Production planning and automated negotiation for SMEs: An agent based e-procurement application

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ABSTRACT

The research proposes an agent based approach, properly linked to production planning activities, able to support negotiation in catalogue based e-marketplace. In this context, production planning tools allow the creation of a link between commercialization and manufacturing activities, providing a better service for all the involved agents. At the same time negotiation tools take into account buyers' and sellers' identities and goals, providing better global satisfaction. A discrete event simulation environment has been properly developed. The simulation results show how to obtain an "e-marketplace mapping" in order to evaluate the real value added in a dynamic environment. This information can support Small and Medium Enterprises in e-marketplace adoption decision making process.

1. Introduction

The development of Information and Communication Technologies (ICT) is greatly changing the way to do business for several manufacturing companies. Especially, Business-to-Business (B2B) applications are demonstrating the capacity to provide real value to manufacturing industries by allowing better global performances. Some researchers are indicating that large manufacturers have adopted B2B e-commerce leaving their suppliers, mostly Small and Medium Enterprises (SMEs), in the manufacturing sector, with little choice but to follow. A recent survey of the Aberdeen Group (2006) evaluated the following benefits for companies that adopt B2B strategies:

- reduction of their requisition-to-order cycles by 75%;
- reduction of their requisition-to-order costs by 48%;
- reduction of their maverick spends by 36%.

The following table reports the trend of the e-procurement applications upon 2001 and 2006 (Table 1).

It is, therefore, very important for SMEs' managers to understand the impact of these activities on their organizations' performance and competitiveness. The literature on e-commerce (Favier et al., 2000) reveals a number of associated benefits. First of all the SMEs can access international markets at minimal cost: it can represent one crucial competitive advantage for SMEs.

Second, it can be obtained at a reduction in transaction costs, especially for e-procurement and economies of scale such as consolidation of sales or group buying. Taking a broader perspective, it can be summarized that e-commerce generates positive impacts on operations management and improves efficiency and effectiveness. Third, in a manufacturing context, e-commerce creates potential opportunities such as faster product design, speedier ordering of parts and components, reduced lead times and lower inventory costs. Moreover, according to Barrat and Rosdahl (2002) it is fundamental to reduce waste and inefficiency in highly fragmented industries, by increasing visibility and a neutral knowledge base for both buyers and sellers. Buyers or sellers usually do not establish such marketplaces, which are frequently set up by an independent company such as an ICT provider or a bank. This is because the external "third part" aims to put together separate group of buyers and sellers in order to establish a sort of "procurement virtual district". The seller benefits generally come from getting access to more buyers expanding its market, while the buyer benefits come from the possibility to get lower procurement costs, wider choice of products and better quality. Differently, the owner gets its income from the transaction fees and eventually from some added value service such as secure transactions or financial services. In such e-marketplace, procurement actions are usually catalogue-based and the relation among traders is generally based on a repetitive "one-off" trade that ends along with the specific transaction, even if several transactions can take place among the same partners in forthcoming periods (Hoffman et al., 2002). Using a broader perspective, e-marketplaces can be classified in: Maintenance, Repair and Operations (MRO) Hubs, Catalogue, Yield Managers and Exchange. Differently, according to

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Table 1
E-Procurement performance.

Performance area	2001	2004	2006
Total suppliers enabled	30	253	361
Total end-users	1000	2309	1381
Users: current vs. planned (%)	12%	43.5%	68%
Transactions per month	1340	5244	2977
Percentage of indirect spend managed by system	18%	37.6%	55%
Percentage of services spend managed by system	–	32.7%	29.3%
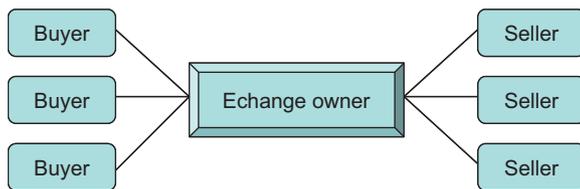
Fig. 1. A private neutral linear e-marketplace.

the buyers' actions, they can be organized in Horizontal and Vertical and, focusing on their centricity, in Buyer Centric, Seller Centric, Neutral linear and Neutral exponential (Grieger, 2003). In particular, in this paper it will be considered a private neutral linear e-marketplace, owned by a third independent part. It is supposed the existence of a set of registered buyers (also called customers) and a set of registered sellers (also called suppliers). They are allowed to play procurement actions (see Fig. 1). Examples of such e-marketplaces are CPGmarket, Tribon Marketplace, ChemConnect, etc.

Specifically, the research presented in this paper aims at understanding what kind of advantages buyers and sellers can gain by the implementation of value added services in an e-marketplace. This kind of business model is most promising for Small and Medium Enterprises (Ordanini et al., 2004). The context of the research is a neutral linear marketplace where a set of registered agents operate in a Make to Order environment. The value added services are concerning: Multi Agent System methodology, negotiation and production planning tools linked among them. Moreover, a simulation environment has been developed in order to test the proposed methodologies in different dynamic conditions. The paper is structured as follows: Section 2 provides a literature review about Multi Agent Systems (MAS) and negotiation tools in B2B applications, the e-market-place context is described in Section 3; in Section 4 the negotiation process is explained and in Section 5 the production planning model is described; in Section 6 the developed simulation environment is briefly presented and the case study is analyzed. The simulation results are reported in Section 7. Finally, conclusions and further research paths are drawn in Section 8.

2. Literature review

Recently, many papers have addressed the problem of developing electronic services, like e-procurement, combined with intelligent decision support systems by the creation of intelligent distributed systems like Multi Agent Systems (MAS) (Maes et al., 1999; Kim and Lee, 2002); also, there exist many research applying agents in B2B e-procurement: in this field, automated negotiation is one of the most utilized approach. Bartolini et al. (2002) analyzed the literature about the intelligence agent in automated negotiation approach. They

developed a negotiation protocol adopting the Foundation for Intelligent Physical Agent (FIPA) standard from a software engineering perspective in a MAS environment. The generalized protocol proposed here has been implemented by using Java Agent DEvelopment Framework (JADE) and it represents a good example of an application for an English auction mechanism. Benyoucef et al. (2002) proposed a rule-driven approach to represent, manage and explore negotiation strategies and coordination information. For that, they divided the behaviour of negotiating agents into protocols, strategies and coordination. They developed simulation examples for both English and Dutch auctions and implemented simple coordination schemes across several auctions. Dumas et al. (2005) proposed an approach to develop bidding agents that participate in multiple alternative auctions, with the goal of obtaining an item with a given probability. The approach consists of a prediction method and a planning algorithm. The prediction method exploits the history of past auctions in order to build probability functions capturing the belief that a bid of a given price may win a given auction. The planning algorithm computes a price, such that by sequentially bidding in a subset of the relevant auctions the agent can obtain the item at that price with the desired probability. The approach addresses the case where the auctions are for substitutive items with different values. Experimental results showed that the approach increases the payoff of their users and the welfare of the market. In the same direction is the work of Wurman et al. (2002): it examined the design space of an auction mechanism and identified the related core activities. The detected formal parameters, qualifying the performance core activities, enable precise specification of auction rules: this specification constitutes an auction description language that can be employed in the implementation of configurable marketplaces. Differently from auction is the approach of Oliver (1997) and Choi et al. (2001): they developed a genetic algorithm to select offers for agents to negotiate with other agents. The strong limitation of this approach, based on genetic algorithms, is the high numbers of trials it needs to achieve good strategies in each round of negotiation. In the same direction, Perrone et al. (2003) presented a new methodology for e-marketplace design. The workflow management methodologies for the conceptual design activities, the agent-based technologies for the implementation phases and open source IT tools for both software platform development and simulative environment (able to test the proposed Multi Agent Architecture) have been utilized. Neubert et al. (2004) proposed a software agent, capable of conducting an automated negotiation in order to assist the human decision-maker in an environment consisting of small independent units. The considered agent can perform an integrative negotiation about multiple interdependent properties of the supply contract, such as price, volume and delivery date. The paper developed a single agent and tested the generation of the offers. Therefore, the main limit of this research is the lack of integration in a Multi Agent System consisting of opponent actors. Wang and Benaroch (2004) investigated agents' decisions on whether or not to join a B2B electronic market. The authors founded that their decisions depend on the revenue structure of the e-market owner. In particular, the buyer pays the supplier to join the e-markets, if the transaction percentage charged to the supplier is lower than the maximum Pareto-improving transaction percentage. The authors did not study the auctioning processes and mechanisms among suppliers in the e-market.

Guillén et al. (2005) presented a novel approach that provides decision support in making optimal offer proposals during the negotiation process between customers and suppliers that takes place in chemical industry supply chains. The main difference with the research proposed in this paper is related to the industry