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Material suppliers' perspective on collaboration in industrial construction projects

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Material suppliers' involvement in construction project planning has been recommended as an effective measure to improve project performance by using their expertise. However, the recommendation is not universal, and some researchers disputed the value of early involvement of suppliers depending on material type. Moreover, prior studies considered main contractors' and owners' perspectives mostly in examining how to increase the involvement of suppliers. To add material suppliers' perspective, this study conducted interviews with experienced professionals from 16 material suppliers including standardized, make-to-order, and custom products. The results are specified by separating the type of materials and sub-phases of planning. The results show that custom product suppliers need to be involved in the feasibility and concept phases, make-to-order product suppliers need to be involved in the concept and detailed scope phases, and standardized product suppliers need to be involved in the detailed scope phase. The excerpts from the interview are provided for detailed benefits from the involvement at a desired time and the issues stemmed from later involvement than desired. From the material supplier perspective, this study establishes the value of material supplier involvement in the planning phase regardless of material type. These findings challenge established viewpoints supporting the later involvement of standardized material suppliers and describe the value such suppliers can add to industrial projects in the planning phase.

KEYWORDS

material suppliers, industrial construction projects, materials management, involvement timing, material type

1 Introduction

Researchers have suggested that construction project performance could be improved if contractors collaborated more with materials suppliers, as they could then more fully engage the latter's expertise in projects (Pala et al., 2014; Caldas et al., 2015; Eriksson, 2015; Broft et al., 2016; Sundquist et al., 2018). Suppliers can contribute to design with a suggestion that the contractor may not be aware of because suppliers typically have specialized knowledge in their product area compared to other stakeholders (Eriksson, 2015; Sariola, 2018). Suppliers' knowledge can also provide accurate lead time and cost estimation which should be considered in

project planning to prevent unforeseen costs and delays (Caldas et al., 2015; Eriksson, 2015). These contributions can be significant because materials suppliers account for typically 50%–80% of a main contractor's total costs (Dainty et al., 2001; Tam et al., 2011; Bemelmans et al., 2012). Despite these projected benefits, material suppliers are not engaged enough in construction projects to achieve the expected benefits (Pala et al., 2014; Broft et al., 2016).

While the literature suggests the benefits of supplier engagement, it is drawn primarily from the perspective of owners and contractors (Bemelmans et al., 2012; Broft et al., 2016; Ben Mahmoud et al., 2024). Through the review of articles published between 2000 and 2023, Ben Mahmoud et al. (2024) found the concentration on the perspective of owner and contractor in supply chain integration research. They suggested investigating suppliers' perspectives on supplier engagement in construction projects. Prior researchers focused on the owner and main contractors' role because their position as focal entities of projects allows them to lead innovation in projects more readily (Sariola, 2018). However, since construction projects involve various interdependent stakeholders, the performance is hard to improve without considering all the parties' perspectives (Akintoye and Main, 2007; Bemelmans et al., 2012; Broft et al., 2016; Ben Mahmoud et al., 2024). Therefore, a comprehensive approach that takes into account the perspectives of all stakeholders, including material suppliers, is crucial for improving project performance. Investigating the state of material supplier engagement in construction projects from the material supplier perspective can contribute to increasing supplier engagement and, in turn, leverage their expertise to achieve better project performance.

This paper contributes perspectives of suppliers supporting the industrial construction sector. The following sections review the relevant literature, methodology, findings, and conclusions. Overall, the research findings indicate that all types of suppliers could be better utilized in a collaborative manner, particularly in the planning phases of the project. The findings extend the current literature and add new perspectives that challenge some of the extant literature.

2 Literature review

2.1 Participation of suppliers in construction project planning

Conventionally, material suppliers are involved in construction projects through bidding processes that are based on issued for construction (IFC) and procurement documents (Hinze and Tracey, 1994; Caldas et al., 2015; Eriksson, 2015; Gosling et al., 2015; Broft et al., 2016). This bidding based on IFC documents is post the detailed design phase of projects. However, some researchers have suggested involving material suppliers early on in planning as an effective way to improve construction project performance. Gray was among the first to notice this trend (Gray, 1996). Eriksson (2015), for example, described that when supplier expertise is reflected in the design of construction projects, change orders can be avoided proactively by reviewing the project scope and equipment design with the supplier's expertise. Moreover, when the owner, the main contractor, and material suppliers collaborate in the design stage, the owner can end up being more thoroughly satisfied and the other stakeholders see more profit (Eriksson, 2015). This occurs because such collaboration clarifies the owner's requirements and provides an opportunity to explore design alternatives. In this collaboration, the supplier's expertise is vital to review the latest techniques that are not well known to other participants since suppliers are typically more experienced in the development of niche technologies than other participants (Eriksson, 2015; Sariola, 2018).

Early involvement of suppliers is not a universal recommendation. Some researchers contend that extended relationships with suppliers have limitations, so a transactional approach should be maintained. Sundquist et al. (2018) argued that some supplier relationships should not consist of strategic partnering or project partnering but rather remain transactional. Their study showed that electronics, ventilation, and heating material suppliers could create value through strategic partnering but concrete and reinforcement bars should be procured through transactional relationships. They argued that, since those materials' specification and availability depended on local conditions, site managers could achieve better contract terms than a central organization. Their study concluded that the relationship type between contractors and suppliers should be determined by the context of each project instead of prioritizing strategic relationships over transactional ones. Sundquist et al.'s study is in the same line as Azambuja et al. (2014) which identified different attitudes of main contractors toward strategic partnering with suppliers. Through case studies of five contractor firms, they found that some contractors did not see the value of collaborative relationships with suppliers while other contractors maintained long-term relationships for their competitive advantage including price and material design quality. Their study showed that the contractor who did not rely on the collaborative relationship still saw the values of transactional relationships such as flexibility in choosing materials and low initial prices.

One of the important factors in determining when suppliers should be involved in construction projects is lead time which is the amount of time required to complete material procurement (Ferreira et al., 2015). Given that the lead time varies by material type (Cheng et al., 2010), the disagreement between researchers about the value of supplier involvement in project planning can be investigated based on the typical lead time of materials by type. Cheng et al. (2010) divide the construction material type into three types—standardized, make-to-order, and custom. Standard commodity products such as wires and tubing usually have high demand and low inventory cost, so suppliers hold these materials before they receive orders. This allows the supplier to fulfill the order in a shorter time than other material types so that they can be involved in construction projects when materials are needed on-site soon.

Cheng et al. (2010) described make-to-order products that are manufactured, assembled, or configured from standard parts such as light fixtures or switchgear. Suppliers in this category usually begin fabricating the products only after the receipt and validation of customer orders to avoid high inventory costs and satisfy various demands for the assembly of standard parts. While standard commodity suppliers need to only deliver raw materials to the site as it is, make-to-order suppliers need to assemble or configure raw materials and deliver them to the site. Due to this

feature, make-to-order suppliers need more time to provide the products to the site than standard commodities.

Lastly, custom products refer to the products designed, developed, and manufactured for unique requests such as heating, ventilation, and air conditioning systems and customized ductwork. While make-to-order suppliers use standard materials as raw materials, custom product suppliers must design and fabricate raw materials. Since components of materials in this category are specially designed for a certain project, it takes a longer time to complete the delivery to the site compared to the former two types of products. To procure custom products no later than the required on-site date, contractors, subcontractors, suppliers, and engineers should cooperate in the design, production, and delivery processes, which demands earlier supplier engagement than the other two types of material. In addition to examples of custom products presented by Cheng et al. (2010), modularized materials are another representative custom product that requires the supplier's active involvement (Choi et al., 2016). Choi et al. showed that supplier involvement in the entire process was one of the most critical success factors of modular projects through case studies.

2.2 Challenges to effective supplier collaboration in construction projects

To examine challenges to effective collaboration between stakeholders in construction projects, Dainty et al. (2001) interviewed main contractors, subcontractors, and material suppliers. Their interview focused on subcontractors and suppliers to highlight new perspectives. They categorized the barriers to collaboration into the issues of finance, schedule, information quality, and attitude. Specifically, in their interview, suppliers noted that contractors' excessive focus on low initial prices and delays in payments severely impact suppliers' businesses. Due to the ignorance about suppliers' businesses, contractors expected that suppliers could deliver materials with shorter lead times and be more flexible in schedule than they actually could. Suppliers also suffered from low-quality information from main contractors, including missing, late, and inaccurate design, and site-related data. This exacerbated the difficulty for suppliers to meet the contractor's schedule requirements since low-quality information resulted in a request for information and extended time for clarification. Lastly, suppliers pointed out the arrogance of contractors' front-line managerial staff which let them give up forming collaborative relationships. Dainty et al. (2001) study noted that most suppliers interviewed complained about competitive bidding as the principal mechanism for supplier selection, indicating involvement in the project after the design was substantially complete.

More recently, Gosling et al. (2015) conducted case studies of five construction projects through interviews with suppliers and subcontractors to find problems in the construction supply chain. They visited the site or factory, interviewed managerial staff, and analyzed business process maps provided by the companies. The suppliers in their study suffered a lack of visibility of demand and site progress, incorrect specifications, and working as outdated schedules. These problems caused late delivery, wrong item delivery, excessive waiting time to unload on site, and cost increases. They suggested, as one of the tactics to overcome vague work scope, an IT (information technology) system that can make inventories, specifications, work-in-progress, flow rates, and orders visible throughout the supply chain. They expected that such IT systems would facilitate proactive communication for joint problem-solving.

On four case studies of projects, Eriksson (2015) found that vague designs and work scope for suppliers frequently occurred. The researcher interviewed 50 personnel of the projects and reviewed relevant documents. The study showed that high time pressure in planning and lack of relevant expertise to review design resulted in change orders and cost overruns. Because the supplier's work scope was determined by non-finalized requirements, suppliers produced the wrong materials or could not begin timely production.

Dharmapalan et al. (2021a) defined information items to inform key decisions of material management and asked material procurement experts to rate the importance, accessibility, and trustworthiness of those information items in recent construction projects. The results showed that materials required at the site (RAS) dates were one of the most important data for procurement decisions but were difficult to access and trust. More broadly, they found that considerable information for supply chain decision-making was often inaccurate and difficult to access. Also, Dharmapalan et al. (2022) found that established bills of material (BOM) were one of the most impactful enablers of information sharing in the construction supply chain but less than frequently shared appropriately on time.

2.3 Summary and research questions

The literature provides some agreement on the value of custom and long-lead suppliers to be involved in project planning. There is less evidence for make-to-order and standardized suppliers apart from the provision of enough lead time. Indeed, some researchers favor transactional purchases to make the most of market competition. With respect to early involvement, the literature recognizes the value of custom and long-lead suppliers' involvement during planning, although it is not specific despite planning being understood as divided into multiple components (CII 2012). The literature also notes the challenges that suppliers face, including poor scope definition, focus on price with concomitant ordering after the design is complete, and poor updating of project timelines such as delivery times and priorities.

As noted by Ben Mahmoud et al. (2024), the literature is predominantly drawn from the owner and contractor perspectives. There is a need for contemporary research collecting supplier perspectives. Basic research questions concern (1) understanding the desired timing for involvement, including the reasons why, and (2) what challenges stem from later than desired involvement. If possible, these questions should be addressed by supplier type.

3 Methodology

The summary above outlines research questions around suppliers' desired timing for involvement in projects as well as the challenges that stem from later than desired involvement. Since the research questions have an explorative nature, an interview is a suitable method to collect quality data (Blumberg et al., 2014). This study aims to capture both common views and individual

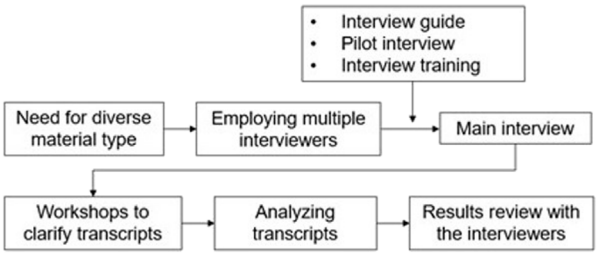

FIGURE 1
Methodology procedure.

opinions among suppliers given that the overarching goal is to complement the literature by exploring the supplier's perspectives on collaboration with contractors. To earn a deep understanding of the context, follow-up questions should be asked based on the first responses to prepared questions. Therefore, a semi-structured interview is the most suitable approach because it allows researchers to explore responses with context (Palinkas et al., 2015; Fellows and Liu, 2021).

This study investigates suppliers covering different material types, including standardized, make-to-order, and custom products, since the material type affects the desirable involvement timing in construction projects. To broaden the material type of interviewees, this study adopted multiple interviewers. According to Fontana and Frey (2000), an interviewer who can form a rapport with the interviewee based on the understanding of the language and culture of respondents can collect profound data. To leverage the existing relationship between interviewer and interviewee, this study formed a group of interviewers consisting of subject matter experts who have abundant experience in construction projects. The group consisted of three contractors, two owners in the industrial sector, two material suppliers, and two service providers.

To minimize the disadvantages of multiple interviewers including the ununiformed interview process, the authors applied a protocol for training multiple interviewers suggested by Sattin-Bajaj (2018). The interviewer group and the authors jointly developed an interview guide as part of the training. The questions in the interview guide were aligned with the research questions: the value of supplier involvement in planning by material type, the specific involvement timing, and the issues caused by late involvement. Using the interview guide developed, pilot interviews were conducted under similar interviewing environments.

The interviewers and the authors determined a list of the suppliers including three types of products identified by Cheng et al. (2010)—standardized, make-to-order, and custom products. The supplier list was limited to those working on industrial construction projects in North America. This focus reduces the response noise from variables such as culture, contracts, and laws (Dharmapalan et al., 2021b; Ercikan and Roth, 2009). After finishing the data collection, through in-person workshops, the interviewers and the authors reviewed the interview transcript to clarify ambiguous points before analyzing the transcripts. The conceptual procedure of methodology is depicted in Figure 1.

A codebook was generated as two coders coded transcripts. The two coders coded sentences in the transcripts where single or multiple codes could be applied. Through the iterative review process, the coders reached a consensus on coding. The coding process followed a standard iterative process (MacQueen et al., 1998; Braun and Clarke, 2012; Elliott, 2018). The following section includes the data validation process using the grounded theory and the results of the interview.

4 Results and discussion

This section presents data validation based on theoretical saturation, supplier interview results regarding involvement timing, and challenges from late involvement. In particular, involvement timing results are presented by material type to clarify the desired involvement timing of each material type.

4.1 Theoretical saturation of data

To determine a legitimate point where to stop data collection, this study examined theoretical saturation using the methods suggested by Guest et al. (2006). Theoretical saturation occurs when new information produces little or no change to the codebook (Guest et al., 2006; Hennink and Kaiser, 2022). This practice defined the number of interviews required to discuss reliable results and opportunities to capture unique responses at the same time. The unit of analysis for examining theoretical saturation is an individual interview, and the data items are individual codes. To apply this method, four interviews formed one set. After each set, code generation was checked to track the changing status of the codebook, and the frequency of code application was noted as well. Investigating the latter can prevent a wrong analysis that happens when codes generated in the first set are never applied in the remaining interviews while codes generated in the later set are applied with the most frequency. These two factors of theoretical saturation over the entire interview progress, which are code development and prevalence, are summarized in Figure 2.

4.1.1 Code development

Overall, the codebook consists of 30 content-driven codes, all of which had been generated from at least one transcript. With the first four transcripts, 25 (83%) codes were generated; within the next four transcripts, another 5 (17%) codes were generated. From the first two sets, in other words, all the codes were generated. Overall, the development of code showed a decreasing tendency as the interview progressed.

4.1.2 Thematic prevalence

Another critical dimension of saturation is the relative prevalence of codes which can be determined by sorting codes by the number of interviewees using that code. For a qualitative study, most of the codes are naturally generated in the first set. Therefore, to verify saturation, researchers should check not only the progress of code development but also the relative prevalence which shows

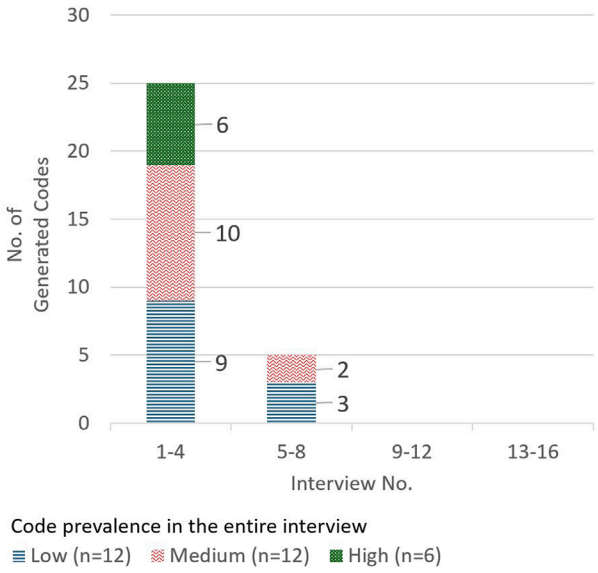

FIGURE 2
Code creation throughout the data analysis.

the extent of the significance of generated codes (Guest et al., 2006). To check whether the codes created in later stages become prevalent across the entire interviews, the authors investigate in reverse order how many codes are created in the first two sets among the codes of high frequency in all the interviews. According to Guest et al.'s guideline, codes mentioned by more than 50% of the participants are considered high frequency, between 25% and 50% are medium, and codes used by 25% or less of the participants are classified as low frequency. From all the interviews,6 codes were identified as being of high frequency, and all these codes were generated within the first four interviews. Therefore, it can be concluded that no significant code appears in the later stages. According to the analysis results, data saturation occurs in the fourth interview, at the end of the first set.

4.2 Interview results

Data was collected from 16 interviews. Table 1 presents a list of the interviewees' firm types, positions, and experience in industrial construction. The diversity of the interviewees' firm types including customized, make-to-order, and standardized is conducive to answering the research question of, the difference in desired involvement timing by material types. Additionally, the materials handled by the suppliers in the interviews show representative materials used in industrial projects in North America. This range of materials satisfies the research objective of investigating the perspective of material suppliers in industrial projects in North America. The collected responses are analyzed by the developed codebook and are organized and presented by the research topics—the value of supplier involvement in planning by material type, the specific involvement timing, and the barriers to collaboration in planning.

4.2.1 Timing of supplier participation in projects

The interviewees answered questions about the timing of their involvement in projects: current timing, desired timing, and any issues or benefits that stemmed from these current and desired timings. In general, interviewees reported that suppliers want to be involved in projects earlier than they currently are, and they were able to provide reasons why earlier involvement adds value, primarily centered around less expensive options or alternatives that add capabilities to the project.

Suppliers see ways they could offer added value to projects by providing alternate technologies, but they have limited opportunities to contribute ideas when they are not involved until after design decisions have been made. For example, both suppliers P5 and P6 said that their customers did not fully take advantage of the latest technologies but would simply "cut and paste" engineering deliverables from previous projects. Supplier P10 noted that some customers were used to a certain type of plant and only wanted that solution, refusing to discuss different options even when the supplier was involved during the planning phase. Supplier P5 also noted that approved manufacturer lists can exclude vendors who have valuable technologies, implying the need to review approved lists periodically and to be open to new possibilities in the market.

Even when project teams are open to new technologies, late involvement can lead to missed opportunities. Supplier P3 commented, "Customers usually have selected sizes or wall thicknesses for piping and there are often more readily available and easy options, which is much easier to identify if we're involved early. If the customer waits until it's too late, we might miss our window to help." Some suppliers noted that early involvement could help them alert customers about opportunities to utilize standard or catalog items instead of custom designs. Similarly, supplier P6 noted, "We can offer pipe bending (induction and cold pipe bending) to replace welded fittings. Without early involvement, we miss the chance to get this considered in design and the right material." This supplier noted a specific example of this situation where not considering pipe-bending technology increased the order cost by 10 percent.

The interview results can be further refined by material type and phase of the project. Cheng et al. (2010) categorize suppliers as standardized, make-to-order, and custom products, each with specific production capabilities and needs. The Construction Industry Institute (CII) defines the phases of a project as planning, detailed design, procurement, construction, and startup (CII 2012). Planning is further divided into feasibility, concept, and detailed scope phases. CII defined the objective of the sub-phases as follows: 1) the feasibility phase (FEL-1) – identifying a potential business opportunity based on a ±50% accuracy estimate, 2) the concept phase (FEL-2) – defining a preliminary schedule and preliminary engineering design documents that can provide a ±30% accuracy estimate, and 3) the detailed scope phase (FEL-3) – defining a detailed scope document with major equipment pricing and the project execution plan to establish a ±10% accuracy estimate. To add specificity to the investigation, the interviewees determined their desired involvement timing by using these sub-phases. The answers of the interviewees about the involvement timing of as-is and to-be are depicted in Table 2.

Custom product suppliers stated that they needed to be involved during the concept phase so that they could provide input into design alternatives. Although custom product suppliers, including

TABLE 1 Profile of the interviewees.

No.	Supply material/service	Supplier type	Position	Years of experience
P1	Pipe, valve, fitting supplier	Make-to-order	Manager	Unk.
P2	Shop fabricated steel/pipe	Make-to-order	Manager	37
P3	Pipe/Fittings/Flanges distributor	Make-to-order	Sr Manager	25
P4	Structural steel fabrication	Make-to-order	Vice President	14
P5	Electrical, safety, and security product	Standardized	Director	16
P6	Piping for petrochemical	Make-to-order	Vice President	15
P7	Structural Steel	Make-to-order	Director	16
P8	Specialty valves used in oil and gas	Custom	Manager	34
P9	Highly engineered construction products	Custom	Director	24
P10	Equipment for natural gas plants (Modularized materials)	Custom	Manager	11
P11	Structural steel fabricator	Make-to-order	Manager	8
P12	Third-party logistics	N/A	Sr Vice President	11
P13	Modular construction contractors	Custom	Manager	37
P14	Process instrument	Make-to-order	Business Unit Leader	24
P15	Cable producer	Standardized	Director	22
P16	Electrical distributor	Standardized	Director	14

P9 (gas plant equipment) and P13 (modularized materials), were involved in the detailed scope phase, the need for earlier involvement was noted by them as well. The project schedule and budget are significantly impacted by decisions regarding major engineered equipment and modular materials (O'Connor et al., 2014; Caldas et al., 2015). Because of this, contractors need to consider the input from these suppliers before the concept phase is completed (Choi et al., 2016). The interview results support previous studies about modular materials. Specifically, P13 showed that they need to collaborate with clients on preliminary engineering design by saying "If the owner does not understand what we can do early on, we lose the chance of additional values …If the client has no in-house capabilities to consider modular aspect, they need to hire someone to get them through the process at the project definition." This is in the same line with P9's statement, "…the things that we need to be involved in is time critical. If we miss the boat, we cannot make up the ground. …(we) trying to tell this story as soon as possible with data to back up our value proposition." This shows that custom product supplier needs to be involved in the concept phase rather than the detailed scope phase because their alternatives cannot be applied if they are not considered in the preliminary engineering design.

Make-to-order product suppliers, such as P2 (shop fabricated steel/pipe) and P11 (structural steel fabricator), also mentioned the need for earlier involvement than the detailed design phase. They commonly noted that raw material procurement could be delayed later than the contractor's estimate despite this type of supplier using standardized raw materials. Supplier P6 (piping) noted that engineering without the supplier's perspective often overlooked critical information and that this omission caused rework. Cheng et al. (2010) argued that suppliers in this category start production only after the contractor validates the order to reduce inventory cost and accurately satisfy the customer's configuration needs. The suppliers in the interviews agreed that they usually minimized risk by waiting until all the required information was agreed upon. The suppliers noted that they did not initiate production until they received the finalized engineering documents and the required raw materials. They often experienced rework occurring when they produced materials based on the draft of drawings or using raw materials the contractor has yet to confirm. All the make-to-order suppliers in this study noted that due to the practice of waiting until engineering documents are finalized and then procuring raw materials, their lead time is usually longer than contractors' estimates. This is exacerbated by a currently volatile raw materials market. As such, suppliers experienced difficulties meeting the schedule if they were not involved until the detailed design phase.

It is noteworthy that suppliers for standardized products (P5 safety/security products; P15 cable producer; P16 electrical distributor) also reported a need for earlier involvement than the detailed design phase. The primary driver for this is to prevent loss

TABLE 2 Material suppliers' involvement timing in industrial construction projects.

No.	Supplier type	Involvement timing	
		Current	Desired
P1	Make-to-order	Detailed scope (FEL-3)	Concept (FEL-2)
P2	Make-to-order	Detailed design	Feasibility (FEL-1)
P3	Make-to-order	Detailed design	Concept (FEL-2)
P4	Make-to-order	Detailed design	Concept (FEL-2)
P5	Standardized	Detailed design	Concept (FEL-2)
P6	Make-to-order	Depending on the project	Feasibility (FEL-1)
P7	Make-to-order	Depending on the project	Concept (FEL-2)
P8	Custom	Depending on the project	Concept (FEL-2)
P9	Custom	Detailed scope (FEL-3)	Feasibility (FEL-1)
P10	Custom	Detailed scope (FEL-3)	Concept (FEL-2)
P11	Make-to-order	Detailed design	Concept (FEL-2)
P12	N/A	Detailed design	Feasibility (FEL-1)
P13	Custom	Detailed scope (FEL-3)	Feasibility (FEL-1)
P14	Make-to-order	Detailed design	Feasibility (FEL-1)
P15	Standardized	Detailed design	Concept (FEL-2)
P16	Standardized	Detailed scope (FEL-3)	Feasibility (FEL-1)

from incompatibility between their products and others specified in the design. P5 mentioned that their products are not compatible with certain devices/materials, so design change would be inevitable unless the compatibility was checked before the owner approved the list of manufacturers. P16 noted the opportunity for early involvement to add value through advice on product selection to meet customer needs. However, such early interaction is often limited to estimator requests for costs, not technical requests from engineers. P15 similarly noted that they often get orders for products that are no longer in production. They indicated value for earlier involvement during detailed scope to avoid such problems. A further reason for earlier than typical involvement is to have enough time to prepare and deliver products. While products are standardized, they are not necessarily easy to ship or process quickly. P15 noted that they hired temporary workers frequently to meet the schedule of recent projects. Although the material they provide is standardized, the workers should be trained to cut cables, package, and unload to comply with safety standards and achieve target productivity. While the provision of enough time to meet orders does not necessarily require involvement before detailed design, it does indicate a need for longer lead times. A recent conversation with a supplier of common parts noted that with "lean inventory and production," it is important to have a better understanding of the scope and quantities required early on so production and inventory holdings can be planned to meet delivery dates, especially for projects in the industrial sector that can have large orders (Martin, 2024; personal communication).

Based on the interviews, it can be argued that all supplier types should be involved in the planning phase of projects. Specifically, a possible conclusion is that custom product suppliers need to be involved in the feasibility and concept phases, make-to-order product suppliers need to be involved in the concept and detailed scope phases, and standardized product suppliers need to be involved in the detailed scope phase. The value of early involvement found through the interviews provides a counterpoint to those who argue that many types of purchases are best accomplished transactionally on a low-cost basis (e.g., Pala et al., 2014; Sundquist et al., 2018). At the least, the supplier interviews suggest that many products, including standardized ones, have aspects of selection beyond cost that influence design choices. Thus, this research does not directly contradict those that argue for transactional purchases but suggests the scope of such purchases may be smaller than previously envisioned.

Similarly, the findings of this study add to the discussion of collaborative contracting approaches by suggesting broader involvement of materials suppliers in these multi-stakeholder agreements. A specific example is the ongoing experimentation with Integrated Project Delivery (IPD), which envisions the early involvement and collaboration of main parties to achieve project cost and schedule objectives (Hall et al., 2018; Rodrigues and Lindhard, 2021). Current representative IPD standards define the main parties of IPD as the owner, designer, and contractor (Ahmed et al., 2021). Material suppliers are considered optional parties. Of note, researchers such as Rodrigues and Lindhard (2021) and Fischer et al. (2017) recommended careful selection of parties in the planning phase, recommending a small group as additional parties may cause unnecessary conflicts and hinder communication. Such an approach would generally limit the involvement of materials suppliers and, as such, limit their potential contributions to projects that are suggested by this study. Expanding contracting approaches to better leverage the expertise of the supplier community is an area ripe for exploration.

4.2.2 Challenges from late involvement

Apart from adding value through early input to designs, most of the suppliers noted production challenges from involvement in the project at times later than desired. These challenges stem from a poor understanding of the project scope and a lack of clarity of project priorities and need dates.

Ten suppliers (63%) noted that their assigned scope and the contractor's requests were vague or hard to understand clearly. P10 (gas plant equipment) remarked, "If a contract is not clear, it can be very challenging as different folks interpret things differently." Supplier P1 (piping, valves, and fittings) said, "The earlier, the better" to address challenges with unclear scope. P1 noted that the Front-End Engineering Design (FEED) stage is the preferred time for involvement because suppliers can fully support the customer and discuss a path forward in this stage. Since involvement at FEED provides enough time to plan, suppliers can prepare deliverables

with more accuracy. A related finding is that nine of the suppliers (56%) noted that the BOM (bill of materials) they receive from the project is often inaccurate or incomplete; this is another indication of unclear scope.

Suppliers also noted that challenges stem from changes in the scope of the project. The content of the contract (including material specifications, schedules, and financial terms) is often revised. They noted that the frequent change in the contract causes confusion and disrupts project execution. P16 (electrical distributor) stated that "what hurts us is when the never-ending 'are we on the right revision?' If we could get real-time access to the 'one source of truth' in engineering or material data, we'd be so much more accurate." P14 (process instruments) described that "instruments are not stocked by the supplier, so any change is essentially resetting the lead time clock and the lead time starts over." Suppliers often receive incomplete drawings or changes to drawings (which, of course, relate to unclear scope). Supplier P6 suggested, "Higher than historical revision rate to IFC isometrics is an issue. Historically, we may have seen up to 10% of spools get revised. Now seeing a 10% revision rate as being excellent; a revision rate of 20%+ on most jobs. When spools are put on hold (regardless of whether eventually revised or not), they must be flagged, removed from the production flow, find all cut sheets for QC, paint, etc., so no one is working off of bad data." These findings extend those of Eriksson (2015), who noted that vague requirements become change orders as the project proceeds, and unexpected change orders significantly delay the suppliers' production.

Related to unclear scope is a lack of clarity around delivery dates and priorities for orders. Many suppliers mentioned the pressures on delivery when orders are late in the process. Customer requests often make unrealistic demands of supplier capabilities and capacities regarding quantity and delivery dates. Thirteen interviewees (81%) reported that the most important information for delivery is established delivery priority (ies) and required at-site (RAS) dates for materials. P3 (pipe distributor) commented that this information should be established and shared at the beginning of the contract so that suppliers could deliver materials in the contractors' desired sequence and dates. They articulated that if RAS dates were not shared with suppliers on time, the material would arrive at the site when the contractor was not ready to unload the material in terms of space, labor, and equipment. Supplier P4 reported, "Where projects always go wrong is the customer not keeping to their own schedule. The curve of drawings to be released will happen in a certain order with certain priorities, for which we reserve shop space. Thus, the changing sequence is pushing out the schedule. We always try to be flexible, but change hurts our ability to help the customer." P4 claimed that the main outcome of not being involved at the right time is not being able to meet the customer's schedule. Others (43%) noted that they barely trust the data contractors provide because of frequent changes in RAS dates. These changes also lead to confusion about which date is correct (a version control issue). These findings are in line with previous studies that showed that lack of visibility of contractor's requirements (including design, demand, updated schedules, and site-related data) disrupted suppliers to meet the schedule and cost of the contract (Dainty et al., 2001; Eriksson, 2015; Gosling et al., 2015; Dharmapalan et al., 2022). Suppliers also noted that better overall knowledge of scope and project priorities through early involvement in the project would give them a better ability to plan their internal production schedules and support the project.

The research findings confirm and extend the previous studies noting the challenges stemming from changes in scope and lack of clear priorities in delivery timing (e.g., Dharmapalan et al., 2021a). The scope is often unclear or requires clarification on orders. Suppliers also note that there is a lack of clarity around delivery priorities, and these priorities frequently change. In addition, order periods that are rushed leave little room for flexibility and can challenge the ability of suppliers to meet delivery dates. Even suppliers of standardized products note challenges here. While changes are common on projects, suppliers generally agree that better collaboration and earlier involvement in projects so they better understand scope and needs will help them support the project and meet delivery needs.

5 Conclusion

This paper examines material suppliers' perspectives on their involvement during the planning stages of the project. As noted by Ben Mahmoud et al. (2024), the literature has been predominantly drawn from the perspective of owners and contractors. There are some notable perspectives drawn from suppliers, but these are somewhat dated (e.g., Dainty et al., 2001; Hinze and Tracey, 1994) or drawn from a few case studies (e.g., Eriksson, 2015; Gosling et al., 2015). This study draws findings through an established method of theoretical saturation showing the number of samples was enough. Particularly, since material types such as custom, make-to-order, and standardized may influence the desirable involvement timing in industrial projects, this study covered all these types of suppliers in the interview. Therefore, the results supplement our understanding of current materials suppliers' perspectives systematically. Overall, the findings agree with the contention that suppliers can add value during the planning stages of projects.

A novel finding of this study is that all suppliers, regardless of type, have arguments for early involvement in planning. Suppliers report benefits to the selection of appropriate technologies, even in the case of firms selling standardized parts. Suppliers note the value of informing projects about available technologies, market conditions, and constraints. At a practical level, design and engineer-procure-construct firms in the industrial sector nominally provide this type of advice to owners; however, suppliers note their early involvement can add value here as they have the most recent information about such data. These findings have implications for collaborative contracting approaches, which currently advocate for suppliers with high value-added or design work to be included in early involvement. Collaborative contract models may achieve additional value by broadening material suppliers who should join the planning based on the potential of standardized and make-to-order suppliers. They can add value to construction project planning by providing a review of planning, increased ability to meet schedules, and up-to-date information about market status, transportation, and technologies. Thus, an implication of this research is that approaches to involving a broader range of suppliers early in the project should be explored.

The research findings in this paper stem from suppliers in the North American market that support the industrial construction

sector. As the industrial sector traditionally has large projects and international sourcing, it is reasonable to expect most of the findings to apply globally within the sector. Although this study reached theoretical saturation, future studies should extend the investigation to suppliers outside the industrial sector and North America to generalize the findings. Such expansion may identify common ground and differences depending on regions and project types. This study is a starting point for a more detailed examination. Future studies can investigate a degree of categorization beyond custom, make-to-order, and standardized to determine the best timing for involvement in project planning. For instance, further interviews with suppliers of standardized equipment will specify the dimensions of their collaboration with projects. Moreover, the dynamics of supplier relationships need to be understood in detail, including the potential for value-added from early involvement weighed against a potential loss of competition. This, in turn, will better inform research about the extent of collaborative contracting approaches and practitioners' decision-making around collaborative versus transactional purchasing arrangements.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institutional Review Board at The University of Texas at Austin. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SC: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Visualization, Writing–original draft, Writing–review and editing. WO: Conceptualization, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The author(s) declare that no Generative AI was used in the creation of this manuscript.

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