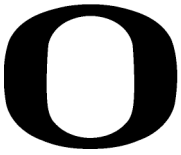

UNIVERSITY OF OREGON
APPLIED INFORMATION MANAGEMENT

Presented to the Interdisciplinary Studies Program:
Applied Information Management and the Graduate School of the University of Oregon
in partial fulfillment of the requirement for the degree of Master of Science

The Role of Software Agents in Supply Chain Risk Management Related to the Procurement Process in the Aerospace Manufacturing Industry

CAPSTONE REPORT

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Software Agents in Supply Chain Risk Management

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ABSTRACT

Supply chain management is a critical component of business planning and assembly, and must be continuously monitored to be effective (Mehra, 2005). This paper reflects on the role of software agents for managing supply chain risks at tactical and operational levels (Mark, et al., 2000). Twenty-nine selected references published between 2000 and 2008 are analyzed to understand how software agents mitigate the effects of risks in supply chain management, supporting complex distributed systems.

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INTRODUCTION

Topic Description & Research Problem

Supply chain risk refers to the possibility of an unpredictable event affecting one or more of the parties within the supply chain or its business setting (Deloitte, 2004). Risk in supply chain management has grown in importance due to the need for designing, coordinating, and operating extended supply chains, while managing supply chain disruptions due to a host of reasons, including intended and unintended events (Narasimhan, Talluri, & Mahapatra, 2006). According to IBM (2004), proper attention to supply chain risk must include the ability to ensure resiliency in the face of supply chain disruptions.

Supply-chain management is the strategic, tactical, and operational decision making that optimizes supply-chain performance (Mark, Barbuceanu, & Teigen, 2000). Over the last fifteen years, supply chain management (SCM) has taken a variety of directions with differing outcomes (Mehra, 2005). According to Johnson (2006), there are three main issues manufacturers should be aware of when sourcing for raw materials: technology, process and people. Technology plays an important role in the success of supply chain management. Even though the supply chain concept pre-dates the Internet, only through the use of web-based software and communication can it truly reach its full potential (Epiq, 2008). Leonard (2003) noted that increased cost, competition and customer pressures have driven companies to review internal processes and tap into the enormous savings potential from indirect spending. Effective management of these flows requires creating synergistic relationships between the supply and distribution partners with the objective of maximizing customer value and providing a profit for each supply chain member (Fugate, Sahin, & Mentzer, 2005).

IBM (2004) stated that supply chain management is a combination of proactive and reactive strategies that keep critical supply processes available without interruption. However,

supply chain requirements go beyond trace and track and need to address security assurance at each point in the logistics network (Carla, 2007). Biederman (2007) stated that risk is present in each functional area of the supply chain from planning and procurement to sales and service, and risk-management capabilities are part and parcel of specific management solutions. Watson (2004) noted that the present enterprise resource planning tool used in managing supply chains is not flexible enough to support the emerging supply chain management of the future (p. 3). Grossman (2004) said the goal of refining and reengineering business processes has been a consistent theme in businesses over the past few decades (p. 4). Technology, however, is necessary to maximize the impact of the business process reengineering; these applications are all about enabling the optimization of the procurement business process (Leonard, 2003). In order to automate supply chain execution and monitoring Cho, Kulvatunyou, Jeong & Jones (2004) suggested that software agent technology can be employed.

Recent developments in supply chain management information systems have greatly increased the ability of firms to integrate processes, systems, and information with their supply chain partners (McLaren, 2006). Software agent technology is being explored as a promising way to support and implement complex distributed systems (Nienaber & Barnard, 2007). Wakefield (2005) provided a broad definition of software agents as a program that performs actions in pursuit of a specific goal. The Organization for the Advancement of Structured Information Standards (2008), defined software agents more specifically as a paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains. Antoniou & Harmelen (2004) noted that software agents provide a uniform means to offer, discover, interact with and use capabilities to produce desired effects consistent with measurable preconditions and expectations. The solution puts the burden for updating content and maintaining data accuracy on the suppliers, but at the same time it provides a

dashboard for procurement executives to monitor their suppliers' activities within the software suite (Reese, 2007). And while software agents improve and simplify the integration process, they do not address the fundamental challenge of integration (Antoniou & Harmelen, 2004, p. 182).

As part of their professional positions, procurement agents are responsible for making and executing decisions based on information retrieved by software agents (Nissen & Sengupta, 2006, p. 4). Software agents can be applied to operating systems, computer applications, databases, networks, and virtual domains (Croft, 2004). In this inquiry, the software agent is defined as an application that automates business processes in a company's supply, production and distribution operations (Ferguson, 2003). The purpose of this literature review is to examine the role of software agents in supply chain risk management, related to the procurement process in the aerospace manufacturing industry.

Information is related to two important areas: (1) examples of key categories of threats/attacks in supply chain management within the aerospace manufacturing industry and the critical technologies that have been used to maintain uninterrupted procurement processes in order to attempt to maintain the supplier-customer relationship (Zhang & Li, 2006); and (2) software agents that may be relevant when evaluating selected supply chain information systems within the aerospace manufacturing industry, currently available on the market (Head, McLaren, & Yuan, 2004). The software agents are investigated as a potential tool to assist with the improvement of supply chain management (Nienaber & Barnard, 2007). Nienaber & Barnard (2007) noted that software agents have the ability to transport themselves from one host to another in a network. In this way, software agents provide a general-purpose, open framework for the development of distributed and networked systems for supply chain risk management (Butte, 2002).

Significance

Deloitte (2004) stated that vulnerability to sudden supply chain disruptions is one of the major threats to today's companies. Terrorism, theft, and disasters are only some of the possible causes of these disruptions (p. 3). Firms are vulnerable not only to attacks on their own assets, but also to attacks on their suppliers, customers, transportation providers, communication lines, and other elements in their eco-system (Sheffi, 2001). It is becoming increasingly clear that traditional supply chain management approaches must be enhanced to include means by which the new uncertainties arising from these trends and developments can be addressed (Deloitte, 2004). At this point, an understanding of developments and uncertainties that could emerge at any point in the supply chain management must be critically examined and potential solutions proffered.

Supply chain management is not only a significant aspect of today's global business environment, but it is also critical to emergency preparedness in disaster planning and response (Nissen & Sengupta, 2006). The United State's Department of Labor has stated that historically, out of the total number of all U.S. companies that have experienced a disaster, approximately 40 percent close up and never re-open. Out of those remaining companies that are able to maintain or rebuild operations following a disaster, roughly 25 percent of those companies close within two years (Curtis, 2008). Those numbers are further confirmed by the National Association of Corporate Treasurers, who stated that 75 percent of financial executives believe a major disruption would cause sustained damage to their companies' earnings or threaten the continuity of their operations (de Waart, 2006). These statistics support the position that effective supply chain management is critical to disaster planning and response (Stackhouse, 2007).

Gunasekaran and Ngai, (2004) acknowledged that the concept of supply chain management has become pertinent to business operations, and that within supply chain

management, software agents are often viewed as tools for overcoming the ever-increasing complexity of systems driving buyer and supplier relationships (p. 2). This supplier-customer relationship is a key evaluative factor in managing supply chains (Hughes, 2006). According to Billington & Jager (2008), procurement activities play a valuable role in an organization, and the advent of information technology has increased the important role that is played by procurement agents within organizations over the years.

Bovet (2005) once stated that no matter the risks, global supply chains continue to grow longer and more complex as companies push deeper into uncharted territory in search of lower costs. One only has to look at a couple of recent examples to understand the consequences of these statements. First, on the morning of September 11, 2001, the United States and the world as a whole entered into a new era – one in which a large scale terrorist attack left significant physical and mental ramifications that the country never expected (Sheffi, 2001). Another example was in 2005 when Hurricane Katrina struck the US Gulf coast. Both examples highlight the need for companies to have a robust risk management system in place before a disaster occurs, providing effective supply chain management (SCM), and thereby reducing or eliminating possible future risks (Hughes, 2006).

According to Lee & Whang (2001), companies that wish to stay competitive during periods of strife must strive to achieve greater coordination and collaboration among supply chain partners in an approach called supply chain integration (p. 3). However, one should keep in mind that there are several important problems in supply chain management that need to be resolved for efficient operation. Most of those problems stem either from uncertainties or the organization's inability to coordinate several activities and partners (Turban, McLean, & Wetherbe, 2004). Monahan, & Nardone (2007) stated that aligning the supply chain with the

organization's business strategy allows that organization to capture cross-enterprise opportunities that not only generate cost and capital efficiencies but also help to drive top-line opportunities.

Sengupta (2008) noted that global macro economic factors have emerged in recent years that are forcing many corporations with well-defined and extended supply chains to rethink the construct of the core supply chain building blocks and operating model. He stated that these structural and economic changes include rapid globalization and convergence of the end customer/consumer channel with the supply base (p. 2). According to Yung et al. (2000), globalization, organizational barrier reduction, rapid growth and changes of product varieties, as well as customer information sharing and analysis are the urgent needs in supply chain management (p. 120). Billington (2008) stated that there are also organizational barriers in adopting supply chain management.

Furthermore, Yung, Yang, Lau and Yen (2000) stated that the driving forces from new technologies determine how supply chain management problems can be solved. These new technologies include software agents, semantic web, and other information technology applications. The agent is designed to respond to "if-then" scenarios, but more complex, model-based agents try to achieve goals such as maintaining specific performance levels in a system (Thibodeau, 2004). Recent work has begun to explore how online internet exchanges have impacted the procurement process and the supply chains of manufacturing companies. For example, Kaplan & Sawhney (2000) researched and developed a framework not only to understand the types of exchanges used for various products but they also examined how those exchanges evolved. Other researchers, such Lee and Whang (2002), have modeled how online markets impact the supply chain management. Pyke and Desmond (2001) have been known for comparing many procurement strategies to traditional strategic alliances.

The literature review is intended for an audience that includes supply chain analysts and procurement agents within the aerospace manufacturing industry. As one example, the supply chain analyst's role at Boeing is to work with internal and external teams, including suppliers and customers, as needed to develop complete value stream maps (Boeing, 2008). Procurement agents often have the authority to commit company resources through contracts and agreements (Boeing, 2004), and they are constantly being challenged to look for new ways to control expenses and generate additional benefits (Avery, 2005). To this end, this inquiry provides supply chain analysts and procurement agents within the aerospace manufacturing industry with information concerning a related set of basic software agents to consider prior to system design and the selection of technology solutions for mitigating the effects of supply chain risk management.

Research Limitations

Focus

One of the critical requirements for managing uncertainty and risk is information (Carla, 2007). Peter, Mojca and Jurij (2005) asserted the successful implementation of supply chain management is not possible without extensive renovation of business processes and technological solutions used in integrating a supply chain. The fundamental goal of supply chain management is to manage and integrate key processes (Peter et al., p. 5). According to Lee (2004), the best supply chains identify structural shifts before they occur, by capturing the latest data, filtering out noise, and tracking key patterns (p. 8).

Businesses of the future will need to deploy a higher form of intelligence not only to visualize, but also to predict business-related events (Anthes, 2003). Focus in this inquiry is on the role of software agents as information mediums that can aggregate and distribute suppliers', partners' and customers' information across a network, for use within the aerospace manufacturing industry. The advantage of these software agents is that they are flexible and able

to react to changing environmental characteristics (Schweiger, Sunyaev, Leimeister, & Krcmar, 2007).

The technical aspects of the study of software agents are beyond the scope of this paper and are excluded. For example, Anthes (2003) noted that software agent-based modeling, while not yet commonplace, is catching on, especially at companies with large, complex supply chain management.

Time frame

Leedy and Ormrod (2001) highlighted the importance of recent research in a literature review. The references provided in this study, with one or two exceptions were published between 2000 and 2008. This period covers the rapid changes in supply chain risk management and usage that shape today's procurement processes. This time frame excludes older research and practices that over time have been replaced by more current procurement practices. In particular, interest in supply chain security has never been higher since the terrorist attacks of September 11th, 2001 (Hale & Moberg, 2005). Since September 11th, university research centers and logistics trade organizations have responded with workshops and conferences on supply chain security and natural disaster mitigation, preparedness, and the associated response and recovery mechanisms (Helferich & Cook, 2002). In 2005, Katrina became one of the most destructive, costly and deadly natural disasters in the history of the United States (Hughes, 2006).

Literature Collection

Hewitt (1998) stated that one important stage in a literature review is peer-review where each article is critically reviewed prior to publication (p. 21). Accordingly, peer review does not thwart new development. Materials used to build this inquiry are selected from academic, professional, and association literature and websites that incorporate some level of peer review. Academic material provides practical and theoretical context for the study (Obenzinger, 2005).

Professional and association literature and websites are reviewed to provide the audiences' view of supply chain risk management and software agents. Databases searched for this study include the EBSCO, Yahoo, Google and Google Scholar. These sources are supplemented with business news magazines and newspaper annual and bi-annual special reports providing coverage of executive education.

Audience

The audience for this inquiry includes supply chain analysts and procurement agents. The supply chain analyst's role is to work with internal and external teams, including suppliers and customers, as needed to develop complete value stream maps (Microsoft, 2008). The goal in this inquiry is to provide procurement agents working in the aerospace manufacturing industry with an understanding of the role of selected software agents in supply chain risk management.

Boeing (2004) refers to procurement agents as authorized agents of the company, with responsibility for managing all supplier-related activities. These agents have the authority to commit company resources through contracts and agreements (Boeing, 2004). Supply chain analysts at Boeing improve inventory management, visibility and develop plans to enhance supply chain performance. They also assess and understand the implications of changes to pre-existing inventory management systems and develop mitigation plans (Boeing, 2008). The increase of automated tracking systems, supply chain transaction systems, and electronic data interchange (EDI) systems have contributed to the rapid increase of data related to supply chain management (Rao, 2000).

Writing Plan Preview

The literature review is designed to summarize past research by drawing overall conclusions from many separate investigations (Cooper, 1998). Specifically, this study is intended to examine the role of selected software agents in supply chain risk management, related to the procurement process in the aerospace manufacturing industry. In order to do this, the study which follows is organized with a specific flow. Following this introduction is a list of definitions of terms culled from the literature. After that comes a description of research parameters, explaining the search strategy, relevance, criteria for selection of authors and articles, and writing strategy. The next section contains an annotated bibliography of the most central works on the material for the focus of this study. A more formal review of the literature follows the bibliography. A conclusions section, based on the literature reviewed, completes the work.

DEFINITIONS

The following research topic terms frequently arise in discussions of software agents and supply chain risk management. This list is not typically exclusive to either field. Rather, the goal is to show the connections between the concepts from the field of software agents and the concepts in supply chain risk management. Software agents, as used in this study, are also often referred to as intelligent software agents.

***Agent system*:** Is a platform that can create, interpret, execute, transfer, and terminate agents. Like an agent, an agent system is associated with an authority that identifies the person or organization for which the agent system acts (Butte, 2002).

***Chain*:** Connotes something that is sequential, that requires handling of information in sequence (Anthes, 2003).

***Disaster*:** Defined as any event that creates an inability on an organization's part to provide critical business functions for some predetermined period of time (Boeing, 2008).

***Enterprise Risk Management*:** A process, effected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives (COSO, Enterprise Risk Management Framework, 2004, p. 2).

***E-procurement*:** Is the ability to perform the full procurement process electronically over the Internet (Saryeddine, 2004)

***Information Technology*:** Is any equipment or interconnected system or subsystem of equipment that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information.

The term 'information technology' includes computers, ancillary equipment, software, firmware and similar procedures, services (including support services), and related resources (U.W., 2000).

***Information integration*:** Refers to the sharing of information among members of the supply chain (Lee & Whang, 2001).

***Intelligent software agents*:** Refers to innovative and useful software, easily customizable by a web surfer, which perform autonomous and continuous research and data gathering tasks on the Internet, analyze the results, then, mission accomplished, deliver personalized, relevant, exploitable information (Agentland, 2008). It's sometimes a synonym for software agent.

***Literature review*:** A review of topic-related literature that "describes theoretical perspectives and previous research findings related to the problem at hand" (Leedy & Ormrod, 2001, p. 70) within a certain time period.

***Multi-Agent Application*:** Refers to a computational system where agents cooperate or compete with others to achieve some individual or collective task (Krupansky, 2005).

***Procurement*:** Refers to the business management function that ensures identification, sourcing, access and management of the external resources that an organization needs or may need to fulfill its strategic objectives (CIPSA, 2005).

***Procurement Agent*:** Boeing (2007) refers to procurement agents authorized agents of the company, with responsibility for managing all supplier-related activities. These agents have the authority to commit company resources through contracts and agreements (Boeing, 2007). Millennium Challenge Corporation defines *procurement agent(s)* as any individual or entity that has or manages a procurement contract and process (Millennium Challenge Corporation, 2007).

***Software Agent*:** A software program that is capable of autonomous (or at least semiautonomous) actions in pursuit of a specific goal (Nienaber & Barnard, 2007).

***Software Agent Application*:** Refers to the system platforms of an Intemet-based SCM system, including the operating systems and the middleware that supports information sharing applications and databases (Zhang & Li, 2006).

***Software Agents-Enabled Systems Coalition*:** Is an integrated environment for the holistic product design from concept to realization and removes the barrier of collaboration between networked and non-networked environment (Tseng, El-Ganzoury, & Abdalla (2005).

***Supply Chain Analyst*:** Microsoft (2008) defined *supply chain analyst* as someone or something that monitors the supply-chain process to ensure smooth and efficient operation from sourcing to delivery. It ensures that products get to the right place at the right time (Microsoft, 2008).

***Supply-chain Event Management* (SCEM)** provides timely event-related information that can be used to identify and correct disruptions and malfunctions in operational supply-chain processes (Bodendorf & Zimmermann, 2005).

***Supply Chain Management* (SCM):** Refers to a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers (Martin & Roth, 2000).

***Supply Chain Management Information Systems* (SCM IS):** Refers to information systems (IS) used to coordinate information between internal and external customers, suppliers, distributors, and other partners in a supply chain (McLaren et al., 2004).

***Supply Chain Risk*:** Refers to an uncertainty or unpredictable event affecting one or more of the parties within the supply chain or its business setting, which can (negatively) influence the achievement of your own business objectives (Deloitte, 2004).

***Supply Chain Risk Management*:** Refers to the identification and management of risks within the supply chain and risks external to it through a co-coordinated approach amongst supply chain members to reduce supply chain vulnerability as a whole (Haywood & Peck, 2003).

***Supplier Enablement*:** Refers to an online portal between companies and suppliers, so they can communicate in real time and synchronize business processes (Manh, 2008).

***Value stream mapping*:** Refers to all the actions (value-added and non-value added) required to take a product from raw material to the customer, the design flow from concept to completion (Krar, 2002).

***Vulnerability*:** Refers to an exposure to serious disturbance, arising from risks within the supply chain as well as risks external to the supply chain and as a condition that is caused by time and relationship dependencies in a company's activities in a supply chain (Svensson, 2000).

RESEARCH PARAMETERS

This section outlines the methods used in locating and selecting literature for this study and provides a description of the way information is framed in the summary review. The search strategy, terms and collected literature are described in detail. The evaluation criteria used to select literature include relevance to the topic, audience and quality. A detailed writing plan is outlined that describes how the selected literature is presented in the Review of the Literature.

Search Strategy

Literature review is defined as a review of topic-related literature that "describes theoretical perspectives and previous research findings related to the problem at hand" (Leedy & Ormrod, 2001, p. 70) within a certain time period. It allows for a wide range of materials related to the research topic to be included in the review. Initial and extensive search was conducted using the terms below via major search engines including University of Oregon libraries website, Yahoo, Ebscohost, MSM, Google and Google Scholar:

1. Supply chain risks in a manufacturing company (Haywood & Peck, 2003).
2. Electronic procurement and risk management (COSO, 2004, p. 2).
3. Supply chain management (Martin & Roth, 2000).
4. Supply chain integration and risk management (Deloitte, 2004; McLaren, 2006).
5. Software agents and risk management (Nienaber & Barnard, 2007; Mark, 2006).

The decision to collect a reference for further review is based on the date the article was published; source of the article; whether the site is trustworthy; cost; availability of related articles; and companies that were surveyed in the article. Google yielded the most relevant articles. The collected literature was published between January 2000 and April 2008, extracted

from search engines, major aerospace companies' sites, supply chain software providers sites and manufacturing companies. The search engine and database search results are displayed in the Summary Table of Search Results (see Table 1).

Search Engine / Database	Search Terms	Results	Quality of Results
Google	Supply chain risks in a manufacturing company	62,700	Excellent
	Electronic procurement and risk management	161,000	Excellent
	Supply chain management	15,200,000	Excellent
	Supply chain integration and risk management	266,000	Good
	Software agents and risk management	311,000	Fair
Google Scholar	Supply chain risks in a manufacturing company	73,300	Good
	Electronic procurement and risk management	46,200	Excellent
	Supply chain management	830,000	Good
	Supply chain integration and risk management	83,100	Good
	Software agents and risk management	176,000	Good
Business Source Database (Ebscohost.com)	Supply chain risks in a manufacturing company	128	Excellent

	Electronic procurement and risk management	85	Excellent
	Supply chain management	18,959	Good
	Supply chain integration and risk management	58	Good
	Software agents and risk management	111	Good
Yahoo	Supply chain risks in a manufacturing company	20,900,000	Excellent
	Electronic procurement and risk management	7,150,000	Excellent
	Supply chain management	157,000,000	Good
	Supply chain integration and risk management	11,200,000	Good
	Software agents and risk management	25,600,000	Good
Onesearch database	Supply chain risks in a manufacturing company	24	Good
	Electronic procurement and risk management	3	Poor
	Supply chain management	39	Good
	Supply chain integration and risk management	0	Poor
	Software agents and risk management	7	Fair

Figure 1: Summary Table of Search Results

Literature Evaluation and Selection Criteria

A preliminary analysis of each article is conducted by scanning the abstract, the introduction, headings and subheadings, tables and figures, discussion and conclusions, and the reference list (Hewitt, 1998). Search results are approached with an open mind and the decision to use is based on review of titles, abstracts, introduction and conclusions (Cooper, 1998). Information from the reviews is not taken at face value, but is grounded in a determination as to whether their conclusions are justified based on the available information (Leedy & Ormrod, 2001, p. 77). Literature sources are synthesized, compared and contrasted with varying perspectives on the topic.

Relevance

The first set of references for use is obtained; duplicates are removed and one assesses the relevance of the material (Hewitt, 1998). If the research paper contributed to the study of the development of the roles of software agents in supply chain risk management, relevant to the aerospace manufacturing industry, then it was kept as potential useful source material and reviewed (Anderson, Beveridge, & Singh, 2007).

Author

Analysis of the author's name and affiliation to a particular organization or institution helped in determining the authenticity of the review (Ormondroyd et al., 2004). Priority was given to authors affiliated with academic institutions, and to businesses and organizations in the subject area of supply chain management. Library databases or Google Scholar were searched to identify other writings by the author. The author's authority in the field of supply chain management was looked at in selecting literature.

Publisher

A reference list that includes articles from a range of journals and years, with books and other formats, is included in the review (Hewitt, 1998). It is important to note that the contents of an article do not necessarily represent facts just because they are in print (Hewitt, 1998). The papers used in this study were published by scholarly journals, universities, and other reputable institutions and have been critically evaluated, been used extensively as a source material, been peer reviewed and are considered to be a recognized authority in the area of supply chain risk management. Journal editorial guidelines were examined to ensure literature is critically reviewed prior to publication (Ormondroyd et al., 2004).

Audience

This study was limited to material intended to address scholarly and professional audiences (Ormondroyd et al., 2004). This literature provides the right level of information to inform the decisions of procurement professionals. Besides, this literature review is intended to directly educate supply chain analysts and procurement agents about the availability of over-the-shelf software that could be used to mitigate the effects of supply chain risk. According to Edmonson (2006), government agencies are researching contingency plans for supply chain risk management after disasters or terrorist attack. However, this aspect is not included in this paper. This research does not include any proprietary information from Boeing.

Writing Plan

The goal of this study was to examine supply chain risk management structures where software agents are applied as an integrator for an effective risk management system. According to Sheffi (2001) manufacturing supply chains involve a network of enterprises and processes, which turn a combination of raw materials into finished products delivered to the consumer (p. 4). Reese (2007) stated that in the aftermath of recent disasters within the United States and

elsewhere around the world, supply chain risk management (SCRM) has been gaining increased executive-level attention in the past few years.

This paper describes and summarizes software agents-enabled systems coalition for integrated manufacturing processes and supply chain management. The writing plan as presented below aligns with the "Swiss Cheese" rhetorical pattern presented by Obenzinger (2005). In accordance with this format, the review of the literature presents current knowledge within the field of software agents and supply chain risk management then demonstrates how current research helps to resolve some of those open issues (Obenzinger, 2005). The use of a thematic approach organizes subject matter around a unifying theme. In this case, the unifying theme is 'software agents', and the goal is to examine ways to integrate software agents within supply chain risk management, so that system and procurement agents and supply chain analysts will be able to perform better on the job.

Writing Plan Outline

Supply Chain Management Overview - Examine the background of supply chain management and procurement process from review of literature in the first group of the Review of the Literature Bibliography.

Literature that examines supply chain management:

1.1 Supply chain management

1.2 Procurement and contracting processes

1.3 E-procurement

1.4 Supply chain problems with off-shoring

1.5 Who are procurement agents and supply chain analysts?

Supply Chain Risk Management - Describe supply chain risk management and disaster recovery based on review of literature in the second group of the Review of the Literature Bibliography.

Literature that examines different types of supply chain risks:

2.1. Brief overview of risks. For example, natural disasters and terrorist attacks and disruptions in supply

2.2. Protecting Your Supply Chain

2.3. Beyond Disaster Recovery

2.4. Reconciling supply chain vulnerability

Software Agents - Describe the principles of incorporating software agents into supply chains based on review of literature in the third group of the Review of the Literature Bibliography.

Literature that examines the incorporation of software agents into supply chain risk management:

3.1. Information system utilization strategy for Supply chain management integration

3.2. Software Agents Overview

3.3. Agent-Oriented Supply-Chain Management

3.4. Charting the Best Course

Conclusions - Present the main benefits of software agents in supply chain risk management mitigation, within the aerospace manufacturing industry. The goal is to mitigate and avoid possible future natural or artificially created emergencies, disasters, or disruptions.

Annotated Bibliography

This annotated bibliography presents the key twenty-nine pieces of literature that support the different sections of this study. Entries are organized in three groups corresponding to key areas of content, listed in alphabetical order, and include a brief summary of contents and relevance to this study. Information is selected from a variety of sources, in an attempt to keep the study valid and credible, and includes seminar reports, papers and thesis written by faculty members, industry executives and published by reputable journals or associations. The bulk of the references concern Group 3: Incorporating Software Agents Into Supply Chains Risk Management.

Supply Chain Management and Procurement Process

Fugate, B., Sahin, F. & Mentzer, J. (2005). Supply Chain Management Coordination Mechanisms. *The University of Tennessee Publication.* Retrieved May 3, 2008, from http://forums.utk.edu/supplychain/Readings/SCMCoord.pdf.

Coordination is essential for successful supply chain management. There is growing interest from industry and academic disciplines regarding coordination in supply chains, particularly addressing the potential coordination mechanisms available to eliminate sub optimization within supply chains. The literature findings support a description of flow coordination mechanisms among suppliers and customers, concluding that they lead to enhanced supply chain performance. The authors examined a number of research papers on supply chain management mechanisms and the elimination of sub-optimization, and addressed ways to optimize supply chain management. This review was published by the University of Tennessee, Department of Marketing and Logistics and was referenced in other supply chain management reviews.

Head, M., McLaren, T. & Yuan, Y (2004). Supply Chain Collaboration Alternatives: Understanding the Expected Costs and Benefits. *Information Systems and eBusiness Management.* Retrieved May 7, 2008, from http://www.business.mcmaster.ca/IS/head/Articles/Supply%20Chain%20Collaboration%20Aternatives_Understanding%20the%20expected%20costs%20and%20benefits.pdf.

This paper discussed collaboration as a recent trend in supply chain management (SCM) that focuses on joint planning, coordination, and process integration between suppliers, customers, and other partners in a supply chain. Authors analyzed alternative information systems approaches for supporting collaborative SCM, including phone, fax, or email systems; Web-based order entry systems; and electronic data interchange. This paper concluded that collaborative SCM results in significant benefits to an organization. Two of the authors of this review are University Professors while the third author is a PHD candidate. This article focused on information technology and supply chain management inter-working relationship.

Infor (2007). *New dimensions in supply chain management: Eight strategies for improving performance from concept to customer*. Retrieved on May 12, 2008, from http://go.infor.com/library/Infor/New_Dimensions_in_SCM.pdf.

Company executives are realizing that they need an expanded view of their company's business environment. Virtually every company from manufacturer to logistics provider to retailer is operating in a much more complex, multifaceted supply chain. The list of forces in supply chain dynamics is long, varied and, in most instances, not a surprise. It includes globalization, a changing competitive landscape due to mergers and acquisitions, changing regulatory requirements, changing consumer expectations, and a high failure rate for new product introductions. There also are forces that are less top of mind, including shortening of product lifecycles, skyrocketing product variety, rising energy costs, increased congestion at

ports and on roads, and the impact of real or potential natural disasters and terrorism. This paper reiterates the importance of incorporating all supply chain business drivers into decision making process. Infor delivers business-specific software that helps enterprising organizations of all sizes adapt to rapid change around the world with an over 70,000 customer base.

Johnson, A. (2006). Supply chain problems with off-shoring. *Manufacturers' Monthly*, Retrieved April 24, 2008, from Business Source Corporate database.

This article presented information related to offshore sourcing of a long chain of products. Technology, process and people are the three main issues that need to be addressed by manufacturers when sourcing products offshore.

Lee, H.L. (2004). The triple-A supply chain. *Harvard Business Review*. 82(10), 102–112.

Building a strong supply chain is essential for business success. Many businesses work to make their chains faster or more cost-effective, assuming that those steps are the keys to competitive advantage. To the contrary, supply chains that focus on speed and costs tend to deteriorate over time. Great companies create supply chains that respond to abrupt changes in markets. Agility is critical because in most industries, both demand and supply fluctuate rapidly and widely. Supply chains typically cope by playing speed against costs, but agile ones respond both quickly and cost-efficiently. This paper stated that companies need to build supply chains that are agile, adaptable, and aligned with the overall company strategy and that no new infrastructure is needed to implement changes in supply chain. This paper was published by *Harvard Business Review*, which gives it credibility. The author is a Professor of Operations, Information, and Technology at the Stanford Graduate School of Business in Stanford, California, and the co editor of the Stanford Global Supply Chain Management Forum. He is also the coeditor of *The Practice of Supply Chain Management: Where Theory and Application Converge* (Kluwer Academic Publishers, 2003).

Sengupta, S. (2008). A Plan for Building a New Supply Chain. *Supply Chain Management Review*, *12*(1), 46-52. Retrieved May 2, 2008, from http://www.scmr.com/article/CA6518143.html.

The article offered a structured way of redesigning the core supply chain building blocks and operating model to cope with the shifting dynamics in the global marketplace. It discussed several structural and economic changes including rapid globalization, convergence of the end customer and higher escalation of commodity prices. This article described the basic need for supply chain re-engineering for the future. The author is a Vice President with Hitachi Consulting, and his explanation of supply chain building blocks is used in this inquiry to provide additional viewpoint.

Supply Chain Risk Management

Biederman, D. (2007). Companies seek to manage supply-chain risk. *Gulf Shipper*, *18*(20), 58-62. Retrieved May 5, 2008, from http://www.accessmylibrary.com/coms2/summary_0286-32845023_ITM

The article deals with the increasing number of carriers using risk management solutions for their supply chains. Supply chains are considered vulnerable to disasters like labor strikes and fluctuations in demand. According to FM Global, significant supply-chain problems can affect the company's revenue. The article is essential because it provides the basis of risk management and placed emphasis on the consequences of supply chain disruptions.

Closs, D., Speier, C., Whipple, J., & Voss, M. (2008). A Framework for Protecting Your Supply Chain. *Supply Chain Management Review*, *12*(2), 38-45. Retrieved April 23, 2008, from Business Source Corporate database.

Recent terrorist threats and security incidents have heightened awareness regarding supply chain security. But many managers still underestimate supply chain vulnerability and struggle with where to focus their security efforts. This article is relevant to this study in that it provides the basis for securing the supply chain of companies.

Curtis, G. (2008). Beyond Disaster Recovery. *Directorship*, *34*(1), 38-43. Retrieved April 21, 2008, from Business Source Corporate database.

The article discussed other approaches adopted by companies to business continuity planning in 2008. Based on the U.S. Department of Labor Statistics, 40% of companies that experience disaster never re-open and around 25% of remaining companies close within two years. Given these figures, companies have resorted to business continuity planning (BCP) measures such as providing remote technologies for employees to perform work outside the office in cases of emergency, installing back-up systems to back-up systems, and hiring in-house legal counsels. This article stated the need for business continuity in case of a disaster.

Edmonson, R. (2006). Post-disaster: U.S. developing transport and supply chain recovery plan. *Pacific Shipper*, *81*(25), 18-19. Retrieved May 8, 2008, from Business Source Corporate database.

The article focused on the development transport and supply chain recovery plan of the U.S. after the devastation of Hurricane Katrina. The Coast Guard set up a task force to address post-hurricane recovery, in which their report will serve as a draft of a national recovery plan for whatever natural disaster or terrorist attack in the future. This article stressed the need for disaster planning, not only by corporations but also by government agencies. The research was coordinated through the Coast Guard, Customs and border Protection and the DHS, all of which are committed to the idea that a disaster at one location will shut down the entire system.

Fisher, K., Holland, S., Loop, K., Metcalf, D., Nichols, N., & Ortiz, I. (2007). Managing Goods and Services Acquisition Risks. *Intel Technology Journal*, *11*(2), 115-125. Retrieved April 22, 2008, from Business Source Corporate database.

This paper looked at risk from the total supply chain perspective with the realization that there are inherent risks at every stage of the supply chain. Although we cannot control all the risks, we may put methods and tools in place to help mitigate risks, especially in the areas that require the most focus. The authors outlined effective tools used at Intel to reduce risks in the supplier sourcing process, prevent the risk of business interruption, and moderate risks related to currency fluctuations in the capital equipment purchasing process. This review demonstrated how Intel used the internet to mitigate the effects of risk. The authors highlight several high-risk areas that Intel currently mitigates and showcased the tools and methods used to address those risks.

Haywood, M & Peck, H, (2002). An Investigation into the management of supply chain vulnerability In UK aerospace manufacturing: *Centre for Logistics and Supply Chain Management*, Cranfield School of Management, Cranfield University.

This paper reported on the findings of a single-in depth exploratory case study into the drivers of risk and the management of supply chain vulnerability in aerospace manufacturing. It examined the problem from a multiple-organization perspective, using an assembler of military aircraft, the Prime Contractor, as its point of embarkation. The paper examined managers' perceptions of supply chain risk, presented here with reference to the industry context. It went on to provide a summary of supply chain risk management tools and mitigation techniques, identified by the managers concerned as currently in use plus others that were believed to be beneficial. Finally, it identified the limitations of existing tools and techniques and puts forward suggestions for improved implementation. This review was conducted by the defense department

in U.K in conjunction with Cranfield University and identified the risks aerospace supply chain military professionals face due to changes in product specifications, together with other continuous improvement initiatives.

Peck, H. (2006). Reconciling supply chain vulnerability, risk and supply chain management. *International Journal of Logistics: Research & Applications*, *9*(2), 127-142. Retrieved April 22, 2008, from Business Source Corporate database.

The purpose of this paper was to provide a critique of the extant canon and to review the positioning of research in the field, together with literature drawn from several relevant and overlapping fields of research and practice. The aim was to foster a more explicit understanding of the relationships between supply chain vulnerability, risk and supply chain management, and in turn their relevance to related fields such as corporate governance, business continuity management, security and emergency planning. The ultimate objective is to clarify the agenda for further research. The paper began with an examination of the concept of a "supply chain" and the scope and nature of supply chain management (SCM), then the fusion of SCM with the many and varied interpretations of "risk" and its faltering relationship to risk management. It was argued that attitudes to risk and approaches to risk management vary greatly within SCM and between related disciplines. This paper threaded together a number of related areas with a common underlying theme—an interest in supply chain vulnerability and supply chain risk management.

Incorporating Software Agents Into Supply Chains Risk Management

Bodendorf, F., & Zimmermann, R. (2005). Proactive Supply-Chain Event Management with Agent Technology. *International Journal of Electronic Commerce*, *9*(4), 57-89. Retrieved May 6, 2008, from the ACM Digital Library.

This review provided a proactive Supply-Chain Event Management (SCEM) system that adheres to requirements derived from the deficits of current SCEM solutions that substantially reduce supply-chain troubleshooting costs. Several mechanisms for proactive SCEM were proposed, encompassing concepts to gather data on suborders in inter-organizational settings, focus on proactive monitoring activities with classified critical order profiles, and analyze, interpret, and distribute information employing fuzzy logic. Software agents' technology is shown to be suitable for implementing proactive SCEM systems, and an agent-based concept was presented. This paper presented selected research results from a project sponsored by the Deutsche Forschungsgemeinschaft (DFG) as part of a priority research program run by the Department of Information Systems and the Department of Artificial Intelligence at the University of Erlangen–Nuremberg, Netherlands.

David, P. & Stone, P. (2007). An Autonomous Agent for Supply Chain. *Handbooks in Information Systems Series: Business Computing.* Retrieved May 1, 2008, from Business Source Corporate database.

Supply Chain Management involves planning for the procurement of materials, assembly of finished products from these materials, and distribution of products to customers. The Trading Agent Competition Supply Chain Management scenario (TAC SCM) provides a competitive benchmarking environment for developing and testing agent-based solutions to supply chain management. This study served as a checklist for autonomous software agents when

implemented in supply chain management. The author is a professor of computer sciences at the University of Texas at Austin.

Exostar (2007). BAE Systems adopts eProcurement for enterprise efficiency: Leveraging a hosted solution to reduce cost and improve service levels: Retrieved on April 16, 2008, from www.exostar.com.

In 2001, BAE Systems undertook an enterprise-wide effort to e-enable key areas of the organization from sales and collaboration to sourcing and procurement. The objective was to drive process efficiency and consistent use of technology platforms. BAE Systems knew that an undertaking of this magnitude would require a shift in the cultural mindset of its staff. When it came to adopting a catalogue ordering system for indirect procurement, BAE Systems purchased an enterprise software platform to support its organizational and process transformation. The goal was to enable web-based ordering of 'low value, high volume' indirect goods and services from catalogues specifically configured for BAE Systems to maximize corporate deals with suppliers. Expected benefits included decreased off-contract spends, enforcement of standard processes, reduced cycle times, and increased visibility into total enterprise spending. This report described the benefits of e-procurement, which remains an effective method of cost reduction. BAE Systems is a premier global defense and aerospace company delivering a full range of products, information technology solutions and customer support services.

Gunasekaran, A & Ngai, T, (2004). Information systems in supply chain integration and management: *European Journal of Operational Research 159 (2004) 269–295.* Retrieved on April 14, 2008, from http://www.whiceb.com/CICEB/document/Information%20systems%20in%20supply%20chain%20integration.pdf.

Supply chain management (SCM) is the 21st century global operations strategy for achieving organizational competitiveness. Companies are attempting to find ways to improve their flexibility and responsiveness, and in turn competitiveness by changing their operations strategy, methods and technologies to include the implementation of SCM paradigm and information technology (IT). However, a thorough and critical review of literature is yet to be carried out with the objective of bringing out pertinent factors and useful insights into the role and implications of IT in SCM. In this paper, the literature available on IT in SCM have been classified using suitable criteria and then critically reviewed to develop a framework for studying the applications of IT in SCM. Based on this review and analysis, recommendations have been made regarding the application of IT in SCM and some future research directions are indicated. This paper demonstrates that IT is an essential ingredient for supply chain activities and improves the competitiveness of firms. This research was supported in part by The Hong Kong Polytechnic University.

Head, M, McLaren, T & Yuan, Y (2004). Supply Chain Management Information Systems Capabilities: An Exploratory Study of Electronics Manufacturers. *Information Systems and eBusiness Management.* Retrieved on April 14, 2008, from http://www.ryerson.ca/~tmclaren/McLaren%20et%20al.%20SCM%20IS%20Capabilities%20Model%20%5BISeBM%5D.pdf.

Supply Chain Management Information Systems (SCM IS) play an increasingly critical role in the ability of firms to reduce costs and increase the responsiveness of their supply chain. This paper develops an empirically supported model of the organizational capabilities enabled by SCM IS. The model integrates and enriches theoretical and empirical studies of competitive strategy, supply chain management, and inter-organizational information systems. Evidence from an exploratory case study of three large firms in the electronics manufacturing industry is

examined to build a better-supported theory of SCM IS capabilities. This study found the concepts of information technology to have shortcomings when applied to supply chain management.

Mark. S.F, Mihai, B., & Rune, T. (2000). Agent-Oriented Supply-Chain Management: *The International Journal of Flexible Manufacturing Systems,* 12 (2000).165–188. Boston: Kluwer Academic Publishers.

The supply chain is a worldwide network of suppliers, factories, warehouses, distribution centers, and retailers through which raw materials are acquired, transformed, and delivered to customers. In recent years, new software architecture for managing the supply chain at the tactical and operational levels has emerged. It views the supply chain as composed of a set of intelligent software agents, each responsible for one or more activities in the supply chain and each interacting with other agents in the planning and execution of their responsibilities. This paper investigated issues and presented solutions for the construction of such agent-oriented software architecture. This reference supports the purpose of this study; in particular describing the coordination plans of supply chain management execution, through the use of software agents.

McLaren, T, (2006). A Measurement Model for Web-enabled Supply Chain Integration. Paper presented at the 19th Bled eConference eValues, Bled, Slovenia. Retrieved April 16, 2008, from http://domino.fov.unimb.si/proceedings.nsf/0/4d3c3c1241bfe7fec1257180003260d0/$FILE/29_McLaren.pdf.

Recent developments in supply chain management information systems have greatly increased the ability of firms to integrate processes, systems, and information with their supply chain partners. Despite the apparent benefits of web-enabled supply chain integration, its further

study and application is hindered by the lack of an empirically supported model for classifying the varying levels of supply chain integration that are now possible using e-business technologies. This paper presented findings from a multiple case study used to explore web-enabled supply chain integration and identify potential questionnaire measures for further study. The main focus of this study was that there is need for more research in supply chain management.

Narasimhan, R., & Kim, S. (2001). Information system utilization strategy for Supply chain integration. *Journal of Business Logistics*, *22*(2), 51-75. Retrieved April 16, 2008, from Business Source Corporate database.

The introduction of information technology by a firm for integrated supply chain management could lead to better efficiency and effectiveness, compared to existing logistics systems. For example, under current warehouse management, it might be necessary to secure sufficient space to keep a large enough inventory for timely delivery. Integrated supply chain management utilizing information systems and a shared supply chain database can enable the company to identify optimal inventory levels, reduce warehouse space, and increase inventory turnover. The new integrated supply chain management systems, if utilized properly, can lead to higher quality products, enhanced productivity, efficient machine utilization, reduced space, and ultimately increase logistics efficiency and flexibility. This research suggested the sequence that must be followed in implementing successful supply chain integration and published by Eli Broad Graduate School of Management, Michigan State University.

Nissen, M., & Sengupta, K. (2006). Incorporating software agents into supply chains: experimental investigation with a procurement task. *MIS Quarterly*, *30*(1), 145-166. Retrieved April 17, 2008, from Business Source Corporate database.

Recently, researchers have begun investigating an emerging, technology-enabled innovation that involves the use of intelligent software agents in enterprise supply chains. Software agents combine and integrate capabilities of several information technology classes in a novel manner that enables supply chain management and decision making in modes not supported previously by IT and not reported previously in the information systems literature. Indeed, federations and swarms of software agents today are moving the boundaries of computer-aided decision making more generally. Such moving boundaries highlight promising new opportunities for competitive advantage in business, in addition to novel theoretical insights. But they also call for shifting research thrusts in information systems. The stream of research associated with this article is taking some first steps to address such issues by examining experimentally the capabilities, limitations, and boundaries of agent technology for computer-based decision support and automation in the procurement domain. Procurement represents an area of particular potential for agent-based process innovation, as well as reflecting some of the greatest technological advances in terms of agents emerging from the laboratory. This text stated that software agents have the potential for effecting sharp improvements in performance in procurement processes. The authors are associate professor of Information science with extensive research publications in management and business value of information technology.

Reese, A. (2007). Enabling Supplier Enablement at Oracle: Supply and Demand Chain Executive. Retrieved on May 12, 2008 from http://www.sdcexec.com/print/Supply-and-Demand-Chain-Executive/Enabling-Supplier-Enablement-at-Oracle/1$9275.

Oracle was challenged was challenged by a supplier content management process that had the company's procurement staff loading and managing vendor catalogs within the e-procurement system. To accelerate supplier enablement and shift its buyers onto more strategic

work, the company began using a new tool that put the suppliers in the driver's seat. This article stated the importance of a software suite for maximizing supply chain efficiency.

SAP, (2005). Charting the Best Course. Retrieved on April 13, 2008, from http://www.sap.com/industries/hightech/pdf/BWP_OV_Strategies_for_Sucess_Semiconductor.pdf.

The aerospace and defense (A&D) manufacturing industry is always changing. What worked yesterday might not work today. That's why A&D manufacturers are constantly seeking better ways to manage complexity, cut costs, and boost productivity. In pursuit of these objectives, A&D manufacturers are looking beyond standard practices to new business strategies that promise solid business results. But what strategies and practices are right for your company? And what are the best solutions for facilitating them? To answer these questions, companies rely on insights and advice from industry thought leaders. SAP is the world's leading provider of business software, SAP delivers products and services that help accelerate business innovation for their customers. This paper particularly focused on the automation of supply chain management in an aerospace manufacturing industry.

Schweiger, A., Sunyaev, A., Leimeister, J., & Krcmar, H. (2007). Information Systems And healthcare xx: Toward Seamless Healthcare with Software Agents. *Communications of AIS*, *2007*(19), 692-710. Retrieved May 1, 2008, from Business Source Corporate database.

Healthcare processes are frequently fragmented and often badly supported with IT. Inter- and intra-organizational communication and media frictions complicate the continuous provision of information according to the principle of information logistics. Its implementation requires the establishment of a communication infrastructure and the deployment of adequate standards in healthcare. There are already comprehensive approaches for dealing with integrating

heterogeneous information systems. However, they lack a common communication infrastructure and do not support proactivity and flexibility which are dominant characteristics in healthcare. This paper proposes a software agent-based approach for realizing the vision of seamless healthcare. The researcher has replaced the concept of healthcare in this review with supply chain risk management as a way to draw implications for IT decision makers in supply chain risk management.

Trunick, P. (2007). Risks Multiply with IT investments. *Logistics Today, 48(4),* 16-16. Retrieved April 19, 2008, from Business Source Corporate database.

The article reported on the use of software applications to fight investment risks in the U.S. According to a report, many legacy software applications that are outdated due to faster transformation logistic supply chains have not kept up with changes in order tracking, receiving, cross docking and other processes. To address the problem, some technology companies like Apriso, Sap, IBM and Solace Systems has developed new software that provides the needs of risk managers.

Watson, K. (2004). Crystal gazing for the 21st century. *Food Manufacture*, *79*(10), 41-42. Retrieved May 6, 2008, from http://www.foodmanufacture.co.uk/news/fullstory.php/aid/599/Crystal_gazing_for_the_21st_century.html.

This report is on the criticisms of Professor Daniel Jones on enterprise resource planning (ERP) system. The author admitted that some of the software agents available on the market have greater capability than the software suites on offer under ERP systems.

Yi Wu, (2007). Implications of Case Study Research in Information Systems in Supply Chain Management. Paper presented at the 16th EDAMBA Summer Academy, Soreze, France. Retrieved April 16, 2008, from http://www.edamba.eu/userfiles/Yi%20Wu.pdf.

This research was concerned with Information System (IS) integration in the context of agile capability of supply chain management (SCM). Case study research was carried out for empirical research. Data was collected on the role and impact of IS in relation to supply chain agility, and to reflect a range of perceptions from 'thick description' of interviews and quantitative presentation. Several strengths and weaknesses were discussed for each method, by highlighting the value of a mixed-methods approach in this study. To validate the credibility of this research, the researcher applied qualitative data to explore the IS in the context of organizations, employing the quantitative information to measure performances as a means of establishing the generalization within supply chain management.

Zhang, C., & Li, S. (2006). Secure information sharing in internet-based supply chain management systems. *Journal of Computer Information Systems*, *46*(4), 18-24. Retrieved April 17, 2008, from Business Source Corporate database.

Information sharing is a key element in any Supply Chain Management (SCM) system and is critical for improving supply chain performance and enhancing the competitive advantage of an organization. However, many organizations are reluctant to share information with their supply chain partners because of lack of trust, the fear of information leakage and security attacks from malicious individuals or groups. Through a review of selected literature, this paper examines the possible security threats/attacks in a SCM system.

REVIEW OF THE LITERATURE

The purpose of this literature review is to examine the role of software agents in supply chain risk management (SCRM) related to the procurement process in the aerospace manufacturing industry. Supply chain risk management involves all the activities involved in the procurement process from customers to suppliers and all the steps in between the various activities. According to Narasimhan (2001) supply chain management deals with the control of material and information flows, the structural and infrastructural processes relating to the transformation of the materials into value added products, and the delivery of the finished products through appropriate channels to customers and markets so as to maximize customer value and satisfaction (p. 1). Kleindorfer and Wassenhove (2003) view the analysis of risk associated with supply chain decisions as strategic to companies in saving costs that arises as a result of risks in the procurement process.

The current research literature increasingly recognizes the importance of supply chain risks (Cavinato, 2004). The importance of global competition and technological change, with firms searching for sources of competitive advantage, has increased the importance of risk analysis in supply chain management (Christopher & Lee, 2004). Supply chain risk management in an aerospace industry has not yet been widely investigated. A search for literature undertaken early in the summer of 2002 revealed a total of 62 articles on supply chain risk/vulnerability (Haywood & Peck, 2002). Only one dealt with aspects of aerospace manufacturing, focusing on how the burden of risk within the industry is being passed on to smaller weaker suppliers (Cook, 2001).

This study is designed to provide procurement agents and supply chain analysts, particularly in the aerospace manufacturing industry, examples of how software agents are being used as part of network applications by aerospace companies, as a way to mitigate supply chain

risks. Software agents are programs that are capable of autonomous (or at least semiautonomous) actions in pursuit of a specific goal (Nienaber & Barnard, 2007).

The review is organized around three groups of selected references: The first group examines supply chains, supply chain management, and the procurement process as they assist procurement agents in sourcing raw materials. The second group describes supply chain risk management and disaster recovery in relations to business continuity in an aerospace manufacturing company. The third group describes the principles of incorporating software agents into supply chain risk management in order to assist in mitigating the effects of risks in a supply chain.

Supply Chain, Supply Chain Management, and the Procurement Process

Supply Chain

A supply chain is the collection of functional activities through which raw materials are converted into finished products for sale to a customer (Head et al., 2002). According to Lee (2004) supply chains possess three key qualities: they are agile, adaptable, and aligned in ways that provide companies with sustainable competitive advantage (p. 2). Lee (2004) explained that the best supply chains aren't just fast and cost-effective, they are also agile and adaptable, and they ensure that the interests of all the companies involved stay aligned (p. 2). The supply chain must create incentives for better performance by exchanging information and knowledge freely with vendors and customers, and lay down roles, tasks, and share risks clearly between suppliers and customers. Furthermore, a company’s internal process encompasses the physical aspects of its business that are largely under its control. These include manufacturing, distribution, or retail capacity, and the time and costs that go into sourcing, producing, and distributing products (Infor, 2007). These activities provide the framework for addressing business forces within the

internal, external, and customer dimensions of supply chain enabling a true multidimensional view of the factors impacting business performance (Infor, 2007).

In addition, supply chains are becoming more and more global with supply chain functions being physically distributed and dispersed (Sengupta, 2008). For example, the Boeing 787 program has transformed its supply base globally, and it is now spread across countries as dispersed as the US, Japan, Italy, and Taipei into design and manufacturing partners (Infor, 2007). However, certain global macro economic factors have emerged in recent years that are forcing many corporations with well-defined and extended supply chains to rethink the construct of the core supply-chain building blocks and operating model (Sengupta, 2008).

Supply Chain Management (SCM)

A supply chain is the collection of functional activities through which raw materials are converted into finished products for sale to a customer (Head et al., 2002). Forger (2007) believed that the goal of the supply chain in the future is not simply efficiency (doing things for less), but it is effectiveness (doing the right things). The supply chain of the future requires that managers recognize that supply chain management (SCM) should become a core competency of a company, including focus on the capability to support current strategic objectives as a way to enable the firm to better serve its critical customers as well as reduce procurement cost.

Trkman, Stemberger, and Jaklic (2004) examine the issue of economics of scale to address costs associated with supply chain management. According to Trkman et al. (2004), the separation of supply chain activities among different companies enables specialization and economies of scale. They believed that there are many important issues and problems that need to be resolved for successful supply chain operation—this is the main purpose of SCM. Leonard (2003) described these problems as using multiple channels, or using many different types of transactions to manage numerous suppliers (which vary in size, respective contracts, and

relationships), which can be time consuming. Additionally, he noted that spreading information across many systems increases the margin of error (p. 2).

Procurement and Contracting Processes

Leonard (2003) referred to procurement as purchasing of goods and services for the day-to-day operation of a business and stated that procurement is an essential part of any organization's ability to function effectively and efficiently. Supply chain management systems are designed to support enhanced information sharing and collaborative planning among partners in an effort to reduce information asymmetries in the supply chain (Lee, 2000). The Chartered Institute of Purchasing & Supply (CIPSA), (2005) stated that procurement includes activities and events before and after the signing of a contract as well as the general supplier management activities associated with a range of contracts. The general supplier management activities include: (a) pre-contract activities such as planning, needs identification and analysis, and sourcing; (b) post-contract activities such as contract management, supply chain management and disposal; and (c) general activities such as corporate governance, supplier relationship management, risk management, and regulatory compliance (p. 5).

There has been a veritable revolution in the literature and practice of contracting in supply chains, through innovations in standard, negotiated contracts between individual buyers and sellers, as well as via business-to-business (B2B) and business-to-consumer (B2C) exchanges (Kleindorfer & Wassenhove, 2003). These activities help companies to be efficient and better prepared for uncertainties in supply chain management.

E-procurement

E-procurement is the purchase of goods and services via electronic media. According to Epiq (2008) e-procurement is more than just a system for making purchases online. A properly implemented system can connect companies and their business processes directly with suppliers while managing all interactions between them. E-procurement has become an important financial and stability opportunity for organizations. Leonard (2007) stated that e-procurement applications are all about enabling the optimization of the procurement business process. According to Saryeddine (2004), the benefits of e-procurement are the following: (a) increasing business volumes within set budget and staff allocations; (b) retiring traditional non-value added activities (e.g., manual input of purchase orders information); (c) improving customer service by redeploying people into more strategic areas (e.g., strategic contracting); (d) improving transparency of processes and increased accountability to customers; and (e) enhancing competitive advantage and strategic positioning amongst suppliers, customers, and competitors (p. 16).

One of the most often-cited benefits of moving to an e-procurement system is the reduction in renegade spending, brought about through the introduction of automated controls and electronic-approval routing (Hannon, 2002). When properly implemented, e-procurement has the potential to be fast, less expensive, and may enable seamless negotiations through electronic media.

Managing Extended Supply Chains

Outsourcing is the process where goods and services are contracted to another company or a third party to execute. According to Craig (2005), outsourcing refers to work or an activity done by people who are not direct employees of the company. Sourcing products off-shore is a growing trend within manufacturing companies around the world (Johnson, 2006). For instance, Boeing outsourced major components of its airplanes to companies within and outside the United States to reduce cost.

An extended supply chain may introduce a number of potential supply chain risks manufacturers might not have taken into account (Johnson, 2006). According to Whitten and Leidner (2006) transaction cost theory (TCT) is a prominent and useful theory to explain why firms may choose to initiate an outsourcing arrangement. However, TCT alone cannot fully explain subsequent decisions to continue or discontinue an outsourcing relationship (p. 607). For example, Infor (2007) noted that product travels more miles, passes through more hands, and crosses more systems on its journey to ultimate customers' destination.

Supply Chain Risk Management (SCRM)

The most important lesson from the past few years of terrorist attacks, dock strikes, regional blackouts, and natural disasters may be that firms finally realize the need to develop effective emergency response strategies within their supply chains to react and recover from inevitable supply chain disruptions (Hale & Moberg, 2003). In the past, firm performance in the area of disaster preparedness has been poor, as noted by Helferich & Cook (2002). For instance, during the workers shipyard strike in Seattle, WA, it took the port three months to get back on schedule and support their customers. Events from the past three years have forced firms to

rethink and restructure their supply chain strategies in order to improve security and minimize the impact of future internal and external incidents (Hale & Moberg, 2003).

Examination of the logistics of supply chain risk and uncertainty uncovers the many new points of intersection the field has with others throughout the corporation and supply and distribution systems (Zsidisin, Ellram, Carter, & Cavinato, 2004). Biederman (2007) states that in a global buy-anywhere, sell-anywhere environment, companies must proactively prepare for disruptions by analyzing their supply chains, creating strategic buffers, and mitigating potential impacts.

However, there are many perspectives on what constitutes a supply chain; there is confusion over the scope of supply chain management (SCM), not least its ambivalent relationship with logistics (Peck, 2006). For example, in an aerospace manufacturing sector, studies by Haywood (2002) found that network complexity and finite resources meant that none of the organizations studied routinely monitored, let alone managed, risk beyond their own organizations or those immediately adjacent to them. And although flow coordination mechanisms are designed to manage product and information flows in supply chains (Fugate et al., 2005), Biederman (2007) noted that supply chains are inherently risky, susceptible not only to natural disasters such as Hurricane Rita but also to smaller disruptions that can be disproportionately damaging, such as labor strikes, equipment shortages, and fluctuations in demand. Any one of these can wreak havoc on even the best-designed supply chain.

In 2002, Sheffi discussed the impact of recent terrorist attacks on managing supply chains. Sheffi suggested that improved relationships between public and private interests are critical in improving the future security of supply chains. He also proposed that firms will have to create more redundancies in their systems and rethink their inventory management strategies to be better prepared against future risks. Haywood and Peck (2002) noted that the disconnection

between supply chain management objectives and changes in business strategy must be addressed for effective supply chain risk management. In the same vein, Curtis (2008) proposed that companies must set up technology applications and software to promote business continuity in their supply chain.

Brief Overview of Risks

The concept of the supply chain can be seen as a network of inter-related entities that combine to enable the satisfaction of customer demand (Stickles, 2002). Peck (2006) noted that supply chains link organizations, industries, and economies and that supply chain vulnerability should be addressed at multiple levels of analysis (p. 6). Supply chains are complex, with many parallel physical and information flows occurring in order to ensure that products are delivered in the right quantities, to the right place, in a cost effective manner (Stickles, 2002). Therefore, supply chain vulnerability is a function of supply chain characteristics, according to Wagner and Bode (2007).

According to Closs et al. (2008) the inter-connectivity of companies, products, and transportation infrastructure in today's high-speed global supply chains results in a growing concern that disruptions can reach beyond an individual firm, which leads to the need for a broader supply chain defense framework. Peck (2006) defined risk from a decision theory perspective as variation in the distribution of possible outcomes, their likelihoods, and their subjective values. In these disciplines, risk management strives to identify, quantify, control, and, where possible, eliminate specific narrowly defined risks (p. 4). As such, firms must proactively enhance their supply chain resiliency against risks (Closs et al., 2008).

The terms ‘risk” and ‘uncertainty’ are sometimes interchangeably used and may refer not only to factors external to companies but also could be internal as well. Cavinato (2004) stated that risks and uncertainties are prominent factors in the competitiveness and viability of

companies and organizations. There are many types of risk and uncertainty—a few of these are noted here: (a) Reese (2007) refers to risks produced by humans (such as devastating terrorist attacks) and (b) natural disasters (such as tsunamis and hurricanes); (c) Atkinson (2008) noted that with the expanding use of technology to enhance supply chain activities and improve supply chain responsiveness comes with the increasing threats and realities of cyber attacks. According to Svensson (2000) the term 'risk,' when used in conjunction with supply chain risk management, automatically acquires downside connotations, while the actual risk may be inadvertently created. The potential for risk, both overt and covert, is part of the daily reality of supply chain management, particularly on the global scale (Atkinson, 2008). For example, Peck (2006) noted that in parts of the aerospace manufacturing industry, supply chain process capacity, rather than raw material or component availability, has produced a risk to delivery schedule adherence.

Once risk areas are identified and prioritized, dealing with them is a matter of using world-class tools and methods for creative supplier and logistics management (Fisher et al., 2007). Recent developments in the area of information technology have enabled firms to increase the degree of interaction that they have with their trading partners as well as establish tighter coordination of their supply chain activities over the Internet (Fugate et al., 2005). According to SAP (2005) business systems must maximize work-in-process visibility to ensure that the customer's request is met. Integrating work-in-process information into planning from external subcontractors ensures that customers receive accurate and timely information (p. 7). Narasimhan and Kim (2001) stated that through the utilization of information systems, companies have been able to integrate similar functions spread over different areas as well as curtail unnecessary activities, thus enhancing their capability to cope with sophisticated needs of customers and meet product quality standards. Haywood and Peck (2002) noted that supply

chain process monitoring and information sharing, via ever better technological solutions, and is a route to more effective supply chain risk management and shared data environments over the Internet. However, Atkinson (2008) noted that with the expanding use of technology to enhance supply chain activities and improve supply chain responsiveness come increasing threats and realities of risks**.**

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How to Protect a Supply Chain

Since the advent of commerce, manufacturing companies have instinctively done things to protect their companies from risk (Barry, 2004). Closs et al. (2008) acknowledged that supply chains are vulnerable to attack and security failures, and suggested that supply chain defense has become an increasingly important issue for both practitioners and researchers. Closs et al. (2008) also defined supply chain management security as the application of policies, procedures, and

technology to protect supply chain assets (product, facilities. equipment, information, and personnel) from theft, damage, or terrorism, and prevent the introduction of unauthorized contraband, people, or weapons of mass destruction into the supply chain (p. 40). Furthermore, according to Closs et al. (2008), companies must design a reliable supply chain strategy to stay afloat before, during, and after disasters. To aid in this effort, a set of terms pertaining to supply chain strategy competency are described (see Figure 2):

Competency	**Definition**
Process Strategy	The executive commitment to enhancing supply chain management and instituting a culture of security within the supply chain
Process Management	The degree to which specific supply chain provisions have been integrated into processes managing the flow of materials and products into and out of the firm
Infrastructure Management	Supply chain provisions that have been implemented to secure the physical infrastructure and products (e.g., buildings, transportation vehicles)
Communication Management	The internal information exchange between employees, managers, and contractors to increase supply chain feasibility
Management Technology	The effectiveness of existing information systems for identifying and responding to a potential security breach
Process Technology	Specific technology (e.g., electronic seals, Radio Frequency Identification RFID) implemented to limit access and trace the movement of goods
Metrics	The availability and use of measures to better identify and manage security threats
Relationship Management	The information sharing and collaboration between the firm and its supply chain partners (e.g., customers, suppliers)
Service Provider Collaboration Management	The information sharing and collaboration between the firm and its logistics service providers (e.g., transportation firms, warehousing providers, and third party logistics company
Public Interface Management	The security related relationships and exchanges of information with the government and the public

Figure 2: Terminology for Supply Chain Strategy, Adapted from Closs et al., (2008, p. 6)

Christopher (2002) believed that the way to reduce supply chain vulnerability is through a coordinated approach among supply chain members. One key to minimizing supply chain disruption is to consider all firms within the supply chain. Moreover, the development of continuity within the supply chain could be an effective approach to improving communication among partners and supporting identification of critical facilities that need access to emergency resources, according to Hale & Moberg (2003). Additionally, Curtis (2008) said business continuity planning and risk management must be part of the agenda for board discussion for the company to overcome inertia and make business continuity planning and risk management part of their ongoing strategic planning.

While the literature supports the position that supply chain risks tend to paralyze most supply chains, the case is not hopeless. Successful companies are the ones that break the risk spiral through a careful review of the tangible elements of their supply chain, as well as addressing the confidence of its users and members through visibility and control (Lee & Whang, 2001). The disaster-management supply chain processes that have been embraced by the most successful organizations can be segmented into three parts: (a) identifying sources of raw materials for the company; (b) identifying where raw materials are warehoused and how they are protected; and (c) describing how raw materials are to be staged and distributed when they are transferred to the customer (Stackhouse, 2007). In addition, companies should explore risk-mitigation strategies such as risk transfer through insurance or alternative supply networks (p. 3).

Principles of Incorporating Software Agents into Supply Chain Risk Management

Supply chains are created by representatives of the various companies involved (David & Stone, 2007). Bodendorf and Zimmerman (2005) noted that irregularities and disruptions produced by the dynamic environments and uncertainties of fulfillment processes threaten the benefits of optimized plans for supply chain management. Software agents can serve as intermediary applications between procurement agents and suppliers when negotiations take place. According to Kumar (2001) advances in autonomous agent technologies have increased the interest in automating the process. The use of the Internet in supply chain management (SCM) is a relatively recent phenomenon. Its principal applications have been in the areas of procurement, transportation, scheduling, vehicle tracking, and customer service (Lancioni et al., 2000).

Software Agents Overview

According to Magenta (2004), intelligent software agents are objects (special types of computer programs) capable of communicating with each other, reasoning about information contained in messages that pass among them, negotiating to resolve conflicts and then conveying outcomes to the system and its users. They are able to make decisions under conditions of uncertainty, to act upon incomplete information, albeit in a narrow knowledge domain. Intelligent software agents live and act in the virtual market of the multi-agent application used to perform assigned tasks (Mark et al., 2000). The emergence of the Internet and the World Wide Web has created a heightened demand for intelligent software agencies. This trend has (and is) driving the intelligent agent development from academic research environments and proprietary corporate uses to mass commercial usage (Nissen & Sengupta, 2006).

In research carried out by Nissen and Sengupta (2006), IS researchers have begun investigating an emerging, technology-enabled innovation that involves the use of intelligent

software agents along the enterprise supply chain. The study of agents deals with integrating software agents to different components in the supply chain (McLaren**,** 2006). These software agents are computer programs that are given or delegated some problem by their "owner," and then the agents can decide for themselves what they need to do to solve this problem (Magenta, 2004). The goal is that the use of software agent technology will help to streamline procurement processes. For example, IBM is building agent technology to support its autonomic computing systems which have the intelligence to reconfigure themselves in response to changing conditions (Thibodeau, 2004).

Information System Utilization Strategy for Supply Chain Management Integration

As companies continuously strive to lower costs, reduce assets and improve quality, their supply chains are transformed, often faster than their ability to recognize the changes that have taken place (Trunick, 2007). A major limiting factor in developing good supply chain strategy has been the lack of information flow across organizations (Martin & Roth, 2000). Sahin and Robinson (2002) describe problems that can incur during the coordination of how products flow and how information is shared in supply chains. Specifically, these experts base their concerns on the degree of information shared between companies and how it is coordinated, according to Kahn (2006).

It is important to note that a supply chain is a competitive feature within a company that is achieved through cooperative partnerships and its results could mean the difference in more business, cost savings, or even profits. Lee (2004) stated that supply chain integration is not new and that many companies have already pursued it as a way to gain competitiveness. For instance, the Exostar (2007) software solution designed for Boeing, allows Boeing and its partners to collaborate on planning schedules, issue purchase orders, track purchase order changes,

exchange shipping information, manage returns, track shipments, and to manage inventory consumption across the multiple tiers involved in the manufacturing process.

The complexity of supply chain management has forced companies to pursue more online communication systems (Gunasekaran and Ngai 2004). According to Narasimhan and Kim (2001), the introduction of information systems (IS) in supply chain management originally is limited to the automation of clerical functions. Today, technology in supply management and in the world of e-business has been expanded to cover both e-commerce (buying and selling online) and the restructuring of business processes to make the best use of digital technologies (eEurope2005, 2005). Trkman (2004) states that the use of information system, networks, and e-business applications alone is not sufficient to realize the benefits. It was found that Internet adoption alone has demonstrated no benefits in terms of reduced transaction costs or improved supply chain efficiency (Wagner et al., 2003). On the other hand, Trkman (2004) believes that it has not led to a decrease in the inventory level in middle-size enterprises.

Information integration is the foundation of supply chain integration (Lee, 2001). For companies across a supply chain to coordinate their product, financial and information flows, they must have access to accurate and timely information reflecting the status of their supply chain. The capability for all supply chain partners to have access to share information on a timely basis is therefore key to improving supply chain performance (p. 6). Connectivity is important to supply chain systems, and decisions on how systems are constructed and how applications and data are distributed carry risks (Trunick, 2007). The Internet and e-businesses offer many possibilities for effective information sharing that enable seamless flow of transactions in the supply chain, and may also facilitate and establish future relationships by their ability to transfer information (Wagner et al., 2003).

CONCLUSIONS

Unpredictable disruptive events and malfunctions in the procurement processes of a supply chain are at the core of the problem to be solved by a proactive supply chain risk management system (Bodendorf & Zimmermann, 2005). This study is intended to provide the main benefits of software agents in supply chain risk management mitigation within the aerospace manufacturing industry.

According to Johnson (2006), all manufacturers do a satisfactory job of understanding unit costs and transportation costs, but most do a poor job on quantifying other things like political risk, natural disasters, and the risks of a lengthened supply chain. Historically, the best supply chains identify structural shifts, sometimes before they occur, by capturing the latest data, filtering out unnecessary information (that may or may not be pertinent to an organization's goal), and tracking key patterns for management to make decisions (Lee, 2004).

Re-Defining Supply Chain Management

Agent-oriented supply chain management involves independent software that operates alone and in conjunction with other software in a system/network. Mark (2000) defined an agent as an autonomous, goal-oriented software process that operates asynchronously, communicating and coordinating with other agents as needed. Mark et al. (2000) conducted a study in which new software architecture for managing the supply chain at the tactical and operational levels emerged. In this study, the supply chain was viewed as composed of a set of software agents, each responsible for one or more activities in the supply chain and each interacting with other agents in planning and executing their responsibilities (p. 2). And while Simon (2001) noted that static supply chains enable the manufacturer to obtain and move the required material from the supplier to the manufacturing plant and finally to the customer, the study by Mark et al. (2000) re-defined supply chain management as an integral part of the manufacturing process (p. 2).

They revealed that with the use of sophisticated planning, scheduling, and coordination methods, the overall quality of the supply chain management can be improved (Mark et al., 2000).

Re-Charting the Procurement Process

Procurement is a related process imbued with considerable ambiguity in its task environment that presents a fundamental limitation to IT-based automation of decision making and knowledge work (Sengupta & Nissen, 2006). For example, Jankowska et al. (2007) stated that agent-oriented supply chain management is a step at aiming to fill the gap between *s*upply chain planning and supply chain execution. Over the years, the transparency of supply chain and business relationships has become a widely discussed topic (Eggert & Helm, 2003). Sengupta and Nissen, (2006) believed that software agents have the potential for effecting sharp improvements in procurement, and show much promise for enabling management and decision making in modes not supported previously by IT. The act of sharing information with everyone has the potential to ensure that everyone will have the right information when it's needed (Liker and Choi, 2004, p. 112). Thus, software agents can be seen as information providers that assist procurement in tasks from sourcing to the end customer. The sharing of information among companies also has the potential to increase productivity and ensure accurate sharing of data. According to Trkman (2004) the sharing of information, enabled by e-business applications, can radically improve business processes and consequently the performance both of a single company and a supply chain as a whole. For example, Exostar (2007) predicted that the Boeing program-enabling technology will help change the way aerospace procurement employees, and not just Boeing employees, will include the Internet and other technologies in their work processes. These forward-thinking tools will play a critical role in allowing the company to develop new business models.

The goal of software agents is to monitor the states of supply chains by observing specific events and exceptions in real-time and alerting managers if problems occur (Reese, 2007). In general, the procurement agent must procure resources and manage the assembly of a product (David & Stone, 2007). Nissen (2001) grouped software agents application into three classes that are insightful for studying procurement: (a) information retrieval agents, (b) advisory agents, and (c) per formative agents. Emerging technology solutions are also leveraging improved analytics, broader data integration, and collaboration.

According to Martin and Roth (2000), the procurement process should focus on strategic supply chain design, execution, and integrating core business strategies with supplier and customer alignment. However, Wise and Morrison (2000) pinpointed that the focus of current electronic procurement discussions have been mostly in the marketplace. Nevertheless, the separation of supply chain activities among different companies enables specialization and economies of scale for successful supply chain operation (eEurope2005, 2005). The coordination of internal and external activities is important to a firm to be successful (Head et al., 2004). The impact of procurement on supply chain management is much larger as it facilitates inter-organizational communication and in turn reduces cycle times and develops collaborative work (Gunasekaran & Ngai, 2004). As companies struggle to achieve improved process efficiency, cost reduction, and enterprise integration, procurement remains a very effective method of reaching these business goals (Exostar, 2007). For example, the introduction of Exostar by Boeing has reduced collaborative efforts necessary to require a business solution that matches supply and demand at line of business level creating precise manufacturing requirements that support customer demand (SAP, 2005).

Re-Framing Supply Chain Management

Hall et al. (2003) noted that agent-based solutions are most applicable to this environment since they are appropriate in highly dynamic, complex, centralized fields as well as diverse situations. According to Nissen and Sengupta (2006) software agents have the potential for effecting sharp improvements in procurement processes. Software agents can simplify supply chain complexity and optimize performance (Anthes, 2003). However, creating fully autonomous software agents for supply chain management is difficult due to the large number of tasks such a software agent must perform.

By leveraging the capabilities of today's technologies, supply management leaders can enhance the value they deliver to their organizations (Hochman, 2007). Moreover, Fontanella and Klein (2008) acknowledged that process industries like consumer product goods and chemicals, particularly in the U.S., are more likely to focus on supply chain technologies. According to Sengupta (2006), software agents provide a new paradigm for designing and implementing systems for a complex, dynamic, and distributed environment where the common currency is negotiation. They can be managed in a way that is beneficial to the overall system performance (Rudowsky, 2004).

Sengupta (2008) stated that technology components should never be at the forefront of a supply chain management redesign effort, even though more than 80 percent of such efforts require the use of technology and automated enablers to ensure sustainability. The total solution should include identification, examination and integration of the infrastructure and application linkage-related items that are necessary for end-to end system and process enablement (p. 7).

The goal when designing a supply chain risk management system is to mitigate and avoid possible future risks, including natural or artificially created emergencies, disasters, or disruptions. The ability to control and coordinate the various supply chains upon which a

company depends will give a means of providing competitive advantage, decreased operating expenses, and enhanced customer service (Martin et al., 2000). The constant changes in product specifications, together with other continuous improvement initiatives within the organization and the wider industry as a whole means that supply chains never actually reach a stable steady state (Haywood & Peck., 2002).

Effective supply chain risk management requires the identification and monetization of risk events, probability of occurrence, and the firm contingencies for alternative sources of supply (Barry, 2004). According to Deloitte (2004) the advantages of effective supply chain risk management can be summarized by the set of outcomes noted below:

1. The ability to anticipate and respond promptly to external trends and developments.
2. A focus on uncertainties rather than the certainties.
3. Greater influence over your supply chain partners.
4. Greater mutual understanding of the interests and problems of all supply chain partners.
5. A better balance between opportunities and threats.
6. Management which is not based on the cost factor alone.
7. Competitive edge through the acceptance of controlled risks.

Gunasekaran & Ngai (2004) demonstrated that IT is an essential ingredient for effective supply chain management and improves the competitiveness of firms. The introduction of software agents in supply chain management shows great potential to help to eliminate redundant information sources, presents information that is readily available, provides predictive information that allows procurement agents and supply chain analysts to be proactive, and indicates urgent actions from various systems that fall within the larger supply chain management system. This technological link between companies provides the essential

information backbone needed to ensure fast, ready access to information (in some cases, real-time point-of-sale information (Hannon, 2002).

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