A PRELIMINARY INFORMATION MODEL FOR A SUPPLY CHAIN SIMULATION

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ABSTRACT

This paper provides an overview of the information model that is under development for the simulation of a manufacturing supply chain. The supply chain simulation is being developed to validate interface specifications as part of the Intelligent Manufacturing Systems (IMS) Modeling and Simulation Environments for Design, Planning and Operation of Globally Distributed Enterprises (MISSION) project. The supply chain simulation is based largely upon the practical business operations of a U.S. power-tools manufacturing company. A high-level graphical representation of the information model is included. The information model is being used to develop neutral interface specifications that can ultimately be used to integrate distributed simulation models that are developed by other manufacturers to model their supply chains.

KEYWORDS

Data exchange, IMS, information modeling, MISSION, simulation, supply chain system

1 INTRODUCTION

The Manufacturing System Integration Division (MSID) of the U.S. National Institute of Standards and Technology (NIST) participates in the Intelligent Manufacturing Systems (IMS) Modeling and Simulation Environments for Design, Planning and Operation of Globally Distributed Enterprises (MISSION) project (MISSION, 1998). A distributed manufacturing simulation architecture has been developed by the NIST MSID to support the MISSION project. The architecture describes the major system modules, data elements or objects, and interfaces between modules (McLean and Riddick, 2000). The purpose of the architecture is to identify the software building blocks and interfaces that will facilitate the integration of distributed simulation systems and enable the integration of those systems with other manufacturing software applications. The architecture, however, does not address the detailed design of individual modules and the information models for shared data elements or objects. The emphasis of our current research is to develop an information model and to build a prototype simulation.

A prototype supply chain simulation is being developed as a test case for MISSION by the U.S. project team. In an early planning meeting by the U.S. team, a common interest in the supply chain simulation was expressed by the simulation software vendors participating in the project. A major objective of MISSION is to enable the development of distributed supply chain simulations for globally distributed enterprises. The test case focuses on modules, data structures, and interfaces that require an information model.

The goal of supply chain management is to integrate suppliers, manufacturers, warehouses, and stores efficiently, so that merchandise is produced and distributed in the right quantities, at the right locations, and at the right times (Simchi-Levi et al, 2000). This is done to minimize system-wide costs while satisfying service level requirements. In a supply chain system, an individual member exchanges data with other members to synchronize their business operations. These exchanged data generally include product specification data, planning data, ordering data, and inventory data, among others. These data are often used to control operations in an individual firm, and are also used for negotiation among chain members that form a virtual organization to provide products and services to customers.

There are several different information modeling methodologies, modeling languages, and implementation methods available to support the development of such a communication mechanism (Lee, 1999). Our approach to developing this communication mechanism and the data specification are listed here:

- Perform a case study to investigate a real supply chain system.
- Identify the scope of the target application.
- Identify core processes of supply chain management.
- Design the prototype supply chain simulation.
- Design the distributed simulation system.
- Analyze communication data flow and identify data requirements.
- Verify the data requirements using the prototype system and the distributed system.
- Layout the data specification.
- Implement the data specification.

2 SUPPLY CHAIN SIMULATION

The U.S. MISSION project team has been working on the development of a supply chain simulation as a test case for evaluating the quality of the supply chain model and validating interface specifications for MISSION. This supply chain simulation will be a prototype, global supply chain system. This section provides a description of the objective, the scope, the scenario, and the communication data requirements of the system.

2.1 Simulation Objective

Successful supply chain management is extremely complex. There are multiple reasons for this complexity. Different supply chain partners may have different, and possibly conflicting, objectives. The supply and demand for goods may change over time. The nature of partner-to-partner relationships may also change over time. The advantage of having a simulation of either a proposed system or existing system is that it can be used to design and optimize the system. The use of simulation allows a manager or engineer to analyze and to view system-wide effects of proposed changes, in a ranging level of detail. The analysis results can then be used to support tradeoff studies, management and engineering decisions, and, consequently, enhance the system. The simulation also allows the validation of the interface specifications defined by the MISSION project.

2.2 Simulation Model Scope

The characteristics of the scope of the supply chain simulation are:

- Span across multiple businesses and organizations.
- Simulate multiple levels of manufacturing systems.
- Use a hybrid push-pull distribution system for product distribution.
- Include multiple software simulation modules in different geographical locations.
- Comprise multiple functional modules, such as simulation engines, display systems, and analysis tools.

The following manufacturing activities are within the scope of the supply chain simulation:

- Production planning, scheduling, and control.
- Transportation planning and scheduling.
- Materials/parts/products flow within the final assembly plant (and possibly suppliers).
- Inventory control.
- Cost control.
- Data communications between business functions.

2.3 Demonstration Scenario

In this section, the configuration of the supply chain simulation is described. The configuration is based on a previous case study of a U.S. power-tools manufacturing supply chain. The chain includes supply chain members, information flows, and product flows. There are seven major types of organizational units included in the supply chain: a supply chain headquarters, parts suppliers (3), warehouse, retailers (3), distributor, a final assembly plant, and a transportation network. Figure 1 shows the configuration of this supply chain simulation.

The simulation system consists of suppliers, manufacturing centers, warehouses, distributors, and retailers, as well as raw materials, parts, finished products, and outsourcing companies, such as transportation providers. The headquarters manages the information flows and provides the products to the customers through the retailers. The final assembly plant assembles finished goods from the components provided by the suppliers. At least two production lines within the assembly plant will be modeled in detail. The final assembly plant manufactures products by using the parts provided from the parts suppliers; the finished products are then sent to the warehouse or to the distributor. The warehouse stores inventory and supplies products to the retailers. Other supply chain members, including the part suppliers, distributors, retailers, and transportation providers, may be independent firms. The part suppliers provide manufacturing parts to the final assembly plant. The distributors provide finished products to the retailers as required or according to other independent contracts. The retailers receive the finished products from the warehouses or from the distributors, and the finished products are then shipped to the customers. The transportation providers deliver the parts or finished products to the required destinations. This supply chain simulation uses a hybrid push-pull distribution system.

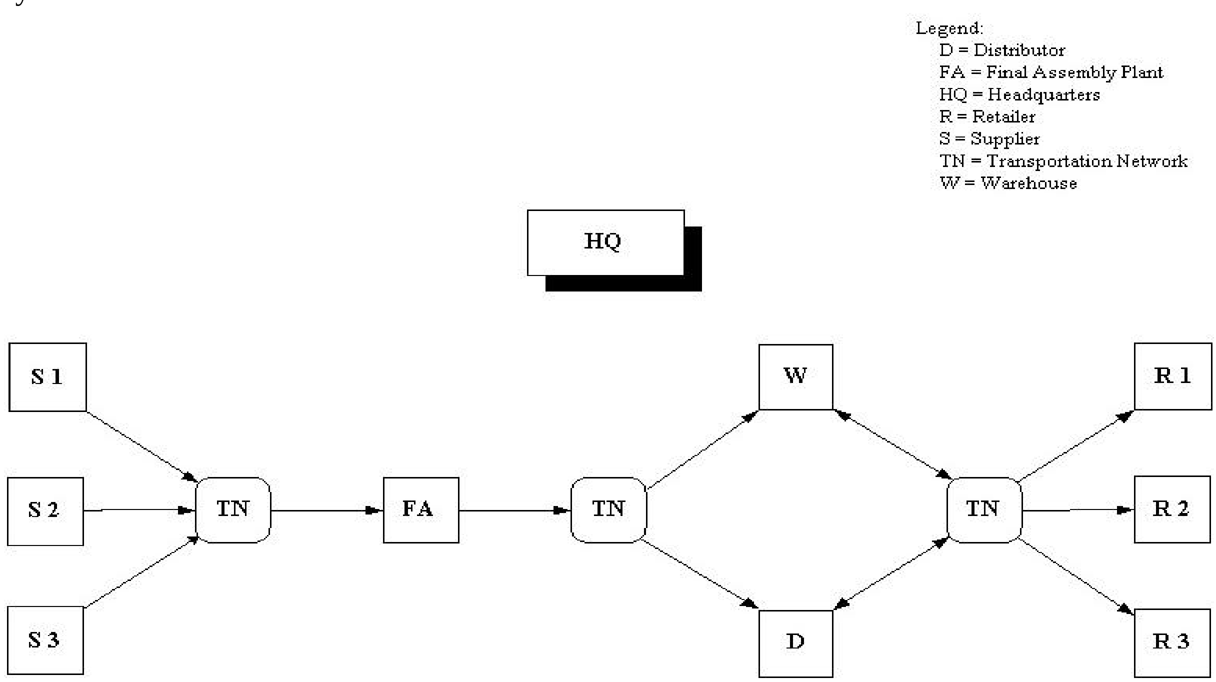

Figure 1. The configuration of the supply chain simulation

2.4 Introduction to the Information Model

In this section, a high-level structure of the information model of the supply chain simulation system is presented in a graphical representation. The information model focuses on the minimal set of data that needs to be exchanged between members of the supply chain. Local data required by supply chain members is not contained within the model. A graphical representation of the model is presented using the EXPRESS-G modeling language (ISO, 1994). An overview of the structure of the information model and selected entities are shown here. Due to page limit restrictions on this paper, the full model is not presented. For more detailed discussion of data contained in the information model, see (Umeda and Lee, 2001).

A communication data flow analysis of the supply chain simulation was performed. As a result, a set of data requirements used to communicate among the supply chain members has been identified. These data requirements are a set of messages or objects; they are grouped into five units of functionality: headquarters, manufacturing plant, warehouse/distributor, transportation network, and retailer. Figure 2 shows the overview of the information model of the supply chain simulation. Figure 3 presents the entities that are used by the transportation network. A transportation network is represented by three sets of information: transportation status, transportation order, and truck dispatch. A transportation order is represented by an order identification (id), a pickup location id, an order originator id, a tracking number, a delivery location, a status code, a request delivery date, a request pickup date, and a set of shipment data including a list id, total weight, cost, container count number, and value. The status code is an enumeration of *On-time*, *Delayed*, and *Cancelled*. A transportation status is represented by a tracking number, an originator id, an originator order id, a shipment list id, a status code, a shipment cost, a truck id, a pickup location id, and a delivery location id. A truck dispatch is represented by a dispatch-action code, a routing id, a step number, and a status code. The dispatch-action code is an enumeration of *No-action*, *On-load*, and *Off-load*.

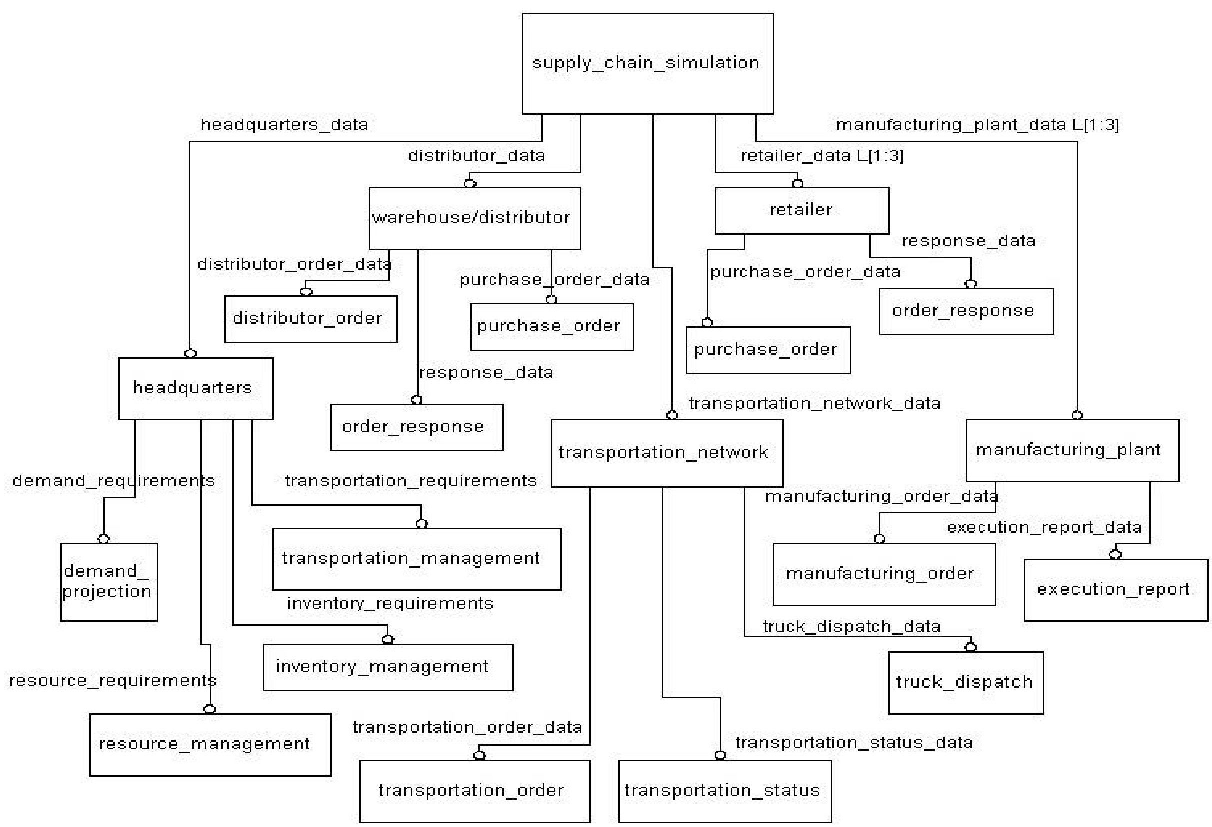

Figure 2. The high-level model structure of the Supply Chain Information Model

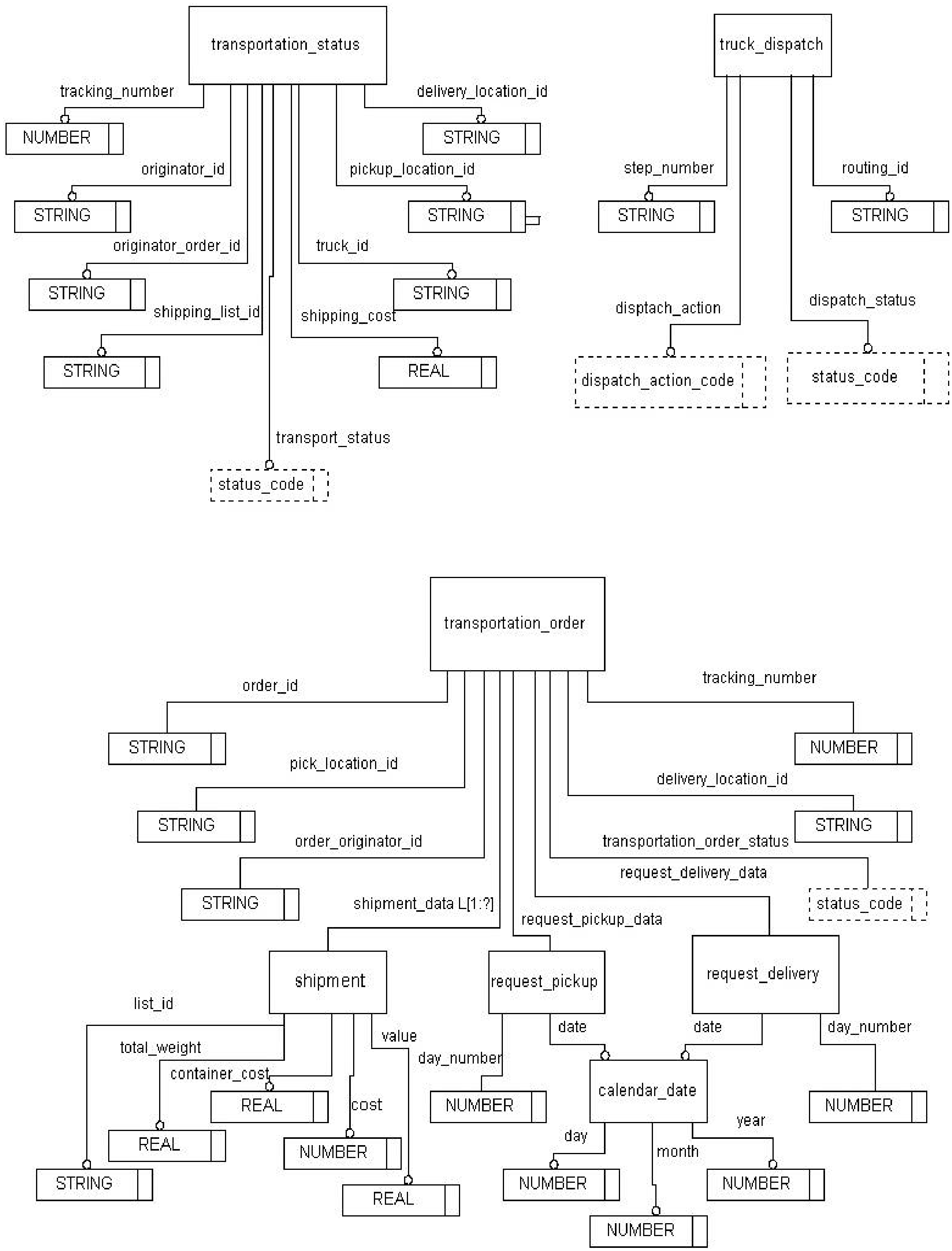

Figure 3. The entity structure of transportation network

3 CONCLUSION

The U.S. MISSION project team is developing interfaces for distributed manufacturing simulation. Currently, we are using a supply chain simulation scenario to test those interfaces. An information model is under development to support the specification of those interfaces. A preliminary version of an information model, in a high-level graphical form, to support the communication within the simulation was described in this paper. The model is being finalized using the eXtensible Markup Language (XML) (WWW, 2001). The information model will continue to evolve based on feedback and experience.

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