

Supplier Selection

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Abstract: Supplier selection is the process by which firms identify, evaluate, and contract with suppliers. The supplier selection process deploys a tremendous amount of a firm's financial resources. In return, firms expect significant benefits from contracting with suppliers offering high value. This article describes the typical steps of supplier selection processes: identifying suppliers, soliciting information from suppliers, setting contract terms, negotiating with suppliers, and evaluating suppliers. It highlights why each step is important, how the steps are interrelated, and how the resulting complexity provides fertile ground for ORMS research.

Today the average U.S. manufacturer spends roughly half its revenue to purchase goods and services [1]. This makes a company's success dependent on their interactions with suppliers. The role of procurement managers (buyers) within companies has become extremely important, often involving staggering dollar values: A recent cross-industry survey of companies — in areas ranging from aerospace to semiconductors — placed companies' average total spend per procurement employee at \$115 million [2].

With so much of a company's money on the line, and increasing reliance on outsourcing of many complex services and products, the job of a buyer is not only important but also challenging. Buyers must define and measure what "best value" means for the buying organization, and execute procurement decisions accordingly. To identify best value, the buyer must interface with technical, legal, and operations experts within the buyer's company, and act as an expert negotiator and coordinator across many internal and external parties.

Supplier selection is the process by which the buyer identifies, evaluates, and contracts with suppliers. The challenges mentioned above make supplier selection a fertile topic for operations and management science disciplines. There is also a growing audience for such research, as the importance of fostering talent by employing buyers with analytical expertise, general management backgrounds, and deep knowledge in a particular purchasing category becomes widespread [3].

This article is organized around the major steps involved in supplier selection. First, the buyer must identify qualified potential suppliers, as described in Section 1. Next, the buyer must evaluate these suppliers. This process is initiated when the buyer formally

solicits information from suppliers, as described in Section 2. Depending on the information request, suppliers respond by providing “bids” for the contract, specifying an offer on the contract terms, such as price, leadtime, quality, etc. Various contract terms, which relate to the type of contract up for bid, are overviewed in Section 3. Suppliers’ offers often evolve over the course of negotiation with the buyer, and negotiation processes are touched on in Section 4. Finally, as discussed in Section 5, the buyer determines which supplier or suppliers will be awarded a contract and subsequently monitors the supplier during the life of the contract to support future supplier selection iterations. Finally, Section 6 discusses ORMS research on supplier selection. While this article introduces the key steps in supplier selection, further readings in this encyclopedia can provide a more detailed picture. Pointers to such readings are suggested throughout this article; most importantly, see Article 4.4.4 for details on procurement contracts and Articles 3.3 and 3.5 for discussions about negotiations.

For consistency in the article we refer to “buyers,” but in practice the role we describe is also called procurement manager, procurement agent, or contracts manager. This article focuses on the complexities and frictions involved in supplier selection (verifying that suppliers are indeed qualified, using historical supplier performance in making award decisions, etc.). Such complexities are present in the supplier selection process for most goods and services. One possible exception are raw materials traded via commodity exchanges; such markets are specifically designed to circumvent the complexities and frictions of supplier selection by instituting highly standardized contract terms, using liquid markets to find prices, and using clearinghouses to guarantee the terms of trade. As such, commodity exchanges will not be covered in this article.

1 Identifying potential suppliers

To survive in the intensely competitive global economy, it is often critically important to not only develop existing suppliers but also to discover new suppliers. This section outlines the process of finding viable new suppliers. Subsection 1.1 first briefly motivates why a buyer might wish to find new suppliers. Subsection 1.2 explains why identifying suppliers is only part of the challenge — the buyer must also be cognizant of the need to ensure such suppliers are qualified. Supplier qualification screening processes are discussed in Subsection 1.3. Because identifying and qualifying potential suppliers can be time-consuming and costly, buyers often develop a long-term supply base consisting of qualified suppliers, as discussed in Subsection 1.4.

1.1 Importance of new suppliers

Several factors make new suppliers important. First, there may exist new suppliers that are superior in some way to a firm's existing suppliers. For example, a new supplier may have developed a novel production technology or streamlined process which allows it to significantly reduce its production costs relative to predominate production technology or processes. Or, a new supplier may have a structural cost advantage over existing suppliers, for example, due to low labor costs or favorable import/export regulations in its home country. Second, existing suppliers may go out of business, or their costs may be increasing. Third, the buyer may need additional suppliers simply to drive competition, reduce supply disruption risks, or meet other business objectives such as supplier diversity (see Subsection 5.2). In recognition of these reasons, buyers and their internal customers may be obliged by company policy to locate a minimum number of viable, potential suppliers for every product or service procured.

1.2 Reasons for supplier qualification screening

Finding a viable new supplier is challenging mainly due to the need to verify the supplier's ability to meet the buyer's myriad requirements [4]. Supplier non-performance on even the most basic level, and for the most simple commodity, can have dire consequences for the buyer, as recounted in the following nursery rhyme:

For want of a nail the shoe was lost. For want of a shoe the horse was lost.
For want of a horse the rider was lost. For want of a rider the battle was lost.
For want of a battle the kingdom was lost. And all for the want of a horseshoe
nail.

While apocryphal, the "for want of a nail" message holds a surprising degree of relevance for today's complex, global supply chains. Boeing's 787 Dreamliner production schedule was significantly affected by shortages of fasteners, essentially bolts that secure sections of the fuselage together [5]. In consumer products many product safety issues have been traced back to suppliers failing to meet a buyer's requirements, resulting in dangerous lead paint in toys [6], unsafe car tires [7], and pet food containing poisonous chemicals [8].

Production delays due to parts shortages and recalls of faulty products produced by noncompliant suppliers have cost buyer firms millions of dollars through recalls, warranty costs, and associated inventory adjustments, and have inflicted untold damage on their reputations and future sales potential. Menu Foods' market capitalization was halved after the

firm recalled its pet food in March 2007; its suppliers are suspected of mixing toxic melamine into their wheat gluten in an effort to make it appear more protein-rich [9]. New Jersey-based tire importer Foreign Tire Sales traced field failures of its tires to an unauthorized design change made by its supplier, whose design engineer decided to omit gum strips, apparently unaware of their role in preventing tread separation [7]. A surprised Foreign Tire Sales was forced by U.S. government authorities to recall a quarter of a million tires, and risked bankruptcy as a result [10].

1.3 Supplier qualification screening process

To avoid the dire outcomes of supplier non-performance, buyers typically take proactive steps to verify a supplier's qualifications prior to awarding them a contract. The primary goal of "supplier qualification screening" is to reduce the likelihood of supplier non-performance, such as late delivery, non-delivery, or delivery of non-conforming (faulty) goods. A secondary goal is simply to ensure that the supplier will be a responsible and responsive partner in the day-to-day business relationship with the buyer [4]. Supplier qualification screening involves many aspects, which are outlined below.

Reference checks. The buyer may contact previous customers and ask about the supplier's delivery performance, adherence to contract terms, what (if any) problems arose and how they were resolved, etc.

Financial status checks. The buyer may use published supplier ratings (e.g., Dunn and Bradstreet) to determine the supplier's financial status and likely financial viability in the short to medium term. For example, if the supplier has recently assumed significant debt, this may raise red flags about the possibility the supplier will declare bankruptcy before fulfilling its obligations to the buyer.

Surge capacity availability. The supplier's capacity to increase delivery quantities within short lead times is important as the buyer may be uncertain about their exact quantity needs over the life of the contract. This is particularly true for long-term contracts where demand for the buyer's product may be heavily tied to unforeseen market events (e.g., demand for an airplane manufacturer's products are highly dependent on the overall economy, which in turn periodically goes through periods of growth and contraction). Surge capacity is available when a supplier has access to second or third shifts, overtime, underutilized facilities, etc.

Indications of supplier quality. The buyer might require that suppliers have ISO 9000

certification (or similar), indicating that the supplier has policies, procedures, documentation, and training in place to ensure continuous adherence to quality standards. However, in some cases the certification documents can be misleading and/or easily forged [4]. To actually see if an adequate level of quality is achievable, the buyer may have to look deeply into the supplier's organization to ensure the supplier is capable and competent to meet the buyer's specifications.

Ability to meet specifications. To rigorously check the supplier's capabilities the buyer might: (i) Request samples of supplier products and test them to ensure conformance to the buyer's requirements. (ii) Visit the supplier's production facility and interview line workers and engineers to ensure that all members of the supplier team understand the critical features of the product in their charge. For example, a buyer seeking to purchase tires from a supplier may interview the design engineers to ensure they understand each aspect of the tire's design (for instance, the role of gum strips in preventing tread separation at high speeds). (iii) Audit the production facilities to ensure that production can and will only proceed in a manner approved by the buyer. For instance, the buyer may require the supplier to restrict their production to small batch sizes in order to prevent contamination outbreaks from spoiling the entire production run.

Buy-in from internal customer(s). Because the buyer typically acts on behalf of an internal customer within the buyer's organization, buy-in from this internal customer is a crucial step prior to contracting. For example, suppose the buyer is purchasing a complex circuit board on behalf of the engineering department (which owns responsibility for this component). To ensure that the internal customer has confidence in the supplier and is willing to work with the supplier, the buyer will set up meetings between the buyer firm's engineers responsible for the part and the supplier's engineers who would be responsible for producing it.

Supplier qualification processes are costly and can be time-consuming. As described above, the processes can involve travel to distant supplier sites. Interviews with suppliers and suppliers' customers are time-consuming. Moreover, the entire process involves not only the buyer but also internal customers throughout the buyer organization. Consequently, qualification can take weeks or months — even for commodity-type parts such as printed circuit boards.

1.4 Creating a supply base

Suppliers who have passed the qualification requirements and are eligible for contract award are commonly referred to as “pre-qualified” suppliers. If the buyer utilizes short-term contracts and frequently re-procures the same item, it typically makes sense to establish a cohort of pre-qualified suppliers who will compete for these contracts. Even if the buyer uses long-term contracts for individual items (meaning contracts for individual items are infrequently re-bid), it might still make sense to use a pre-qualified supply base: If the supply base members can potentially supply many different items, they can compete to produce whichever item’s long-term contract is up for re-bidding. Finally, using a supply base not only reduces qualification screening costs but also allows for the development of standardized contracts, terms and conditions for pre-qualified suppliers, thereby streamlining administrative processes involved in contracting.

2 Information requests to suppliers

Once the buyer has identified potential suppliers, the next step in supplier selection is to formally request that the suppliers provide information about their goods or services. While there is no agreed-upon terminology, generally the buyer makes one of three types of information requests to suppliers. The request types, each appropriate for a different situation, are described below.

Request For Information (RFI) is issued when the buyer seeks to gain market intelligence regarding what alternatives and possibilities are available to meet the buyer’s needs. Typically the buyer asks suppliers what goods and services they could potentially provide, what differentiates them from other vendors in the marketplace, etc. With an RFI the buyer does not state a particular intention to award a contract. However, since responding to an RFI is time-consuming for suppliers, generally suppliers will only respond to the RFI if they expect that the buyer will eventually issue an RFP or RFQ, which is discussed below.

Request For Proposal (RFP) is issued when the buyer has a sense of the marketplace and has a statement of work which contains a set of “performance” requirements which it needs fulfilled. For example, the RFP may describe a formed part with certain strength, flexibility, and fire resistance requirements, but not specify the particular composition of the material. Suppliers respond to the RFP with details on how they would satisfy the buyer’s performance requirements and the price they would be willing to accept to do so.

Upon learning the supplier's proposed pricing, the buyer may revise its requirements and/or negotiate exact terms with suppliers. Thus, the process is generally iterative. An RFP is appropriate for procurement of items that are non-standard or highly complex, requiring supplier input and expertise about the best way to meet the requirements set forth in the RFP.

Request For Quote (RFQ) is issued when the buyer can develop a statement of work that states the exact specifications of the good or service needed. This is the case, for example, if the buyer seeks a part made of a particular plastic and formed to a specific set of thickness, density and shape specifications. RFQs are often used in conjunction with highly structured competitive tendering processes. Typically there is no need for detailed negotiations with suppliers after bid receipt, as lowest price or some other objective criteria is used to evaluate bids. Due to their up-front specification requirements, RFQs are appropriate for procurement of items that are standard and well-known in the marketplace. For example, in the electronics industry this would include commodity components such as cables, connectors, and circuit boards.

3 Contract terms

The supplier selection process culminates in a contract between the buyer and one or more suppliers. The information received from suppliers via the requests described in Section 2 ultimately must be translated into formal contractual terms before contracting can occur. A contract with a supplier specifies what the supplier should do and how they will be paid by the buyer. At the highest possible level, contract terms relate to either monetary transfers (payment terms) or how the contract will be executed (non-payment terms). Contracts can specify any number of payment and non-payment arrangements. A few common ones are listed here to provide the reader with a sense of what types of contract terms the buyer might consider during negotiations and when making a contract award decision. The choice of the particular contract structure (e.g., long-term or short-term, fixed cost or cost plus, etc.) is beyond the scope of this article, but procurement contracts are covered in detail in Article 4.4.4.

Payment terms. In a fixed-price contract, the price term specifies what the supplier will be paid regardless of the actual cost to execute its contractual obligations. In a cost-plus contract, a formula is specified which determines how much the supplier will be paid;

for example, under a cost-plus contract the supplier could receive a fixed percentage (e.g., 107%) of the total cost incurred, or simply receive payments for time and materials. Various payments can also be specified as contingent on certain actions by the supplier (these can also take the form of penalties). Examples include a payment made only upon delivery or upon maintaining a certain target inventory service level, an award fee granted for meeting budget targets in a cost-plus contract, an award fee for completing the project within a certain timeline, etc. Liquidated damages clauses [11] can be used to specify an amount that either the buyer or supplier must pay to the counterparty upon breaching the contract.

Non-payment terms. The contract can specify all kinds of details related to how the contract will be executed, for instance, delivery quantities, delivery frequencies, delivery locations, service level, quality level, technical specifications, duration of the contract, etc. Contracts where goods must be transported typically assign “incoterms” (see [12]) defining the precise point at which the buyer takes control of the shipment (and hence the associated costs and risks).

4 Negotiation process

As we will discuss in Section 5, when making contract award decisions the buyer considers each supplier’s qualifications as well as the contract terms they offer (e.g., price). A supplier’s qualifications are generally considered exogenous, for example, a supplier’s reputation is based on historical performance and is not alterable in the short term. Contract terms, on the other hand, can be “negotiable” between the buyer and supplier. In a negotiation the buyer attempts induce favorable terms from suppliers, and likewise the suppliers attempt to induce favorable terms from the buyer. There are many different possible negotiation processes. This section overviews a few canonical negotiation processes, but a detailed discussion is reserved for Articles in 3.3 and 3.5 of this encyclopedia. For convenience we adopt the viewpoint of a buyer when discussing negotiations.

For better or worse, negotiations often are viewed as zero-sum games where the buyer gains what the supplier gives up. An extreme example of this is the **take it or leave it offer** approach whereby a powerful buyer essentially dictates the terms to the suppliers. For instance, the buyer might demand a certain price and simply refuse to consider the supplier unless they agree to this price. Take-it-or-leave-it offers are rather draconian, and buyers may be reluctant to utilize them for short-term gains if suppliers perceive them as unfair.

Furthermore, take-it-or-leave-it offers require the buyer to credibly commit to not renegotiate with the supplier should the supplier choose to reject the buyer’s offer. If the buyer cannot make such a commitment, the threat imputed in a take-it-or-leave-it offer is meaningless.

Competitive tendering is an alternative way to extract concessions from suppliers whereby suppliers are played off one another. Typically, suppliers simultaneously submit bids (in response to an RFP or RFQ). Competitive tendering approaches differ in the amount of visibility that suppliers have regarding competitors’ bids. At one extreme is the dynamic open-descending-bid format. In this format, suppliers see all bids submitted and can respond by lowering their own bid, until all but one bidder has dropped out (typically bidding lasts an hour or so, [13]). At the other extreme is the sealed-bid format in which each bid is known only to the buyer and the supplier who submitted it. U.S. government competitive tendering is typically done through sealed bidding.

It is also possible that the buyer can utilize neither competition nor take-it-or-leave-it offers. Instead, the buyer and a single supplier might **bargain** in some general and unstructured way. Negotiation processes in practice may combine take-it-or-leave-it offering, competitive tendering, and bargaining. For instance, the buyer could employ price-based competitive tendering with a reserve price (the reserve price imposes an upper bound on the amount the buyer is willing to pay for the contract and thereby acts like a take-it-or-leave-it offer) to home in on the most promising supplier, then bargain with this supplier to finalize the contract terms.

Negotiations do not always take a zero-sum approach. The buyer and supplier can potentially both benefit if they realize their incentives are aligned rather than in conflict. Research to help buyers and suppliers realize shared interests has led to numerous advances in software-enabled “expressive bidding” in combinatorial auctions; see Article 3.5.1.5. For instance, in transportation auctions for truckload procurement, both the shipper (buyer) and the carrier (supplier) benefit if the shipper’s lanes up for bid complement the carrier’s existing transportation networks in a way that minimizes empty truck movements (e.g., see [14] and references therein).

5 Supplier evaluation and contract award

This section describes how the buyer evaluates suppliers, determines the contract winner(s), and performs follow-up monitoring to inform future supplier selections. Supplier evaluation is the process by which the buyer rank orders the suppliers, as we describe in Subsection 5.1.

The buyer then uses this rank ordering, along with other business considerations, to determine which supplier(s) will be awarded the contract, as we describe in Subsection 5.2. Finally, after contract award the buyer can monitor supplier performance and use this information during future supplier selection processes as described in Subsection 5.3.

5.1 Supplier evaluation

The buyer begins the supplier evaluation process by identifying the “dimensions” it wishes to use when evaluating suppliers. [15] surveyed 76 papers on supplier selection in the purchasing literature and found that price, quality and delivery were the most commonly listed supplier evaluation dimensions. Additional dimensions are also used. [15] provides an extensive list of such dimensions, categorized by prevalence in the purchasing literature. Frequently appearing dimensions include production capacity and flexibility, technical capabilities and support, information and communication systems, financial status, and innovation and R&D. Dimensions that appear with moderate frequency in the literature include quality systems, management and organization, personnel training and development, performance history, geological location, reputation and references, packaging and handling ability, amount of past business, warranties and claim policies, procedural compliance, attitude and strategic fit, labor relations record, and desire for business. Of course, buyers often employ new dimensions in response to prevailing business issues and challenges. Dimensions that have emerged recently include environmental and social responsibility, safety awareness, domestic political stability, cultural congruence with the buyer organization, and terrorism risk. See [15] and the literature cited therein for more details.

Once suitable dimensions are identified, the ability to rank order suppliers is crucial for reaching an informed supplier selection decision. Rank ordering is simple when supplier bids are differentiated by a sole dimension such as price. This might be the case, for example, if the buyer has issued an RFQ for a highly standardized component delivered in a certain quantity by a certain date and suppliers are asked to respond with their price for the contract. However, rank ordering suppliers becomes complex when bids must be evaluated across multiple dimensions. For example, if the buyer wishes to evaluate suppliers’ bids on the dimensions of price *and* leadtime, the buyer must construct a tradeoff between these two dimensions to determine whether it prefers, say, a bid with a high price and short leadtime to a bid with a low price and long leadtime. The challenge of supplier evaluation lies in constructing this tradeoff in a way that accurately reflects the buyer’s preferences.

Research addressing this challenge dates back decades. A detailed review is beyond the scope of this article but is provided in [16]. A variety of methodologies are proposed in this literature, but the overall approach is usually one of three types. The first approach is to capture the tradeoffs with a simple relationship between the dimensions, e.g., a linear function of the dimensions. This is simple, transparent, and is often used in practice for these reasons. However, the simplicity of this approach has a downside: The buyer can find it difficult to construct weights that truly reflect its preferences. The second approach is to go beyond simple weighting in order to reflect the buyer's preferences with more detailed models. For instance, the buyer can value leadtime using inventory models from ORMS and then trade this valuation off against the price offered by the supplier. This approach is less transparent, which makes it more difficult to implement in practice. Success has been enjoyed particularly in domains in which the tradeoffs are relatively clear but how to evaluate them is not, for example, a multi-product buy in which suppliers can produce subsets of items and offer quantity discounts over the entire order. In such cases, OR tools like mathematical programming can be quite beneficial; see Article 4.6.1.3, which covers combinatorial auctions. Finally, a third approach recognizes that buyers at times find it difficult to articulate their preferences in a quantitative way, and answer this difficulty by proposing ways to infer quantitative preferences over attributes by observing the buyer's qualitative choices between options involving these attributes.

5.2 Contract award

Once the buyer has a sound methodology for evaluating suppliers, the process of contract awarding can begin. During this phase the buyer determines which supplier or suppliers to award a contract to. Supplier evaluation is a key ingredient in this process, but award decisions can hinge on more than just how the buyer evaluates the supplier.

For example, even if suppliers are closely matched the buyer may choose to award the contract to just one of them. **Sole award** contracting may be favorable if the scope of work is best accomplished by a single supplier. For example, the contract may require significant capital investments on the part of the supplier and/or buyer, creating strong economies of scale effects. Sole-award contracting may also be used if it is unduly costly or risky to deal with multiple suppliers. For example, the buyer may be sourcing an item with intellectual property value (e.g., fabricating a proprietary part) and need to closely monitor the supplier to prevent leakage of this intellectual property. A buyer outsourcing sensitive back-office

operations (e.g., processing of client data) may need to invest a tremendous amount to train its supplier to ensure robust security measures.

Likewise, even if one supplier dominates another, the buyer might choose to give business to both of them. **Multiple-award** contracting can be useful if the buyer wishes to diversify its supply sources to mitigate disruption risks (see Article 4.4.11), or if suppliers have insufficient capacity or reverse economies of scale. There are also more strategic reasons for multi-sourcing. For example, a buyer might wish to prevent any supplier from becoming a monopolist, meaning it is the only viable supplier for a particular good or service needed by the buyer. This would happen, for example, if all the supplier's competitors exited the market due to bankruptcy. A buyer facing a monopolist supplier cannot leverage competition. To avoid this fate, the buyer may award contracts to several suppliers to keep them solvent and thereby encourage their continued presence in future contract competitions.

In general, there are many considerations which might tip the scales in favor of one supplier or another, as evidenced by the long list of potential supplier evaluation dimensions provided in Subsection 5.1. The buyer might deliberately favor incumbent suppliers to foster trust and loyalty or, for example, to avoid the administrative costs of training a new supplier on the buyer's invoicing and payment procedures. Supplier location may also be a concern in a way not manifested in logistics costs. For instance, if the buyer's potential customers are governments, these customers may be more likely to purchase the buyer's products when the government's home suppliers benefit from the purchase. The buyer might also consider supplier diversity objectives when making award decisions. If the buyer organization has supplier diversity goals, preference is given to historically underrepresented or disadvantaged businesses, such as small businesses, minority- and woman-owned businesses, sheltered workshops and non-profit organizations, etc. Supplier diversity is typically not legally mandated in private industry, and the amount of preference the buyer grants to under-represented or disadvantaged businesses in any one supplier selection event is typically situation-dependent. However, specifically mandated preferences may apply to government contracts [17].

Regardless of which award criteria are used by the buyer, making such criteria transparent makes it easier for the buyer organization to monitor its contract award decisions, to ensure the reasons for contract award are sound (e.g., due to the merits of the bid). For example, a "low price wins" rule makes it difficult for procurement managers to "cheat" the buyer organization by negotiating a sweetheart deal with a supplier in return for a bribe. For these and other reasons, the U.S. government, for example, generally favors competitive negotiations for procurement with clearly announced rules for determining the winner [17].

5.3 Supplier monitoring

Many contracts specify the provision of goods over an extended duration of time, ranging from weeks to years. Monitoring supplier performance during the life of the contract has several aims. For example, it supports quality if the buyer inspects incoming goods to ensure they conform to quality specifications. Monitoring also supports cost containment: if there is a problem with quality, it can be identified and charged back to supplier. For supplier selection itself, however, monitoring is most important in so far as it helps the buyer make more informed supplier selections in the future.

In particular, during supplier evaluation the buyer may consider factors which influence the total cost of doing business with the supplier. Such costs can include, for example, the conformance and non-conformance costs which the buyer anticipates incurring during the life of the contract (e.g., costs of inspections and defect correction, respectively). (These fall under the supplier evaluation dimension of “past performance” listed in Subsection 5.1.) The buyer may forecast these costs for each supplier — see [18] for examples of how this is done in practice. These forecasts can be constructed using historical performance data collected through supplier monitoring. For instance, the supplier’s historical percentage of defective items can inform the buyer’s forecast for nonconformance costs during the life of a contract. (If, on the other hand, the supplier is new and thus the buyer’s protocols require more careful inspection of incoming material (conformance costs), this also needs to be taken into account by the buyer at the time of supplier evaluation.) Historical information about supplier performance can also be leveraged during the negotiation process with suppliers. The buyer may choose to directly incorporate this information into a competitive bidding process via a bid markup or some other means to send a clear signal to the supplier about the importance of performance; see [18].

6 Supplier selection research

Extant research on supplier selection can be divided into two broad streams. The first stream dominates the purchasing literature and identifies appropriate criteria and methods supporting supplier evaluation. The primary goals are to help the buyer decide what its objectives are, what dimensions to evaluate suppliers over, and how to evaluate suppliers using these dimensions. The second stream assumes that the buyer knows what it wants and has an existing methodology for evaluating suppliers. It focuses on decisions such as

what types of negotiation formats or contracts to employ, and how to elicit information that suppliers may be reluctant to reveal.

ORMS research on supplier selection typically falls into the second stream of research (although powerful OR tools such as math programming are also very useful in the first stream). This research typically employs parsimonious models of the supplier evaluation process, providing clean objectives for the suppliers and buyer. As such, these models often most closely align with RFQ processes for the award of a well-specified contract, for which supplier evaluation issues are relatively transparent. Typically the perspective taken is that of a buyer seeking to award a contract to one or more competing suppliers possessing private information about their cost to fulfill the contract. The competitive negotiation process is often modeled as an auction or auction-like procedure — see Article 3.5. To ensure a consistent model of behavior, typically all actors (buyer and suppliers) are assumed to be fully rational — see Article 3.3.4.

For illustrative purposes, in the next subsection we provide examples of ORMS models applicable to supplier selection. We then conclude this section, and the article, with examples of supplier selection research topics which employ such ORMS models, Subsection 6.2.

6.1 Examples of supplier selection models in ORMS

As mentioned above, ORMS supplier selection models often focus on RFQ settings. The typical setting studied is one in which it is relatively easy to evaluate supplier bids, but the supplier has private information about what contract terms (e.g., payment size) it would be willing to accept. For example, the buyer would like to find the lowest cost supplier, and each supplier i knows its cost to perform the contract is x_i while the buyer only has a prior belief that the cost follows some probability distribution F .

Auctions are common in practice and are also convenient for modeling. They are often invoked as a structured way to model the act of soliciting information (bids) from suppliers and negotiating contract terms. An auction is no more than a set of rules determining how suppliers will pass information to the buyer, and how the buyer will use this information in determining the contract award winner(s) and payment(s).

Once auction rules are combined with assumptions on the suppliers' behavior, the model can be used to predict the contract winner and payment. This perspective is quite useful for analyses, as it allows such questions as “how will different auction formats affect the contract winner and payments?” For example, suppose all bidders are fully rational. If the auction is a second-price format, it is a dominant strategy for bidders to continue

bidding down until they either win the auction or reach their true cost. This implies that for n suppliers the auction winner will be the bidder $j = \arg \min_{i=1, \dots, n} \{x_i\}$ and the expected contract price is $E[X_{2:n}]$, where $X_{2:n}$ is the second lowest order statistic of n draws from distribution F .

Thus far we have discussed buyer beliefs, auctions rules, and supplier behavior, comprising the core ingredients of many ORMS supplier selection models. Additional embellishments to the core model can be added to address specific research questions. For illustrative purposes we will briefly describe a a model of supplier qualification screening.

With an auction model, an ORMS researcher can answer questions such as “what is the effect of an additional bidder on the expected contract payment?” Clearly, the expected contract payment decreases with the number of suppliers, raising the natural question of how many suppliers the buyer should invite to its auction. From Section 1, we know that identifying suitable suppliers is costly for the buyer. This motivates ORMS supplier selection models which incorporate costs associated with supplier qualification screening. Qualification screening can be thought of as a process whereby the buyer incurs a cost to learn information about the supplier’s qualification. The following model discussion is from [19], which to our knowledge is the first paper in the ORMS and economics literature to model supplier qualification screening.

The model begins by parameterizing qualification screening requirements. To this end, define a continuum of qualification requirements, with zero representing requirements that every supplier satisfies and one representing requirements that virtually no supplier satisfies. Let $q_0 \in [0, 1]$ be the scalar along this continuum that represents the buyer’s pre-award requirements. For each supplier i , define its qualification level q_i as the maximum qualification threshold that supplier i can pass. Due to opaque qualification requirements set by the buyer (as discussed in Subsection 1.3, e.g., gaining rapport with the buyer’s internal customer), supplier i does not precisely know its true qualification level q_i , but the buyer and supplier share the common belief that q_i is distributed according to probability distribution H . This setup could model, for instance, a buyer deciding to outsource a portion of its production currently done in-house, facing new suppliers she knows little about and who in turn know little about her (possibly idiosyncratic) qualification requirements. The strictness of the buyer’s pre-award requirements is captured by $1 - H(q_0)$, the probability that $q_i \geq q_0$.

Under this model, the buyer and each supplier responding to the RFQ are equally unsure of the supplier’s qualification until costly qualification verification is undertaken by the buyer. If $q_i \geq q_0$, the buyer’s qualification process on supplier i would reveal that supplier

i is qualified. The cost the buyer would incur to do so is denoted by K , the total cost to the buyer of verifying that an individual supplier meets all requirements to be deemed qualified. For example, K may include the cost of purchasing and testing supplier products, travel to supplier facilities abroad, etc. For simplicity, this model assumes that K is the same for all suppliers. This assumption is most appropriate when suppliers are similar, at least in terms of the cost drivers of qualification, such as distance from the buyer or number of units that the buyer must purchase to run a test sample.

On the other hand, if $q_i < q_0$, supplier i would be rejected during the buyer's qualification process after failing to meet a requirement. In this latter case, how much cost would the buyer incur? Assuming that the requirements are nested (passing a larger threshold implies passing a smaller threshold, but not vice-versa), the cost strictly increases with q_i and approaches K as q_i approaches q_0 . One may assume that the cost is linear and normalized such that a threshold of zero costs zero to verify, implying that weeding out an unqualified supplier i costs the buyer $\frac{q_i}{q_0}K$. This is without loss of generality, because any nonlinear and strictly increasing cost function of q_i over $[0, q_0]$ can be renormalized to be linear by redefining q_i and renormalizing the distribution H . This completes the supplier qualification screening model.

This subsection provided a glimpse of ORMS supplier selection research models. The next subsection provides examples of ORMS supplier selection research topics which could be explored with such models.

6.2 Examples of ORMS supplier selection research

As the above discussion in the present article indicates, there are many complexities and tradeoffs involved in supplier selection, providing many opportunities for ORMS research. The following lists just a few of the complex tradeoffs that need to be understood by the buyer, illustrating the types of questions that can be addressed by ORMS research.

Timing of supplier qualification. While a buyer will typically only contract with a supplier who has passed qualification screening, a buyer may choose to consider bids from suppliers who have not yet passed qualification screening but may be needed to add competition. Delaying some or all supplier qualification screening until after bids have been tendered can save time and money wasted on qualifying suppliers who are unable to offer competitive pricing. Industrial (i.e., non-government) buyers generally do consider bids even if the supplier has not already been fully qualified (e.g., [4]). The optimal timing of supplier

qualification screening processes and price negotiations is studied in [19].

Scope of negotiations (RFPs). Future ORMS research can be expected to inform practitioners about how best to include evaluation criteria that are currently considered to be too complex or subjective. These criteria will, with more advanced research, be quantified and subject to analytical comparisons. In industry, efforts at total-cost modeling date back decades [18]. One goal for supplier selection might be to refine the total-cost or life-cycle-cost analysis so that it is more readily useable during negotiations with suppliers. To this end, ORMS research has studied so-called multi-attribute negotiation mechanisms (also called multi-attribute auctions, [20, 21]) and expressive bidding mechanisms (see Article 3.5.1.4 on combinatorial auctions), and many supplier evaluation methodologies have been developed in the purchasing literature [16].

Negotiation formats. There is a wide body of economics literature that seeks to determine which rules of negotiation (or which “mechanism”) will work well in what situation. Due to the many complexities and the variety of situations encountered in supplier selection, a natural opportunity exists to study which rules of negotiation work well in supplier selection. For example, the buyer’s preference between total-cost open-bid and sealed-bid auction formats can be driven by how dissimilar the suppliers are in terms of their non-price factors such as historical conformance and non-conformance costs [22].

Supply base design. When suppliers are concentrated in the same region, the buyer is vulnerable to cost risks such as spikes in transportation costs between the buyer’s location and the supplier region, e.g., due to a strike at the port of origin. Choosing suppliers in different regions lessens the correlation between suppliers’ total costs, but this helps the buyer only if she is able to prevent windfall profit-taking by low-cost suppliers. [23] studies the relationship between the buyer’s bargaining power (ability to prevent suppliers from taking windfall profits) and the optimal level of diversification of the supply base across regions.

Additional research topics include understanding supplier collusion and methods to mitigate its effects, and research refining the typical assumptions of ORMS supplier selection research (such as laboratory tests of bidder rationality in auctions, see Article 3.6).

The present article provides a very basic introduction to the goals, complexities, and terminology of supplier selection. Interested readers are encouraged to visit the Further

Reading section below for articles that can serve as a point of departure for further study into supplier selection.

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Further reading

Single-source models

- **Basic auction theory**

Krishna, V. 2002. *Auction Theory*, Academic Press. Pages 1-31.

- **Mechanism design**

Myerson, R. B. 1981. Optimal Auction Design, *Mathematics of Operations Research*, (6):58-73.

- **Multi-attribute auctions**

Che Y.K. 1993. Design Competition Through Multidimensional Auctions, *RAND Journal of Economics*, (24):668-680.

Multiple-source models

- **Split-award contracts**

Anton, J. J. and Yao, D. A. 1989. Split Awards, Procurement, and Innovation, *RAND Journal of Economics*, (20):538-552.

- **Quantity flexible contracts**

Dasgupta, S. and Spulber, D. F. 1990. Managing Procurement Auctions, *Information Economics and Policy*, (4):5-29.

- **Entry fees**

Seshadri, S. et al. 1991. Multiple Source Procurement Competitions, *Marketing Science*, (10):246-263.

- **Repeated sourcing events**

Rob, R. 1986. The Design of Procurement Contracts, *American Economic Review*, (76):378-389.

Competitive bidding and moral hazard

- **Bidding competition and risk-sharing**

McAfee, R. P. and McMillan, J. 1986. Bidding For Contracts: A Principal-Agent Analysis, *RAND Journal of Economics*, (17):326-338.

- **Cost plus versus price only contracts**

Bajari, P. and Tadelis, S. 2001. Incentives Versus Transaction Costs: A Theory of Procurement Contracts, *RAND Journal of Economics*, (32):387-407.