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MODELING INFORMATION FOR MANUFACTURING-ORIENTED SUPPLY-CHAIN SIMULATIONS

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ABSTRACT

This paper discusses a new approach that facilitates the use of simulation in supply chain applications, especially for manufacturing-related activities. A neutral information representation methodology, which is based on the eXtensible Markup Language (XML), referred to as the Manufacturing Information Model for Simulation (MIMS), is being developed at NIST to address the needs of information integration and exchange along supply chain applications. This information model can be applied to create a data-driven simulation that supports supply chain optimization. An example of a manufacturing-oriented supply-chain simulation is also discussed.

1 INTRODUCTION

The irreversible process of globalization and virtual enterprise development has fundamentally changed the way enterprises do business. To meet these complex challenges, companies are realizing that information technology is more than a tool -- it is a strategic weapon. Enterprises recognize that they need a seamless integration of design, engineering, manufacturing, and distribution systems and processes to succeed. With respect to their supply chains, enterprises are faced with the urgent requirement to develop supply chain strategies that allow them to stay ahead of the competition and to achieve their growth and profitability objectives. In fact, a responsive supply chain is increasingly a requirement just to maintain existing levels of business activity (Kleijnen and Smits 2003, Kubota et al. 1999).

For manufacturing enterprises, a delay in the supply of a component can lead to reduced productivity and increased waste. Many supply chain management (SCM) researchers focus on developing the demand planning, inventory planning, and replenishment planning capabilities needed to deliver the right products to the right customers at the right time. These problems, while complex, are logistics problems. For supply chain management to support the actual production of products, more issues need to be addressed. There is definitely a need for issues relating to material handling, warehousing, transportation, etc., to be addressed, but there is also a need for problems relating to the efficient and effective sequencing and execution of manufacturing processes to be solved.

Supply chain simulation is an effective way to allow industrial partners to analyze the state of their supply chains. In supply chain simulations, the manufacturing activities needed to produce a product, as well as the associated information flows necessary to support the manufacturing process, are evaluated along with the logistical concerns of getting the right materials to the right place (supplier, factory, transportation system, warehouse, etc.) at the right time.

Supply chain simulation can help to reduce costs and improve customer service. Supply chain simulation can be used to develop strategies for dealing with situations that might affect their supply chains, whether those situations involve adverse business conditions for which mitigating strategies must be developed, or new business opportunities that might require modifying of expanding the existing supply chain structure. Supply chain processes can be analyzed and optimized to increase their speed and effectiveness.

The objective of the research described in this paper is the development of a comprehensive approach that improves the information exchange for supply-chain supporting applications, especially supply-chain simulation. Three issues will be discussed: (1) determining the information needed for supply chain simulation applications; (2) modeling supply-chain information to enable effective exchange; and (3) the application of supply-chain simulation in the manufacturing environment.

2 INFORMATION REPRESENTATION AND EXCHANGE: A KEY CHALLENGE FOR SUPPLY CHAIN APPLICATIONS

Manufacturing processes can be very complex, especially for products with thousands or millions of parts such as airplanes and automobiles. A smoothly operating supply chain is very important for successfully producing these products. Moreover, in today's ever-growing consumer-driven market environment, supply chains need to be able to quickly respond to changing market conditions by efficiently managing production and inventory levels. To support the management and analysis of complex supply chains, many kinds of supply chain management applications have been developed, including simulations of supply chain operations (Tan et al. 2003). To create applications that can manage, analyze, or simulate supply chain operations, two problems must be overcome:

1. Conceptually, how should the information about the supply chain be represented?
2. How can this conceptual model be realized to facilitate application development and information exchange between supply chain applications?

Several recent efforts have been undertaken by different organizations to tackle these problems. The Supply Chain Operations Reference-model (SCOR), developed by the Supply Chain Council, is a process reference model designed to facilitate communication between supply chain partners. It defines a standard for common terms used to describe supply chain processes. Following the SCOR approach, companies have a framework to describe supply chain configurations, specify common measurements to understand the performance of the supply chain, which in turn allows them to evaluate different supply chain configurations. As a reference model, SCOR provides a conceptual framework for companies to assess their supply chains, but it does not provide a concrete realization of that framework that can be integrated to a company's existing systems.(see http://www.supply-chain.org/)

Electronic Business using eXtensible Markup Language (ebXML) is a set of specifications based on XML that is meant to facilitate conducting business worldwide over the internet. It was developed by the United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) and supported through the Organization for the Advancement of Structured Information Standards (OASIS). A key motivation for ebXML is that it be a more cost effective replacement for Electronic Data Interchange (EDI) based solutions that support electronic commerce (see www.ebXML.org). ebXML provides mechanisms for describing business processes that potential trading partners might engage in, registering and storing those business processes for sharing and reuse, defining business service interfaces that describe how trading partners will interact to execute a business process, and define business messages that hold the information exchanged between the trading partners (ebXML Technical Architeture Team 2001).

Another group that has developed standards to support supply chain operations is RosettaNet (www.rossettanet.org). RossettaNet is an international consortium of vendors for several technology-related domains that seek to create and implement open standards for electronic business processes. With RosettaNet's approach, a business process that can be conducted between trading partners is defined in an XML-based document called a Partner Interface Process® or PIP®. To facilitate the exchange of information using PIPs®, RosettaNet provides dictionaries of common terms to be used in PIP definition, directories of existing PIPs®, and an implementation framework to reduce the effort of creating RossettaNet-based business exchange implementations (Rosettanet Standards 2004).

Each of the aforementioned efforts in supply chain specifications can provide a firm foundation for creating applications to support supply chain management. They all provide some mechanism for describing the business processes through which partners can interact in a supply chain. This is adequate for creating many applications, including some supply chain simulations applications, where the analysis focuses on logistical issues.

3 SUPPORTING INFORMATION EXCHANGE FOR MANUFACTURING-ORIENTED SUPPLY CHAIN SIMULATIONS

A shortcoming of the efforts described in the previous section is that only rudimentary support is provided for describing what is necessary to manufacture the products exchanged between participants in the supply chain. In manufacturing-oriented supply-chain simulations not only enterprise level business processes but also the manufacturing processes required to produce products need to be considered for their effect on the supply chain. Supporting these kinds of simulations requires the definition and exchange of information that supports production in addition to information about how enterprises interact with each other in a supply chain (Rattner and Hsu 1989, Hus et al. 1994, Duvivier et al 2003).

To address these issues the National Institute of Standards and Technology (NIST) has been working on developing XML-based standards that facilitate the creation and exchange of information needed for manufacturing-oriented simulations, including supply-chain simulations.

As part of the Intelligent Manufacturing Systems (IMS) Modeling and Simulation Environments for Design, Planning and Operation of Globally Distributed Enterprises (MISSION) project, NIST developed a specification to fa-

cilitate the exchange of supply chain information and the creation of supply chain simulations (Lee and Umeda 2001). Several supply-chain simulation prototypes were developed at NIST using this specification.

As a part of the Engineering Institute's (SEI) Technology Insertion, Demonstration, and Evaluation (TIDE) project, NIST is developing the Manufacturing Information Model for Simulation (MIMS). The goal of this specification is to describe the attributes and inter-relationships of the entities necessary to create manufacturing-oriented simulations (McLean et al. 2002). Several simulation prototypes and simulation case studies have been done based on information described using MIMS (Lu et al. 2003). NIST has been working with representatives from major manufacturing companies, small manufacturing enterprises, and academic and private research institutions to: (1) verify that the content of MIMS can be used to reduce the effort to create manufacturing-oriented simulations and support the information exchange between other manufacturing applications and (2) extend MIMS to facilitate the representation of supply-chain information. In the effort to extend MIMS, consideration will be given to existing supply-chain modeling efforts, such as NIST's efforts and the efforts produced by other groups, such as SCOR, ebXML, and RosettaNet. If possible, MIMS will be extended so that it is compatible with some of the other work.

4 APPLYING MIMS TO MANUFACTURING-ORIENTED SUPPLY CHAIN SIMULATIONS

Although MIMS will be extended to support the full range of supply chain representation needs so that supply-chain simulations can be made with less effort, it currently has a great deal of support for describing supply chains. MIMS already has support for defining information about products, resources, organizations, bill of materials, and orders. These structures are as necessary for defining production related information as they are necessary for supply-chain operation information. Once MIMS is extended to support the full range of supply-chain information, it will be able to facilitate the creation of simulations and other applications that provide many different kinds of analyses of supply chains. Applications could be created to support:

- Inventory planning, where inventory levels are intelligently balanced against customer demand, supplier requirements, and the manufacturing capacity and capabilities of the supply chain participants.
- Transportation planning, where optimal daily or multi-period transportation schedules can be determined, the most advantageous carrier capacity can be planned, and alternative routing strategies can be evaluated.
- Vendor selection, where potential vendors for components for products in a supply-chain can be evaluated based on cost, quality, delivery time, etc.

4.1 Using a manufacturing-oriented supply chain simulation to support a vendor selection

In this section, an example of how MIMS can be used to facilitate the creation of a supply chain simulation to support vendor selection will be explained.

Figure 1 shows a factory which needs to evaluate potential supply-chain partners to provide the components needed for its assembly line. There are three potential choices to supply the component, Supplier A, Supplier B, and Supplier C. Each supplier has certain advantages and disadvantages. One supplier may provide components at a very competitive price. Another supplier may provide components of high quality (which will increase yield and reduce scrap) but also with a high cost. Each supplier may only have the manufacturing capacity to commit to providing a limited amount of the component per week. Also, each vendor may only provide a limited choice of delivery options. There are potentially many other factors, such as lot size restrictions, which may factor into the decision of which vendor to choose. A supply-chain simulation can be used to determine how each partner might perform in a supply-chain, based on different evaluation criteria.

The study will be carried out in four phases:

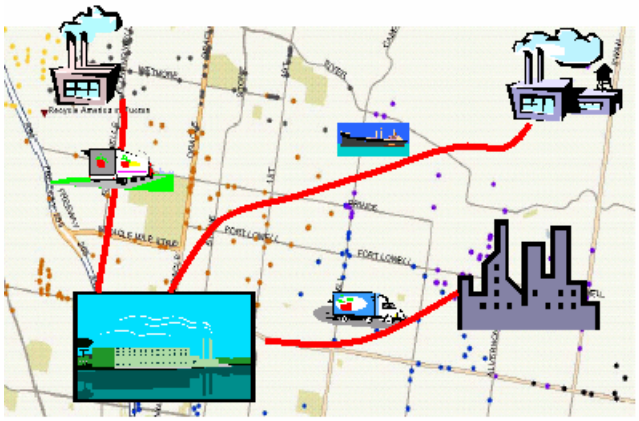

Figure 1: A Vender Selection Supply Chain Scenario

1. Identify the information needed to define a supply chain simulation based on the vendor study scenario, including all product, process and resource information. This information should be stored in an XML file adhering to the MIMS specification.
2. Create a simulation model based on the vendor selection scenario information. The most advantageous way to accomplish this step is to create a data-driven simulation that can import the information stored in the MIMS documents.

3. Run several executions of the simulation, where each run focuses on examining one or more of the evaluation criteria for each supplier.
4. Assess the output of the simulation runs. The simulation may provide visual output for inspection, statistical reports describing and summarizing the performance of each vendor in the simulated supply chain, or a combination of visual output and reports.

Using an approach such as this, selection of a supplier for the supply-chain component can be accomplished, even if the selection criteria are interdependent or if a combination of the different criteria is used for evaluation.

4.2 Creating the supply-chain simulation using a data-driven approach

To create the simulation for the vendor selection study, DELMIA™ QUEST® will be used. One factor in the selection of QUEST® is it allows the creation of a simulation model from scratch using its two built-in programming languages, Batch Control Language (BCL) and Simulation Control Language (SCL). By using a program which translates the information in a MIMS file into BCL and SCL, the QUEST® models needed to evaluate the different vendor selection alternatives can be created by just changing the information in the MIMS file. This approach facilitates the rapid generation of simulation alternatives for evaluation, which has the added benefit of allowing the examination of more alternatives during the allotted time for a study that would otherwise be possible.

Figure 2 shows how the data-driven supply-chain simulation is implemented. The information necessary to generate the simulation is entered in an XML file using the MIMS format. This information will include information about the proposed supply chain and about the manufacturing capabilities of the suppliers and assembly plant. Since the MIMS file is XML, eXtensible Stylesheet Language Transformation (XSLT) is used to create a translator to convert the information in the MIMS document into BCL and SCL files. These files can be directly executed by QUEST®. As stated before, creating simulations to evaluate different scenarios only involves modifying the information in the MIMS file. For a more detailed explanation of this process, see (Qiao et al. 2003).

5 CONCLUSION

Supply chain simulation bridges the gap between planning at the enterprise level and execution of the manufacturing level. It provides companies with the ability to make product delivery promises that can be kept by implementing production plans that best meets their customers' delivery requirements while simultaneously taking into account component sourcing, manufacturing, and distribution constraints.

The possibilities of using simulation technology in supply chain management are endless. A neutral informa-

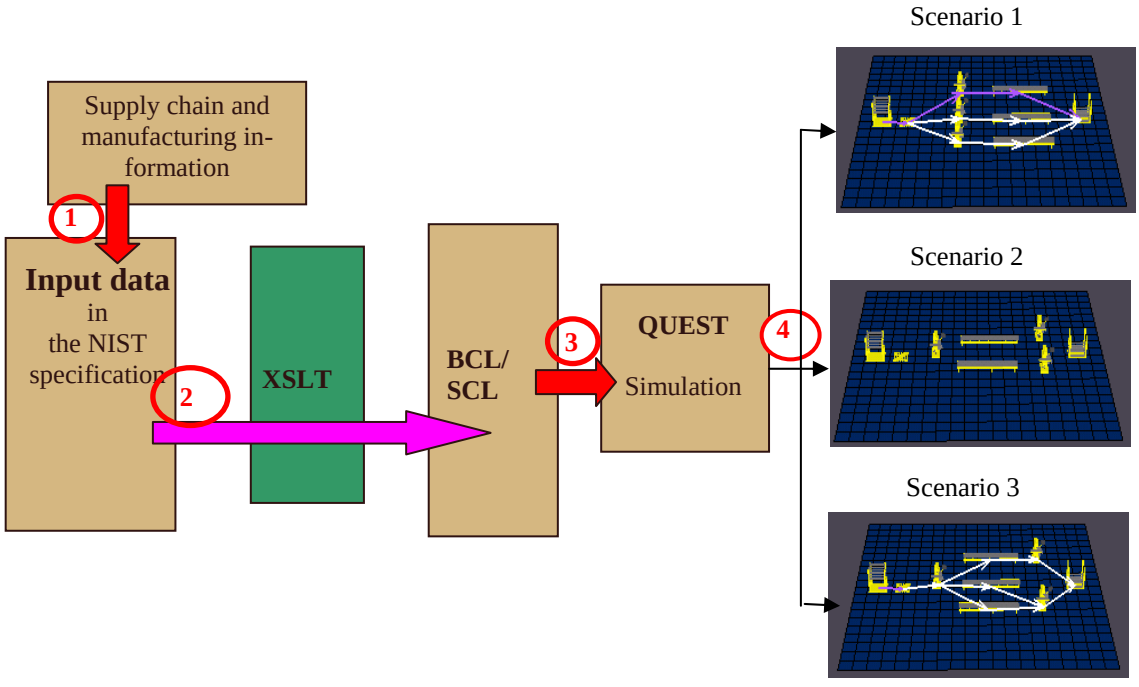

Figure 2: A Data-driven Supply Chain Simulation

tion model that can be exchanged among various supply chain participants is an essential tool needed to integrate and simulate the supply chains, to maintain competitiveness, and to provide the services demanded by today's customers.

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