be the most chosen response.

For all stakeholders, the most noteworthy benefit appears to be time savings in procurement. In framework agreements, substantial time is spent in selecting a supplier and negotiating the terms and conditions of the agreement, but when it is in place, significant time savings are achieved since there is no need to use competitive bidding for those items anymore.

Also, the improvement of product design due to long-term relationships was also chosen by a high number of respondents, especially owners and suppliers. As it was mentioned by one of the contractors interviewed, with a long-term relationship, more collaboration is achieved, and suppliers and clients can work together to find the best possible design.

Intriguingly, a decrease in operation and maintenance cost and reduction of inventory of spare parts was chosen by a relatively low number of suppliers and owners. The research team expected these items to rank higher since with framework agreements, there is more consistency across projects for owners, and that can affect inventory (no need to keep different models of spare parts) and maintenance cost (savings in training personnel).

Finally, the relationship between framework agreements and trust and information sharing was investigated (Figure 53). Respondents were asked if they thought that the use of framework agreements with suppliers could increase trust and information sharing. All respondents indicated that it is possible. This is consistent with the indicated benefits: With more trust and information sharing, a more collaborative relationship can be built, and that

collaboration is translated into improvements in the design and the reduction of legal disputes.

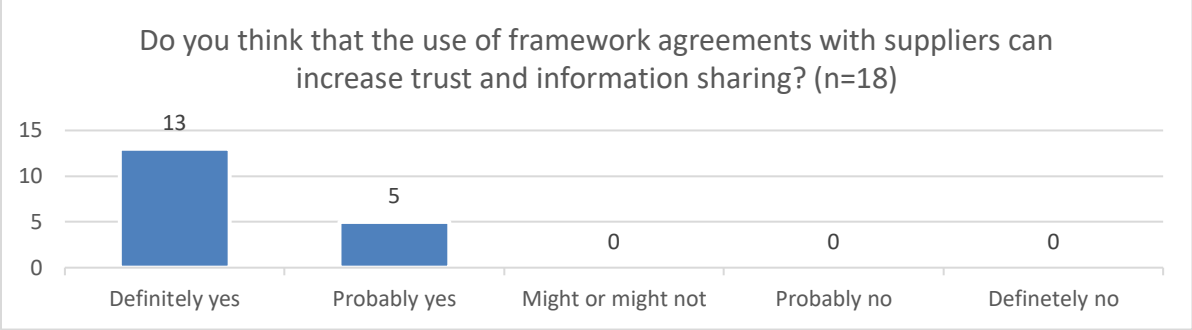


Figure 53 - Trust and information sharing created by framework agreements suppliers-clients

Improved coordination around owner furnished equipment (OFE)

As stated in the literature review, the owner may decide to buy the major pieces of equipment to save the contractor mark-up. In that case, as there is no contractual relationship between the contractor and the supplier, issues may arise. Respondents were asked about how often was the supplier-contractor coordination a challenge, and responses are shown in Figure 54.

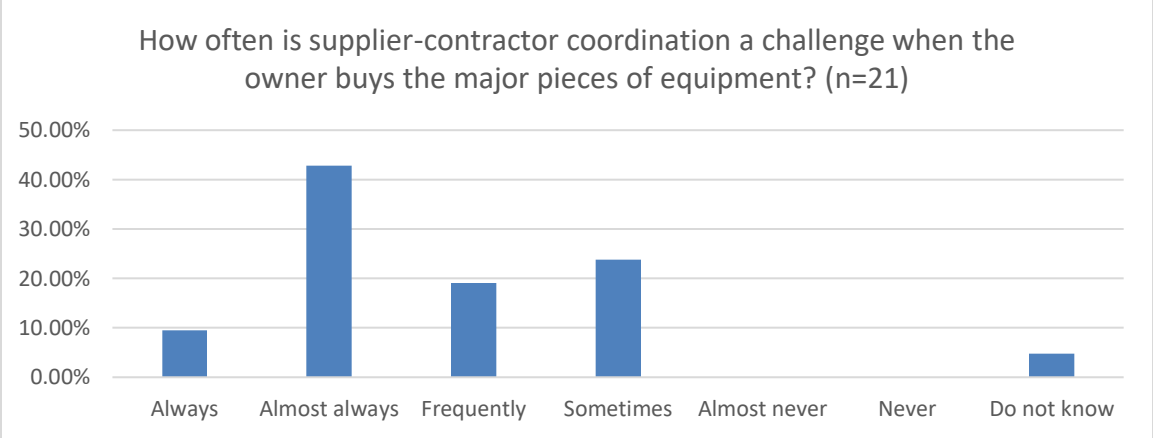


Figure 54 - Supplier-contractor coordination with OFE

All respondents indicated that the coordination challenge is always present to some extent, with most of them denoting that it is almost always an issue. When they were asked about what specific problems arise, their response was:

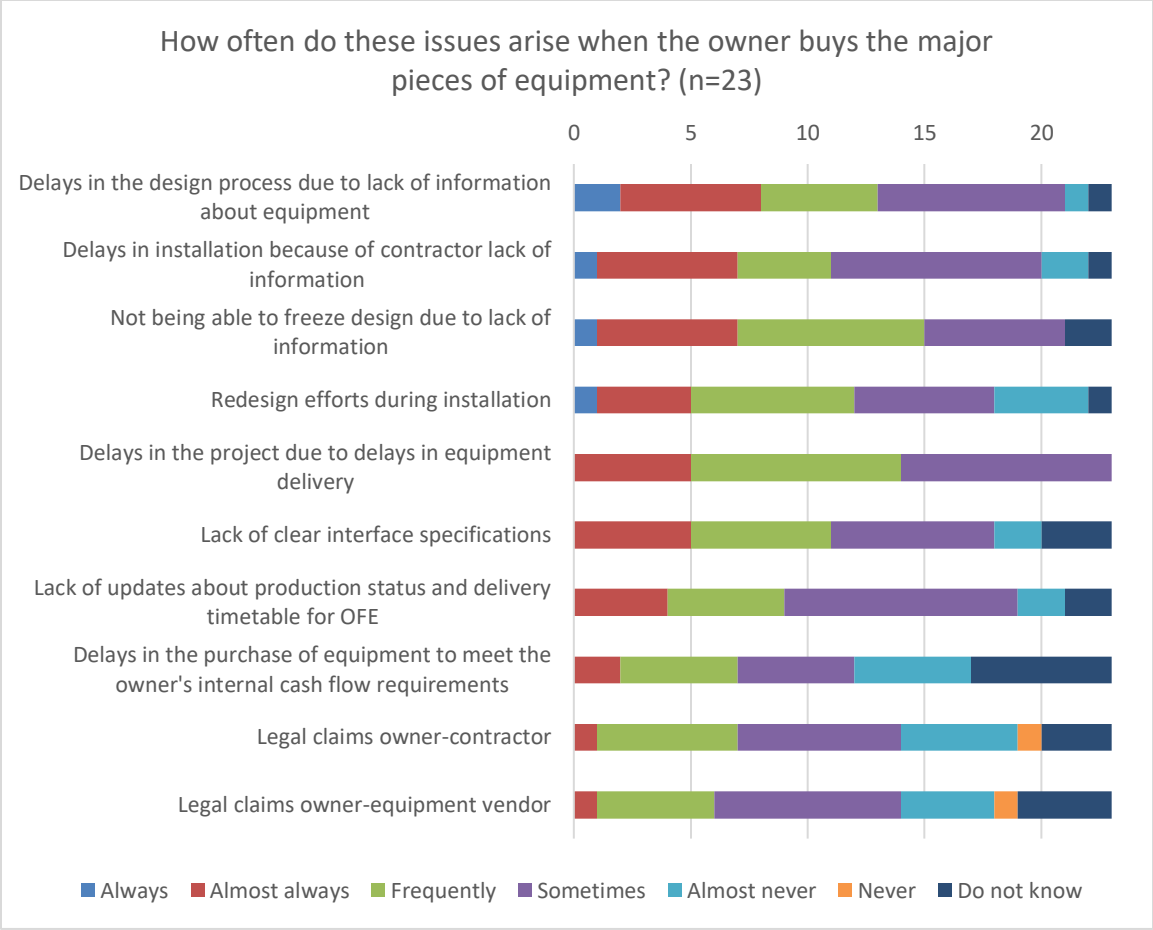


Figure 55 - Issues that arise when the owner buys the major piece of equipment

In order to simplify the analysis, the categories of Figure 55 were grouped into Always/almost always/frequently, sometimes, almost never/never, and do not know (Figure 56).

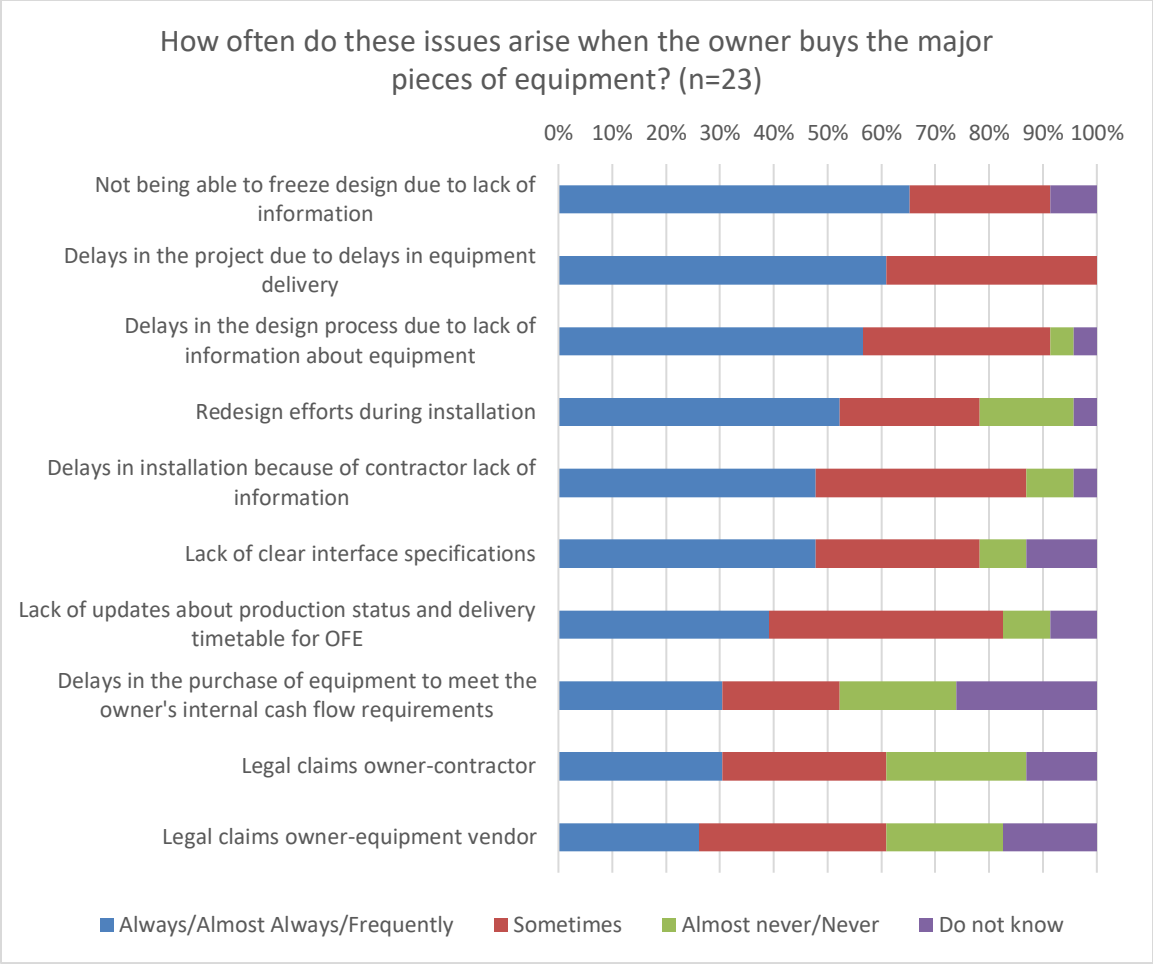


Figure 56 - Issues that arise when the owner buys the major piece of equipment - Condensed categories

The lack of information exchange between the contractor and the supplier is the most common issue, and the main consequence is project delay. Lack of exchange of equipment specifications generates delays in the design process, difficulty to freeze the design early and redesign efforts when the equipment has to be installed. Also, lack of information about delivery dates and no visibility into need dates generate delays during construction.

Considering that the contractor-supplier coordination is frequently a challenge with OFE (Figure 55), and that information exchange seems to be one of the main issues (Figure 56), respondents were asked to indicate which opportunities can significantly improve supplier-contractor coordination (Figure 57).

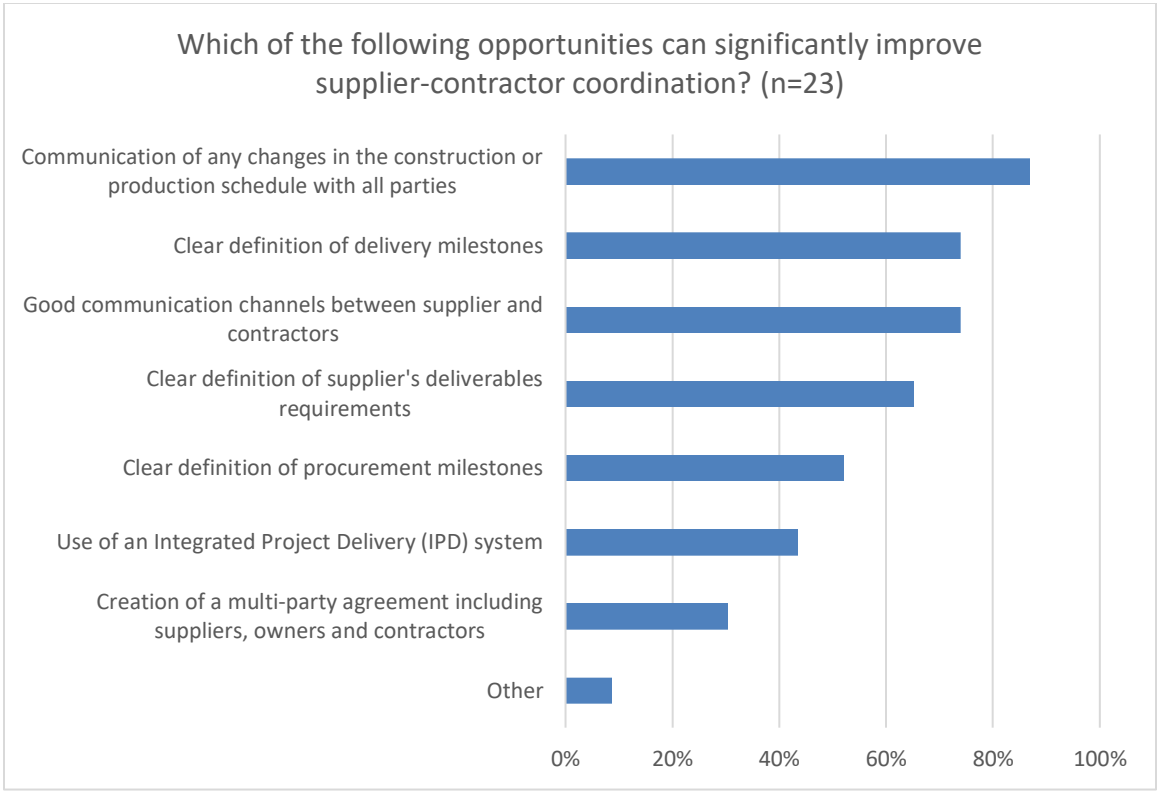


Figure 57 - Opportunities to improve supplier-contractor coordination

The most selected alternative is related to the communication of changes in construction and production schedule. This means keep suppliers updated with the require at site dates and notified them of any construction delay. Also, suppliers should inform if any change in priorities or issues with production may affect the delivery date of materials

or equipment. As mentioned several times in this section, better communication appears to be the most promising opportunity to improve supplier-contractor coordination.

Interestingly, IPD was only selected by around 40% of the respondents. The research team expected this number to be higher.

Implementation of Automated Materials Identification, Locating and Tracking Technology (AMILTT)

A question about the value of using AMILTT was included in the survey (Figure 58).

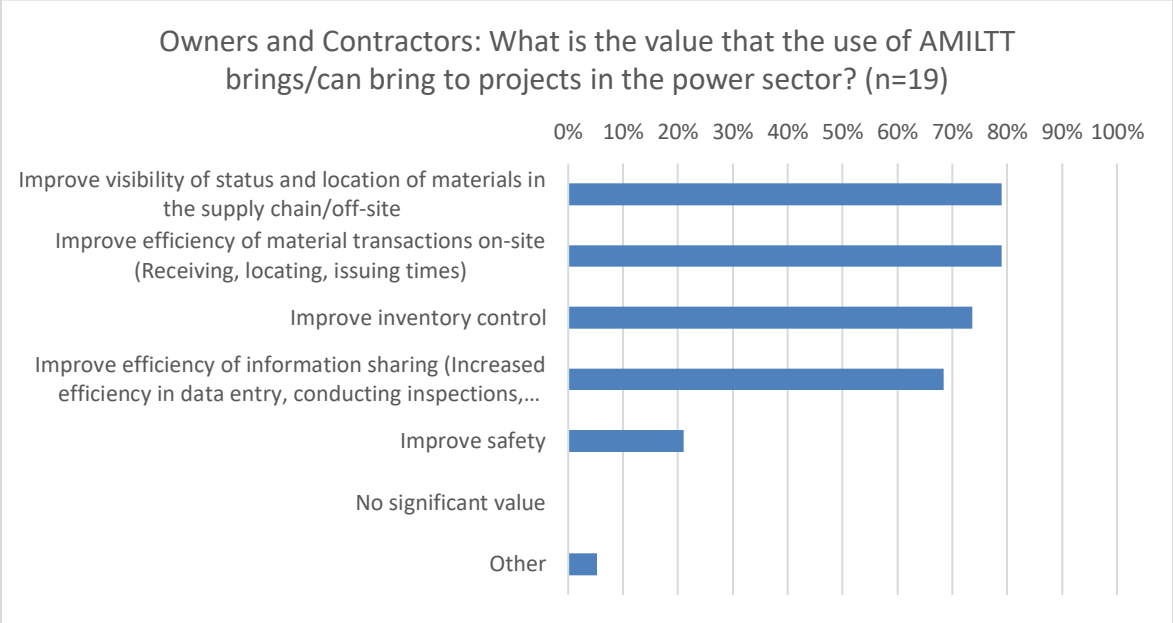


Figure 58 - Value of AMILTT to projects in the power sector

As expected, more visibility into the status and location of materials in the supply chain and improved efficiency of material transactions on-site are the options with more responses.

Increased use of catalog in place of custom components

As opposed to what the research team expected, this opportunity ranked in the last place. Respondents were then asked about the number of projects where catalog components would be a feasible option instead of custom designs. As can be seen in Figure 59, all respondents indicated that this was feasible for at least one project, being 21% - 40% the most chosen option.

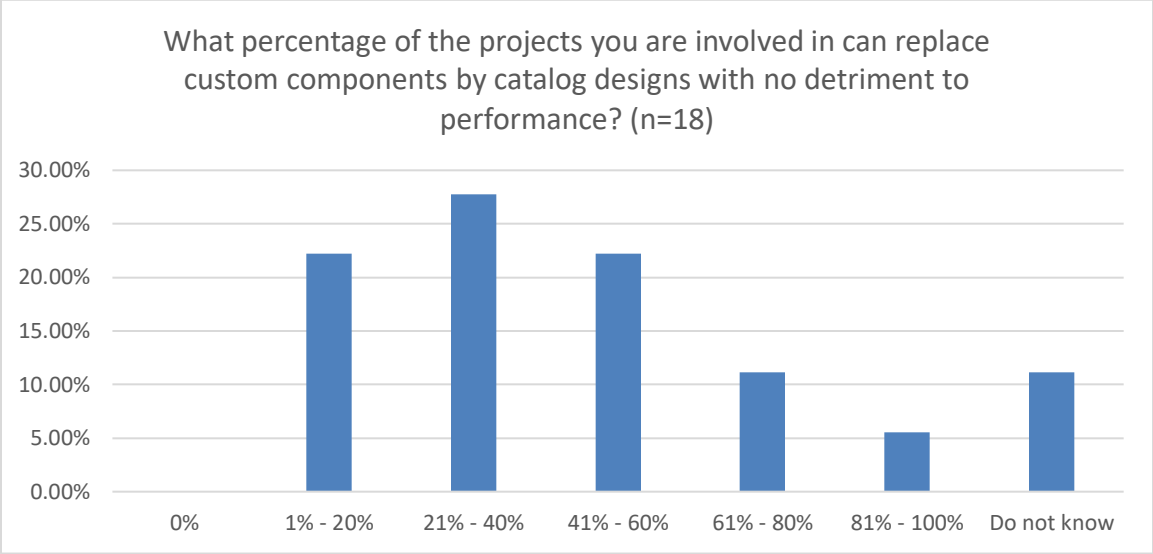


Figure 59 – Projects that can replace custom components with catalog designs

Finally, in terms of the benefits of an increase of use of catalog components in place of custom solutions (Figure 60), improvements in project quality and reduction of operation and maintenance cost were chosen by most than half of the respondents. An explanation of this can be the fact that a catalog design is more likely to have a more reliable performance since it is supposed to have been perfected over time and used multiple times. Using catalog components can improve the accuracy of estimates since it is easier to obtain accurate estimates from suppliers.

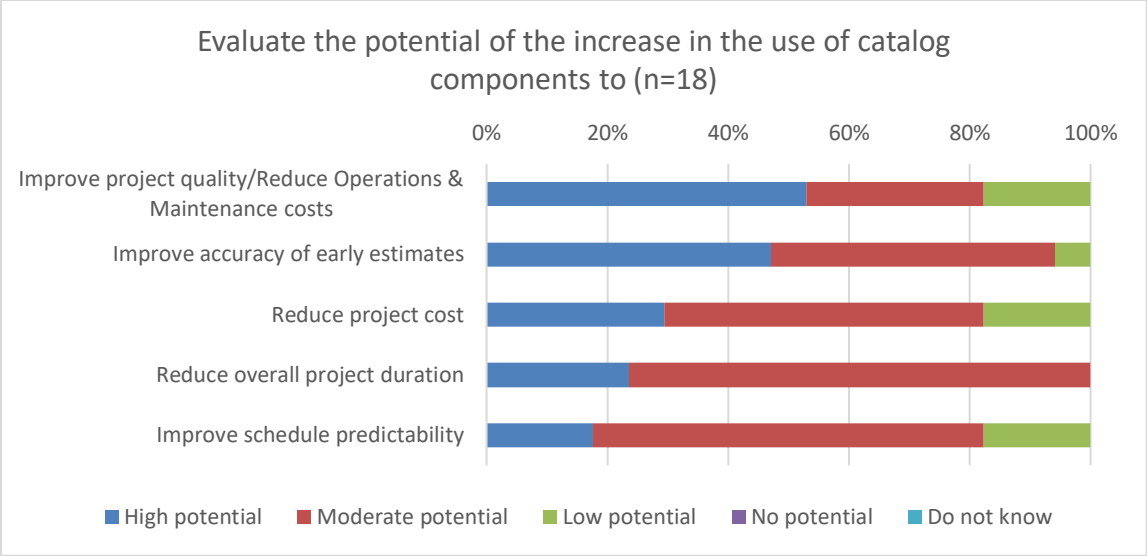


Figure 60 - Benefits of increase in the use of catalog components

Chapter 7: Conclusions, contributions, and recommendations

CONCLUSIONS

Complex supply chains are the norm on power projects. To cope with this complexity, better engagement of the supply chain is needed, which can, in turn, improve project performance. This research identified through expert interviews and a review of existent literature eleven opportunities that can engage suppliers better and used a survey to determine the potential of those opportunities to improve project performance.

The identified opportunities are (in order to reflect their potential to improve project performance): Use of standard designs across projects, early involvement of suppliers, supplier integration with Advanced Work Packaging (AWP), modularization and off-site fabrication, improvements in supplier contracts (collaborative contracting/IPD/ incentives/ plain English), use of BIM and sharing of BIM models, early design freeze, use of framework agreements with suppliers, improved coordination around owner furnished equipment (OFE), implementation of Automated Materials Identification, Locating and Tracking Technology, and increased use of catalog in place of custom components.

The survey allowed the research team to obtain more insight into each of the opportunities. From its results, while preliminary, the following conclusions can be mentioned:

The use of standard designs across projects is an effective strategy to reduce the cost and the overall duration of projects. This strategy can also be useful to improve the accuracy of early estimates for contractors working in fixed price power projects. For this opportunity to be successful, it is essential to incorporate lessons learned into the design and to replicate the approach to project execution from one job to another.

Early involvement of suppliers can bring benefits in terms of schedule, but currently, suppliers are not involved as early as it would be optimal. Since vendors are a source of innovation for the industry, their recommendations about equipment choice and specification can add value to projects. Finally, in terms of documentation, there is room for improvements in the request of quotations and purchase orders that suppliers receive from clients.

More integration of suppliers into advanced work packaging can leverage the benefits of AWP, particularly productivity and project performance predictability. Similar to what was found for the opportunity about early involvement of suppliers, schedule predictability seems to be the most important benefit of this opportunity.

Modularization and off-site fabrication was ranked first for owners, and more integration of suppliers into this process can enhance the benefits of building with this approach, particularly project cost and productivity.

Moreover, contracts with suppliers have multiple areas where they can be improved, especially regarding the clarity of deliverables and the level of detail of the schedule included in contracts. Also, IPD as a contract strategy can be evaluated by owners looking for improvements in performance and increased collaboration.

In order to improve the quality of the information shared between stakeholders, BIM is a tool that can be implemented. However, it is important to share well-developed models among stakeholders so that they can add value in multiples stages of the project.

Early design freeze represents an opportunity to reduce project cost and schedule. However, when trying to accomplish this, the lack of equipment information from suppliers appears to be a challenge. In that context, all stakeholders recognize that early involvement of equipment providers can help the project to accomplish an early design freeze since it will allow vendors to provide accurate information about specifications and lead times.

A change in the procurement strategy, from competitive bidding to long term framework agreements involves the following benefits: Time savings in procurement and the possibility to improve product design due to more collaboration, trust, and information sharing between the framework partners.

When owners buy the major pieces of equipment, the coordination between the supplier and contractor is always a challenge. The main consequences of the coordination challenge are delays in design, construction, and startup. Communication of changes in construction and production and improved interaction between contractors and suppliers are opportunities to improve this coordination.

Automated Materials Identification, Locating and Tracking Technology (AMILTT) can help to increase the visibility into the status and location of materials in the supply chain, as well as to increase the efficiency of material transactions on-site.

Finally, even though most projects can replace custom components by catalog designs, and this can improve project quality and the accuracy of early estimates, this opportunity was ranked in the last place.

CONTRIBUTIONS TO PRACTICE

This work presents a list of opportunities that companies working in power project can implement if they want to increase the level of engagement and integration they have with the supply chain. The list constitutes a checklist of areas and ideas that, if applied, can also affect project performance.

Some of the areas can be implemented only at a corporate level, since they involve a broader effort that transcends one project, such as framework agreements with suppliers and use of standard designs across projects. The others are project specific and can be considered by any project manager.

In the survey results, this work also highlights the main benefits that each of the opportunities can bring to projects, which can be useful to identify which one to implement depending on the objective or the issues project managers or companies are facing.

CONTRIBUTIONS TO ACADEMIA

This work builds on the existent knowledge about supply chain engagement in construction and expands it to cover mainly projects in the power sector. It provides a list of areas related to power projects' supply chain engagement in a more coordinated way, identified through literature review and expert interviews. It also creates, based on an industry survey, a classification of those opportunities according to their relationship with project performance.

RECOMMENDATIONS

This research can be extended in several ways. First, more survey responses can be collected so the analysis can be expanded, and comparisons of the responses of different stakeholders can be performed. Also, due to the low number of suppliers that have taken the survey, some of the questions that would have added value were not included in this report.

Second, a more detailed quantification of the effect of the implementation of the identified opportunities on project performance can be performed. The objective of this work was to determine the potential of each opportunity and to identify what dimension of project performance could be impacted if implemented, but no improvement metrics are included.

Third, for some opportunities, owners and contractors have significantly different opinions, such as early design freeze and supplier integration with advance work packaging. Subsequent research can be done to understand and clarify these differences.

Finally, this research can be extended to include implementation guidelines about each of the opportunities.

Appendices

APPENDIX A – SURVEY

Increasing engagement with the supply chain in power projects to improve performance

Start of Block: START & COMPANY INFORMATION

Q1.1

Survey: Opportunities to increase the engagement with the supply chain to improve the performance of power sector projects We recommend using a computer or tablet to take the survey.

Identification of Investigator and Purpose of Study

You are invited to participate in a research study, entitled **"Opportunities to increase the engagement with the supply chain to improve the performance of power sector projects".** The study is being conducted by **the Department of Civil, Architectural and Environmental Engineering** of The University of Texas at Austin, and is sponsored by the Construction Industry Institute. **(**E. Dean Keeton St. Stop C1700, Austin, Texas 78712-0273 | Phone: (512) 471-4921)

The purpose of this research study is to examine **opportunities to better engage suppliers into power projects**. Your participation in the study will contribute to a better understanding **the potential of those opportunities to improve project performance.** You are free to contact the investigator at the above address and phone number to discuss the study. You must be at least 18 years old to participate.

If you agree to participate:

- You will complete a survey.
- The **survey** will take approximately **20** of your time.
- You **will not** be compensated.

Risks/Benefits/Confidentiality of Data

There are **no known risks.** There will be no costs for participating, nor will you benefit from participating. Your name and email address **will not** be kept during the data collection phase**.** A limited

number of research team members will have access to the data during data collection.

Participation or Withdrawal

Your participation in this study is voluntary. You may decline to answer any question and you have the right to withdraw from participation at any time. Withdrawal will not affect your relationship with The University of Texas in anyway. If you do not want to participate either simply stop participating or close the browser window.

If you do not want to receive any more reminders, you may email us at **gcarlosena@utexas.edu.**

Contacts

If you have any questions about the study or need to update your email address contact the researcher **Gabriel Carlosena** at (**737)414-9515**or send an email to **gcarlosena@utexas.edu.** This study has been reviewed by The University of Texas at Austin Institutional Review Board and the study number is **[STUDY NUMBER].**

Questions about your rights as a research participant.
If you have questions about your rights or are dissatisfied at any time with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

If you agree to participate, please continue to next page.

Thank you.

Please print a copy of this document for your records.

Page Break

Q1.2 To which of the following categories does your company belong?

- ○ Owner (1)
- ○ Designer/Engineer (3)
- ○ Contractor/EPC (2)
- ○ Supplier (4)

Q1.3 To which of the following categories does your company belong?

- ○ Utility (1)
- ○ Investor - Developer/Execution (2)
- ○ Investor - Operation (4)
- ○ Other: (3) _____

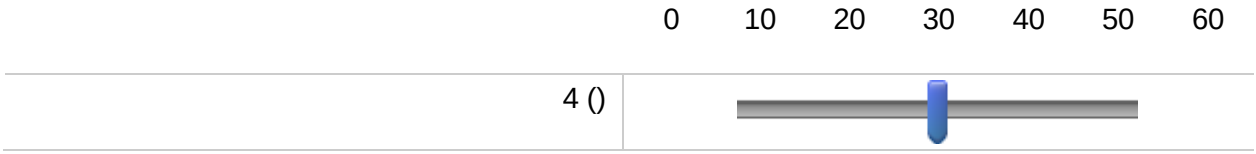
Q1.4 What types of materials does your company produce/sell? If more than one, please choose the most representative

- ○ Bulk Materials (1)
- ○ Engineered Materials (2)
- ○ Prefabricated Materials (3)
- ○ Other: (6) _____

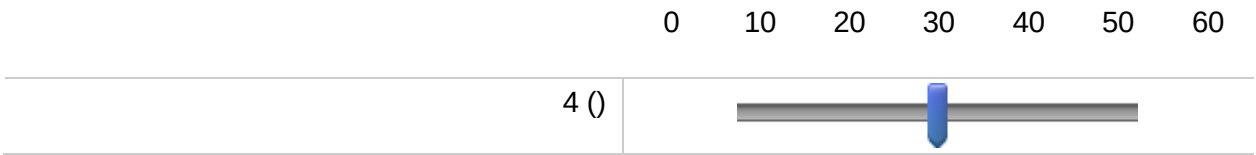
Q1.5 To which of the following categories does your company belong? If more than one, please choose the most representative

- ○ General Contractor (1)
- ○ EPC Firm (2)
- ○ Specialty Contractor (3)
- ○ Construction Manager (4)

Q1.6 How many years of professional experience do you have?



Q1.7 How many years of experience in design, construction or facilities management do you have?



End of Block: START & COMPANY INFORMATION

Start of Block: OPPORTUNITIES

Q2.1 From your perspective, what are the challenges (if any) in today's construction power projects? Please select all that apply

- [ ] Low field productivity (1)
- [ ] No productivity improvements (2)
- [ ] Low adoption of technology innovation compared to other sectors (3)
- [ ] Projects not meeting deadlines (4)
- [ ] Inaccuracy of early cost estimates (5)
- [ ] Low safety performance (7)
- [ ] Low quality performance (8)
- [ ] Lack of collaboration between stakeholders (12)
- [ ] Lack of trust between stakeholders (13)
- [ ] Materials deliveries that deviate from original schedule (9)
- [ ] Cost overruns (14)

zQ2.2 Evaluate the following opportunities according to their potential to improve project performance in any metric (cost/schedule/quality/safety or other project attributes):

	High potential (5)	Moderate potential (4)	Low potential (3)	No potential (2)	Detrimental to performance (1)	Do not know (66)
Use of framework agreements with suppliers (1)	○	○	○	○	○	○
Early involvement of suppliers (2)	○	○	○	○	○	○
Early design freeze (3)	○	○	○	○	○	○
Increased use of catalog in place of custom components (4)	○	○	○	○	○	○
Use of standard designs across projects (20)	○	○	○	○	○	○
Improved coordination around owner furnished equipment (OFE) (5)	○	○	○	○	○	○
Use of BIM and sharing of BIM models (6)	○	○	○	○	○	○
Modularization and off-site fabrication (7)	○	○	○	○	○	○
Implementation of Automated Materials Identification, Locating and Tracking Technology (AMILTT) (8)	○	○	○	○	○	○
Supplier integration with Advanced Work Packaging (AWP) (9)	○	○	○	○	○	○
Improvements in supplier contracts (Collaborative contracting/IPD/incentives/plain English) (12)	○	○	○	○	○	○

Q2.3 Please specify other significant opportunity that can improve project performance that is not listed above (You may skip this question)

_____

_____

_____

_____

_____

End of Block: OPPORTUNITIES

Start of Block: EARLY INVOLVEMENT OF SUPPLIERS

Q4.1 **EARLY INVOLVEMENT OF SUPPLIERS**

You have selected that the opportunity "EARLY INVOLVEMENT OF SUPPLIERS" has potential to improve project performance. Please, answer the following questions about this topic:

Q4.2 Select the stage of the project when your company is **typically first involved**

- Project Planning (1)
- Early Design (2)
- Detailed Design (3)
- Procurement (4)
- Construction (5)
- Start-Up (6)

Q4.3 Select the stage of the project when it **would be optimal** (i.e. more impact on project success) to become involved:

- ○ Project Planning (1)
- ○ Early Design (2)
- ○ Detailed Design (3)
- ○ Procurement (4)
- ○ Construction (5)
- ○ Start-Up (6)

Q4.4 Select for each category the stage of the project when you see that these stakeholders are **usually first involved**, and when it would be **optimal (i.e. more impact on project success) to have them involved**

	Usual time of first involvement					Optimal time to have them involved				
	Project Planning (1)	Early Design (2)	Detailed Design (3)	Procurement (4)	Construction (5)	Project Planning (1)	Early Design (2)	Detailed Design (3)	Procurement (4)	Construction (5)

Suppliers of major engineered materials/equipment (1)	○	○	○	○	○	○	○	○	○	○
Suppliers of minor engineered materials/equipment (2)	○	○	○	○	○	○	○	○	○	○
Suppliers of bulk materials (3)	○	○	○	○	○	○	○	○	○	○
Suppliers of prefabricated materials (4)	○	○	○	○	○	○	○	○	○	○

Q4.5 Evaluate the potential that your early involvement (i.e. in project planning or early design) in power projects can have to:

	High potential (12)	Moderate potential (13)	Low potential (14)	No potential (15)	Do not know (16)
Reduce the cost of the products you supply (1)	○	○	○	○	○
Improve overall lead times (22)	○	○	○	○	○
Improve your forecasting ability (23)	○	○	○	○	○
Improve the quality of the products you supply (25)	○	○	○	○	○
Increase safety (26)	○	○	○	○	○

Q4.6 Evaluate the potential of early involvement of suppliers (i.e. in project planning or early design) to

	High potential (1)	Moderate potential (2)	Low potential (6)	No potential (7)	Do not know (8)
Reduce project cost (2)	○	○	○	○	○
Reduce overall project duration (3)	○	○	○	○	○
Improve schedule predictability (4)	○	○	○	○	○
Improve project quality (10)	○	○	○	○	○
Increase safety (11)	○	○	○	○	○

Q4.8 Which of the following can be significantly improved (i.e. by more than 5%) by suppliers' recommendations for equipment choice and/or specifications? Please select all that apply

- ☐ Capital Costs (1)
- ☐ Lead times (8)
- ☐ Predictability of lead times (9)
- ☐ Quality (10)
- ☐ Equipment performance (e.g. Higher yield per unit of feed-stock or energy input/flexibility of feed-stock) (11)

Q4.10 Which of the following can be significantly improved (i.e. by more than 5%) by your recommendations for equipment choice and/or specifications? Please select all that apply

- [ ] Capital Costs (1)
- [ ] Lead times (8)
- [ ] Predictability of lead times (9)
- [ ] Quality (10)
- [ ] Equipment performance (e.g. Higher yield per unit of feed-stock or energy input/flexibility of feed-stock) (11)

Q4.11 In what percent of your projects are you asked to make recommendations about equipment choice and/or specifications?

- ○ 0% (1)
- ○ 1% - 20% (6)
- ○ 21% – 40% (7)
- ○ 41% - 60% (8)
- ○ 61% - 80% (9)
- ○ 81% - 100% (10)

Q4.12 Of those projects, which percent implement your recommendations?

- ○ 0% (1)
- ○ 1% - 20% (6)
- ○ 21% – 40% (7)
- ○ 41% - 60% (8)
- ○ 61% - 80% (9)
- ○ 81% - 100% (10)

Q4.13 What is the involvement that you are willing to have during the development phase of a project without the customer commitment to purchase your equipment? Please select all that apply

- ☐ Provide general information (e.g., Online information about equipment) (1)
- ☐ Offer design specifications (6)
- ☐ Suggest technology to implement (7)
- ☐ Customize your designs to fit into the project, for all customers (8)
- ☐ Customize your design to fit into the project, for some customers (9)
- ☐ Other (5) _____

Q4.14 For projects where owners are prescriptive in supplier selection, what is the approximate percentage of **project cost savings** that you would achieve if you have more flexibility in the selection of suppliers.

- More than 20% (35)
- 10% - 20% (34)
- 5% - 10% (33)
- 1% - 5% (32)
- No cost savings (31)

Q4.15 For projects where owners are prescriptive in supplier selection, what is the approximate percentage of **project time savings** that you could achieve if you have more flexibility in the selection of suppliers.

- More than 20% (35)
- 10% - 20% (34)
- 5% - 10% (33)
- 1% - 5% (32)
- No time savings (31)

Q4.17 In general, how would you evaluate Requests for Quotation (RFQs) for equipment regarding:

	Excellent (11)	Good (12)	Acceptable (13)	Poor (14)	Bad (15)	Do not know (16)
Clear scope of work (31)	○	○	○	○	○	○
Clear information deliverables (38)	○	○	○	○	○	○
Clear delivery schedule (33)	○	○	○	○	○	○
Clear definition of payment terms (34)	○	○	○	○	○	○
Clear definition of the award criteria (36)	○	○	○	○	○	○

Q4.18 In general, how would you evaluate Purchase Orders (POs) for equipment regarding:

	Excellent (16)	Good (17)	Acceptable (18)	Poor (19)	Bad (20)	Do not know (21)
Clear scope of work (31)	○	○	○	○	○	○
Clear information deliverables (37)	○	○	○	○	○	○
Clear delivery schedule (33)	○	○	○	○	○	○
Clear definition of payment terms (34)	○	○	○	○	○	○

Q4.16 To improve your efficiency (e.g. reduce costs/improve forecasting ability), how important is it to:

	Very important (47)	Important (48)	Slightly important (49)	Not important (50)
Increase visibility into the detailed project schedule/required at site dates (31)	○	○	○	○
Increase the quality and specificity of Purchase Orders (32)	○	○	○	○
Increase quality and specificity of Request for Quotation (33)	○	○	○	○

End of Block: EARLY INVOLVEMENT OF SUPPLIERS

Start of Block: USE OF FRAMEWORK AGREEMENTS WITH SUPPLIERS

Q3.1 **USE OF FRAMEWORK AGREEMENTS WITH SUPPLIERS**

You have selected that the opportunity "USE OF FRAMEWORK AGREEMENTS WITH SUPPLIERS" has potential to improve project performance. Please, answer the following questions about this topic:

Q3.2 Select from the following list significant benefits that can be achieved by the use of framework agreements with suppliers *(Significant translates to at least 5% improvement in cost/schedule/quality/safety or other project attributes)*

- ☐ Cost savings due to volume purchases (1)
- ☐ Decrease in operations and maintenance costs (26)
- ☐ Reduction of inventory of spare parts (27)
- ☐ Time savings in procurement (28)
- ☐ Availability of supplier input during early stages of the project (i.e. in project planning or early design) (29)
- ☐ Increase the use of catalog in place of custom components (30)
- ☐ Improve product design due to long-term relationships (31)
- ☐ Reduction in Legal Disputes (32)
- ☐ Other (34) _____

Q96 Select from the following list significant benefits that can be achieved by the use of framework agreements with suppliers *(Significant translates to at least 5% improvement in cost/schedule/quality/safety or other project attributes)*

- [ ] Cost savings due to volume purchases (1)
- [ ] Time savings in procurement (28)
- [ ] Decrease in operations and maintenance costs (26)
- [ ] Reduction of inventory of spare parts (27)
- [ ] Availability of supplier input during early stages of the project (i.e. in project planning or early design) (29)
- [ ] Increase the use of catalog in place of custom components (30)
- [ ] Improve product design due to long-term relationships (31)
- [ ] Reduction in Legal Disputes (32)
- [ ] Other (34) _____

Q97 Select from the following list significant benefits that can be achieved by the use of framework agreements between engineers/contractors and suppliers *(Significant translates to at least 5% improvement in cost/schedule/quality/safety or other project attributes)*

- ☐ Cost savings due to volume purchases (1)
- ☐ Time savings in procurement (28)
- ☐ Availability of supplier input during early stages of the project (i.e. in project planning or early design) (29)
- ☐ Increase the use of catalog in place of custom components (30)
- ☐ Improve product design due to long-term relationships (31)
- ☐ Reduction in Legal Disputes (32)
- ☐ Other (34) _____

Q3.3 Do you think that the use of framework agreements with suppliers can increase trust and information sharing?

- ○ Definitely yes (1)
- ○ Probably yes (2)
- ○ Might or might not (3)
- ○ Probably not (4)
- ○ Definitely not (5)

End of Block: USE OF FRAMEWORK AGREEMENTS WITH SUPPLIERS

Start of Block: EARLY DESIGN FREEZE

Q5.1 **EARLY DESIGN FREEZE**

Completion and client's final approval of the design and associated processes, (i.e. design substantially complete - no major changes are contemplated or accepted) as early as possible in the project development time-line to avoid costly changes.

You have selected that the opportunity "EARLY DESIGN FREEZE" has potential to improve project performance. Please, answer the following questions about this topic:

Q5.2 How often do the following challenges arise when trying to accomplish an early design freeze?

	Always (51)	Almost always (52)	Frequently (53)	Sometimes (54)	Almost never (55)	Never (60)	Do not know (61)
Lack of equipment information from suppliers (28)	○	○	○	○	○	○	○
Lack of construction input (31)	○	○	○	○	○	○	○
Lack of Operations & Maintenance input (32)	○	○	○	○	○	○	○
Lack of clarity on specifications (33)	○	○	○	○	○	○	○
Changes initiated by the owner (34)	○	○	○	○	○	○	○

Q5.3 Evaluate the potential of early design freeze to:

	High potential (26)	Moderate Potential (27)	Low potential (28)	No potential (29)	Do not know (30)
Reduce project cost (5)	○	○	○	○	○
Reduce project duration (17)	○	○	○	○	○
Increase schedule predictability (18)	○	○	○	○	○
Streamline the procurement process (19)	○	○	○	○	○
Improve the accuracy of early estimates (20)	○	○	○	○	○
Reduce field rework (21)	○	○	○	○	○
Reduce RFIs/Change orders (22)	○	○	○	○	○

Q5.4 How important is early involvement of suppliers to accomplish an early design freeze?

- ○ Very important (31)
- ○ Important (32)
- ○ Slightly important (33)
- ○ Not important (34)

Q5.5 What can suppliers do to help the project to achieve an early design freeze? Please select all that apply

- ☐ Consult about alternative equipment/product selection (14)
- ☐ Increase the clarity of information about equipment/product specifications (19)
- ☐ Provide detailed BIM/digital models (21)
- ☐ Provide accurate information about equipment/product lead times (22)
- ☐ Other (24) _____

End of Block: EARLY DESIGN FREEZE

Start of Block: INCREASED USE OF CATALOG IN PLACE OF CUSTOM COMPONENTS

Q6.1 **INCREASED USE OF CATALOG IN PLACE OF CUSTOM COMPONENTS**

You have selected that the opportunity "INCREASED USE OF CATALOG IN PLACE OF CUSTOM COMPONENTS" has potential to improve project performance. Please, answer the following questions about this topic:

Q6.2 What percentage of the projects you are involved in can replace custom components by catalog designs with no detriment to performance?

- 0% (1)
- 1% - 20% (6)
- 21% – 40% (7)
- 41% - 60% (8)
- 61% - 80% (9)
- 81% - 100% (10)
- Do not know (13)

Q6.3 Evaluate the potential of the increase in the use of catalog components to:

	High potential (33)	Moderate potential (34)	Low potential (35)	No potential (36)	Do not know (37)
Reduce project cost (1)	○	○	○	○	○
Improve accuracy of early estimates (6)	○	○	○	○	○
Reduce overall project duration (7)	○	○	○	○	○
Improve schedule predictability (8)	○	○	○	○	○
Improve project quality/Reduce Operations & Maintenance costs (9)	○	○	○	○	○

Q6.4 Evaluate the potential of the increase in the use of catalog components to:

	High potential (1)	Moderate potential (2)	Low potential (3)	No potential (5)	Do not know (6)
Reduce your lead times (2)	○	○	○	○	○
Improve your forecasting ability (12)	○	○	○	○	○
Reduce your design and production costs (13)	○	○	○	○	○
Reduce owner Operations & Maintenance costs/supplier warranty costs (14)	○	○	○	○	○

End of Block: INCREASED USE OF CATALOG IN PLACE OF CUSTOM COMPONENTS

Start of Block: USE OF STANDARD DESIGNS ACROSS PROJECTS

Q7.1 USE OF STANDARD DESIGNS ACROSS PROJECTS

Use of a standard project design (e.g. power plant design) at several sites.

You have selected that the opportunity "USE OF STANDARD DESIGNS ACROSS PROJECTS" has potential to improve project performance. Please, answer the following questions about this topic:

Q7.2 Evaluate the potential of the use of standard designs to:

	High potential (33)	Moderate potential (34)	Low potential (35)	No potential (36)	Do not know (37)
Reduce project cost (1)	○	○	○	○	○
Improve accuracy of early estimates (6)	○	○	○	○	○
Reduce overall project duration (7)	○	○	○	○	○
Improve schedule predictability (8)	○	○	○	○	○
Improve project quality/Reduce Operations & Maintenance costs (9)	○	○	○	○	○

Q7.3 Please rate the importance of the following items to achieve benefits from the use of standard designs

	Very important (65)	Important (66)	Slightly important (67)	Not important (68)	Do not know (70)
Continuity of the project team from one project on another (1)	○	○	○	○	○
Use of the same approach to project execution (e.g. Similar sequencing, equipment, etc.) (6)	○	○	○	○	○
Use of the same supplier base (7)	○	○	○	○	○
Ability to incorporate lessons learned into the design (8)	○	○	○	○	○

End of Block: USE OF STANDARD DESIGNS ACROSS PROJECTS

Start of Block: IMPROVED COORDINATION AROUND OWNER FURNISHED EQUIPMENT (OFE)

Q8.1 **IMPROVED COORDINATION AROUND OWNER FURNISHED EQUIPMENT (OFE)**

You have selected that the opportunity "IMPROVED COORDINATION AROUND OWNER FURNISHED EQUIPMENT (OFE)" has potential to improve project performance. Please, answer the following questions about this topic:

Q8.2 How often is supplier-contractor coordination a challenge when the owner buys the major pieces of equipment?

- ○ Always (31)
- ○ Almost always (32)
- ○ Frequently (33)
- ○ Sometimes (34)
- ○ Almost never (35)
- ○ Never (36)
- ○ Do not know (37)

Q8.3 How often do these issues arise when the owner buys the major pieces of equipment?

	Always (11)	Almost always (12)	Frequently (13)	Sometimes (14)	Almost never (15)	Never (17)	Do not know (16)
Delays in the purchase of equipment to meet the owner's internal cash flow requirements (1)	○	○	○	○	○	○	○
Delays in the project due to delays in equipment delivery (2)	○	○	○	○	○	○	○
Delays in the design process due to lack of information about equipment (3)	○	○	○	○	○	○	○
Delays in installation because of contractor’s lack of information (4)	○	○	○	○	○	○	○
Not being able to freeze design due to lack of information (5)	○	○	○	○	○	○	○
Redesign efforts during installation (6)	○	○	○	○	○	○	○

Lack of updates about production status and delivery timetable for OFE (10)	○	○	○	○	○	○	○
Lack of clear interface specifications (9)	○	○	○	○	○	○	○
Legal claims owner-equipment vendor (8)	○	○	○	○	○	○	○
Legal claims owner-contractor (12)	○	○	○	○	○	○	○

Q8.4 Which of the following opportunities can significantly improve supplier-contractor coordination?

(Significant translates to at least 5% improvement in cost/schedule/quality/safety or other project attributes)

- ☐ Use of an Integrated Project Delivery (IPD) system (4)
- ☐ Creation of a multi-party agreement including suppliers, owners and contractors (5)
- ☐ Clear definition of procurement milestones (6)
- ☐ Clear definition of delivery milestones (7)
- ☐ Good communication channels between supplier and contractors (8)
- ☐ Clear definition of supplier's deliverables requirements (9)
- ☐ Communication of any changes in the construction or production schedule with all parties (10)
- ☐ Other (11) _____

End of Block: IMPROVED COORDINATION AROUND OWNER FURNISHED EQUIPMENT (OFE)

Start of Block: USE OF BIM AND SHARING OF BIM MODELS

Q9.1 **USE OF BIM AND SHARING OF BIM MODELS**

You have selected that the opportunity "USE OF BIM AND SHARING OF BIM MODELS" has potential to improve project performance. Please, answer the following questions about this topic:

Q9.2 What is the potential of the use of BIM in power projects to:

	High potential (11)	Moderate potential (12)	Low potential (13)	No potential (14)	Do not know (16)
Increase the level of standardization in designs (7)	○	○	○	○	○
Increase the level of modularization in designs (13)	○	○	○	○	○
Improve the quality of information shared (15)	○	○	○	○	○
Facilitate the selection of equipment/products (8)	○	○	○	○	○
Achieve time savings in procurement (16)	○	○	○	○	○
Increase collaboration with suppliers that provide engineering information (17)	○	○	○	○	○
Facilitate the creation of fabrication drawings from drawings provided by owner/contractor/engineer (18)	○	○	○	○	○

Q9.3 Are you generally satisfied with the quality (usefulness) of the BIM models that the following stakeholders share with you?

	Extremely satisfied (4)	Somewhat satisfied (5)	Somewhat dissatisfied (8)	Extremely dissatisfied (9)	Do not share (10)
Contractors (35)	○	○	○	○	○
Suppliers (36)	○	○	○	○	○
Engineers (37)	○	○	○	○	○

Q9.4 In general, how easy (in terms of effort needed/time required) is it to adapt the BIM models you receive from the following stakeholders to be useful for the operation of the project once finished?

	Very easy (4)	Easy (5)	Neither easy nor difficult (6)	Difficult (7)	Very difficult (8)	Do not share (9)
Contractors (36)	○	○	○	○	○	○
Suppliers (37)	○	○	○	○	○	○
Engineers (38)	○	○	○	○	○	○

Q9.5 Are you generally satisfied with the quality (usefulness) of the BIM models that the following stakeholders share with you?

	Extremely satisfied (7)	Somewhat satisfied (5)	Somewhat dissatisfied (8)	Extremely dissatisfied (9)	Do not share (10)
Owners (35)	○	○	○	○	○
Suppliers (36)	○	○	○	○	○
Engineers (37)	○	○	○	○	○

Q9.6 In general, how easy (in terms of effort needed/time required) is it to adapt the BIM models you receive from the following stakeholders to be useful for construction:

	Very easy (7)	Easy (5)	Neither easy nor difficult (6)	Difficult (8)	Very difficult (9)	Do not share (10)
Owners (35)	○	○	○	○	○	○
Suppliers (41)	○	○	○	○	○	○
Engineers (37)	○	○	○	○	○	○

Q9.7 Are you generally satisfied with the quality (usefulness) of the BIM models that suppliers share with you?

- ○ Extremely satisfied (48)
- ○ Somewhat satisfied (49)
- ○ Somewhat dissatisfied (51)
- ○ Extremely dissatisfied (52)
- ○ Do not share (53)

Q9.8 In general, how easy (in terms of effort needed/time required) is it to adapt the BIM models you receive from suppliers to be useful for the completion of the project BIM model:

- ○ Very easy (35)
- ○ Easy (36)
- ○ Neither easy nor difficult (37)
- ○ Difficult (38)
- ○ Very difficult (39)
- ○ Do not share (40)

Q9.9 With which customers do you share your BIM models prior to contract award?

- ○ Does not apply (1)
- ○ All potential customers (4)
- ○ Only selected potential customers (5)
- ○ Do not share BIM models (8)
- ○ Do not know (9)

Q9.10 With which customers do you share your BIM models after contract award?

- ○ Does not apply (1)
- ○ All customers (4)
- ○ Only selected customers (5)
- ○ Do not share BIM models (8)
- ○ Do not know (9)

Q9.11 What is the level of detail of the models that you typically share with customers prior to contract award?

- ○ Does not apply (5)
- ○ Conceptual/Wire-frame (10)
- ○ Approximate geometry (6)
- ○ Precise geometry (7)
- ○ Fabrication level (8)
- ○ Do not know (9)

Q9.12 What is the level of detail of the models that you typically share with customers after contract award?

- ○ Does not apply (1)
- ○ Conceptual/Wire-frame (5)
- ○ Approximate geometry (6)
- ○ Precise geometry (7)
- ○ Fabrication level (8)
- ○ Do not know (9)

Q9.13 What percentage of your customers share their project BIM models with you?

- ○ Does not apply (8)
- ○ 0% (1)
- ○ 1% - 20% (2)
- ○ 21% - 40% (3)
- ○ 41% - 60% (4)
- ○ 61% - 80% (5)
- ○ 81% - 100% (6)
- ○ Do not know (7)

Q9.14 How will the following be improved if you have access to the project design BIM model instead of 2D drawings when developing a quotation?

	Significantly improve (1)	Improve (2)	Slightly improve (3)	Not improve (5)	Do not know (4)
Ability to provide a better design (Improve understanding of customer needs) (8)	○	○	○	○	○
Ability to provide a better estimate (Improve knowledge about quantities) (1)	○	○	○	○	○
Ability to provide a faster estimate (due to better access to information) (2)	○	○	○	○	○

End of Block: USE OF BIM AND SHARING OF BIM MODELS

Start of Block: MODULARIZATION AND OFF-SITE FABRICATION

Q10.1 **MODULARIZATION AND OFF-SITE FABRICATION**

You have selected that the opportunity "MODULARIZATION AND OFF-SITE FABRICATION" has potential to improve project performance. Please, answer the following questions about this topic:

Q10.2 Which of the following can be significantly improved (i.e. by more than 5%) with more integration of suppliers into modularization and off-site fabrication processes? Please select all that apply

- [ ] Project costs (9)
- [ ] Overall project duration (17)
- [ ] Amount of waste (18)
- [ ] Schedule predictability (19)
- [ ] Quality (20)
- [ ] Safety (21)
- [ ] Productivity (22)

End of Block: MODULARIZATION AND OFF-SITE FABRICATION

Start of Block: IMPLEMENTATION OF AUTOMATED MATERIALS ID., LOCATING AND TRACKING TECHNOLOGY

Q11.1 **IMPLEMENTATION OF AUTOMATED MATERIALS ID., LOCATING AND TRACKING TECHNOLOGY (AMILTT)**

You have selected that the opportunity "IMPLEMENTATION OF AUTOMATED MATERIALS ID., LOCATING AND TRACKING TECHNOLOGY (AMILTT)" has potential to improve project performance. Please, answer the following questions about this topic:

Q11.2 Where do you see value in the use of AMILTT? Please select all that apply

- [ ] Opportunity to receive more orders from customers (1)
- [ ] Improve visibility of status and location of materials in the supply chain/off-site (4)
- [ ] Improve efficiency of material transactions on-site (Receiving, locating, issuing times) (11)
- [ ] Improve efficiency of information sharing (Increased efficiency in data entry, conducting inspections, reporting progress) (7)
- [ ] Improve inventory control (5)
- [ ] Proof of delivery of products to customers (6)
- [ ] Improve safety (10)
- [ ] No significant value (8)
- [ ] Other (9) _____

Q11.3 Where do you see value in the use of AMILTT? Please select all that apply

- ☐ Improve visibility of status and location of materials in the supply chain/off-site (1)
- ☐ Improve efficiency of material transactions on-site (Receiving, locating, issuing times) (17)
- ☐ Improve efficiency of information sharing (Increased efficiency in data entry, conducting inspections, reporting progress) (11)
- ☐ Improve inventory control (12)
- ☐ Improve safety (13)
- ☐ No significant value (8)
- ☐ Other (9) _____

End of Block: IMPLEMENTATION OF AUTOMATED MATERIALS ID., LOCATING AND TRACKING TECHNOLOGY

Start of Block: SUPPLIER INTEGRATION WITH ADVANCED WORK PACKAGING (AWP)

Q12.1 **SUPPLIER INTEGRATION WITH ADVANCED WORK PACKAGING (AWP)**

You have selected that the opportunity "SUPPLIER INTEGRATION WITH ADVANCED WORK PACKAGING" has potential to improve project performance. Please, answer the following questions about this topic:

Q12.2 Which of the following can be significantly improved (i.e. by more than 5%) with more integration of suppliers into the AWP process? Select all that apply

- [ ] Cost (31)
- [ ] Cost predictability (32)
- [ ] Schedule (33)
- [ ] Schedule predictability (34)
- [ ] Safety (awareness and performance) (14)
- [ ] Quality (38)
- [ ] Productivity (36)
- [ ] Profitability (37)
- [ ] Alignment among stakeholders (35)

Q12.3 Which of the following can be significantly improved with more integration of suppliers in the AWP process? Select all that apply

Significant translates to at least 5% improvement in cost/schedule/quality/safety or other project attributes

- ☐ Quality of sequencing and scheduling decisions during Front End Planning (FEP) (14)
- ☐ Quality of equipment selection and design choices during Front End Planning (FEP) (40)
- ☐ Clarity and specificity of request for quotations (41)
- ☐ Clarity and specificity of purchase orders (42)
- ☐ Information sharing about equipment/product information during design (43)
- ☐ Information sharing about need dates during execution (44)
- ☐ Visibility of status and location of materials during execution (45)

End of Block: SUPPLIER INTEGRATION WITH ADVANCED WORK PACKAGING (AWP)

Start of Block: IMPROVEMENTS IN CONTRACTS WITH SUPPLIERS

Q13.1 **IMPROVEMENTS IN SUPPLIER CONTRACTS**

You have selected that the opportunity "IMPROVEMENTS IN SUPPLIER CONTRACTS" has potential to improve project performance. Please, answer the following questions about this topic:

Q13.2 In general, how do you evaluate the contracts you have with suppliers regarding:

	Excellent (1)	Good (2)	Average (3)	Poor (6)	Bad (4)	Do not know (5)
Clear scope of work (1)	○	○	○	○	○	○
Clear definition of deliverables (4)	○	○	○	○	○	○
Clear detailed delivery schedule (5)	○	○	○	○	○	○
Clear definition of payment terms (6)	○	○	○	○	○	○
Clear dispute resolution mechanism (7)	○	○	○	○	○	○
Balance of responsibilities between parties (8)	○	○	○	○	○	○
Ease of understanding (Less legal language) (9)	○	○	○	○	○	○

Q13.3 Evaluate the following opportunities around contracts with suppliers according to their potential to improve project performance

	High potential (1)	Moderate potential (2)	Low potential (3)	No potential (4)	Detrimental to performance (6)	Do not know (5)
Use of collaborative contracting/IPD (Integrated project delivery) (1)	○	○	○	○	○	○
Inclusion of incentives clauses (4)	○	○	○	○	○	○
Inclusion of penalty clauses (5)	○	○	○	○	○	○
Contracts written in plain English to facilitate understanding (6)	○	○	○	○	○	○

Q13.4 Please specify any other characteristics of contracts with suppliers that can be improved

_____

Q13.5 In general, how do you evaluate your contracts with clients regarding

	Excellent (1)	Good (2)	Average (3)	Poor (6)	Bad (4)	Do not know (5)
Clear scope of work (1)	○	○	○	○	○	○
Clear definition of deliverables (4)	○	○	○	○	○	○
Clear detailed delivery schedule (5)	○	○	○	○	○	○
Clear definition of payment terms (6)	○	○	○	○	○	○
Clear dispute resolution mechanism (7)	○	○	○	○	○	○
Balance of responsibilities between parties (8)	○	○	○	○	○	○
Ease of understanding (Less legal language) (9)	○	○	○	○	○	○

Q13.6 Evaluate the following opportunities around contracts with clients according to their potential to improve project performance

	High potential (1)	Moderate potential (2)	Low potential (3)	No potential (4)	Detrimental to performance (6)	Do not know (5)
Use of collaborative contracting/IPD (Integrated project delivery) (1)	○	○	○	○	○	○
Inclusion of incentives clauses (4)	○	○	○	○	○	○
Inclusion of penalty clauses (5)	○	○	○	○	○	○
Contracts written in plain English to facilitate understanding (6)	○	○	○	○	○	○

Q13.7 Please specify any other characteristics of contracts with clients that can be improved

_____

End of Block: IMPROVEMENTS IN CONTRACTS WITH SUPPLIERS

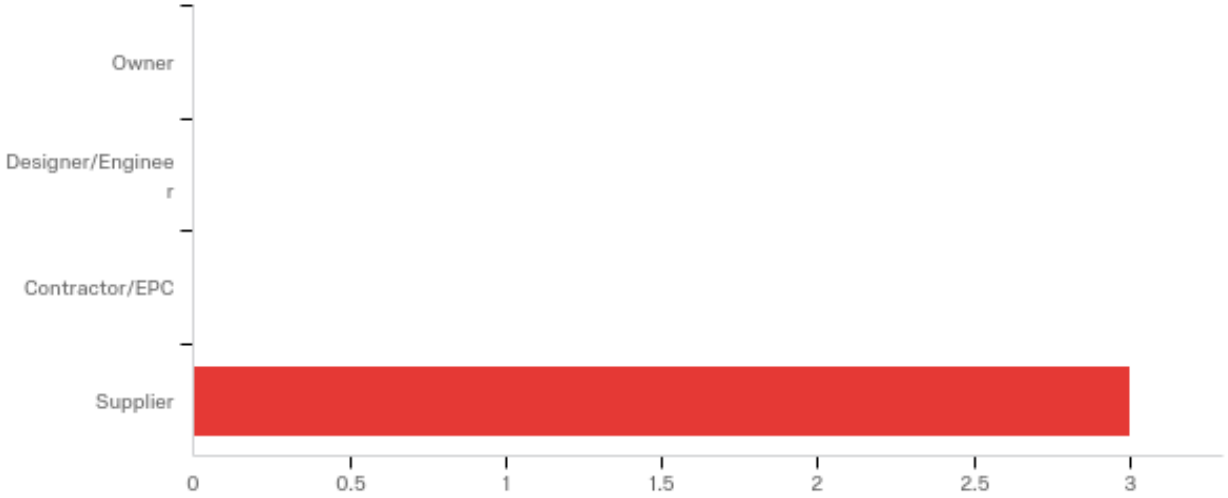
APPENDIX B – SURVEY RESULTS FOR SUPPLIERS

Supplier

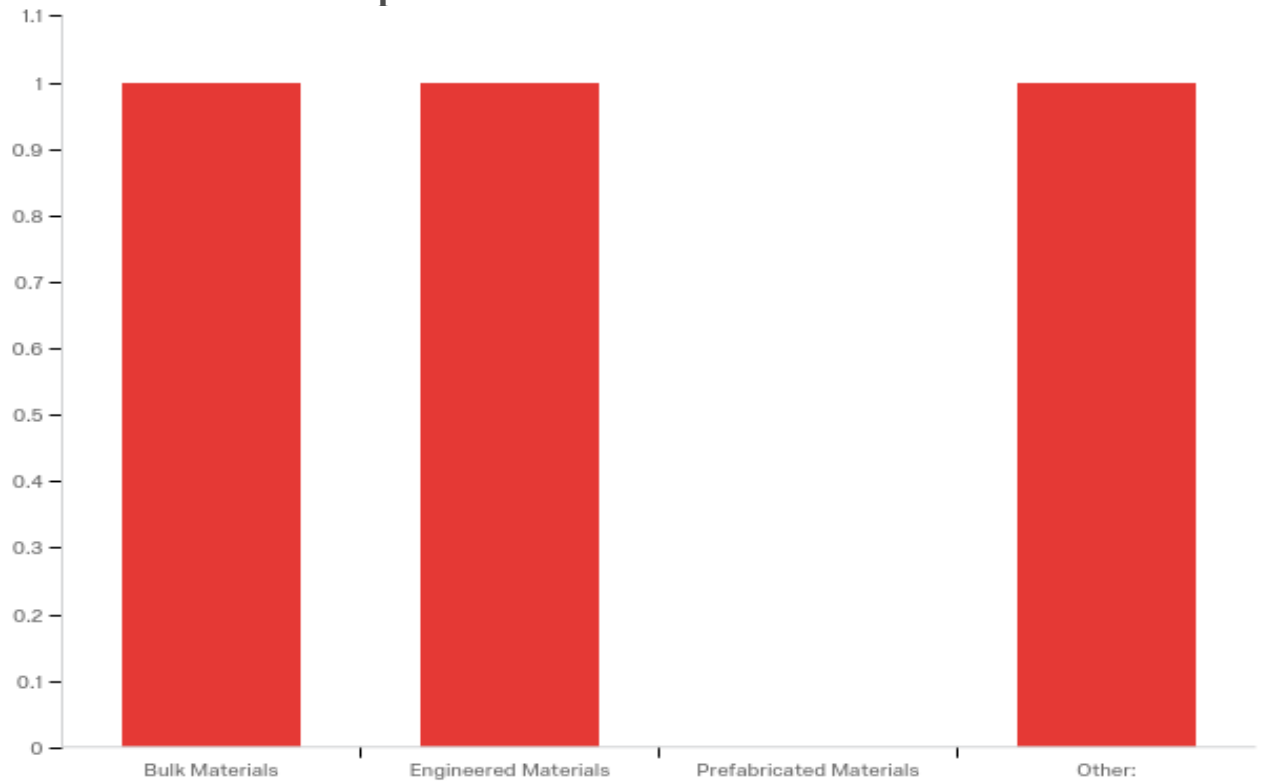
Increasing engagement with the supply chain in power projects to improve performance

April 16th 2019, 10:45 pm MDT

Q1.2 - To which of the following categories does your company belong?



Q1.4 - What types of materials does your company produce/sell? If more than one, please choose the most representative



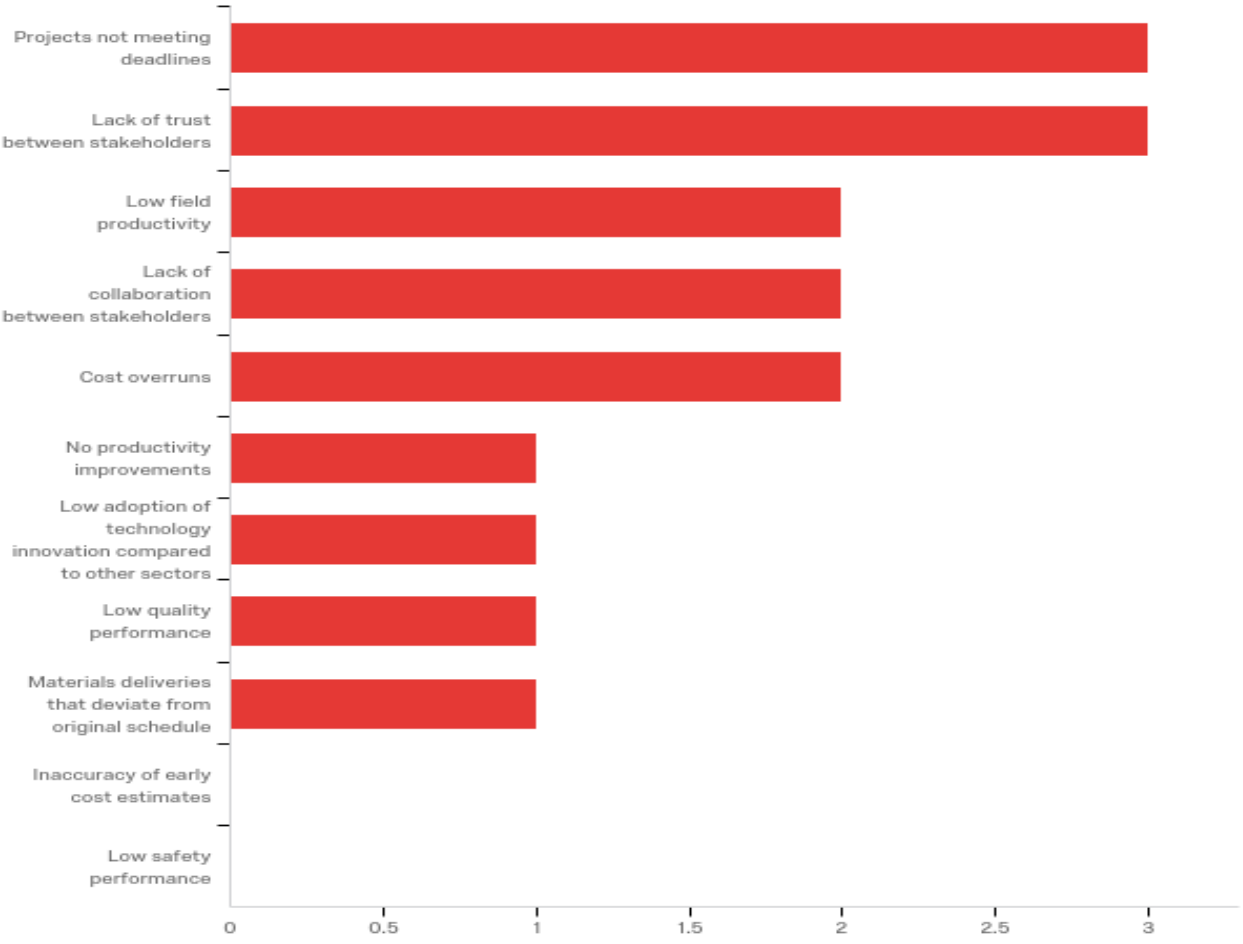
Q1.6 - How many years of professional experience do you have?

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	4	10.00	45.00	24.33	14.97	224.22	3

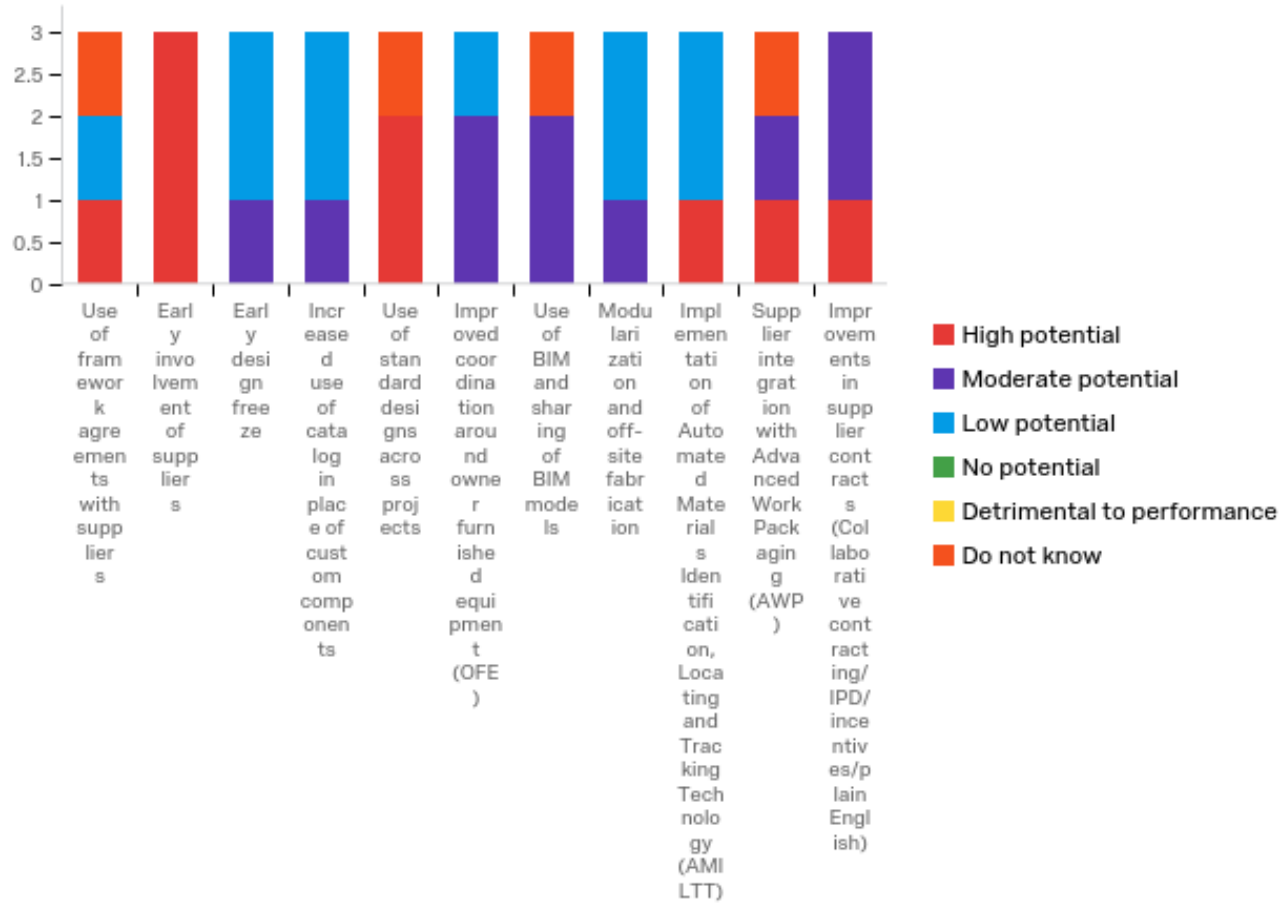
Q1.7 - How many years of experience in design, construction or facilities management do you have?

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	4	10.00	12.00	11.00	1.00	1.00	2

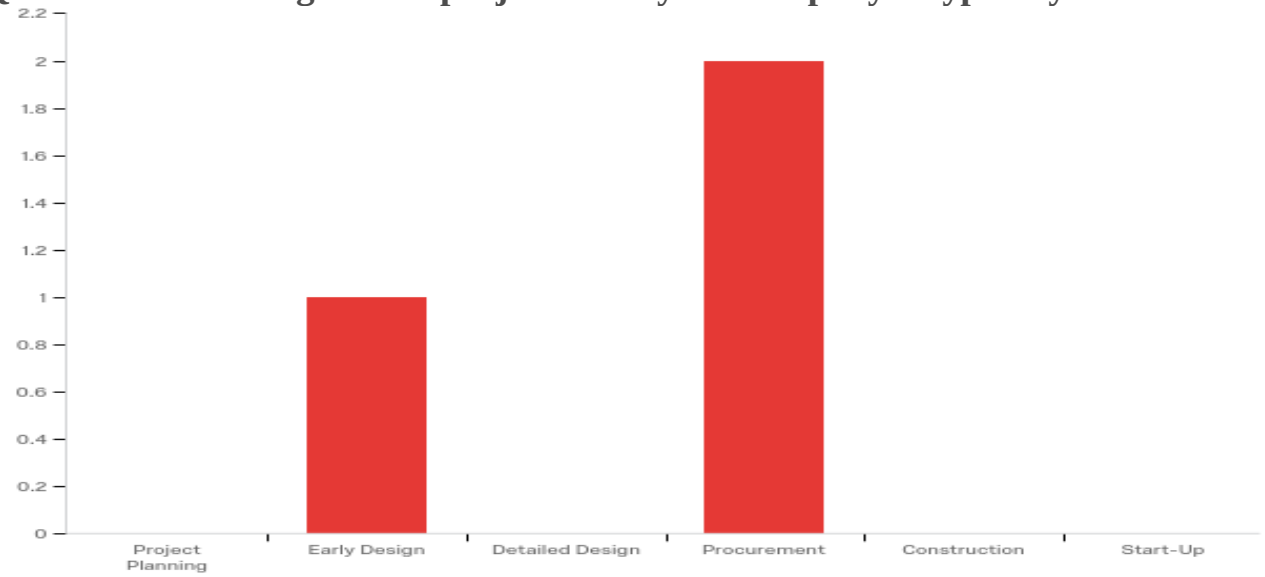
Q2.1 - From your perspective, what are the challenges (if any) in today's construction power projects? Please select all that apply



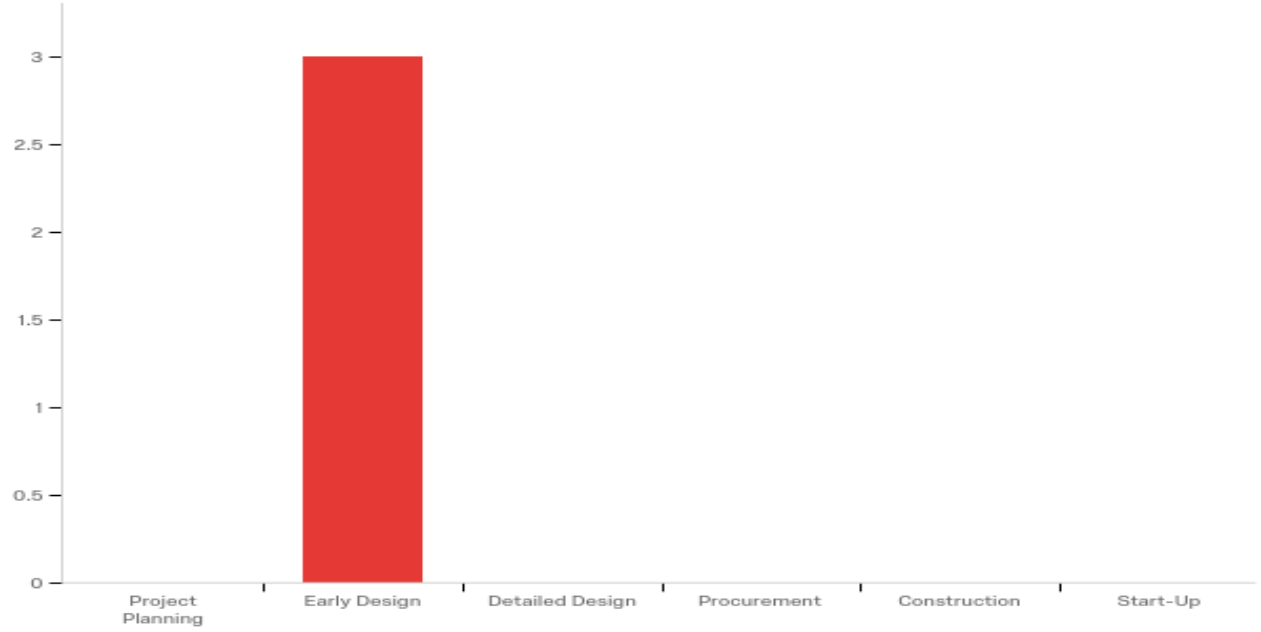
Q2.2 - Evaluate the following opportunities according to their potential to improve project performance in any metric (cost/schedule/quality/safety or other project attributes):



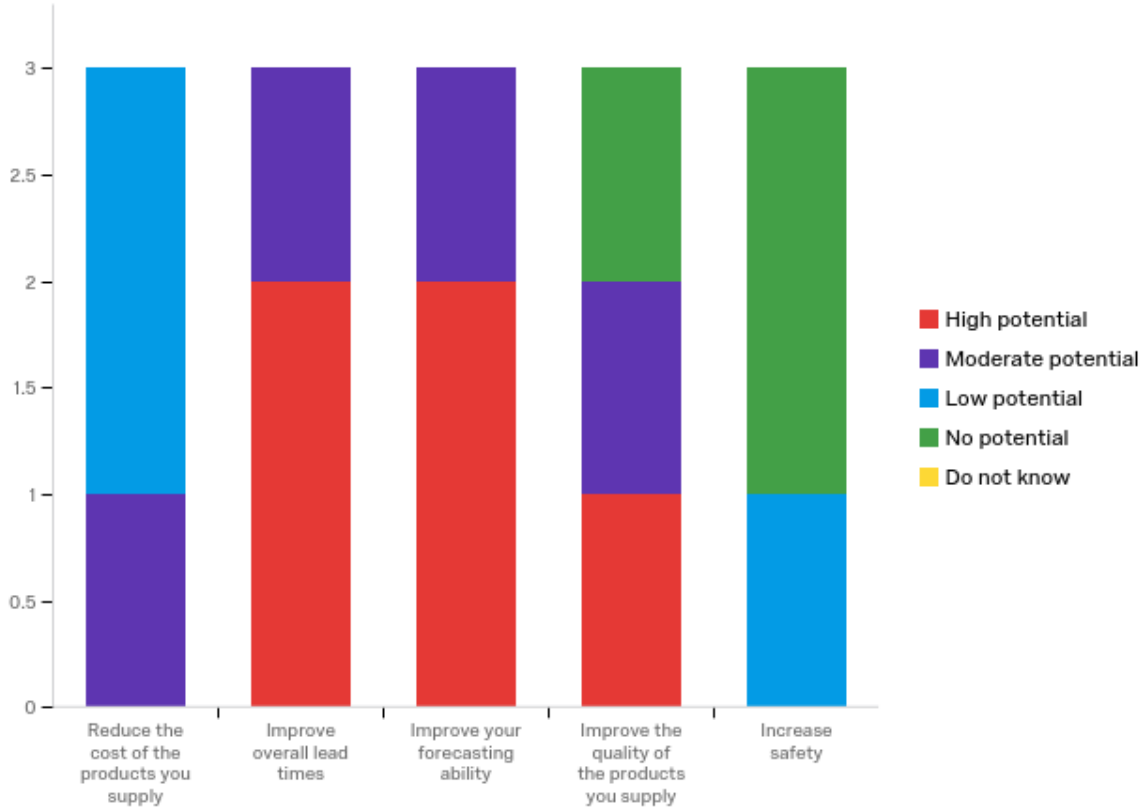
Q4.2 - Select the stage of the project when your company is typically first involved



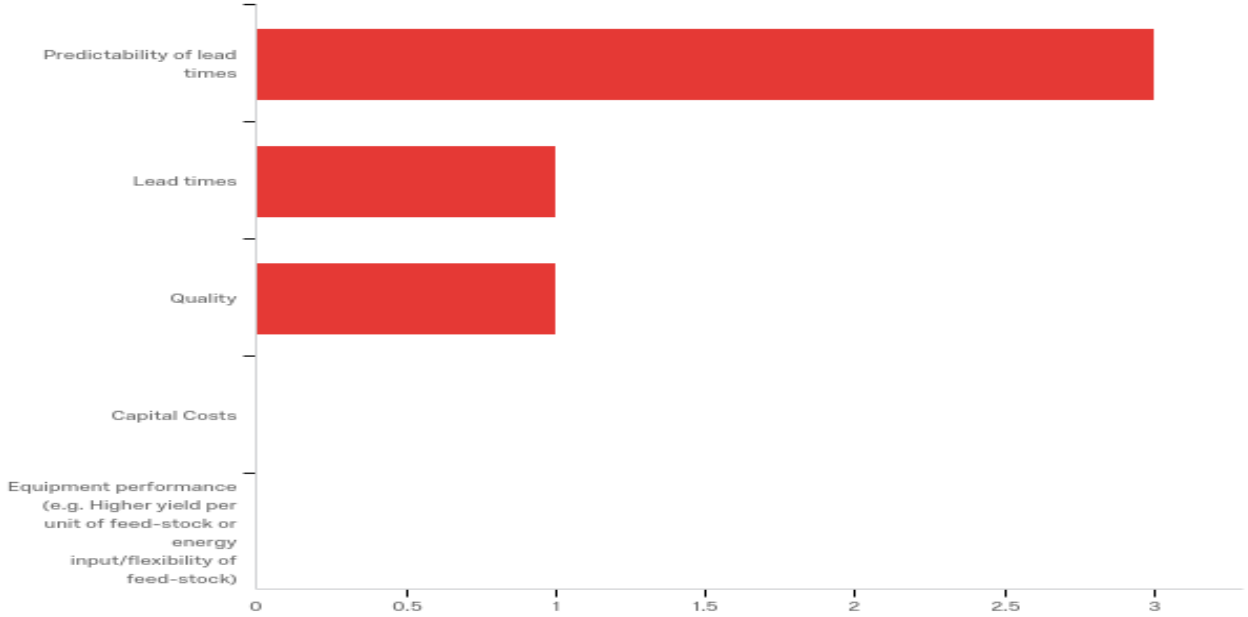
Q4.3 - Select the stage of the project when it would be optimal (i.e. more impact on project success) to become involved:



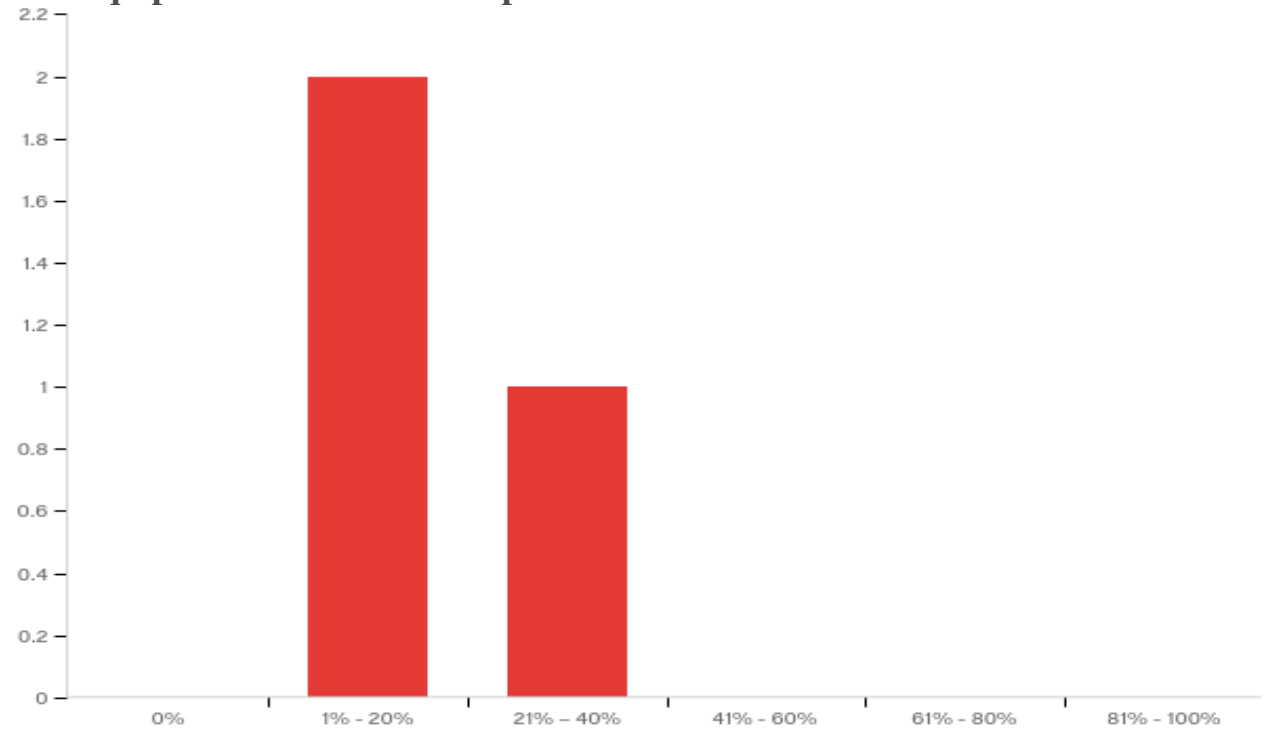
Q4.5 - Evaluate the potential that your early involvement (i.e. in project planning or early design) in power projects can have to:



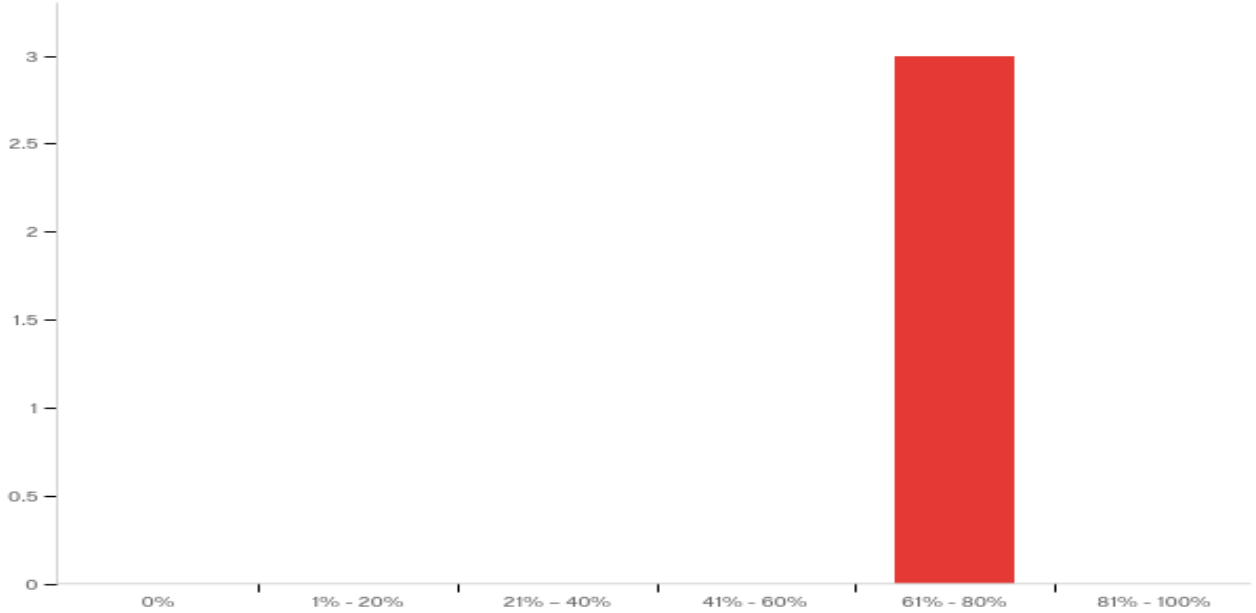
Q4.10 - Which of the following can be significantly improved (i.e. by more than 5%) by your recommendations for equipment choice and/or specifications? Please select all that apply



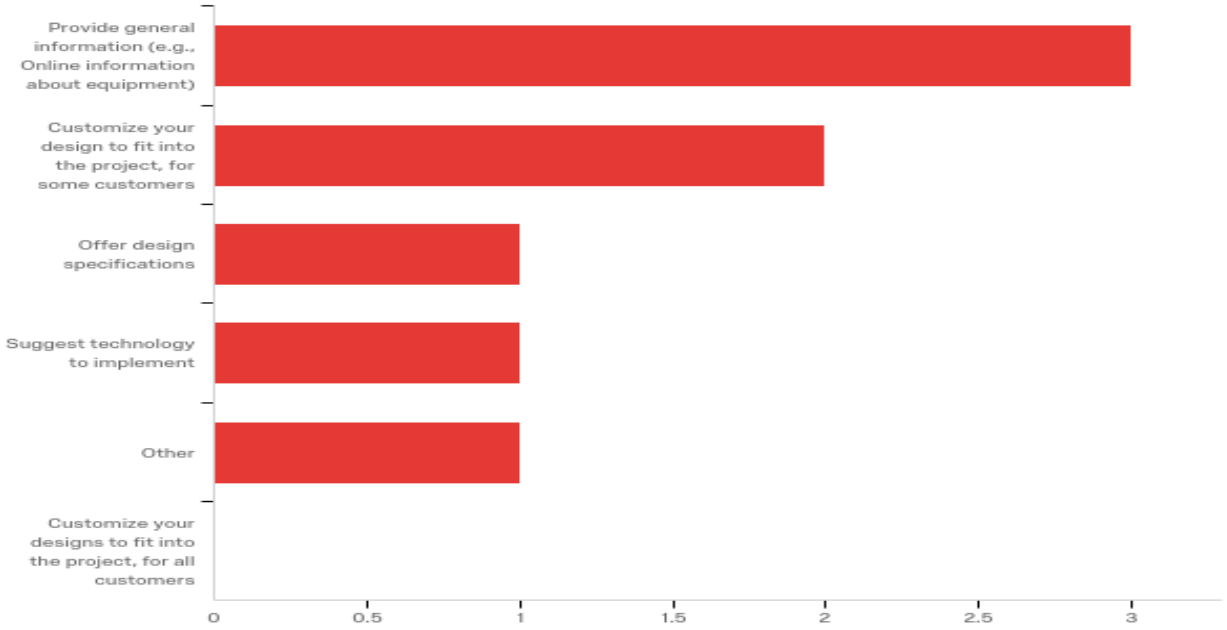
Q4.11 - In what percent of your projects are you asked to make recommendations about equipment choice and/or specifications?



Q4.12 - Of those projects, which percent implement your recommendations?



Q4.13 - What is the involvement that you are willing to have during the development phase of a project without the customer commitment to purchase your equipment? Please select all that apply

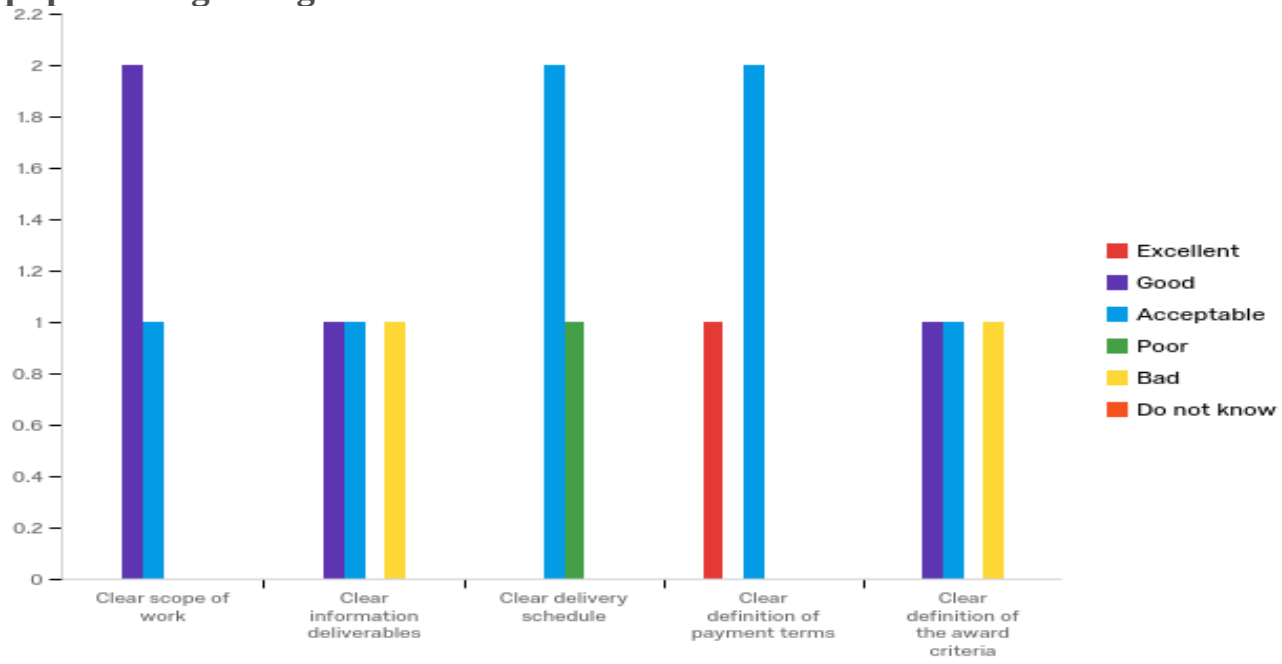


Q4.13_5_TEXT - Other

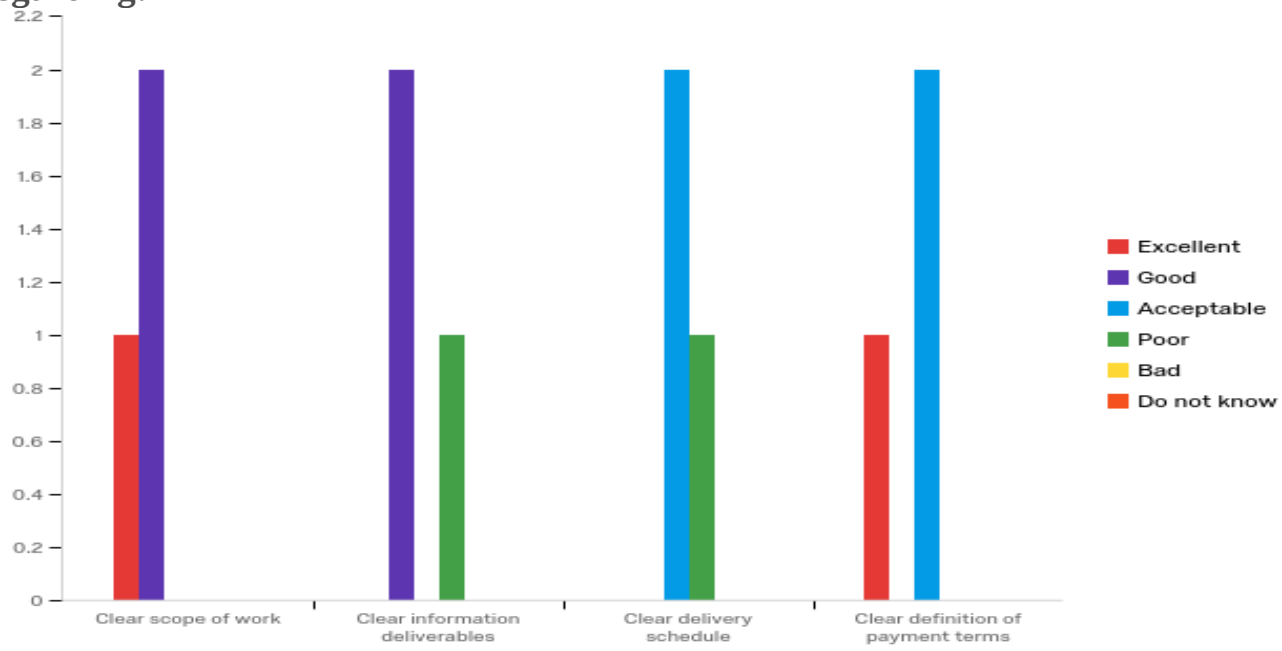
Other - Text

Provide Example Reporting and Schedule visibility

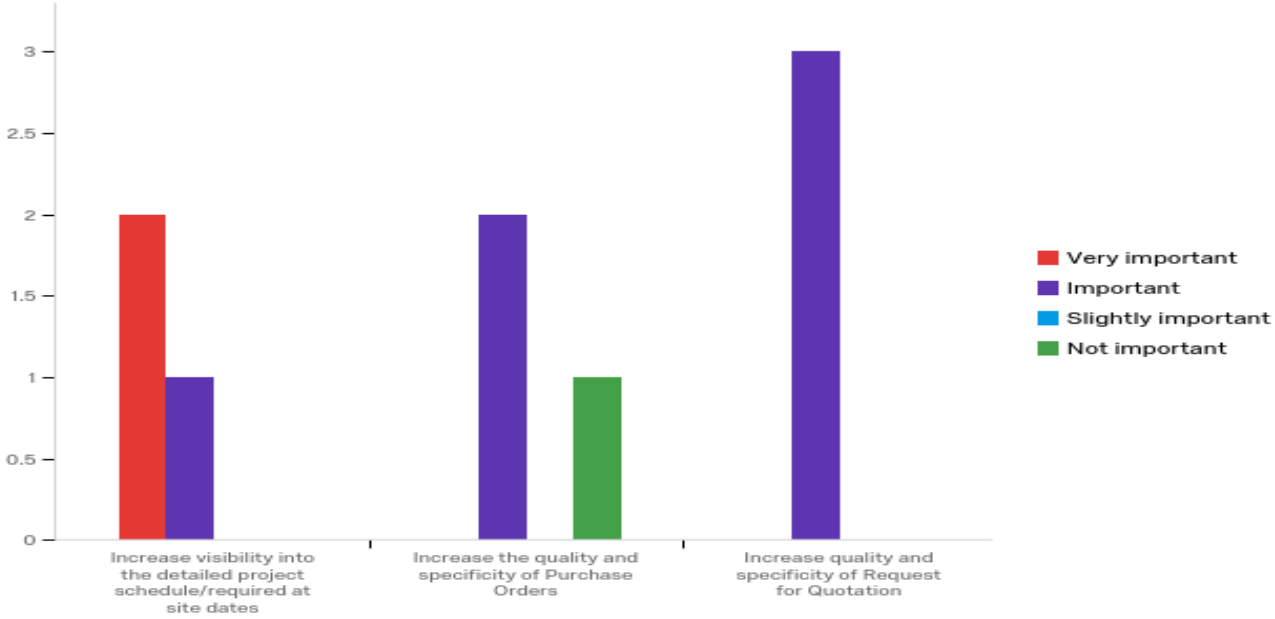
Q4.17 - In general, how would you evaluate Requests for Quotation (RFQs) for equipment regarding:



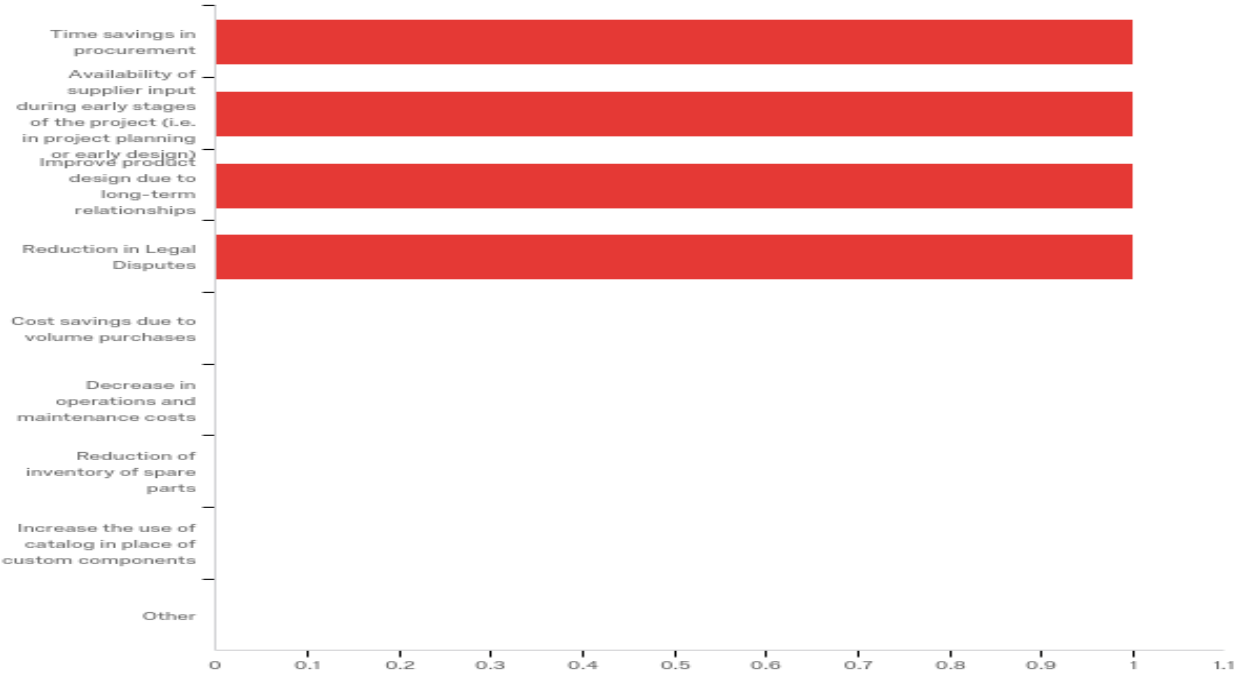
Q4.18 - In general, how would you evaluate Purchase Orders (POs) for equipment regarding:



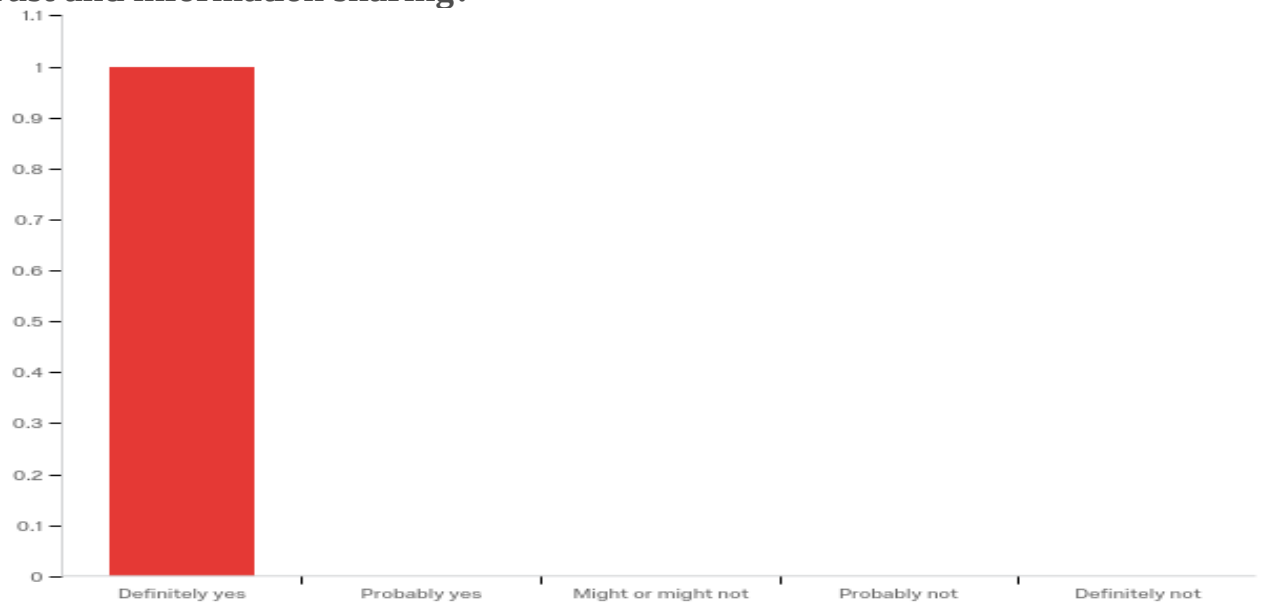
Q4.16 - To improve your efficiency (e.g. reduce costs/improve forecasting ability), how important is it to:



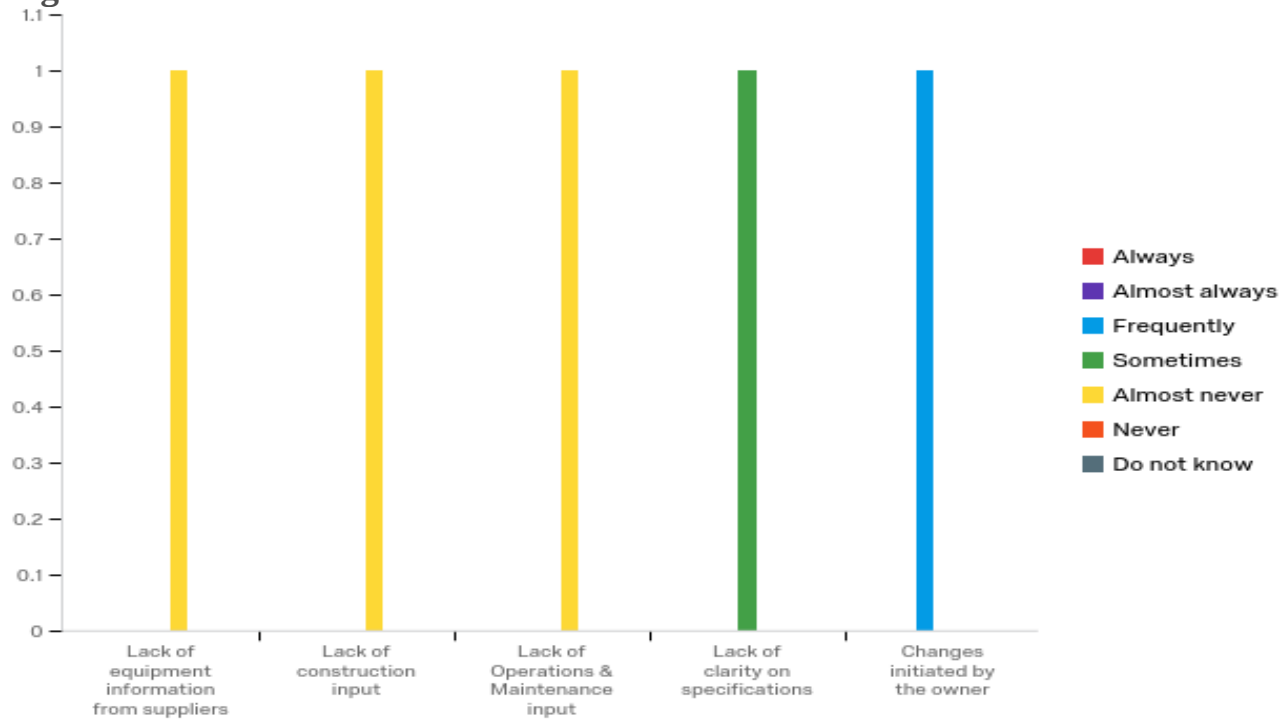
Q96 - Select from the following list significant benefits that can be achieved by the use of framework agreements with suppliers (Significant translates to at least 5% improvement in cost/schedule/quality/safety or other project attributes)



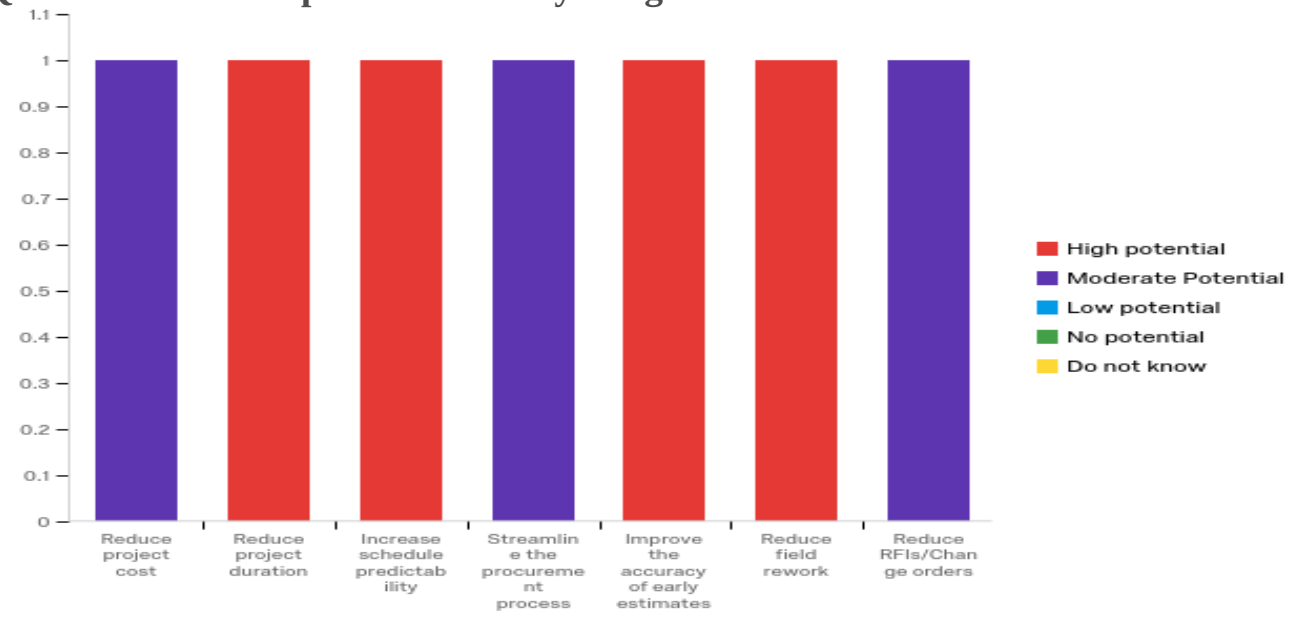
Q3.3 - Do you think that the use of framework agreements with suppliers can increase trust and information sharing?



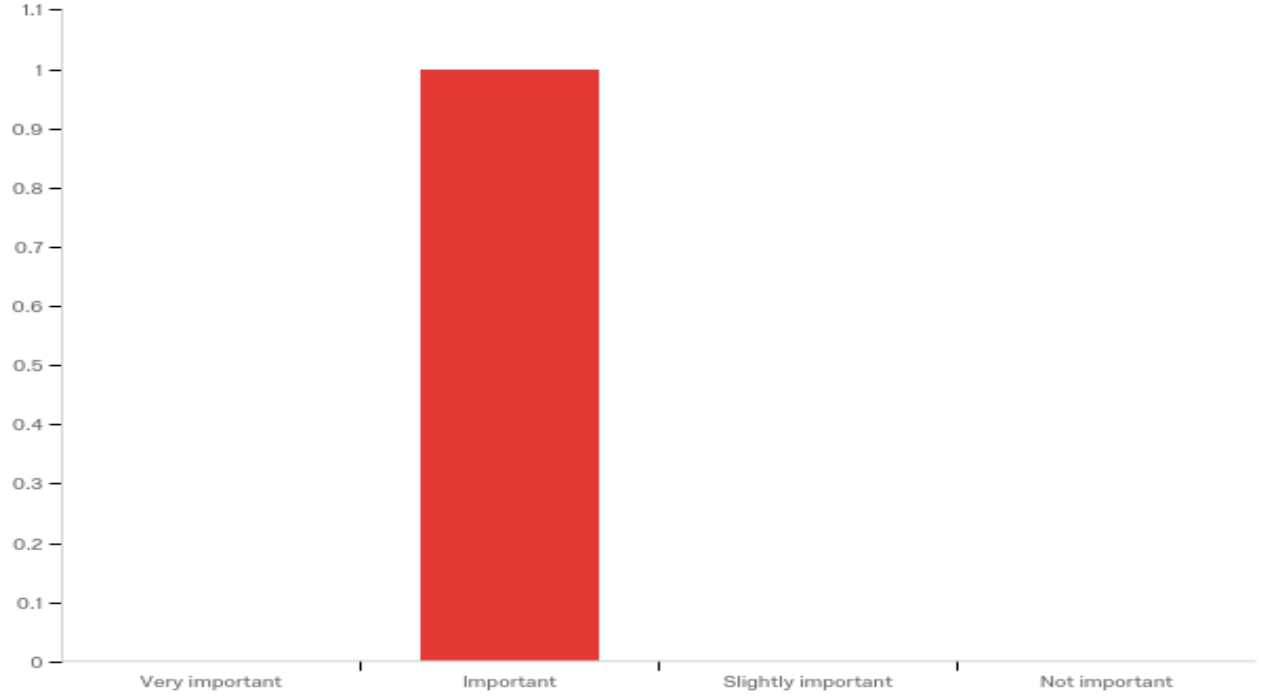
Q5.2 - How often do the following challenges arise when trying to accomplish an early design freeze?



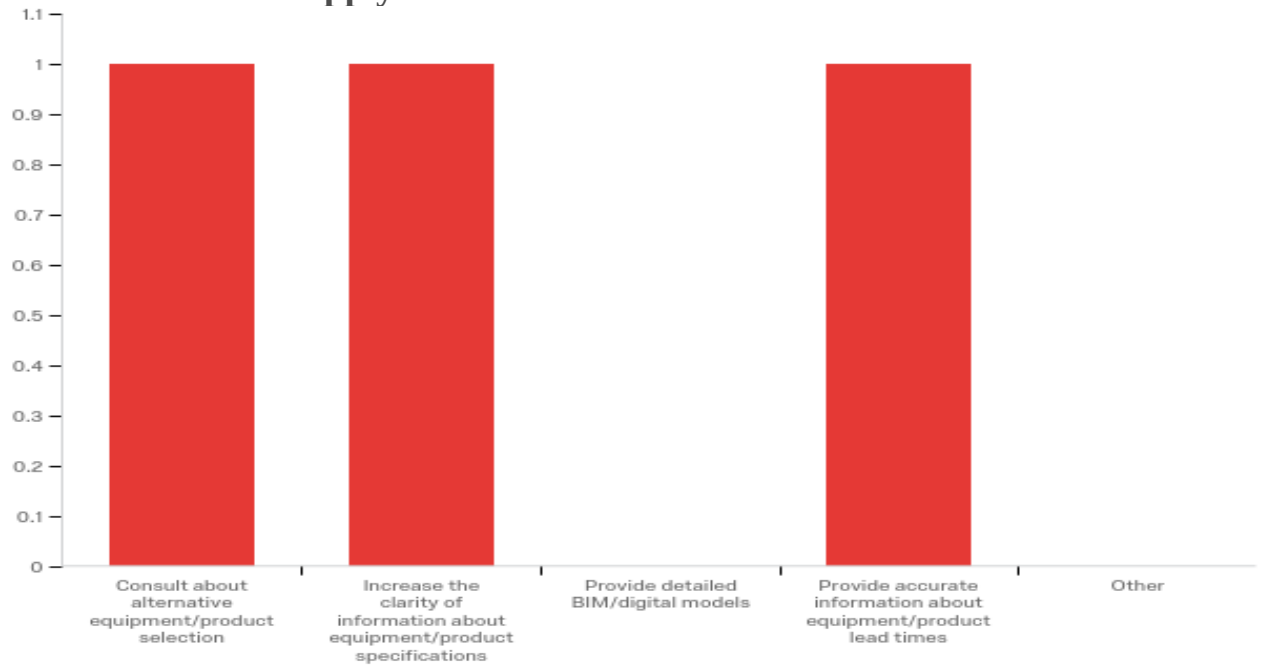
Q5.3 - Evaluate the potential of early design freeze to:



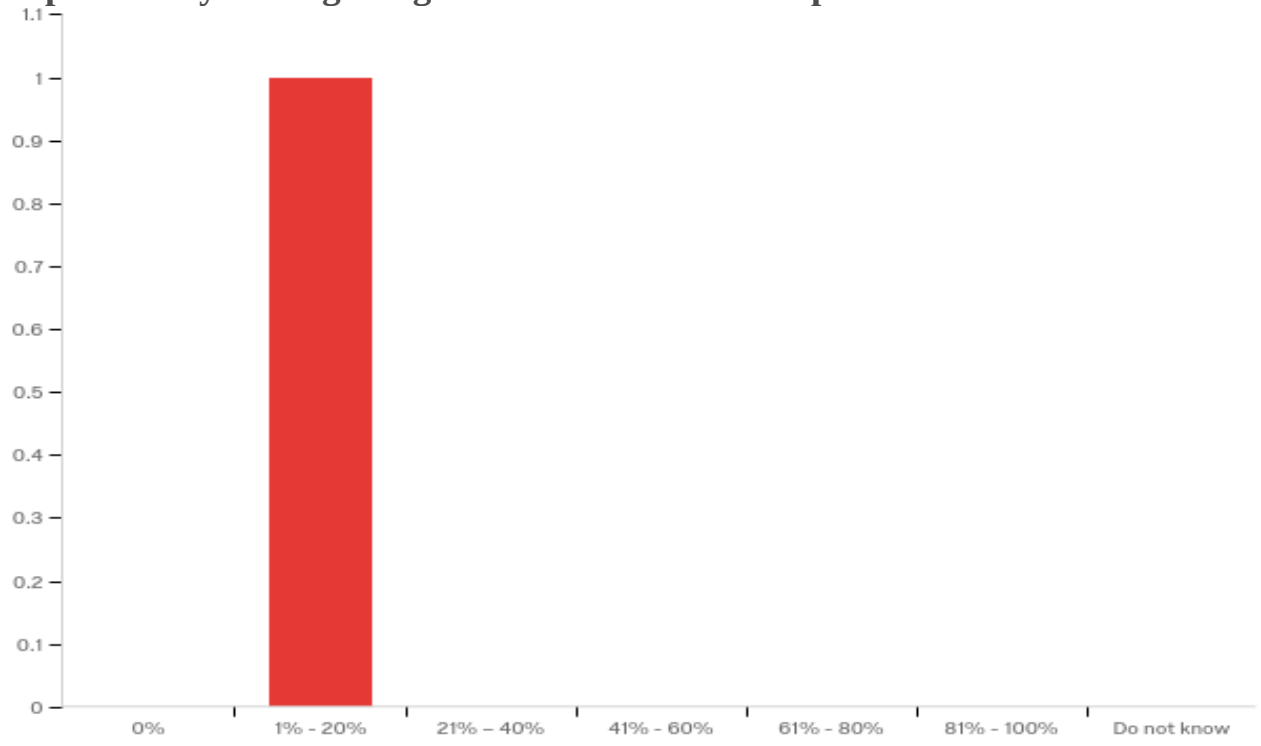
Q5.4 - How important is early involvement of suppliers to accomplish an early design freeze?



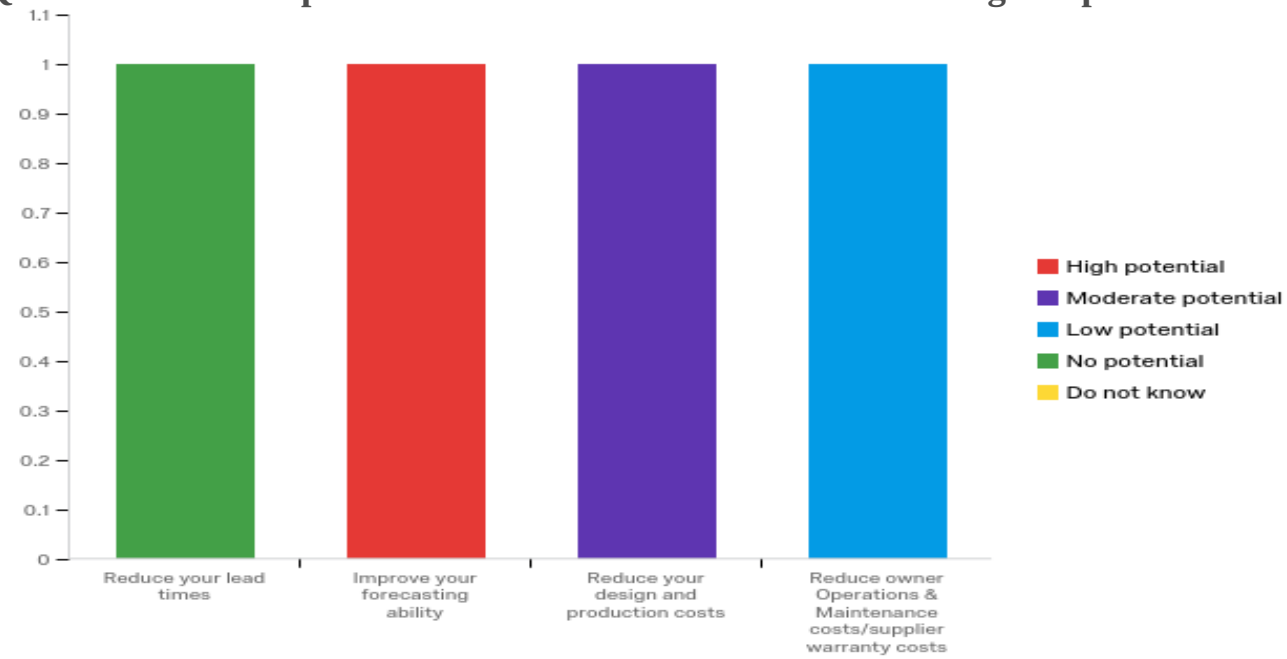
Q5.5 - What can suppliers do to help the project to achieve an early design freeze? Please select all that apply



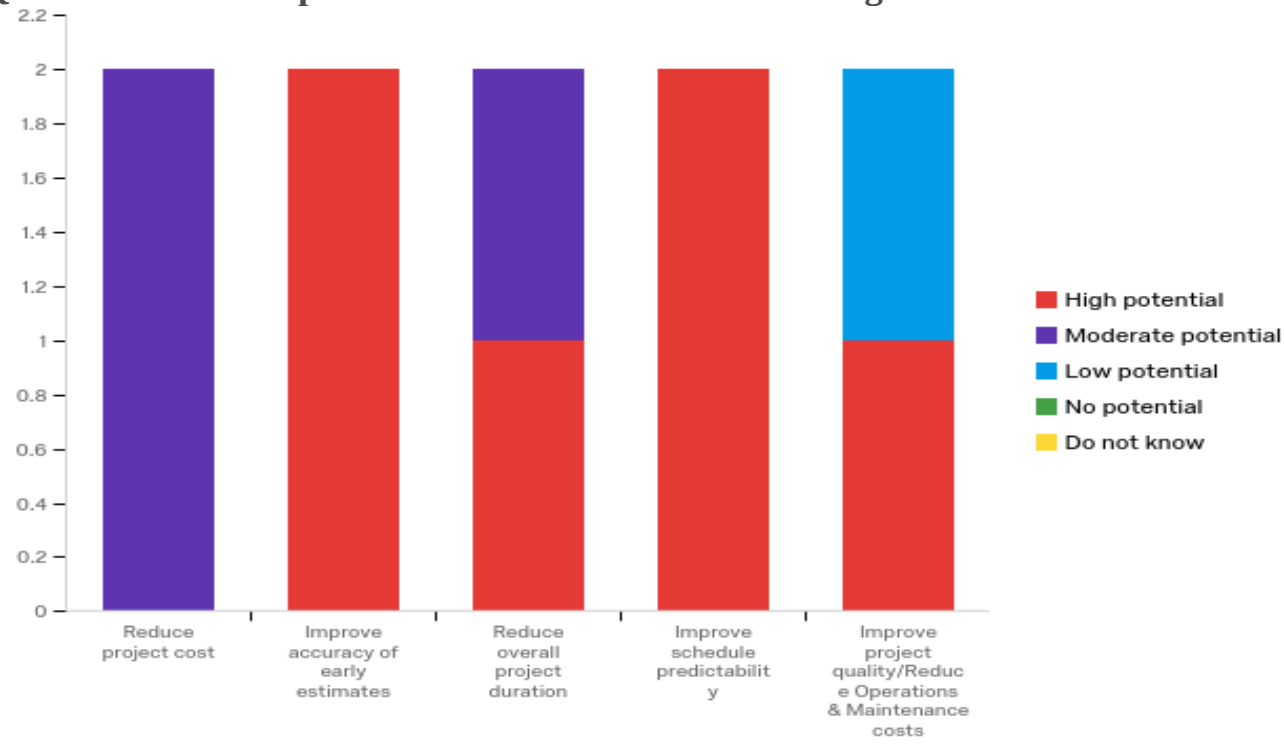
Q6.2 - What percentage of the projects you are involved in can replace custom components by catalog designs with no detriment to performance?



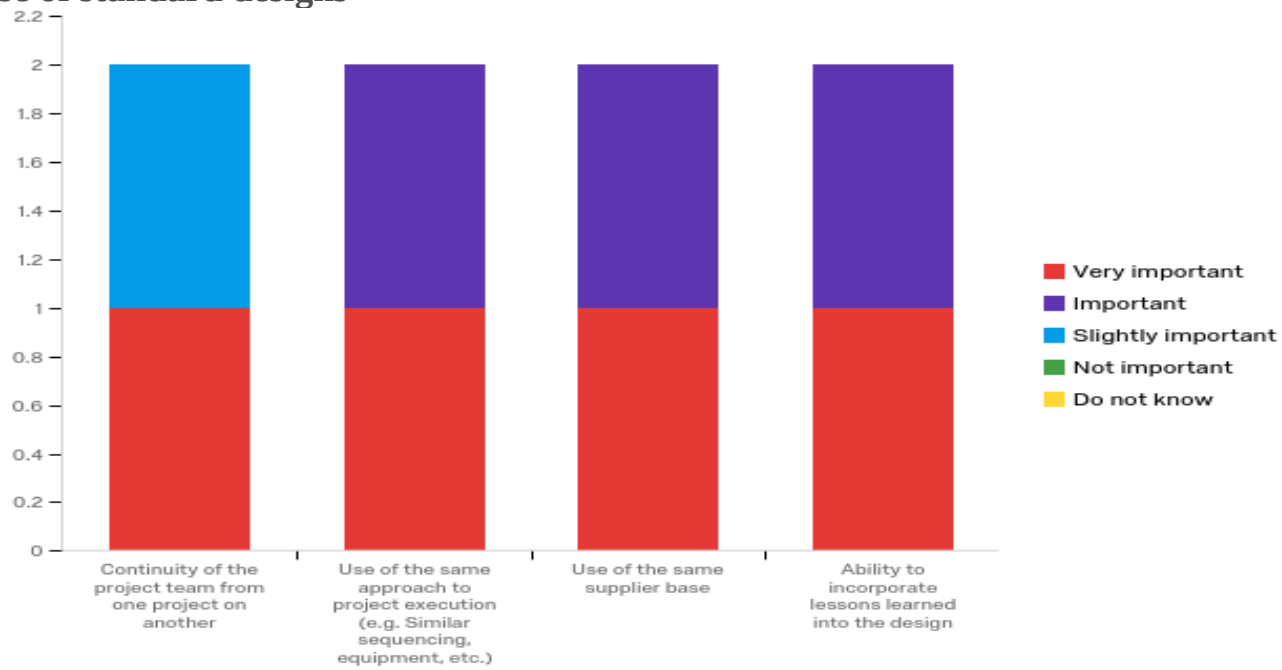
Q6.4 - Evaluate the potential of the increase in the use of catalog components to:



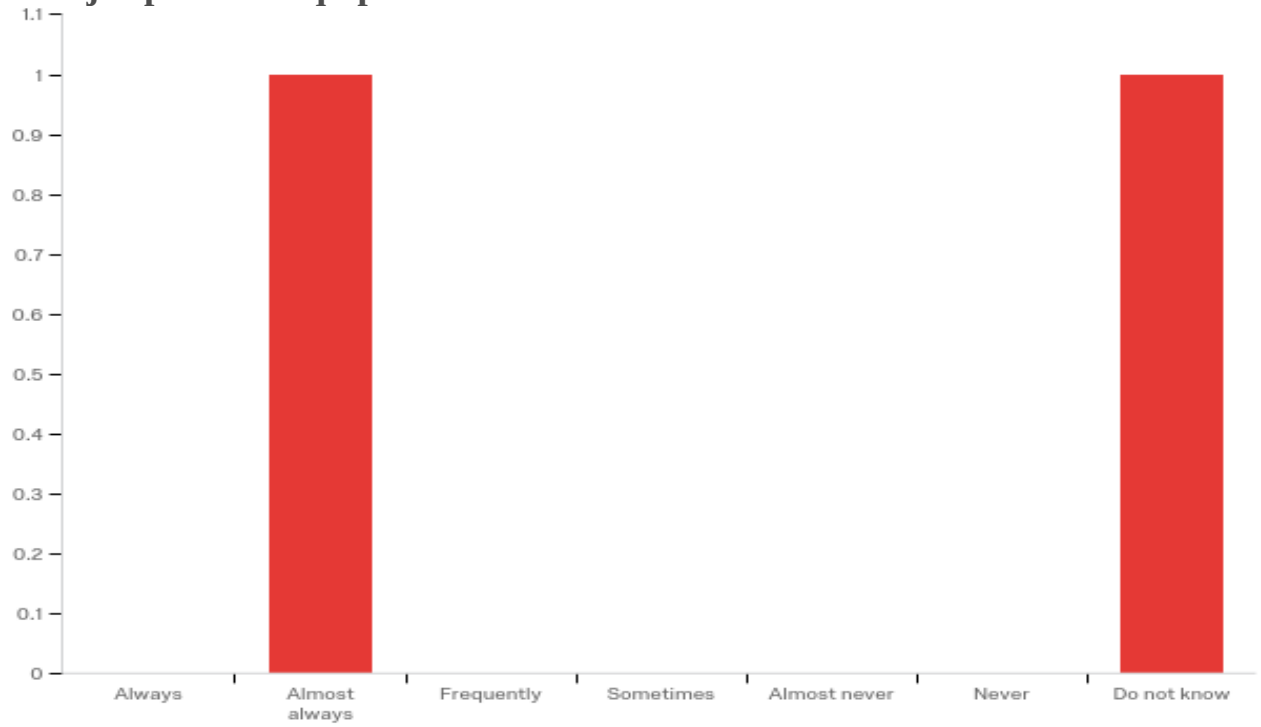
Q7.2 - Evaluate the potential of the use of standard designs to:



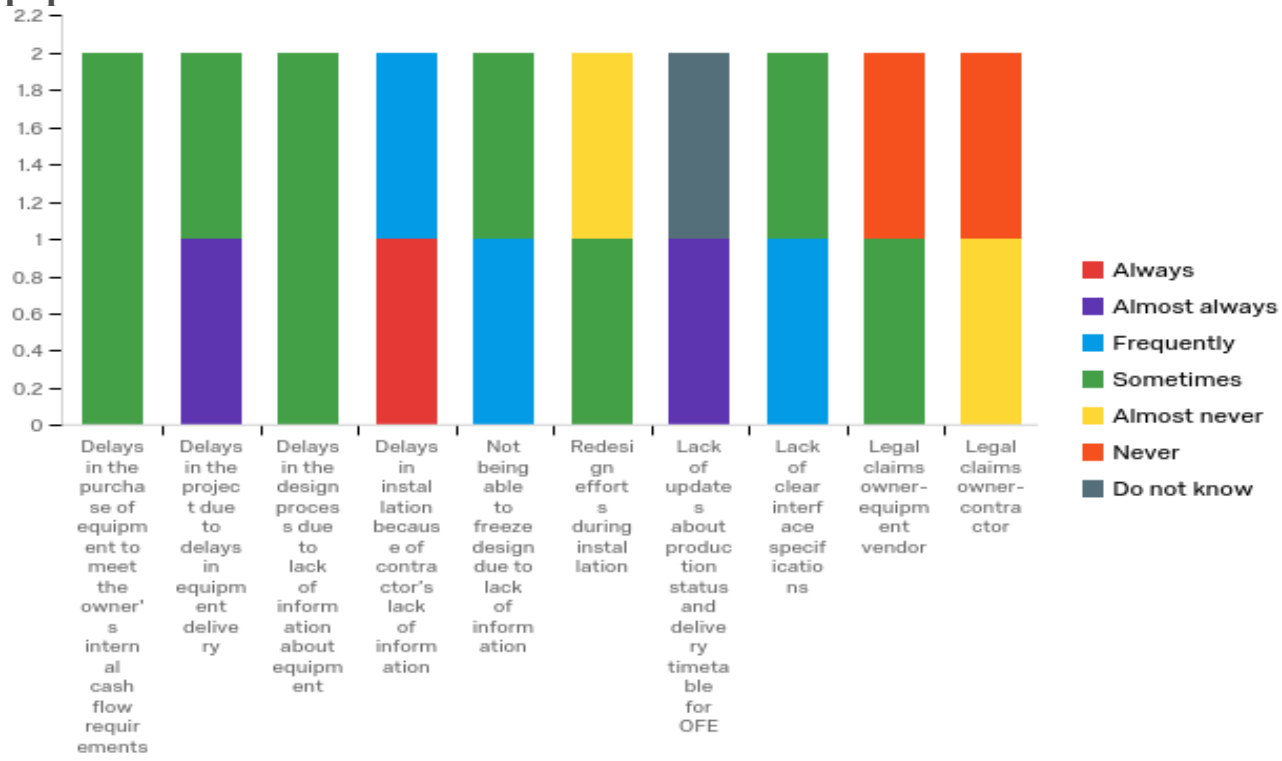
Q7.3 - Please rate the importance of the following items to achieve benefits from the use of standard designs



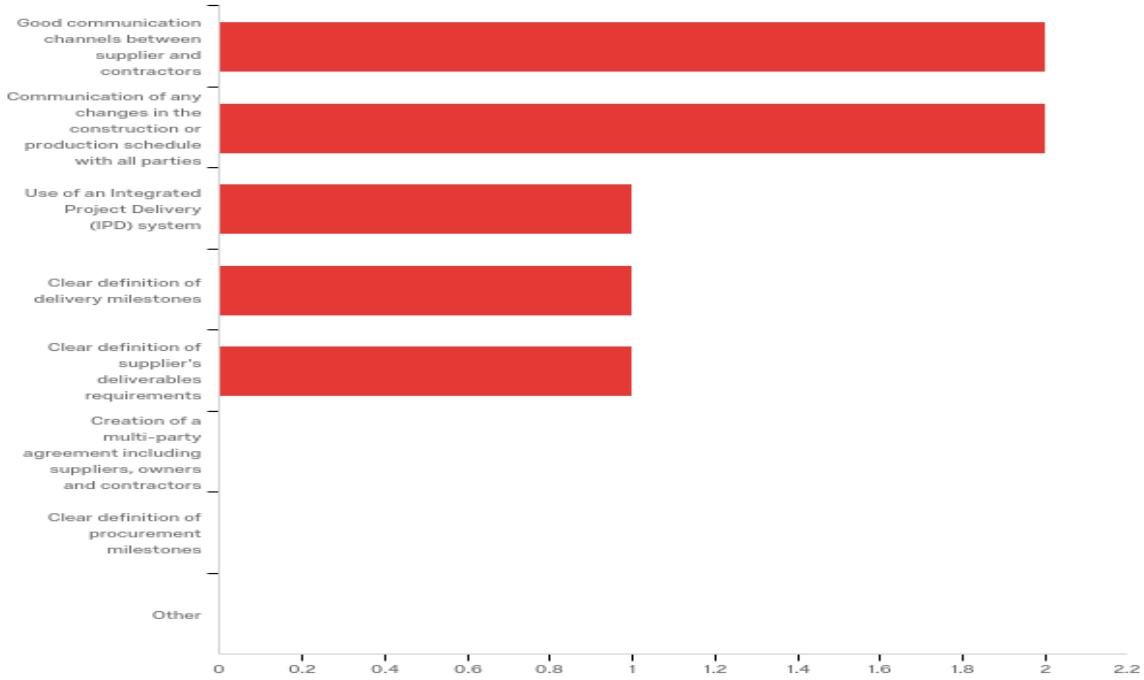
Q8.2 - How often is supplier-contractor coordination a challenge when the owner buys the major pieces of equipment?



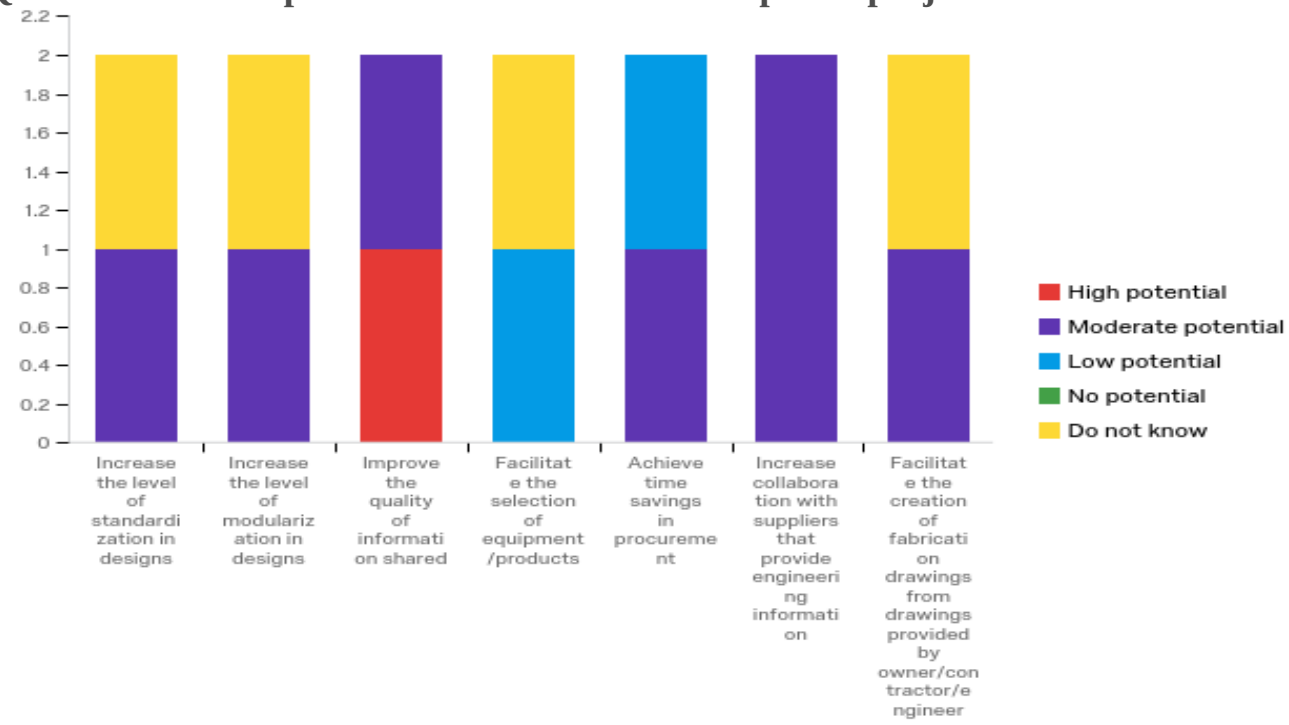
Q8.3 - How often do these issues arise when the owner buys the major pieces of equipment?



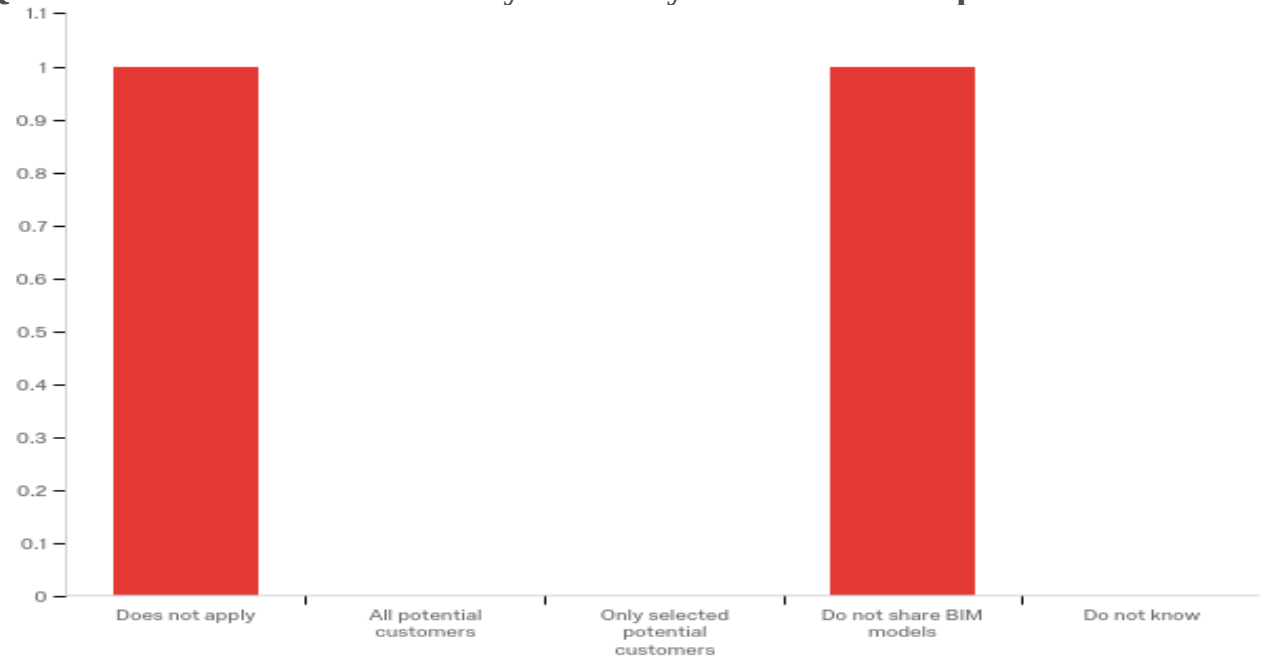
Q8.4 - Which of the following opportunities can significantly improve supplier-contractor coordination? (Significant translates to at least 5% improvement in cost/schedule/quality/safety or other project attributes)



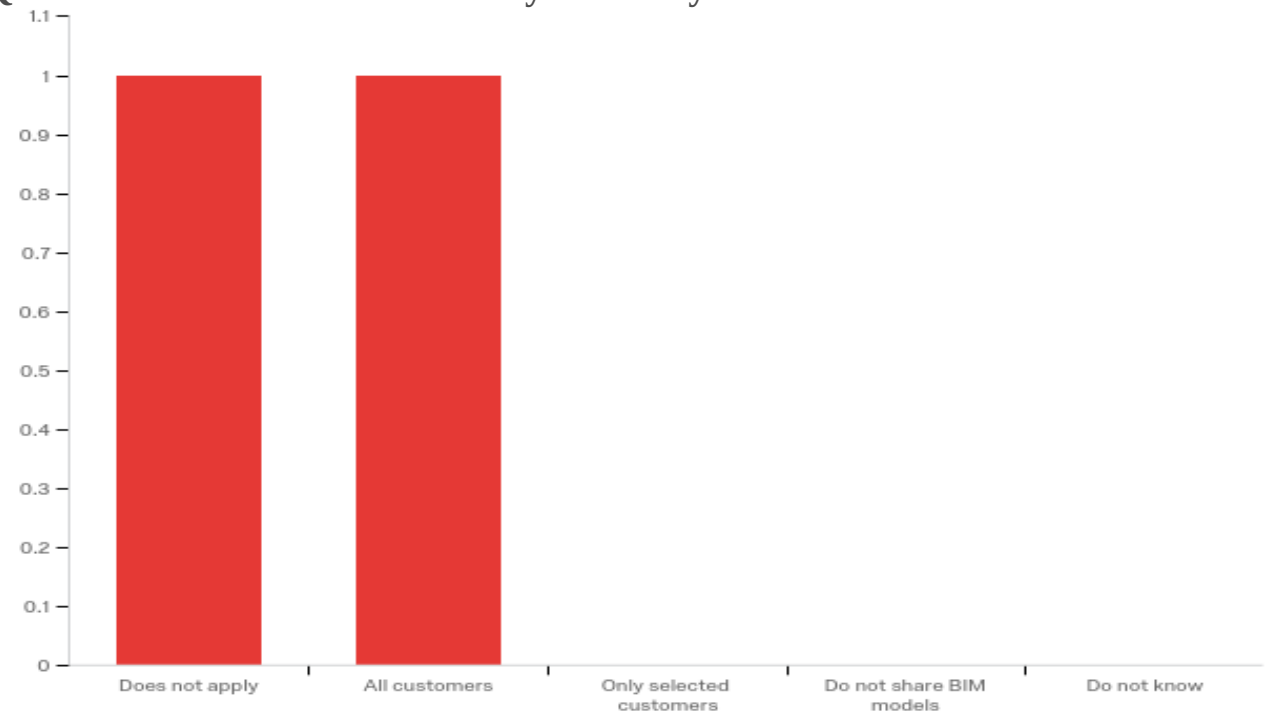
Q9.2 - What is the potential of the use of BIM in power projects to:



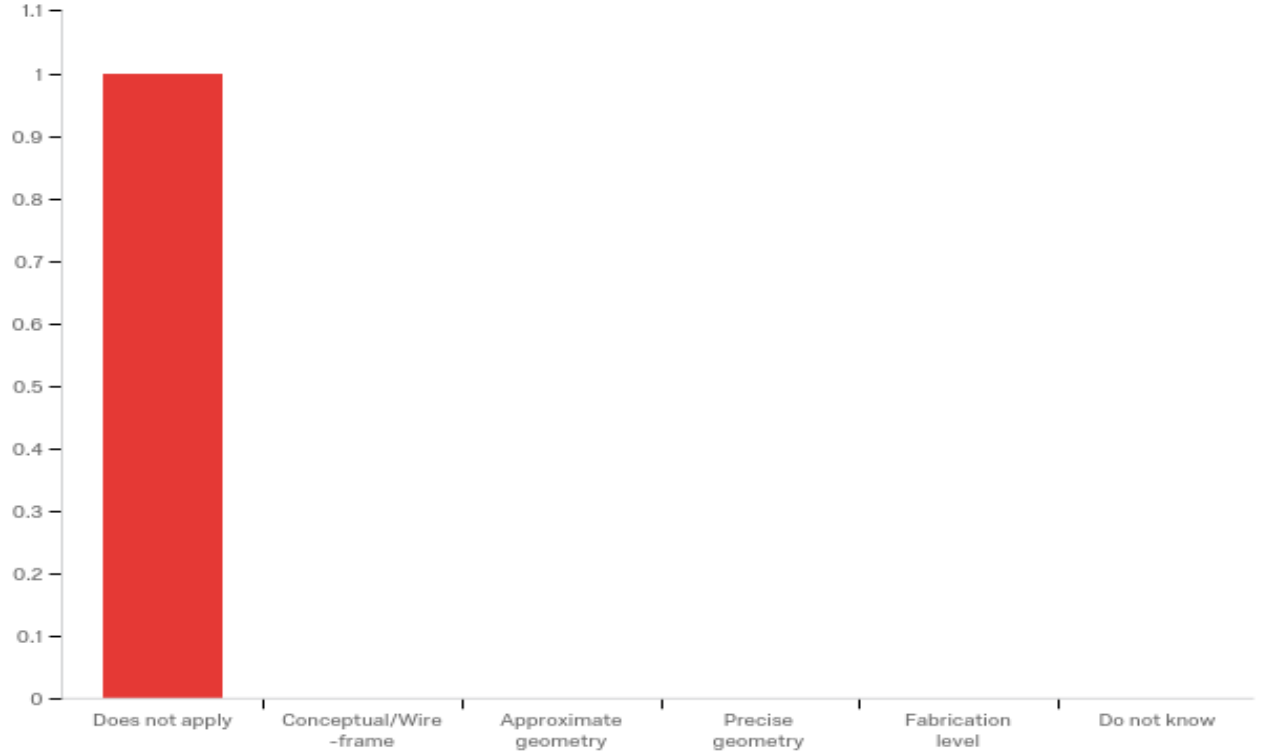
Q9.9 - With which customers do you share your BIM models prior to contract award?



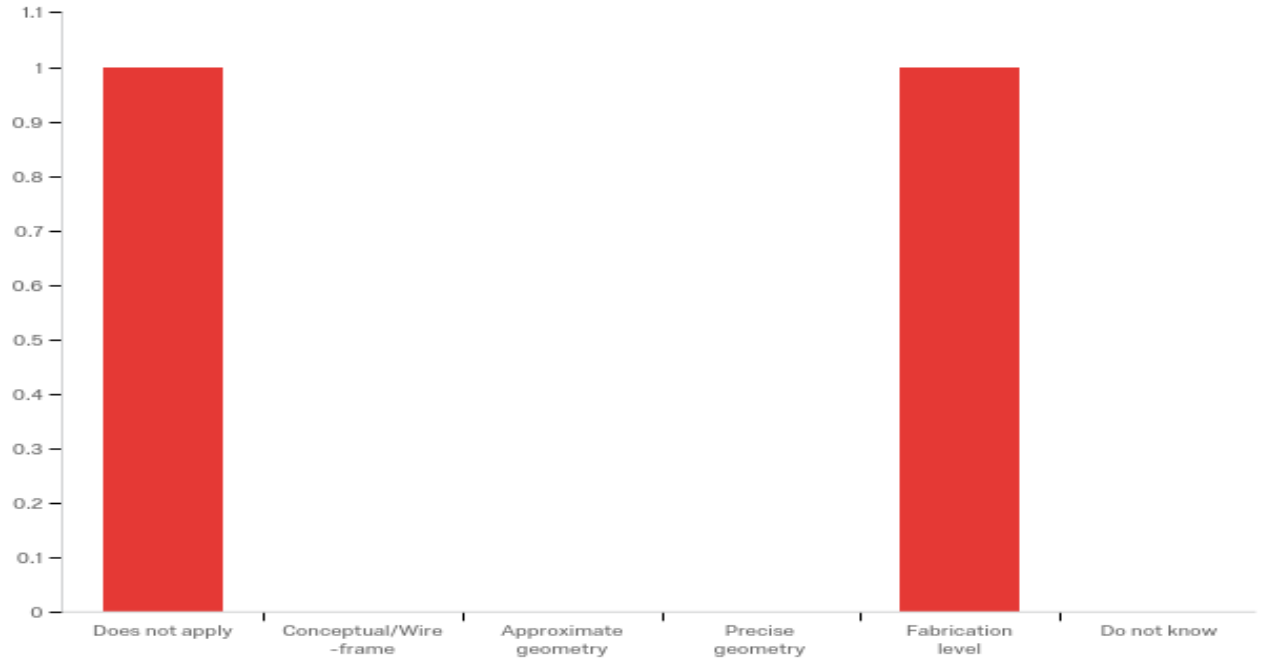
Q9.10 - With which customers do you share your BIM models after contract award?



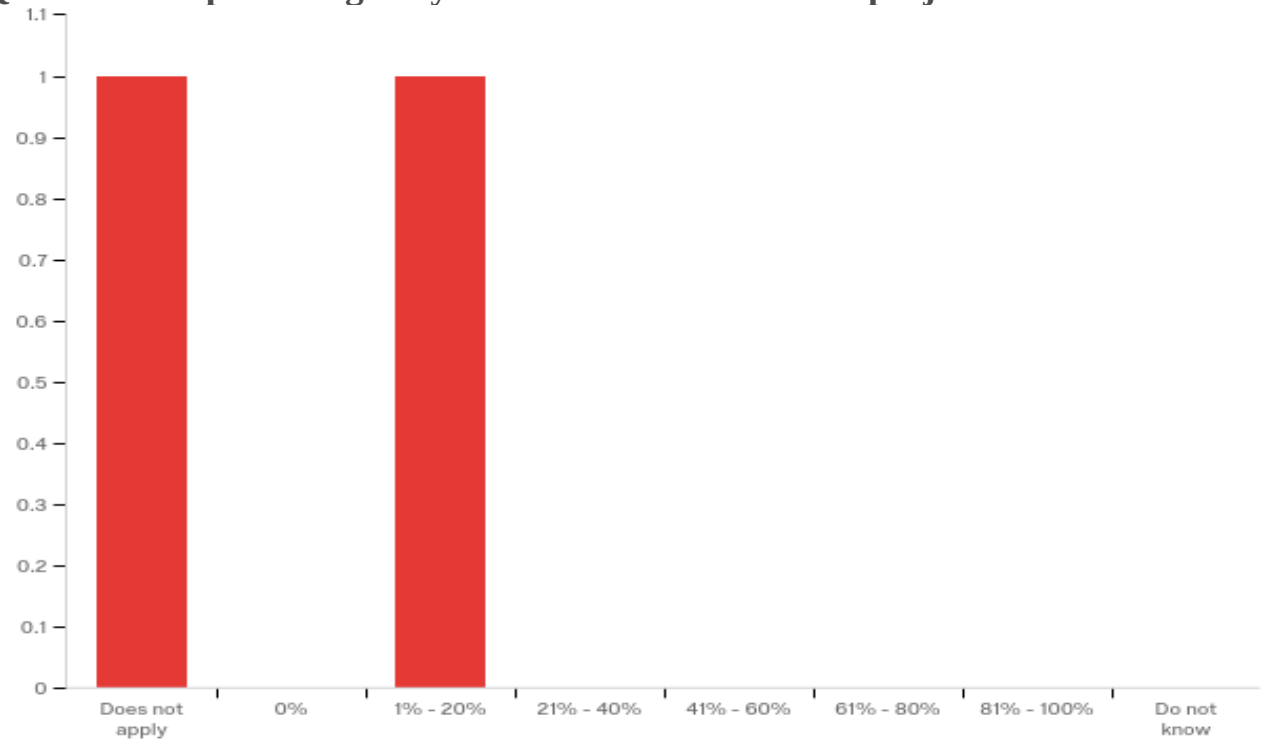
Q9.11 - What is the level of detail of the models that you typically share with customers prior to contract award?



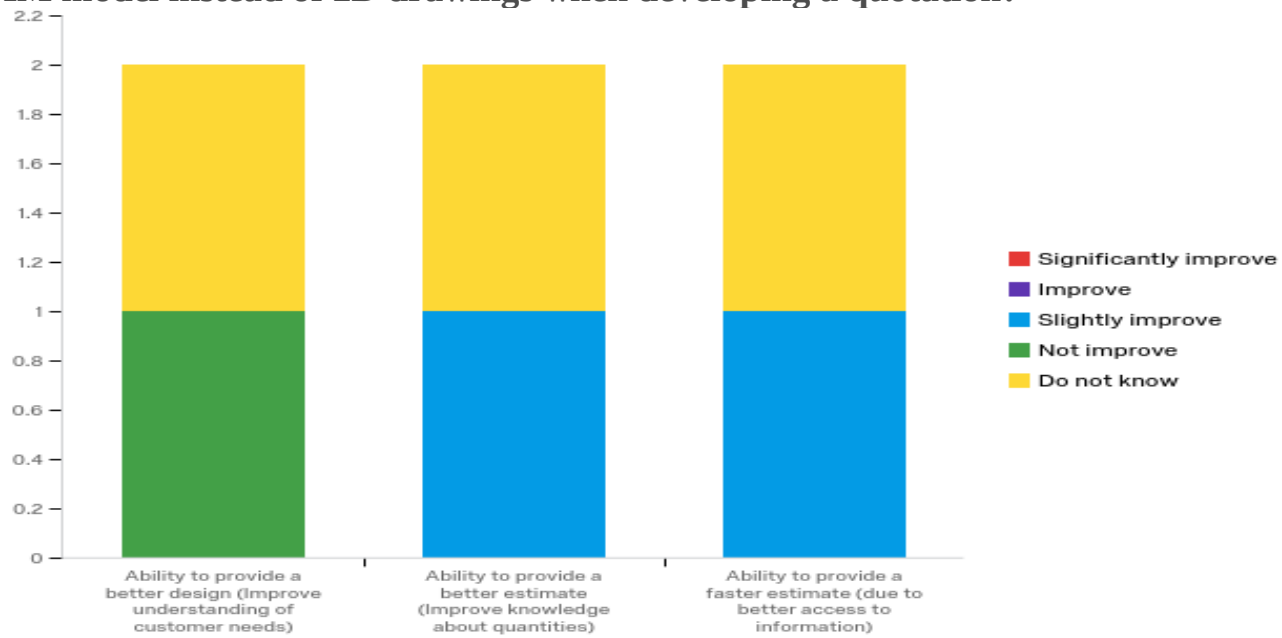
Q9.12 - What is the level of detail of the models that you typically share with customers after contract award?



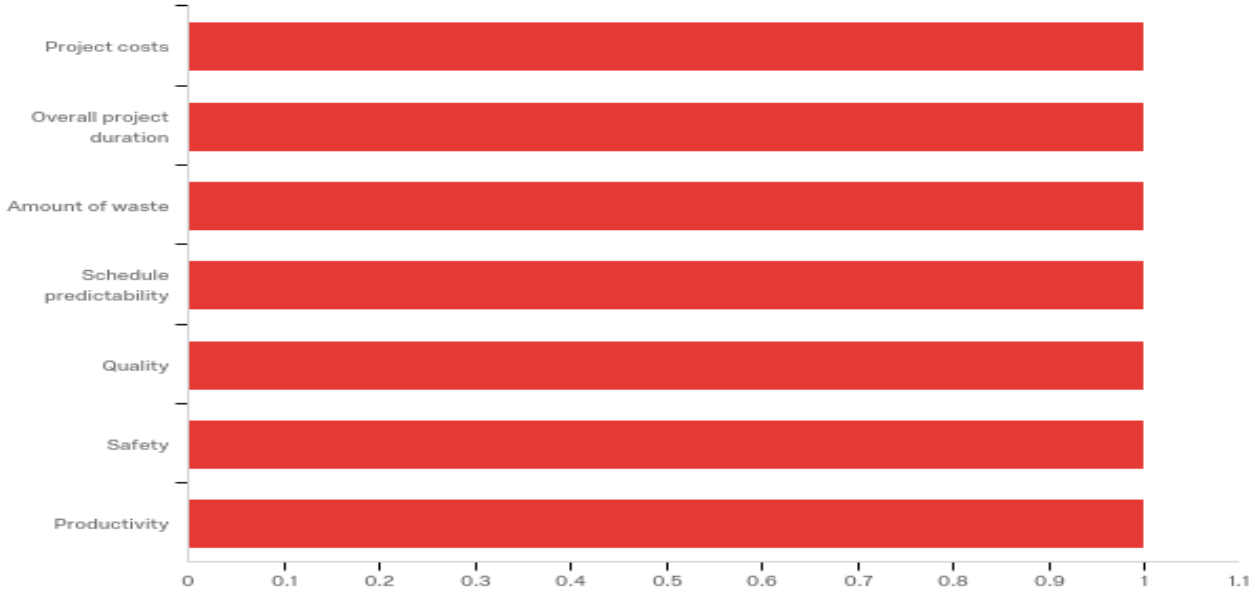
Q9.13 - What percentage of your customers share their project BIM models with you?



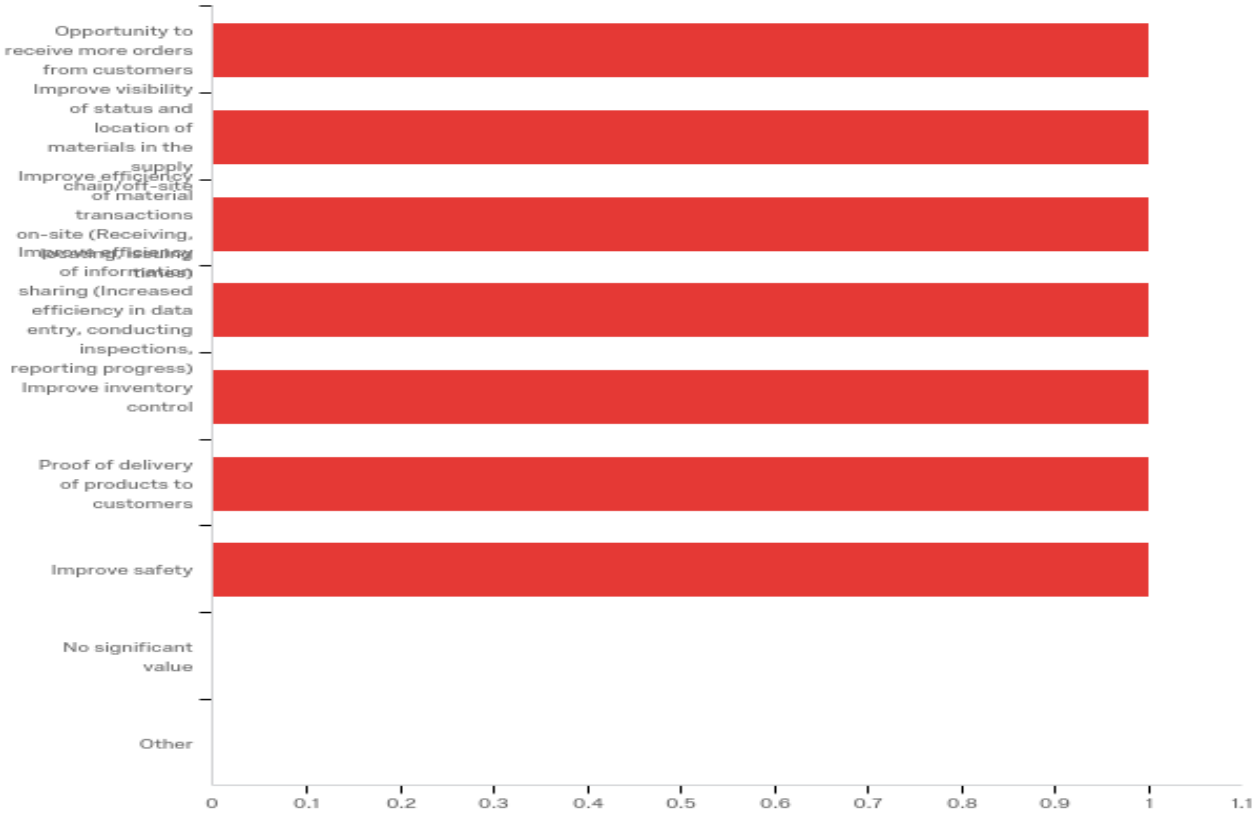
Q9.14 - How will the following be improved if you have access to the project design BIM model instead of 2D drawings when developing a quotation?



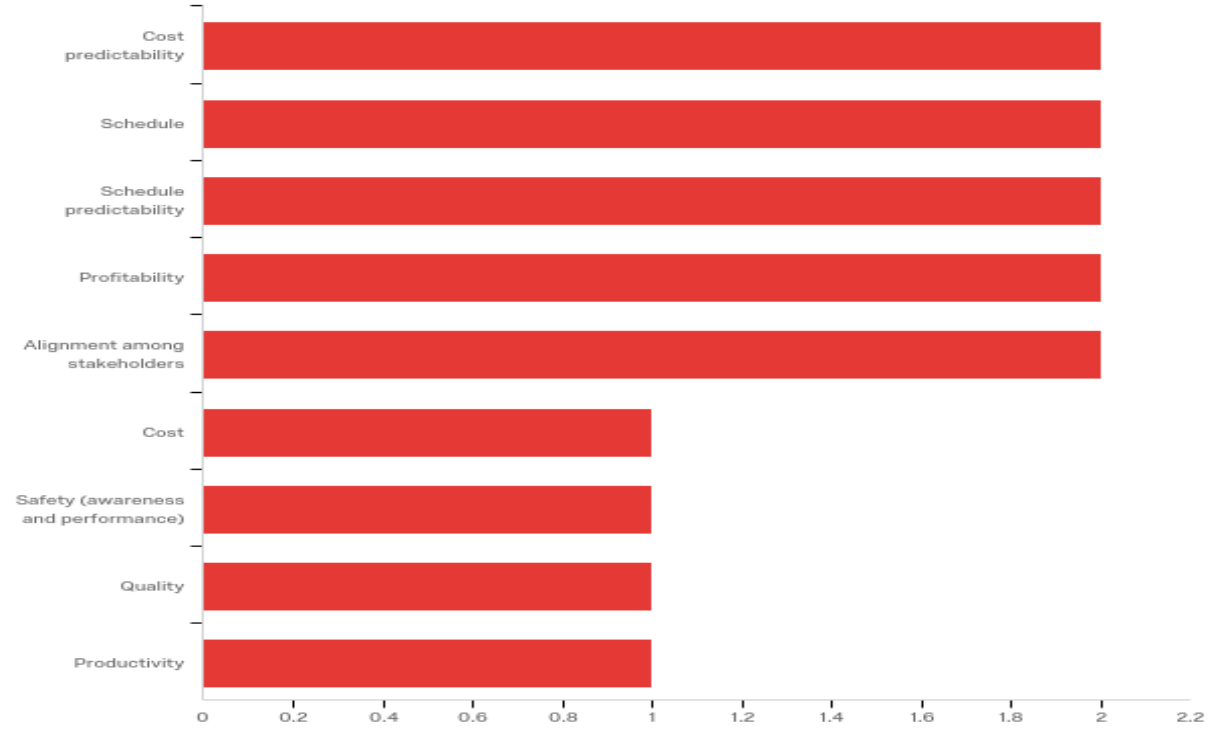
Q10.2 - Which of the following can be significantly improved (i.e. by more than 5%) with more integration of suppliers into modularization and off-site fabrication processes? Please select all that apply



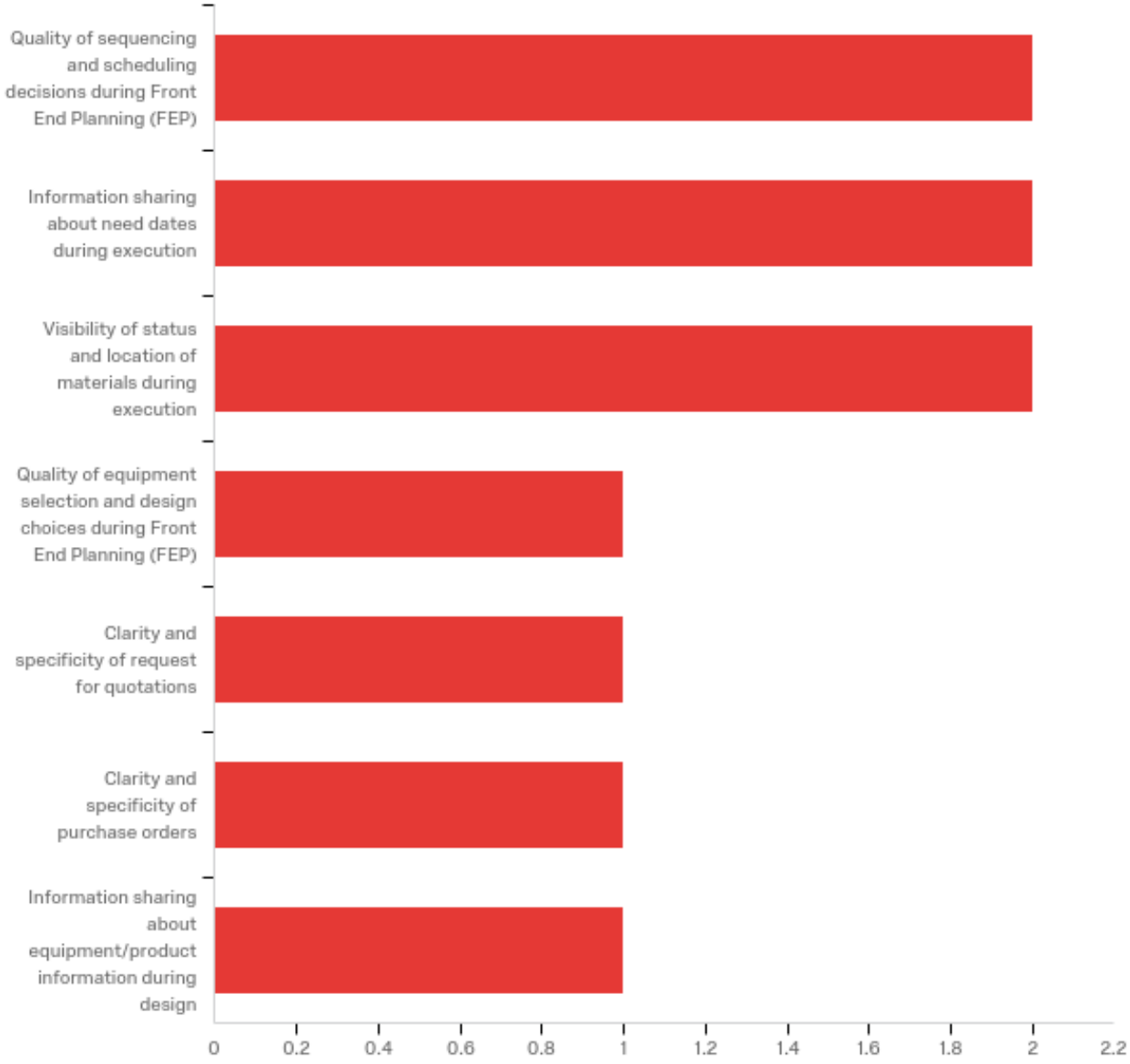
Q11.2 - Where do you see value in the use of AMILTT? Please select all that apply



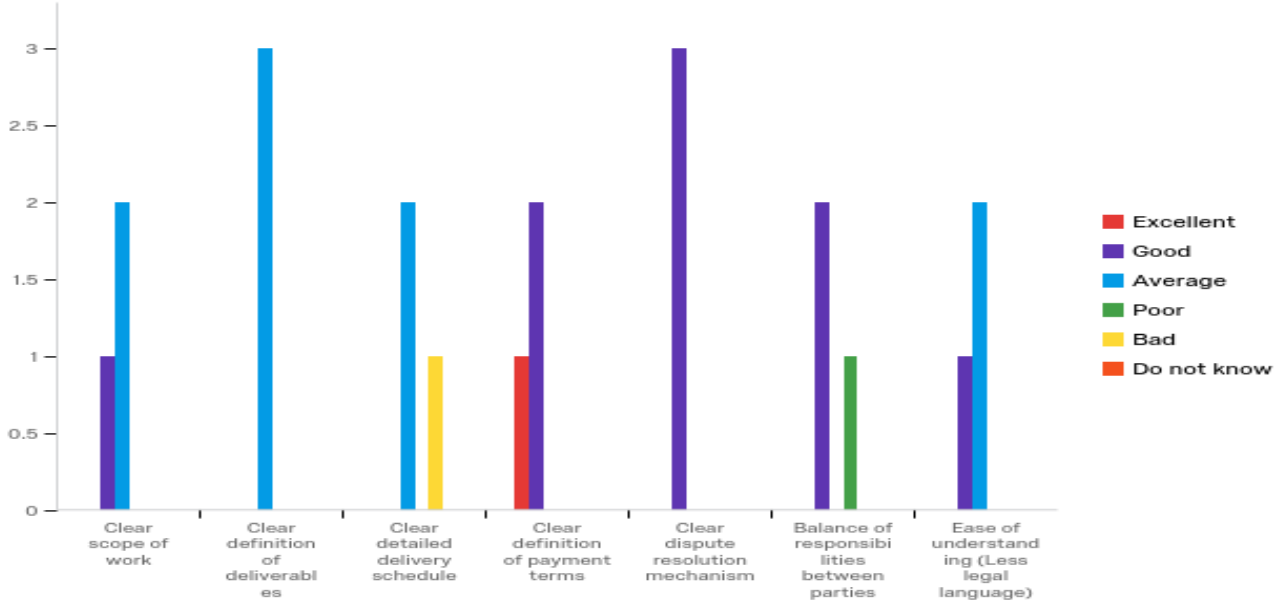
Q12.2 - Which of the following can be significantly improved (i.e. by more than 5%) with more integration of suppliers into the AWP process? Select all that apply



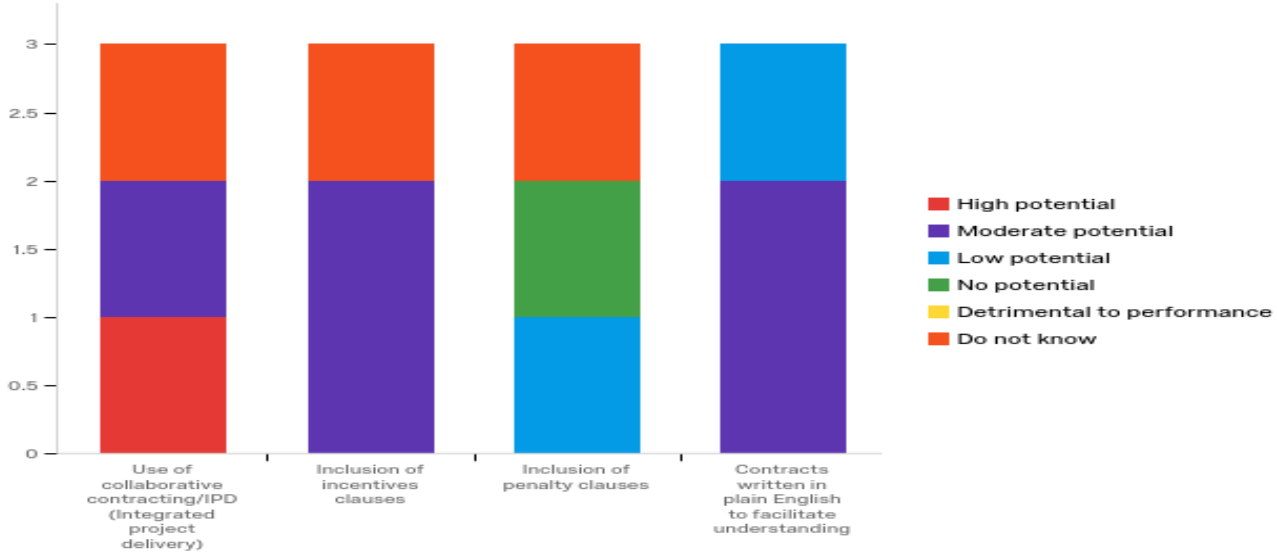
Q12.3 - Which of the following can be significantly improved with more integration of suppliers in the AWP process? Select all that apply Significant translates to at least 5% improvement in cost/schedule/quality/safety or other project attributes



Q13.5 - In general, how do you evaluate your contracts with clients regarding



Q13.6 - Evaluate the following opportunities around contracts with clients according to their potential to improve project performance



Q13.7 - Please specify any other characteristics of contracts with clients that can be improved

Please specify any other characteristics of contracts with clients that can be improved
Increased sharing of Project Schedule and construction need dates

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