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Negotiation support for Make-To-Order operations in business-to-business electronic commerce

T. Calosso, M. Cantamessa*, M. Gualano

Dipartimento di Sistemi di Produzione ed Economia dell'Azienda Politecnico di Torino – Corso Duca degli Abruzzi 24, 10129 Torino, Italy

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Abstract

This paper deals with the problem of supporting negotiations among manufacturing firms that operate on a Make To Order (MTO) basis. First, an analytical model of negotiation between a generic customer–supplier pair is presented. Then, the paper proposes a system based upon an intervenor which allows the parties to reach efficient utility-sharing solutions. Results of numerical experiments in an industrial environment are reported.

Keywords: Make-To-Order operations; Production planning; Multidimensional negotiation

1. Introduction

In many industries, the value chain is fragmented both horizontally and vertically and manufacturing firms operate on a Make to Order basis. In this scenario, firms negotiate on Requests For Quotation (RFQs) issued by customers and upon bids submitted by suppliers. In Make to Order operations, manufacturing activities are strongly order-specific. This reduces the relative importance of inventory planning with respect to the planning of manufacturing capacity. It can therefore be stated that in MTO operations, the commodity being traded consists in production capacity, rather than in physical goods. For both suppliers and customers, the negotiation process will therefore be tightly integrated to production planning, with price and the due date of the order being the main dimensions on which negotiation occurs.

The complexity of the negotiation process and its tight relationship to production planning may be considered to be a significant hindrance to the diffusion of business-to-business (B2B) electronic commerce. In the absence of appropriate systems which are able to support this crucial process, firms will continue to rely upon human expertise. This constitutes a bottleneck on the number of negotiation processes that can be managed at the same time and does not allow firms to take advantage of all of the trading opportunities that arise from the association to a B2B trading platform or an electronic marketplace. To put it more directly, if the process of order negotiation and production planning must anyway go through the mind of a manager who cannot avail him/herself of an adequate decision-support system, then it would not make a great difference to run the process on a traditional medium such as a telephone.

The following section presents some basic concepts of negotiation theory. Section 3 discusses an analytical model of negotiation among a customer–supplier pair who try to agree upon the two dimensions of price and due date. Section 4 presents mathematical programming models that can support customers and suppliers optimise their local production plan in view of negotiation. Finally, Section 5 proposes an intervenor, i.e. a third-party entity that may facilitate negotiations occurring in a single customer-multisupplier environment. Preliminary experiments on the application of an intervenor in an industrial setting are then briefly described.

2. Elements of negotiation theory

The topic of negotiation has been studied within a number of different disciplinary areas, each tackling the

*Corresponding author. Fax: +390115647299.
E-mail address: marco.cantamessa@polito.it (M. Cantamessa).

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subject from a specific perspective. In the domain of manufacturing systems engineering, negotiation has been a popular concept associated to agent-based manufacturing systems (see Krothapalli and Tirupati [1] for a review). In this stream of research the agents undertaking negotiation represent the resources belonging to a same manufacturing system, and negotiation is used as a time-efficient technique for obtaining a decentralised solution to a complex scheduling problem. This specific context has pushed research towards the issue of analysing alternative negotiation protocols, while local decision making by the agents has purposely been kept as simple as possible. When dealing with different firms which operate as profit-maximising agents in a value chain, local decision-making becomes more important and must be tackled appropriately. In this paper, the negotiation process has been approached by borrowing concepts from different fields such as economics [2,3], negotiation support systems [4] and decision-making [5]. This is obviously not a comprehensive list of references, but, with the brief literature review in [6], it is a starting point for readers interested in the topic. A few main concepts serving as a basis for the discussion are now presented, following the formal terminology introduced in [4].

2.1. Main concepts in negotiation theory

A negotiation is essentially characterised by the number N of issues, or objects, being simultaneously contracted upon. Each issue is defined by the dimensions that are relevant to the parties involved. In formal terms, this implies the existence of a dimension function $D(I)=\{D_1,D_2,\ldots,D_m\}$ which identifies all the m dimensions of issue I. For each dimension there should also be a range function $r_i=r(D_i)$ defining their limits in the negotiation space they are going to define. In this way, the issue space is represented by the Cartesian product between all the range functions, $I=r_1\times r_2\times\cdots\times r_m$. In the case of multiple issues, the entire negotiation region may be explicated as $I=I_1\times I_2\times\cdots\times I_N$ with N being the number of issues. The set of points of the negotiation region in which a party is willing to take part in the bargain is called acceptance region for that party and is indicated as $ACCEPT_i=ACCEPT_i(I, e_i, R, A, t)\subseteq I, \forall e_i \in E$, where R is a set of rules, A refers to the presence of an intervenor, as later discussed, and t is the time to which the region is related. The solution of the negotiation—if it exists—belongs to the agreement region, which is defined as the intersection between the acceptance regions of each party, $AGREE^I=\cap_i ACCEPT_i$

For the sake of simplicity, this paper assumes an individual decision-maker in each firm, neglects reputation effects that may—in the context of repetitive negotiation processes—bias the behaviour of parties and covers a single issue (i.e., only one order is negotiated at the same time) defined on two dimensions—order price and due date.

2.2. Intervenors

Negotiation processes may be facilitated by agents called intervenors. Intervenor roles are usually classified in four main categories. A facilitator is a person who simply brings the parties to the negotiation table and supports them in the implementation of the agreement. A moderator helps the parties understand their needs and suggests possible agreement solutions, albeit without being allowed to impose one. An arbitrator has the authority to decide on the resolution of the bargain in the event that disputants do not reach an agreement by themselves. Finally, a rules manipulator has the power to decide or change the rules and the process which are to be followed by the parties during the negotiation process.

2.3. Utility functions and the Pareto-efficient frontier

Let us consider a pair of agents involved in a negotiation and let us suppose that the utility of each party as a function of the dimensions relevant to the negotiation is known. It is therefore possible to express the utility of the first agent as a function of the second agent's and to plot the two utilities associated to each point of the negotiation space (i.e., to each alternative) in a two-dimensional space. The set of points where, given the utility of one participant, the utility of the other party is the maximum possible is called the Pareto efficient frontier. Parties acting rationally will reach an agreement lying on the Pareto efficient frontier, since a different solution could be improved with an increase in the utility of one party without lowering the utility of the other.

The set of all the solutions that are at the same time individually rational and Pareto-efficient is called bargaining set. Individual rationality is concerned with the willingness of a party to participate in the negotiation. This will occur for those points of the negotiation region which grant the party a utility that is at least as large as the one that he could achieve on his own if an agreement were not reached. The acronym BATNA (Best Alternative To a Negotiated Agreement) is often used in this context. An example is given in Fig. 1, where the utility of negotiator 2 is drawn as a function of the utility of negotiator 1, thus defining the Pareto efficient frontier. The bargaining set is a subset of the Pareto efficient frontier (the bold line), delimited by the individually rational point at $\boldsymbol{\delta}$, which depends upon the BATNAs of the parties (respectively δ_1 and δ_2) (Fig. 2).