Optimizing Procurement Decisions in Networked Virtual Enterprises

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ABSTRACT

A virtual enterprise is an ad hoc coalition of independent business entities who collaborate on the manufacturing of complex products in a networked environment. This collaboration is enabled by the concept of a transaction, a mechanism with which members acquire necessary components from other members. An external procurement request submitted to the enterprise launches a tree-structured series of transactions among its members (similar to supply chains). Each such transaction is associated with a purchase price, but also with a risk of failure. That members have the option to procure components from different co-members, each charging its individual price and posing its specific risk, raises challenging optimization problems related to the fulfillment of business objectives. This paper defines a transaction model for virtual enterprises, with formal concepts such as price, risk, and business objectives. The Decision Guidance Query Language (DGQL) is presented, a language for modeling and solving optimization problems in a database setting, and shows how DGQL can provide intuitive and efficient solutions to the optimization problems raised in the model. The model, the optimization programs, and the experimentation promote strong collaboration and common objectives among its members, and one in which collaboration is limited, with members retaining much of their autonomy and individual objectives.

Keywords: Collaborative Decision Making, Decision Support, Optimization, Supply Chain, Transaction, Virtual Enterprise

INTRODUCTION

A virtual enterprise is a coalition of autonomous business entities, usually of small or medium scale, who collaborate on the manufacturing of complex products, often with the intention of competing with large, monolithic enterprises. The members of a virtual enterprise often possess complementary skills and technologies whose combination is deemed necessary for the target product, and the collaboration is often ad

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hoc, for a specific product only, after which the virtual enterprise might dissolve.

Within this general framework, the level of collaboration among enterprise members, and the extent of sharing of information and strategic decisions can vary substantially, creating virtual enterprises of significantly different styles. In one setup, enterprise members preserve their independence to the greatest degree possible. They share only a minimal amount of information (e.g., the products they are willing to make available to others and the prices they charge), and they optimize their performance according to their own interests and criteria. At the opposite extreme, enterprise members share all their information (e.g., manufacturing processes, sources of supply, costs, and risks), and abide by a global optimization process that instructs them on their production steps. We refer to the former setup as an autonomous enterprise, and to the latter as a coordinated enterprise.

The primary means for enabling collaborations in virtual enterprises are transactions: bilateral exchanges between two enterprise members in which goods are delivered in return for payment. The fulfillment of a target product may thus propagate into a tree-structured set of transactions among the members of the enterprise. Since the same product can often be procured from multiple enterprise members, a target product may be fulfilled with alternative transaction trees. Since each procurement decision is associated with performance parameters such as product price and the risk of non-delivery, members must select their transaction partners judiciously. This presents substantial optimization challenges.

In this paper we explore issues of optimal decision making in virtual enterprises using the Decision Guidance Query Language (DGQL), a language for solving decision optimization problems. A brief overview of the language is provided in the section *The Decision Guidance Query Language*. The section that follows it describes our formal model for virtual enterprise transactions, including concepts such as transaction cost, product price, and procurement risk. Using expected profit as optimization target, the subsequent section presents the DGQL programs for two types of virtual enterprises: autonomous and coordinated. A system that implements (compiles and executes) such DGQL programs is described in the next section. This section also reports on experiments with both autonomous and coordinated virtual enterprises. The final section summarizes our findings and suggests various directions for future work. We begin with a brief review of work related to this research.

**BACKGROUND**

To put this work in context, we review briefly of related work in two areas: virtual enterprises and optimization tools.

**VIRTUAL ENTERPRISES**

Cooperatives of independent entities that collaborate on the manufacturing of goods have been around for decades. Often the members of such cooperatives reside in the same industrial district. This geographical proximity provides advantages of common culture and mutual trust (Brusco, 1992). The collaborating entities are often of small and medium size, and their strategic approach is to focus on their core business (i.e., excel in a limited section of the “value chain”), and to seek collaborations with neighboring entities to perform the other requisite activities in the value chain.

Essentially, virtual enterprises (also referred to as virtual organizations or corporations) are modern versions of these cooperatives, from which geographical constraints have been removed. By means of communications and information technology, the entities participating in an alliance need not be confined to a particular location. Virtual enterprises are often characterized as agile, flexible, dynamic, proactive, and unconstrained by predefined structures. The essential principles of virtual enterprises may be summarized thus (Davidow & Malone, 1992; Goldman, Nagel, & Preiss, 1995; Camarinha-Matos, 2003; Barbini & D’Atri,
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