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An Intelligent Agent-Based Decision Support System for Supply Chain Management in E-Business

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ABSTRACT

This paper proposes a web-based decision support system (DSS) for supply chain management (SCM) decision making. In SCM, there is always the likelihood of having disagreements among parties for a certain decision making process. This phenomenon increases when the business environment becomes more competitive and turbulent. Much research has been done on the topic of decision support systems. However, there have been few publications dedicated solely to web-based DSS study. To date, no research has been done on a web-based DSS specifically designed for SCM decision making. A lack of study on Intelligent Agent-Based Web DSS drives this study. It is expected that this research will provide additional insights for existing supply chain management and information systems literature. The proposed web-based DSS is comprised of model management agents. We will describe the mechanism of the proposed web-based DSS with an emphasis on the role of model management agent. An aggregate production and inventory control model is used for the proposed system's application example.

INTRODUCTION

Recently, decision support system (DSS) approaches have been receiving more attention from researchers and practitioners as information technology advances rapidly. In literature, many algorithmic approaches as well as behavioral approaches have been proposed to coordinate a conflict of decisions. As the Internet-based telecommunications environment is prevailing in the modern firm, integration of DSS and the Internet emerges as a promising alternative for coordinating decision-making processes, which often take place in separate and remote areas. Accordingly, a web-based DSS is considered capable of accomplishing the task of coordinating those processes.

Much research has been done on the topic of DSS. It has been integrated into many different parts of the business industry, such as; logistics, inventory management, supply chain, and the World Wide Web. In the area of logistics, Min (1998) found that computer-based DSS aids logistics managers in numerous ways. Robinson (1997) states that a DSS helps logistics managers make facility network design decisions. In the area of inventory management, Harrison (1998) found that many companies are using DSS tools to analyze sales figures and track business strategies. On the World Wide Web, O'Keefe and McEachern (1998) explain how a customer DSS connects a company to its customers and provides support for some of the decision-making process. Since no research has been done on a web-based DSS for SCM decision making, the purpose of this paper is to explore the possibility of developing exactly that type of DSS. It is expected that this research will provide additional insights to existing supply chain management and information systems literature.

This paper is composed of five sections. Section two reviews literatures on related topics. Section three attempts to build a web based DSS model. An illustrative example using the web-based DSS for an aggregate production and inventory control model is given in Section four. Section five is composed of concluding remarks.

LITERATURE REVIEW

Logistics Management

Min (1998) reports that a personal computer assisted decision support system is aimed at aiding logistics managers in selecting the most appropriate transportation choice between private and common carriers. In contrast with a traditional stand-alone system, this decision support system is designed for integration with the company's internal data base systems, the analytic hierarchy process model base and user controlled dialog systems for "what-if" scenarios. Robinson (1997) states that logistics managers frequently utilize a DSS to make facility network design decisions. Many DSSs do not provide optimization capabilities, but instead rely on scenario evaluation as a means for developing solutions. Decision-makers generate relatively high quality solutions using the DSS variants. The type of design problem solved does significantly impact overall problem solving performance. However, performance degraded and variability in solution quality escalated as problem size was increased. The availability of incremental solution cost improvement in the DSS significantly increases solution quality and reduces performance variability. Kogan, Sudit, and Vasarhelyi (1997) explain that recent development in Internet technology and electronic commerce will have a profound effect on the role of management accounting systems in decision support, internal auditing, and control. Internet technology will likely become increasingly more hospitable to electronic commerce. More companies are experimenting with Electronic Data Interchange type systems over the Internet. A number of Enterprise Resource Planning (ERP) information systems are now available commercially. Internet-based ERP systems provide management accountants with a working set of comprehensive inter-organizational, intra-organizational and global decision support systems. Internet technology also stimulates electronic commerce significantly. It increases analytical power, relevancy, and reach of management accounting.

Inventory Management

Verity (1997) states that in the fall of 1996, several major retailers in the consumer packaged goods and retailing industries-including Wal-Mart Inc., Sears, Roebuck and Co., Sara Lee Corp., and Warner-Lambert Inc-rallied around a promising new web-based scheme called CFAR (collaborative forecasting and replenishment). CFAR promised a formalized way for manufacturers and retailers to collaborate on future demand for products. By posting selected internal data on a shared Web server, supply chain partners could share and jointly de-

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velop forecasts that are more accurate. However, getting CFAR to work as promised and to be adopted widely as an industry standard is taking longer than was predicted in 1996. Wal-Mart and other potential users have deemed its original scope too limited, and are now scrambling to expand it into CPFR (collaborative planning forecasting and replenishment). Hammering out the current definitions of CPFR are technologies from nearly 50 different retailing and manufacturing companies. Harrison (1998) explains that a growing number of companies are turning to decision support tools to analyze sales figures and keep track of business strategies. Managers at Service Merchandise Company, Inc., decided that the firm's economic survival hinged on a transition to a more traditional retail operation. Service Merchandise had sales data sitting on an IBM mainframe, but managers had no way of looking at sales figures by store, market, or region to determine which catalog items were the fastest sellers in various parts of the United States. To solve the problem, they pulled its legacy data from the mainframe into an Informix data warehouse where it could capture sales and product information by market and region. Then, they selected the DecisionMaster DSS tool, which allowed the company to identify less profitable products and eliminate the slower-moving merchandise. With this DSS tool, managers can compare a specific market, region, district, or individual store with data from the entire chain, as well as confirm store inventory levels and forecast projected sales.

Supply Chain Management

Foster (1998) describes how GAF Materials Corp., the largest manufacturer of asphalt-based roofing materials in the US, is about to take the plunge into supply chain optimization. The company has decided to test the waters, trying optimization on a smaller scale. Its first venture into this area has been a freight management DSS that the company developed on its own. The purpose of this freight optimization model is to find the lowest cost dispatching option for each day's shipments. However, freight optimization is just a small part of the proposed enterprise-wide supply chain optimization plan.

Web-Based Decision Support Systems

Curtis (1998) discusses how getting ahead in e-business means having valid information on which to base decisions. The first step in defining an approach to e-business site design and metrics gathering is understanding and articulating the questions that need to be answered. A good place to start is to develop an understanding of how each of the pages of the e-business site is performing. Various tools on the Internet today will measure Web site hits and can report several types of information, yet their usefulness to business line managers is questionable. The conclusion is that Web sites need to be designed with metrics for measuring business success in mind. O'Keefe and McEachern (1998) report that a customer decision support system (CDSS) is a system that connects a company to its existing or potential customers, providing support for some part of the customer decision-making process. CDSS is one way of conceptualizing second-generation Web-based marketing systems. It is a well-planned framework for those developing substantial systems particularly in the business-to-business environment. All parts of the customer decision process can be supported. A CDSS must be placed within the context of the other Web and Internet facilities available to a customer. This is done through a simple framework based on consumer behavior. King (1998) states that Chrysler Corp. is giving 2,000 business users point-and-click access to large amounts of real-time manufacturing and production data. In doing so, the $61 billion carmaker is extending decision-making to business analysts, line personnel, and almost anyone with an Internet browser. The enormous effort integrates 21 mainframe transaction systems and users throughout the world. The web-based "Do All" system lets users view everything from vehicle ID numbers and parts lists to quality and warranty data. Wilson (1997) explains that to access decision-support information with a browser, software is needed that sits between the Web server and the data warehouse. The software's sole mission is to translate the HTML (hypertext mark-up language) of the Web into the structured query language of relational databases. If the data warehouse sits on top of a database that uses a different type or proprietary form of query language, translation software will have to work with that as well. Web-enabled Online Analytical Process products use one of three basic approaches. The first approach lets developers transform data from a warehouse into static HTML reports. The second approach gives users more options about what data they view and how they view it. It uses Java applets to provide a richer GUI (graphical user interface) and maintains the overall framework of an HTML page at the same time. The third approach is a Java-only environment. This provides a rich graphic environment and the flexibility to do ad hoc queries because it does not limit users to the restrictive structure of HTML pages.

In summary, much research has been done on the topic of decision support systems. DSSs have been integrated into many different parts of the business industry, such as: logistics, inventory management, supply chain, and the World Wide Web. In the area of logistics, Min (1998) found that a computer assisted DSS aids logistics managers in numerous ways. Robinson (1997) states that a DSS also helps logistics managers make facility network design decisions. In the area of inventory management, Harrison (1998) found that many companies are using DSS tools to analyze sales figures and track business strategies. On the World Wide Web, O'Keefe and McEachern (1998) explain how a customer DSS connects a company to its customers and provides support for some of the decision-making process. Wilson (1997) tells about the relationship of a data warehouse and a web server. He also discusses three approaches that are used. However, no research has been done on web-based DSS for logistics decision-making from the SCM (supply chain management) perspective.

A WEB-BASED DECISION SUPPORT SYSTEM

Characteristics and Architecture

A web-based DSS is characterized by the following properties:

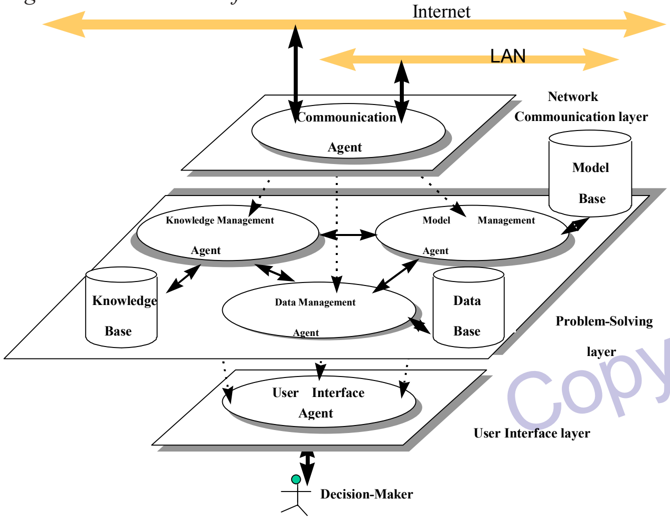
- It can run on the Internet that has open connectivity
- Multiple web-based DSSs can be easily interconnected to each other
- A web-based DSS consists of several intelligent agents that perform problem-solving tasks

The web-based DSS is composed of three layers: (1) a network communications layer, (2) a problem solving layer and (3) a user interface layer. Descriptions of both network communication layers and user interface layers are straightforward. The network communication layer is to support various protocols such as TCP/IP, http, ftp, gopher, and X.25, etc. The user interface layer is to generate an effective user interface form. The problem–solving layer is composed of three agents: a knowledge management agent, a model management agent, and a data management agent. However, the characteristics of SCM coordinating decisions lead to investigating the role of model management agent because SCM coordination problems require coordinating interactions between a supplier and a manufacturing plant. Therefore, we will discuss the main agents for model management in the subsequent section. Figure 1 depicts the architecture of the proposed web-based DSS for coordinating SCM decisions.

Intelligent Agents

The Web-based DSS consists of several intelligent agents for problem solving purpose. Intelligent agents have been defined variously by researchers according to their application domain problems (Franklin & Graesser 1996). The concept of "intelligent agent" is used in information technology to describe a broad range of computational entities. Intelligent agents participate actively in accomplishing tasks, rather than serving as passive tools, as do conventional applications. The user needs only to specify a high-level goal instead of issuing explicit instructions, leaving the "how", "what", and "when" decisions to the agent. Exact definitions of intelligent agents are yet to be made. However, user knowledge and/or user need is the principal

Figure 1: Architecture of a Web-based DSS



determinant of intelligent agent-enabled application usage today (Hermans 1996). In the field of expert systems, for example, some researchers define the intelligent agents as an extension of the expert system with additional communication and meta-problem solving capabilities (Lee & Lee 1997). Since our focus is on SCM coordinating decisions, we define the intelligent agent as *software capable of performing highly complex coordination tasks under turbulent situations*.

The applications of intelligent agents are not limited to specific engineering problems. The concept of intelligent agents is now actively applied to the areas of system and network management, mobile access/management, mail and messaging, information access and management, collaboration, workflow and administrative management, electronic commerce, and adaptive user interface. Our problem is one of either collaboration or workflow and administrative management. It is assumed that the intelligent agent used in the proposed web-based DSS is limited to the model management agent. Its main architecture can be depicted in Figure 2 (a) and (b). The model management agent concept is explained in Figure 3.

SUPPLY CHAIN MANAGEMENT DECISION MAKING: A CASE OF AGGREGATE PRODUCTION AND INVENTORY PLANNING

An illustrative example for SCM decision making is shown in Figure 4, in which several parameters are supposed to be determined by decision-makers. They are production cost, inventory cost, demand estimate for each time period. Since the total production and inventory costs should be minimized, an optimization model like a linear programming can be used for such a case.

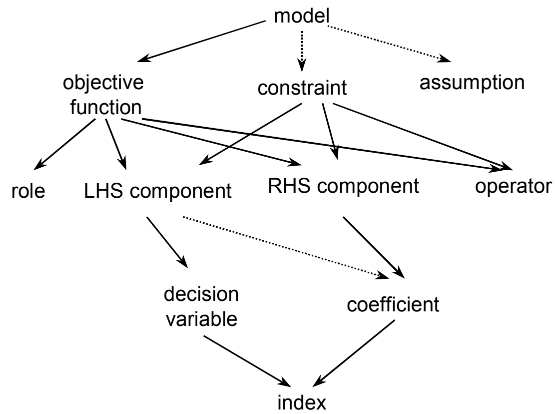
The linear programming model is formulated as following:

$$\text{Min } Z = C_1 X_1 + C_2 X_2 + \ldots + C_n X_n + H_1 I_1 + H_2 I_2 + \ldots + H_{n-1} I_{n-1}$$

Subject to:

$$X_1 = I_1 + D_1 - I_0$$
$$X_2 + I_1 = D_2 + I_2$$
$$X_3 + I_2 = D_3 + I_3$$
$$\ldots.$$
$$X_n + I_{n-1} = D_n$$
And X_j, H_j (j = 1, 2, 3, ……. n) 0

Figure 2: Architecture of model management agent: (a) schematic representation; (b) frame-based representation



(a)

```
MODEL : model_name = {
    OBJECTIVE_FUNCTION = {
        LHS_COMPONENT : lhs_component_name = {
                        NOTATION: notation
                        ROLE: role type
                        ENTITY_NAME:    corresponding_
                        entity_name }
        OPERATOR : [“=” | “>” | “<“ | “>=” | “<=”]
        RHS_COMPONENT : lhs_component_name = {
                        NOTATION: notation
                        ROLE: role type
                        ENTITY_NAME:    corresponding_
                        entity_name }
                        }
CONSTRAINT = {
        LHS_COMPONENT : lhs_component_name = {
                        NOTATION: notation
                        ROLE: role type
                        ENTITY_NAME:    corresponding_
                        entity_name }
        OPERATOR : [“=” | “>” | “<“ | “>=” | “<=”]
        RHS_COMPONENT : lhs_component_name = {
                        NOTATION: notation
                        ROLE: role type
                        ENTITY_NAME:    corresponding_
                        entity_name }
                        }
     ASSUMPTION = { assumptions }
}
```

(b)

Where: Z = Total Production and Inventory Cost; X_t = Production scheduled for period *t*; D_t = Expected demand in period *t*; I_t = Net Inventory at the end of period *t*; I_0 = Initial inventory; C_t = Unit variable cost of production during periods *t*; H_t = Inventory carrying cost per unit (from period *t* to period *t*+1).

WEB-BASED DECISION SUPPORT SYSTEMS FOR SCM

In Figure 5, a web-based DSS for SCM decision making is illustrated. Decision makers at remote sites access the web and input their information for such parameters as Ct, Ht, Dt, etc. listed in the previous section. Then the proposed system should optimize the decision making process and provide the solution. JavaScript, Active Server Page, and HTML, are convenient tools for programming a DSS on the Web.

Figure 3: The work of model management agent in a Web-based DSS

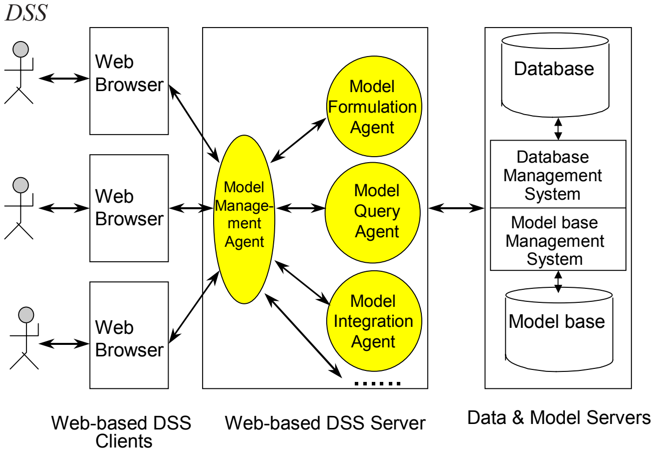


Figure 4: SCM example: Production and inventory control model for t=3

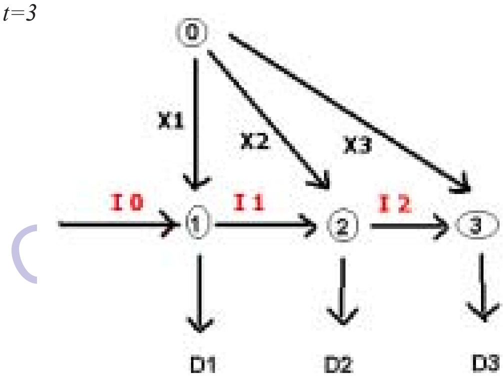
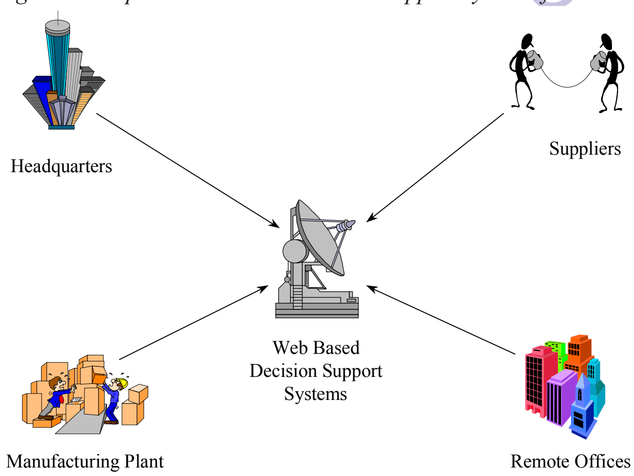


Figure 5: Proposed Web-based decision support systems for SCM



The model management agent in Figure 6 processes the SCM model. Based on the schematic representation form in Figure 2, the model management agent can inform users of noteworthy components during use of the web-based DSS.

Figure 6: Frame-based representation of production and inventory control model processing by model management agent

MODEL : Production and Inventory Control Model ={
OBJECTIVE_FUNCTION = {
LHS_COMPONENT : Total Production and Inventory Cost = {
NOTATION: Z
ROLE: calculate
ENTITY NAME: time}
OPERATOR:'='
RHS_COMPONENT : Production Cost = {
NOTATION: CtXt
ROLE: retrieve
ENTITY_NAME: time },
Inventory Cost = {
NOTATION: HtIt
ROLE: retrieve
ENTITY_NAME: time },
}
CONSTRAINT = {
LHS_COMPONENT : Production and Inventory = {
NOTATION: $X_n + I_{n-1}$
ROLE: calculate
ENTITY NAME: time}
OPERATOR:'='
RHS_COMPONENT : Expected Demand = {
NOTATION: D_n
ROLE: retrieve
ENTITY_NAME: time },
}

ASSUMPTION = { UNIT: dollar }
}

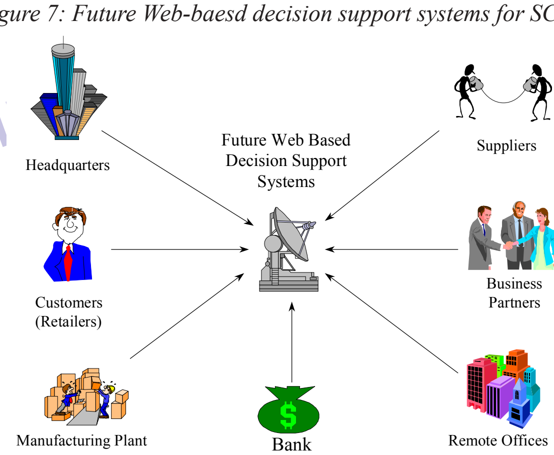
CONCLUSION

To solve the SCM coordination problem, this study extended conventional DSS concepts into the web-based DSS using an intelligent agent approach. The mechanism of the model management agent was also described with an illustrative example. The potentiality of the model management agent proved to be effective in the illustrative example, where many functions of a firm can be integrated to the extent of coordinating SCM decisions.

On the other hand, there are several concerns about the proposed systems. Security issues on the Internet have been widely discussed lately. The proposed DSS is not immune to such threats. Hardware, training, and maintenance, can be problems as well.

Further studies may reveal more applications for the web-based DSS concept. One example can be an expanded model including customers (retailers), financial institutions (banks), business partners, and so on. Figure 7 illustrates this new concept.

Figure 7: Future Web-baesd decision support systems for SCM



In conclusion, this research attempted to build a web-based DSS for SCM decision making. It will enhance a firm's productivity, as well as effectiveness, if it is properly designed and implemented.

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