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ABSTRACT

The advent of the Internet is reshaping the landscape of B2B commerce in a significant manner. Emerging e-marketplaces are offering firms an opportunity to optimize their supply chain decisions across a variety of sourcing scenarios. In this paper, we have specifically focused on decision-making for systematic sourcing of make-to-order (MTO) items. We minimize sourcing and purchasing costs in the presence of fixed costs, shared capacity constraints, and volume-based discounts for bundles of items. We consider a private-exchange that facilitates collaborative sourcing and enables a buyer firm to aggregate demand across different units to gain savings from volume-based discounts on individual items or groups of items, avoiding the duplication of tooling investments, and reducing setup costs. Due to the computational complexity of this problem, we develop a heuristic procedure based on Lagrangian relaxation technique to solve the problem. The computational results show that the procedure is effective under a variety of scenarios.

INTRODUCTION

In 1998, public exchanges were touted to offer large corporations with substantial savings in their procurement costs. A multitude of public electronic B2B exchanges mushroomed across a large number of industries that initially seemed attractive to large corporations. Everyone from automakers to plastics and metals manufacturers jumped into a frenzy to promote these third-party marketplaces. However, the euphoria eroded quickly as firms began to recognize the challenge of making a drastic switch from traditional procurement that is primarily based on developing and managing personal relationships to one driven by cutthroat competitive bidding in a public electronic exchange environment. Subsequently, it created serious reservations in the minds of both buyers and suppliers. Suppliers balked to join these exchanges primarily because of the perceived threat of being unduly squeezed by large buyers. Even buyers did not like the notion of advertising to their competitors their every need.

Today, a growing number of companies are turning to private exchanges to establish links with a specially invited group of suppliers and partners. These suppliers are generally certified and are preferred because of their overall ability to support the procurement needs of the buyer. Companies such as Hewlett-Packard, International Business Machines Corp., and Wal-Mart Stores Inc. are already operating substantial private exchanges. In contrast to a public exchange, a private exchange allows firms to automate their procurement and collaborate with trusted suppliers in real time without having to risk providing sensitive information to unwanted eyes. They also don't have to give control of their precious supply chains to third parties that may also use them to serve competitors. A firm may set up a private exchange with its suppliers for a variety of reasons. Some are set up between a company and its suppliers to purchase goods and track their whereabouts. Companies like Ace Hardware use the system to enhance the effectiveness of matching demand and supply by establishing visibility between suppliers, distribution centers, and retailers. Others may develop one to strengthen relationships and facilitate and consolidate commerce among subsidiaries within a company.

In addition, a company may generally choose to operate through their private exchange for bulk of their procurement, but choose to participate in a public exchange as and when required. A private exchange may also be setup by a major supplier to link it with its downstream customers in the supply chain. Trane Company, a maker of air-conditioner parts operates a private exchange that allows its 5000 dealers to browse, purchase equipment, schedule orders, and process warranties. This has provided Trane Company with a greater efficiency without losing control of the presentation of its brand name or running the risk of rubbing elbows with competitors in an open exchange [1]. Dana Corporation, a major automotive supplier is operating a private exchange in addition to being a part of Covisint, an exchange supported by General Motors, Ford, and DiamlerChrysler.

MOTIVATION

AMR Research now calls private exchanges the cornerstone of B2B commerce and predicts that most of the $5.7 trillion in commerce transacted over the Internet by 2004 will pass through a private exchange [2]. It also predicts that the world's largest firms will spend somewhere between $50 million and $100 million each to build the infrastructure for their private exchange. Based on the lessons learned from a rapid growth and quick demise of public exchanges in 2000, a key factor that will govern the fate of these private exchanges is the extent to which buyers and suppliers in a private exchange can strike a balance between the cost efficiencies of competitive bidding using electronic transactions and the need to maintain strong personal relationships that is central to effective procurement in these large firms.

Major manufacturers have been relatively successful in getting their suppliers to join their private exchange. Hewlett-Packard, which makes computers, printers, and a variety of technology-based gadgets, outsources most of its manufacturing activity. Their supplier for computer keyboards contracts with an injection molder that in turn contracts with a plastic resin manufacturer. H-P developed a web-enabled system that provides visibility to their preferred suppliers all through the supply chain.

IBM started moving its supplier relations to the Web in 1998 in the spirit of a private exchange in spite of the fact that prevailing conventional wisdom was predicting a sustainable thrust towards big public exchanges. The system linked over 20,000 IBM suppliers, from keyboard and monitor manufacturers to makers of chips and storage devices. According to John Paterson, IBM's chief procurement officer, their Web procurement strategy is estimated to have saved them $400 million in 2000.

The motivation for this research is to develop a decision-making framework for e-marketplaces that address an engineered or make-to-order (MTO) environment entailing a deeper level of collaboration between buyers and suppliers. Specifically, we focus on how buyers' demand for customized and engineered products can be aggregated or bundled by such an exchange. The exchange provides value-added services to the buyers and sellers by using a decision framework to make the supplier allocation decisions after taking into account the supplier capabilities and their cost structure. We specifically model the supplier fixed costs from setups, tooling, and building relationships, and make this an integral part of the exchange's decision model. Our proposed model is described in more detail next.

BRIEF LITERATURE REVIEW

Kaplan and Sawhney [6] provide a conceptual framework to understand the link between the nature of opportunity and incentive for suppliers and buyers to interact in a B2B marketplace that leads to a specific configuration of the marketspace. Recently, several researchers have recognized the opportunity for operations research to add value in gaining the efficiencies being sought through B2B marketplaces (Geoffrion and Krishnan [5], Sodhi [9], Keshinocak and Tayur, [7]). Optimizing vendor selection and allocations decisions offer a significant opportunity to gain cost efficiencies in this setting.

A vast majority of the previous research in sourcing has addressed strategic and tactical issues using conceptual or survey based methodology (Soukup [10], Timmerman [11]). There is limited work that provides a decision support framework using mathematical models (Bender et al, [3], Weber at al, [12], Rosenblatt, et al, [8]). We believe that the advent of sophisticated enterprise resource planning systems provide a greater opportunity to track costs to assess the model parameters required in these models. In the past, model parameter estimation has been difficult and has seriously limited the applicability of normative models in both research and practice in the area of sourcing and purchasing management. The ability to embed decision support systems in the electronic exchanges provides an opportunity to bring enhanced rigor to the field of purchasing management.

This paper is an early attempt to provide a framework and a normative model to enable a firm to realize the savings from reverse aggregation in a private or public exchange environment. The paper is primarily focused on a make-to-order approach in a private exchange environment. The model can be easily extended to both make-to-stock and make-to-order procurement approaches in both private and public exchange environments without loss of tractability. However, the reverse aggregation for distinct firms in a public exchange raises additional issues about how the buyers would share the savings gained by participating in an exchange.

MODEL

Overview

We model a private exchange wherein different units of a major manufacturer procure a range of items from a potential set of certified suppliers that are invited to be a part of the exchange. This private exchange is setup by the major manufacturer to consolidate and coordinate requirements across multiple divisions, different business units, and facilities within a company. Each of these units within the company represents a buyer. The manufacturer is assumed to have the ability to coordinate the needs of its various units and consolidate the requirements for a given item across different units. These manufactured items need significant tooling that need to be duplicated across all selected supplies. The buyer also incurs a fixed administrative cost of maintaining a relationship with a chosen supplier. The suppliers have a wide range of generic process technologies that will share capacity across a given set of items. Further, there might be some additional savings due to shared set-up across a family of items, if the buyer were to procure a bundle of items from a given supplier. An interested supplier offers an incentive to the buyer by quoting a price structure that is a function both the bundle of items and the associated volume being procured by the buyer. The supplier declares the total capacity available to provide an item individually or as part of a bundle that shares this common production resource. In this make-to-order environment, the decision variables are the set of suppliers selected to supply an item and the associated volumes that will be contracted.

Notation

The following notation will be used throughout the paper:

I	set of suppliers
J	set of items
B_i	set of bundles for supplier i

D_j demand for item j

MD_{ijb_i} minimumrequirement for item j as part of bundle b_i for supplier i

RC_i fixed cost of establishing a relationship with supplier i

TC_{ij} tooling cost for supplier i to manufacture item j

SC_{ibi} setup cost incurred by supplier i to manufacture bundle bi

vc_{ijb_i} purchase cost for a unit of item j procured from supplier i' s bundle b_i

max_{ij} maximum capacity for supplier i to produce item j alone

The decision variables are

V_{ijb_i} = number of units of item j procured from supplier i's bundle b_i

$$Xij = \begin{cases} 1 & \text{if supplier } i \text{ supplies item } j \\ 0 & \text{otherwise} \end{cases}$$

$$Y_i = \begin{cases} 1 & \text{if supplier } i \text{ is selected} \\ 0 & \text{otherwise} \end{cases}$$

$$U_{ib_i} = \begin{cases} 1 & \text{if bundle } b_i \text{ from supplier } i \text{ is selected} \\ 0 & \text{otherwise} \end{cases}$$

Formulation

Minimize

$$\sum_{i\in I} RC_i Y_i + \sum_{i\in I}\sum_{j\in J} TC_{ij} X_{ij} + \sum_{i\in I}\sum_{b_i\in B_I} SC_{ib_i} U_{ib_i} + \sum_{i\in I}\sum_{j\in J}\sum_{b_i\in B_I} vc_{ijb_i} V_{ijb_i}$$

Subject to

$$X_{ij} \le Y_i \qquad \forall i\in I, \forall j\in J \qquad (1)$$

$$\sum_i \sum_{b_i} V_{ijb_i} \ge D_j \qquad \forall j\in J \qquad (2)$$

$$V_{ijb_i} \ge MD_{ijb_i} \qquad \forall i\in I, \forall b_i\in B_I, \forall j\in J \qquad (3)$$

$$V_{ijb_i} \le Max_{ij} X_{ij} \qquad \forall i\in I, \forall j\in J \qquad (4)$$

$$\sum_j V_{ijb_i}/Max_{ij} \le U_{ib_i} \qquad \forall i\in I, \forall b_i\in B_I \qquad (5)$$

$$\sum_{b_i}\sum_j V_{ijb_i}/Max_{ij} \le 1 \qquad \forall i\in I \qquad (6)$$

$$Y_i \le \sum_{b_i} U_{ib_i} \qquad \forall i\in I, \forall b_i\in B_I \qquad (7)$$

$Y_i, X_{ij}, U_{ibi} \in B^+$

$V_{ijbi} \in Z^+$

Constraint set 1 indicates the relationship between the supplier and the item. Thus a supplier can supply a particular item only if the supplier is selected. Constraint set (2) enforces the demand constraint, i.e. the minimum demand for all the items must be met. If items are bundled then there is often a minimum quantity requirement on the number of individual items, which form a part of the bundle. This is given by constraint set (3). Constraint set (4) limits the number of units of an item that can be sourced from a supplier to his maximum capacity for producing that item alone. Constraints sets (5) and (6) are the capacity constraints on the suppliers. Set (5) is on the capacity of the bundle and (6) is on the total supplier capacity. If a supplier is selected then he has to supply some bundle. This is enforced by constraint set (7).

Solution Procedure

We employ a Lagrangian relaxation procedure (Fisher [4]) that has been utilized successfully in other complex problems. Additionally, this technique develops a heuristic solution procedure for the problem. The heuristic procedure is developed as an integral part of a subgradient optimization algorithm. Therefore, when the subgradient optimization procedure terminates, the user is provided with, not only a good feasible solution to the problem, but also with a lower bound on the optimal solution value. The gap between this lower bound and the best feasible solution value provided by the heuristic is used to judge the quality of the feasible solutions provided by this procedure.

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