THE CONTRIBUTIONS OF INFORMATION SYSTEMS TO THE EVOLUTION OF THE SUPPLY CHAIN

THESIS

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ABSTRACT

THE CONTRIBUTIONS OF INFORMATION SYSTEMS TO THE EVOLUTION OF THE SUPPLY CHAIN

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The advancements of this most recent technological revolution, as well as the ones from the past, have worked to evolve the fields in which the technology is implemented. Just-In-Time (JIT), Electronic Data Interchange (EDI), and Enterprise Resource Planning (ERP) were not just valuable contributions to the traditional supply chain model, they laid the foundation for what was about to come, the e-supply chain. Once again, the Internet and Agent technology changed the model from the e-supply chain to that of a supply network. Due to the advancements in information systems that have occurred, the supply network of today now has the characteristics of being dynamic, nonlinear, and intricate while responding in real time. However, a major limitation to the effectiveness of information systems was identified, resistance to change. We have reached the point at which technology is growing exponentially, and, as a society, we

have to decide whether we continue to grow exponentially or succumb to resistance to change and plateau. The future of the supply chain seems to be in the ability to incorporate the changes promoted in information systems by a technological evolution.

CHAPTER I

INTRODUCTION

In 1949, Donald Hebb pointed out in his book, "The Organization of Behavior", that neural pathways are strengthened each time they are used (Hebb, 1949). The contributions of individuals such as Donald Hebb led to the creation of the first neural network, the Perceptron, by Frank Rosenblatt (Kay, 2001). At the time of Rosenblatt's invention, people thought the claims of what neural networks could do was greatly over-exaggerated and their contributions limited by technology. Since then, however, there has been a technological revolution; what these individuals once dreamed but thought could never happen has become yesterday's technology. The contributions to date have been great, and the potential is there for even greater contributions in the near future.

One area in which the contributions of information systems have been significant is the supply chain. Technologies such as Electronic Data Interchange (EDI), Enterprise Resource Planning (ERP), the Internet, Agents, and Evolutionary Systems have all helped to make the supply chain more robust, responsive, and intricate. These technologies have not only contributed to the supply chain by facilitating the flow of information, reducing costs, and opening up new markets, but have changed the shape of the supply chain.

Just-In-Time (JIT), Electronic Data Interchange (EDI), and Enterprise Resource Planning (ERP) were not just valuable contributions to the traditional supply chain model, they laid the foundation for what was about to come, the e-supply chain. Once again the Internet and Agent technology changed the model from the e-supply chain to that of a supply network. Where are the current contributions of evolutionary systems, such as Neural Networks (NN), Fuzzy Logic and Genetic Algortihms going to take us now?

Research Objectives

The objectives of this research were:

- To identify the problems, opportunities, and limitations of using information systems in the supply chain.
- To collect and document the contributions of information systems to the evolution of the supply chain.

Research Questions

The advancements of this most recent technological revolution, as well as the ones from the past, have worked to evolve the fields in which the technology is implemented. This led to the first hypothesis that was researched:

H1: Advancements in information systems have led to a concurrent evolution in the supply chain.

These advancements have been hindered by some of the problems that have plagued the new technologies. One of those problems has been the arduous task of learning how to use the various systems. While some recommendations have been made, such as using an iterative top-down / down-top approach to learning, the difficulties of using various evolutionary systems have limited their use (Inelman & Ibrahim, 2003). The lack of good user interfaces is one aspect of evolutionary systems that has made their use so difficult.

However, the difficulty of using the systems isn't the only hurdle to overcome. In most cases, it takes an expert to interpret the results of evolutionary systems. "The neural network does not know what it is doing or why it may be successful, and the typical user of a neural network is unlikely to know or understand why either" (Freeman & Rennolls, 1994). For evolutionary systems to truly be successful, it takes someone who can not only use the systems, but has extensive experience in the areas in which the systems are being used. In addition, a lack of money and support from top management has limited their use even more. This leads to the second hypothesis that was researched:

H2: Lack of understanding of opportunities in the supply chain may have limited the use of information systems in the supply chain.

When one organization applied neural networks to inventory management, total inventory was reduced by 50% while maintaining the same level of probability that the inventory would be on hand to meet customer's demands (Bansal, Vadhavkar, & Gupta, 1998). Contributions such as these have led to the third hypothesis that was researched:

H3: The impact of the contributions of information systems on the supply chain has been significant.

This research focused on the contributions, problems and limitations of information systems in the supply chain and their effect on the evolution of the supply chain. Presented in Table 1 are the specific systems that were studied.

Table 1: Systems of Study

The Traditional Supply Chain	The E-Supply Chain	Supply Network Tools
Just-In-Time	Internet	Fuzzy Logic
Electronic Data Interchange	Agents	Neural Networks
Enterprise Resource Planning		Genetic Algorithms

Scope

This paper presents a review of the literature pertaining to the contributions of information systems to the evolution of the supply chain. Information systems is defined as the ongoing process of using technology to solve business problems. The review focused on the past and future use of information systems in the supply chain. The value of this research was to highlight the areas in which contributions have been significant, as well as those areas in which the contributions have been diminished due to the lack of understanding and limited use of information systems in supply chain management.

The review was targeted for two audiences. First, the review was intended to alleviate some of the misconceptions about the understanding and use of information systems to industry practitioners. Secondly, the review defined areas of interest for future researchers in the areas of supply chain management.

Sources of Data

The following is a list of the databases and journals that were used in my research.

Databases – ABI / Inform, Applied Science and Technology Full Text, Business Source Premier, Business Wire News, ComDex, Computer Literature Index, Computer Source: Consumer Edition, Discovering Science, Econlit, Emerald, IEEE Computer Society Digital Library, Inspec, Journal of Citation Reports, JSTOR, Lexis-Nexis Academic, Science Citation Index Expanded, Science Direct

Journals – *European Journal of Operational Research, Expert Systems, Fuzzy Sets and Systems, IEEE Transactions of Software Engineering, Intelligent Data Analysis, International Journal of Approximate Reasoning, International Journal of Artificial*

Intelligence Tools, International Journal of Pattern Recognition and Artificial Intelligence, International Journal of Systems Science, Journal of Intelligent and Fuzzy Systems

Methods

A comprehensive search of the literature is conducted, including scientific and business journals, books, previous research, industry data and reports, etc. The approach was as follows; first, a general search of several of the databases and the ISI Citation Index was used to help define the most relevant articles for my research. After reviewing those articles, information was gathered to narrow down the topics of interest, i.e., the most relevant information systems for the purpose of this research. Secondly, that information was used to conduct further searches into those areas. From reviewing those areas, a methodology was developed for clustering and analyzing the information based upon three areas of the supply chain's development that were identified: The Traditional Supply Chain, The E-Supply Chain, and Supply Network Tools. The systems being researched were those that were identified as being significant contributors to each of the three areas of the supply chain's development.

Limitations

One of the major limitations of this research was the availability of previous research and secondary data in the application of several of the systems to the supply chain. While this was a very significant limitation, it was an opportunity in the fact that this research might open the door for further research in these areas.

Another limitation also related to the application of these systems to the supply chain is that this research was limited to what was already known by the industry and academia. An analysis was done to help discover those areas where the potential of information systems are not being utilized; however, due to time constraints, only the most significant were analyzed.

Implications

The research identified the areas in which the contributions of information systems have been made to inform other businesses that are not using the technology about the potential that exists for cost savings, efficiencies and real time data. The research also identified areas for further contributions, as well as areas for more in-depth research.

CHAPTER II

HISTORY OF THE SUPPLY CHAIN

Vertical Integration

The vertically integrated organization was one of the first structures for managing the flow from raw materials to a finished product. Businessmen such as Henry Ford would try to own and control all stages of the process from raw material to finished product. At this time, it was common for companies in the chain to compete for resources, have independent relationships, and operate in an arm's length manner. The practice of operating in an arm's length manner proved beneficial in the cost savings to the companies and continued until vertical integration began to flatten out. At that time, the increasing pressures from technological advancements and globalization began to form a new type of organizational structure, that of the supply chain (Williams, Esper, & Ozmont, 2002). The transition to the supply chain is diagramed in Figure 1 below.

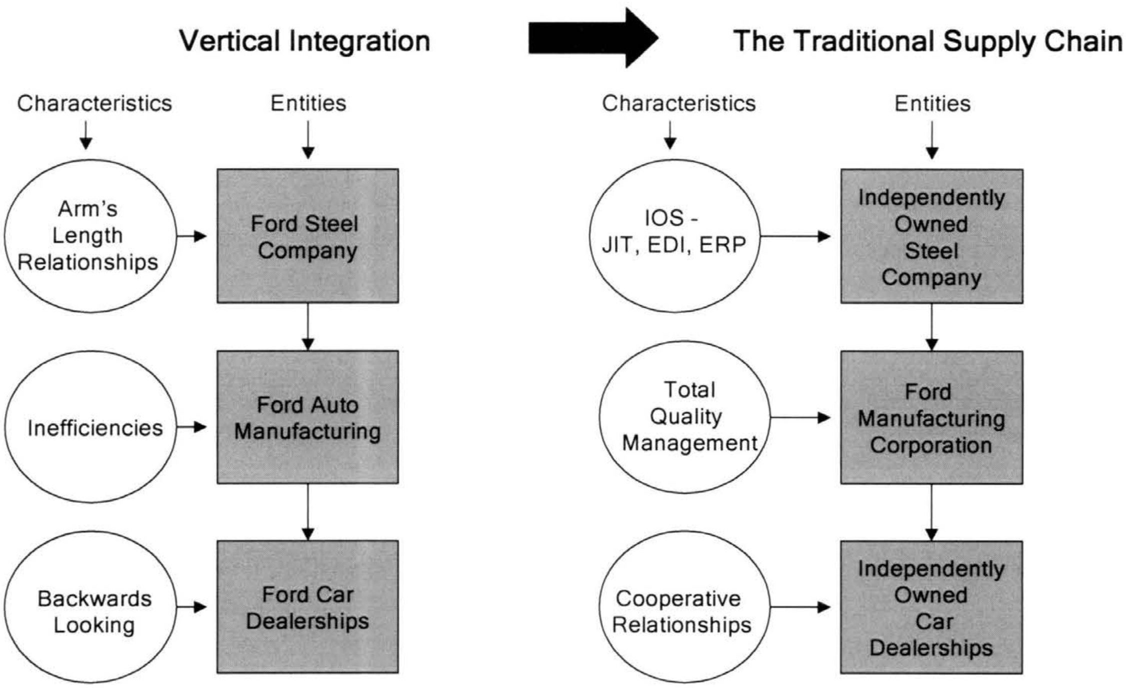

Figure 1: Vertical Integration to The Traditional Supply Chain

The Traditional Supply Chain

No longer could companies obtain cost saving from operating in arm's length manner. Rather than dealing with suppliers and customers in an arm's length manner companies found it profitable to cooperate. During this transition the supply chain suffered from many inefficiencies due to large inventory costs and product unavailability (Lummus & Vokurka, 1999). The main reason for these inefficiencies in the traditional approach to supply chain management was that the traditional model was backward-looking compared to the forward-looking model of today. The backward-looking model used past average depletion rates to predict future depletion rates. This uses the same logic as using yesterday's weather to predict tomorrow's weather. While in some cases this can work, it misses in the important instances of being out without your umbrella when the big storm comes or, in the case of supply chain management, being out of stock when the new rage hits.

The textile industry's Quick Response (QR) program marked the beginning of a new forward-looking era in 1985. The goal of the quick response program was to create an environment where information would flow freely between suppliers and retailers, enabling them to react quicker to consumer needs (Vokurka & Lummus, 2000). From the textile industry's Quick Response program came the grocery stores Efficient Consumer Response (ECR) program in 1992. A key concept pursued under the ECR program was Continuous Replenishment (CRP) changing the idea "from pushing products from inventory holding areas to pulling products onto grocery shelves based on consumer demand" (Vokurka & Lummus, 2000, p.91).

The E-Supply Chain

It is during the time of QR, ECR and CRP that companies began to adopt the Deming Method, Total Quality Management, and form closer and more collaborative relationships with their suppliers (Williams et al., 2002). However, new pressures from the Internet once again changed the face of the supply chain, and companies were forced to adopt new philosophies toward supply chain management. Figure 2 shows some of the changes that occurred in the transition to the e-supply chain.

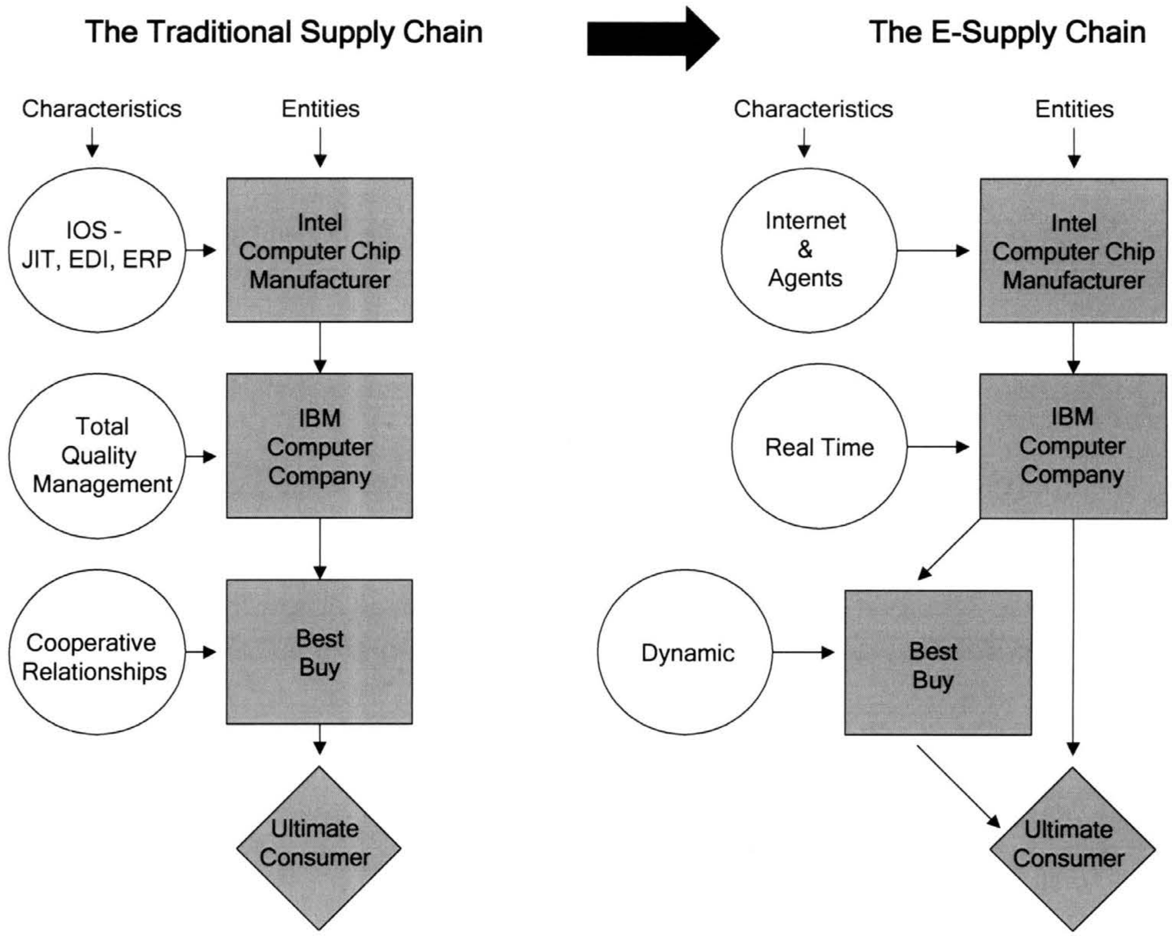

Figure 2: The Traditional Supply Chain to The E-Supply Chain

Information technology has contributed to the evolution of the supply chain, changing it into a dynamic forward-looking model that is capable of adapting in real time to its environment. Previously, companies looked to their internal processes for cost savings, but, with intense competition emerging facilitated by globalization and technological advancements, this is no longer sufficient. Coupled with the publicity of the success stories of companies that have focused on the supply chain, a new strategic imperative has been formed, an emphasis on the supply chain (Julka, Srinivasan, & Karimi, 2002).

The Supply Network

In a May 2002 article from the *Supply Chain Management Review*, Joseph Cavinato (2002) talked about the confusion that is created by trying to measure every company's supply chain by one definition. "In essence, no two companies' supply chains look alike". (Cavinato, 2002, p. 64).

While the definition of "supply chain" is obfuscated by the different approaches and goals of the companies implementing them, Cavinato (2002) noted one of the things that is clear, "….most companies don't have one chain…they have many and several of them are actually networks" (Cavinato, 2002, p. 62). By focusing on what is clear about supply chains and the fact that companies today are moving towards a network approach to their supply chain, one can begin to understand the true nature of a supply chain.

Merriam Webster defines "network" as an interconnected chain, group, or system. Therefore, a "supply network" is an interconnected group of organizations working to achieve the goals of the independent organizations and, while doing so, achieve the greater goal of the supply chain.

"In essence, research indicates that there are 16 basic forms of supply chains/networks in use today. Each brings with it relative strengths and weaknesses and varying degrees of complexity" (Cavinato, 2002, p.62). At the highest degree of complexity with the largest competitive advantage is the type of chain, "Information Networks". Due to the large competitive advantage of the Information Network form, this is the type of chain/network to which all supply chains aspire.

This form of the supply chain is quite different from the original idea due to the advancements that have been made in the area of information technology. Information technology has allowed us to do things quicker and better, at a level that Deming would have thought unfathomable in his time.

> One of the enablers of the development of the supply chain management concept is the advancement of information technology. Just as early advances in computing power led to MRP and MRP II, continued developments in technology are contributing to supply chain management. Through the progress in computer power, electronic data interchange (EDI), bar coding, and other advances, remote locations can be linked together to exchange information. As these advances continue, further progress will be made in the integration of functions and organizations. (Vokurka & Lummus, 2000, p.95)

Information technology has changed the way supply chain management is done and, in turn, supply chain management has shifted the business focus. Johnson and Whang (2002) and Kopczack and Johnson (2003) have identified six shifts in focus that have occurred:

1. From Cross Functional Integration to Cross-Enterprise
2. From Physical Efficiency to Market Mediation
3. From Supply Focus to Demand Focus
4. From Single-Company Product Design to Collaborative, Concurrent Product, Process and Supply Chain Design
5. From Cost Reduction to Breakthrough Business Models
6. From Mass Market Supply to Tailored Offerings (Johnson & Whang, 2002; Kopczack & Johnson, 2003)

These shifts in the business focus of companies have culminated in the emergence of the supply network shown below in figure 3.

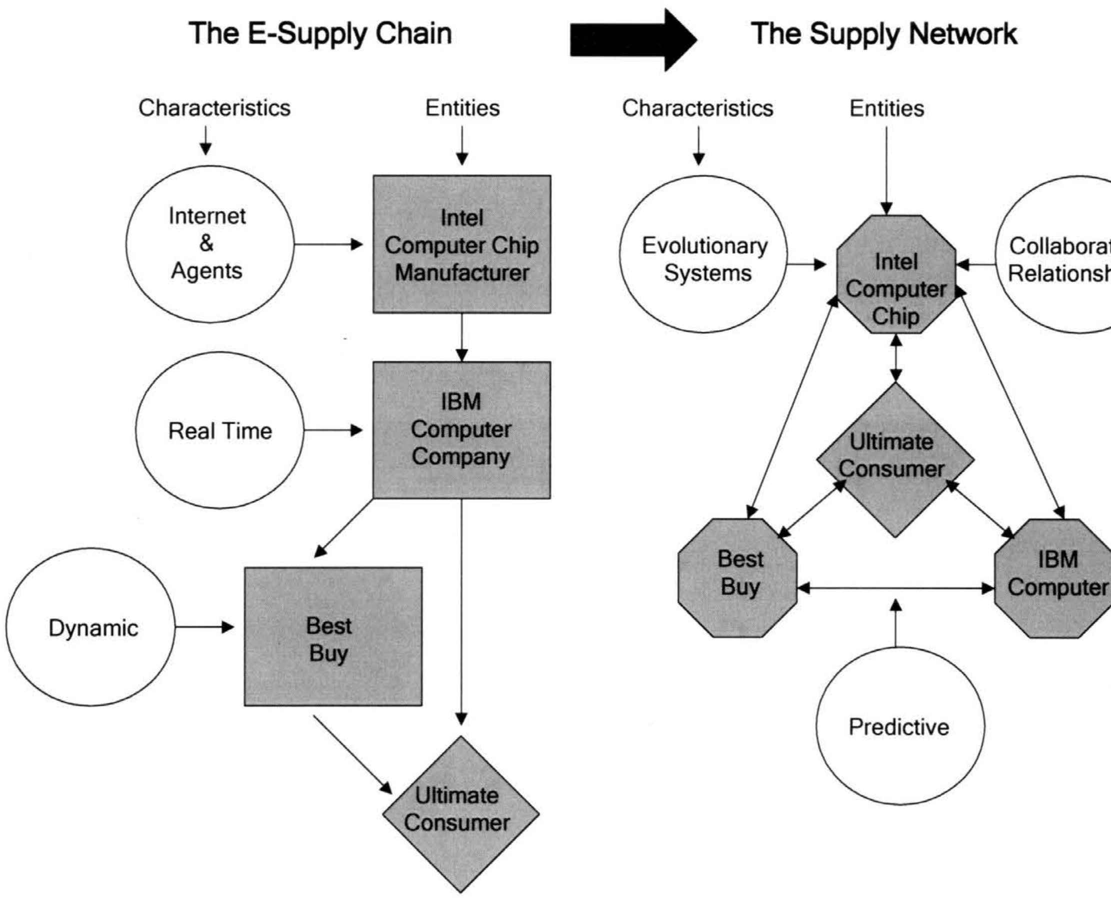

Figure 3: The E-Supply Chain to The Supply Network

The Bullwhip Effect

The Bullwhip Effect has been one problem that has plagued the supply chain since its beginning; while it may be known by other names, such as the whipsaw or whiplash effect, the ultimate results are the same (Lee & Padmanabhan, 1997). The Bullwhip Effect is the amplified variability in demand that comes as one moves further up the supply chain from the final consumer. Lee and Padmanabhan stated in "The Bullwhip Effect in Supply Chains" that the Bullwhip Effect is a consequence of a player's rational behavior in the supply chain infrastructure. Therefore, those companies that intend on controlling the Bullwhip Effect need to look to modifying the chain's infrastructure and related processes rather than the decision- maker's behavior (Temponi & Nash, 2004).

Peter Senge takes this thinking one step further in his book, *The Fifth Discipline*, in which he uses the classic beer game to demonstrate how structure influences behavior. By identifying the underlying structures that shape individual actions and create the conditions where types of events become likely, it becomes apparent that the system causes its own behavior (Senge, 1994). Senge goes on to make the distinction between structure, not as the logical structure of a carefully developed argument, but rather the "systemic structure" that is concerned with the key interrelationships that influence behavior over time.

It is important to note that these key interrelationships are not among individuals, but rather the key variables in the system; you are not external to the structure, but rather a key component that has the power to alter the structures in which you are operating. "However, more often than not, we do not perceive that power. In fact, we usually don't see the structures at play much at all. Rather, we just find ourselves compelled to act in certain ways" (Senge, 1994,). One of the lessons to learn from the game is that, in order to create a strategy for success, you have to consider how your position interacts with the whole system and how your actions influence the outcomes of the other variables in the system (Temponi, 1997).

The Emergence of the Supply Chain as a Self-Organizing System

Learning this lesson requires that it is necessary to have a change in thinking from viewing the supply chain as an external entity to that of an interconnected system in which a company is only one subsystem within a larger system. While this change has been beneficial to supply chain management, this thinking should be taken a step farther in order to think of the supply chain as what it really is, a self-organizing system. No one entity in the supply chain controls the system, but rather every entity in the supply chain is controlled by the systemic structure of the whole supply chain (Lichtenstein, 2000).

By viewing the supply chain in this way, it becomes obvious that patterns evolve over time, and it is easier to understand the underlying factors that cause the evolution.

> Observing patterns is especially useful if we can associate different phases of the system with other characteristics; for example, there is a strong relationship between business cycles and other variables such as demand, interest rates, the availability of credit, vendor lead times, and the tightness of the labor market (Levy, 1994, p.172).

Chaos theory has been one method for modeling the complex factors that make up an evolution in various fields in the natural sciences. The application of chaos theory to business problems, however, has been limited though it has been recognized. “One of the most provocative and controversial elements of chaos theory is that chaotic systems can spontaneously self-organize into more complex structures” (Levy, 1994, p.171).

One traditional paradigm shift that results from this mode of thinking is that small changes in parameters do not lead to small changes in outcomes (Levy, 1994). The traditional linear way of looking at things would say that a small increase in demand would lead to a correspondingly small increase in production from the manufacturer, but in looking at the Bullwhip Effect, that is not the case. Another paradigm shift results from trying to assign the blame to one particular party, just as in the beer game, to that of it arising from the dynamics of the system. “In order to understand indirect or counterintuitive means to an end, a system needs to be understood as a whole. If systems are very complex, then simulation models might prove helpful in finding the most effective way to achieve a goal” (Levy, 1994, p.173).

CHAPTER III

THE TRADITIONAL SUPPLY CHAIN

The traditional supply chain refers to the old paradigm of moving raw materials through the chain from producer to end consumer. At each stage of the chain, value is being added to the work-in-progress through the addition of features, parts, etc. Just-in-Time, Electronic Data Interchange, and Enterprise Resource Planning were the information systems that contributed the most to this era of the supply chain.

Just-In-Time (JIT)

"As a result of increased global competition in the 1970s, responsiveness emerged as the third strategic imperative. Buyers became more sophisticated and they demanded more customization and shorter lead-times" (Vokurka & Lummus, 2000, p.89). Buyers became more sophisticated as a direct result of the corresponding changes in technology. This increase in sophistication resulted in an increased importance on quality and hence total quality management was introduced. Total Quality Management brought many contributions to supply chain management, including just-in-time inventory control. The move towards just-in-time inventory control led to a greater sharing of information between suppliers and retailers, developments that would not have been possible without the contributions of information systems.

Officially introduced in the 1970's, much of the recognition for the development of the theory of just in time was credited to Taiichi Ohno from Toyota despite the fact that many mangers were practicing just in time principles long before Toyota's time (Vokurka & Lummus, 2000; Beard & Butler, 2000). One of the most well known examples is Henry Ford and his introduction of the assembly line. By implementing a just in time philosophy Henry Ford was able to cut down production time from 21 days to 4 in 1921 and in doing so reduced the cost of a Model T from $850 to $290 (Boyd, 2001). When done right, JIT crosses all aspects of an organization not just as a program but rather as an operating philosophy (Boyd, 2001). "Setting up a JIT system, however, involves the entire business, from suppliers to production to customers-even to administrative aspects such as accounting" (Beard & Butler, 2000, p.61).

JIT: *Contributions*

When done right, JIT not only manages inventory but transforms the company. Beard and Butler (2000) cited lower inventory carrying costs, space and cost savings in the factory and warehouse, reduced risk of obsolescence, and reduced response time to customers' orders and delivery times as benefits to JIT implementation. Chong, White, and Prybutok's (2001) review of the literature identified the following additional benefits to JIT implementation.

- Reduced throughput time
- Improved internal quality
- Improved external quality
- Improved labor productivity
- Improved employee behavior
- Reduced inventory levels
- Decreased unit cost

Each of these benefits translates into an improved bottom line for the company. Boyd (2001) showed that over time a company committed to JIT would reap the benefits of higher earnings per share and cash flow per share. The key words in Boyd's findings were "over time"; a company planning on implementing a JIT program needs to be prepared for a long and arduous experience. In reality, many companies do not see these benefits because they take shortcuts and only implement a few of the JIT management practices, expecting to see immediate results (Chong et al., 2001). This "piecemeal approach," as Chong et al. describe it, occurs in spite of the fact that evidence shows expected benefits are only achieved under a holistic focus. Unfortunately, many of the practices implemented by companies are the easiest ones to implement rather than the ones with the biggest benefits (Chong et al., 2001). Nevertheless, if a company maintains its perseverance, then the results will follow. Studies have shown that greater benefits come to those companies that have had their JIT systems in place longer, as well as those companies who implemented a larger scope of JIT principles (Chong et al., 2001).

As was mentioned in the beginning of the section, JIT is not a new initiative but rather an old paradigm. Technology itself has worked to evolve the role of JIT and will continue to change it in the future. Olhager mentions the future of competition won't be between organizations but the supply chains in which those organizations are embedded. Taking the principles of just-in-time inventory control and applying them to the whole supply chain, one can get a synchronized, integrated supply chain that is capable of competing in the information age (Olhager, 2002). As with any system, there are limitations. These will be examined below.

JIT: *Limitations and Problems*

The overall objective of JIT is to eliminate waste (Chong et al., 2001). When put this way, the idea of JIT sounds practical and simplistic; however, numerous companies fail to achieve the benefits that are afforded to well managed JIT systems. Beard and Butler noted that, when surveyed, purchasing managers cited JIT as the most mentioned failure among inventory strategies (Beard & Butler, 2000).

How is an idea that is so simplistic the most mentioned failure among inventory strategies? To answer this question, it was necessary to consider some of the problems that companies face when implementing a JIT system, including the potential disadvantages of implementation. Vokurka and Lummus listed the following implementation problems: cultural resistance to change, lack of resources, lack of top management understanding or commitment, and a lack of performance measures (Vokurka & Lummus, 2000). It is no surprise to find that a lack of top management understanding and commitment is a major contributor to failure, given that organizational support is the main ingredient in a recipe for success (Chong et al., 2001). In the article, "Relationship among Organizational Support, JIT Implementation, and Performance," Chong et al. (2001) showed that the maximum benefit of JIT is reached by the permeation of organizational support through the company.

A lack of organizational support is indeed a huge problem faced by companies implementing JIT, although it is only one of several potential problems. Another problem faced by companies is the large disconnect between JIT theory and practice (Beard & Butler, 2000). By interviewing five manufacturing companies, Beard and Butler were able to identify five different reasons for not implementing JIT in its theoretical form. In one case, a company was forced to purchase goods from overseas making it a necessity to order goods in large quantities; another company had to maintain a four-week surplus of a critical part; laws mandate that a food processor had to have food inspected before using it; a tire manufacturer had to allow certain chemicals to age before being used; and tax laws made it difficult for an air conditioning equipment manufacturer to obtain suppliers who would cooperate with its JIT program (Beard & Butler, 2000). The authors concluded that, while each of these manufacturers faced impediments to implementing JIT, every one of them was able to design around these barriers and gain some cost savings from implementing a few JIT principles (Beard & Butler, 2000).

Even when JIT principles are implemented successfully, a balancing act can occur forcing companies to choose between improving their processes and hindering that of their partners (Vokurka & Lummus, 2000). "As Bechtel and Jayaram point out, programs like JIT may benefit a certain functional area through optimization of inventory or other initiatives, but other non-targeted functions or companies may actually be harmed" (Vokurka & Lummus, 2000, p.90). Vokurka and Lummus went on to give the hypothetical example of a supplier who would be forced to carry more inventory due to a customer's JIT efforts.

In addition, many small-sized firms suffer from their own implementation problems. In a study done by Temponi and Pandya (1995), it was found that the priorities of the management in small sized firms were not conducive to the implementation of two of the eight elements necessary for successful implementation of a just-in-time program. Management was more concerned with basic manufacturing requirements such as lowering cost and satisfying the customer. Management's preoccupation with these basic requirements is one reason for their loyal customer base; however, the pressure from large firms to drive down costs and deliver products at net speed will ultimately make small firm management rethink their priorities.

Electronic Data Interchange (EDI)

Electronic Data Interchange (EDI) emerged in the mid-1960's, as what some would call a quixotic attempt to create the paperless office (Witte, Grunhagen, & Clarke, 2003). The idea of a paperless office never became a reality; however, EDI did dramatically decrease the number of times that a document was handled by people (Witte et al., 2003). Before anyone had ever heard of the Internet, EDI became the first method of E-commerce (Williams & Frolick, 2001). By linking computer-to-computer, EDI facilitated the flow of communication between trading partners. When EDI originated, the intent of its design was to speed information delivery by allowing a buyer to extract a purchase order from a purchase application and transmit it to its supplier, where it would feed into a sales order entry application without human intervention (Sawabini, 2001). Since its conception, EDI's applications have ranged from ordering and paying for goods from suppliers, arranging transportation with carriers, receiving orders from customers, invoicing customers and collecting payment from customers (Sriram, Arunachalam, & Evancevich, 2000).

"Electronic data interchange (EDI) is a system that translates structured business documents into a globally understood business language and transmits them between supply chain trading partners using secure telecommunication links" (Witte et al., 2003, p.58). In order to use a secure telecommunication link, each company is required to subscribe to a value-added network (VAN) that charges per bit for information sent across the network (Williams & Frolick, 2001). Due to the high subscription fees for VANS, many companies chose alternatives to EDI. One senior project manager in the early 1990's remarked that EDI actually took longer to arrive than did a fax, was less reliable and more susceptible to corruption (Pawar & Driva, 2000). Recently, technological developments have motivated this account manager and many others to rethink their decisions regarding EDI. When reconsidering EDI, management has had to weigh its strategic advantages to its limitations and shortcomings.

EDI: *Contributions*

One strategic advantage of EDI is the significant improvement it offers over the traditional paper-based exchange of information. The improvements of EDI over the traditional paper-based exchange offers benefits to companies by way of processing more accurate information in a timely manner (Bhatt, 2001). Since data are transmitted electronically, it reduces the redundant entry of data among employees (Bhatt, 2001), while eliminating the need for any human intervention due to preprogrammed transfers of data (Williams & Frolick, 2001). Witte, Grunhagen & Clarke (2003) listed the following additional advantages of EDI:

- Information integrity
- Handling increasing business volume
- Usable information
- Reducing logistics costs
- Current information
- Consistent information
- Secure interchanges

- Widely available tools and service providers
- Lack of viable alternatives

A few of these advantages were explored further to emphasize their importance. First, to say that EDI reduces logistics costs is a vast understatement. Witte et al. (2003) cited that RJR Nabisco estimated the cost of processing a paper-based purchase order is $70.00, compared to less than a dollar via EDI. Second, the real time information that was provided by EDI allowed companies to implement a JIT inventory style and reduce the time that account balances remain outstanding, thereby improving the cash flow of the company and allowing its employees to focus more on value-added job responsibilities (Williams & Frolick, 2001).

EDI: *Limitations and Problems*

If those factors listed above were the only factors to consider, management's decision to implement EDI would be simple, but management must compare these advantages to a multitude of disadvantages, one of the biggest being the enormous commitment of time and resources. Implementation of an EDI system requires the expertise of programmers who can design a system around the companies' needs. Since many companies do not have this in-house expertise, they must outsource (Williams & Frolick, 2001). The need for outside expertise doesn't end at implementation but in most cases continues through the life of an EDI system. As companies gain new suppliers and customers their EDI system must be updated to reflect those changes. This is due to the fact that each company uses EDI in its own unique way, limiting the effectiveness of EDI's standards (Williams & Frolick, 2001). Exacerbating this problem further is the reluctance of companies to upgrade their EDI systems. Consequently, numerous companies are left in the dark as to whether their partners have or have not updated their systems (Williams & Frolick, 2001). Witte et al. (2003) made note of these shortcomings in addition to a few others:

- High implementation costs
- High, ongoing operations costs
- High data transmission costs
- Difficulty in maintaining and updating standards, multiple versions
- An inflexible message format
- One-way communication aspects
- Lack of commitment from chain partners

Earlier, an anecdote from a senior project manager was discussed. The purpose of the anecdote was that recent technological advancements had forced him to reconsider his thinking towards EDI. The reason was that the Internet has all but eliminated the majority of the disadvantages of the traditional EDI system that Witte et al. listed above.

Internet EDI

Lankford and Johnson (2000) list the following advantages of Internet EDI: it is free and much closer to real-time, linking browser technology with forms-based EDI eliminates the continuous updating that occurs between trading partners, and furthermore, the security concerns of the Internet are disappearing. In the past, major disadvantages to Internet EDI have not only been security concerns but the Internet's lack of organization and unreliable performance (Lankford & Johnson, 2000). As the Internet grows older and older, more concerns will continue to fade, making the Internet a much more attractive alternative for conducting EDI. Ultimately, the low cost and universal standards of the Internet will leave no choice but adoption for those companies that want to compete in the twenty-first century.

Pawar and Driva (2000) also noted though that the Internet has brought down some of the barriers of implementation for small-sized firms. The low cost of the Internet and its universality are increasing the standardization of EDI and overcoming the other obstacles that once stood in the way of small-sized companies adopting the technology. At one time EDI's cost often ran into the millions and limited its use to only the biggest companies (Presutti, 2003). A lack of standardization was another major limitation in the use of traditional EDI. Previously companies had been forced to link to only those trading partners that share their same standards. "Although the advantages of EDI are clear, progress has been hindered by the lack of universal standards and high changeover costs" (Pawar & Driva, 2000, p.25). However, despite the increase in EDI's advantages and the decrease in its limitations, implementation is still being hindered by the unpredictability of delivery, security issues, and a fear for yet another paradigm shift that could make the adopted technology obsolete (Pawar & Driva, 2000).

EDI: *Strategies for Success*

With all of the potential threats that a company faces upon implementing EDI, it is worth noting some of the strategies that work to increase a company's chances for success. Chatfield and Yetton's research determined that the strategic payoff from EDI was a function of EDI embeddedness. The concept of embeddedness is that the structure and quality of social ties between firms shape their economic action (Chatfield & Yetton, 2000). Therefore, those companies participating in arm's length relationships exhibit a low degree of embeddedness, while those companies participating in cooperative relationships exhibit a high degree of embeddedness (Chatfield & Yetton, 2000). Taking the MIT 90's Model, Chatfield and Yetton explain how interfirm relationships affect the organization by the model's premise of the theory of fit. The theory of fits says that high performance is a result of a tight fit between the five domains of strategy, structure, management processes, individual roles and skills, and technology (Chatfield & Yetton, 2000). Through three case studies Chatfield and Yetton tested their theories and found that low-level EDI embeddedness did not facilitate strategic gains (Chatfield & Yetton, 2000). On the other hand, those companies that were characterized by close, cooperative relationships with their partners had a high level of EDI embeddedness and, in turn, received the greatest strategic payoffs (Chatfield & Yetton, 2000). "EDI impact on strategic performance, therefore, depends on the level of EDI embeddedness. Specifically, high interfirm interdependence accompanied by high EDI embeddedness enables high strategic performance" (Chatfield & Yetton, 2000, p. 217).

Sriram et al.'s research focused on the organizational attributes of EDI to provide managers with a tool to help formulate strategies for successful implementation. They found that the "spokes," referring to customer-encouraged EDI users, received more strategic benefits than did the "hubs" or voluntary users who received more operational benefits from EDI. Strategic benefits are such things as reduced cost of operations, greater productivity, and alliances, while operational benefits include quick response time, greater accuracy, reduced clerical work, and standardized procedures (Sriram, Arunachalam, & Evancevich, 2000). Their research also found a direct correlation between length of use and perception of operational and strategic benefits (Sriram et al., 2000). This indicates the importance of viewing EDI as a long-term investment rather than a quick fix. A difference was also found between the perceived benefits of small and large firms. Smaller firms mentioned better customer service and convenience as benefits from implementing EDI, while larger firms named a greater number of operational and strategic benefits from EDI (Sriram et al., 2000). The authors explain this difference by the greater number of opportunities that larger firms have to take advantage of systems such as EDI.

Regardless of large or small, hub or spoke, the future holds an ever-increasing role for EDI. Nevertheless, that future role of EDI points to a shift towards Web-based systems due to its cost effectiveness, flexibility and accessibility (Jun, Cai, & Peterson, 2000).

Enterprise Resource Planning (ERP)

Enterprise Resource Planning, or ERP, evolved as a means to overcome the deficiencies of Manufacturing Resource Planning (MRP). MRP was designed as a tool to manage the resources of an organization in the most efficient and profitable way (Barker & Frolick, 2003). ERP's advantages stem from its ability to link all functional divisions of a business together, unlike its predecessor MRP. Furthermore, ERP goes one step farther than MRP by connecting the manufacturing division to its suppliers and customers (Gupta, 2000). How far an ERP system spans in the company is up to the customer. Some customers view it as a "do it all" system, while others only make use of its data storage and retrieval capabilities (Gupta, 2000). Regardless to what extent a company wants to take advantage of an ERP system, it allows the organization to share common data and activities throughout the entire enterprise, automate and integrate the common parts of its business processes, and generate and access information in a real time environment (Willis & Willis-Brown, 2002). Gupta (2000) describes how an ERP makes all of this happen. Before ERP, each functional department had its own application system unlinked to each other; however, now an ERP system makes the data stored in the system available to any user for a variety of different purposes (Gupta, 2000). This eliminates the redundant entry of data among the many users and decreases the potential for errors during data entry.

The implementation of an ERP system requires the dedication of a massive amount of time, energy and resources from an organization, not to mention the risk of the downside potential when an implementation goes sour. To combat this risk, Chen's article, "Planning for ERP Systems: Analysis and Future Trend," helps a company assess whether an ERP system is right for the organization. Chen listed the following reasons as convincing for the adoption of an ERP system.

- The use of multiple points of input with duplicated effort in the existing system;
- The inability of the existing system to support organizational needs;
- The requirement of extensive resources for maintenance and support;
- The consideration of an enterprise to reengineer its business process;
- The growth of the enterprise and subsequent incompatibility of several information systems;
- The inability of employees to respond easily to questions or information requested by key customers and suppliers (Chen, 2001).

Indeed the answer by most organizations is a resounding "YES" when asked if an ERP system is required, so the attention is then directed towards what type of ERP to implement (Chen, 2001). The starting point for deciding what type of system to implement begins with outlining the company's goals and objectives, as well as the goals of the project. A strategy for successful implementation hinges on the results of this step. "...most of the pitfalls relate directly to the implementation and the organization itself, and can usually be avoided. Without the proper planning and organization, an ERP project is sure to fail" (Barker & Frolick, 2003, p.44). This insight sheds a whole new light on the old adage, 'when you fail to plan you plan to fail.'

A review of the literature by Nah, Lau & Kuang (2001) aimed at identifying the critical factors of successful implementation of enterprise systems revealed 11 factors. Using Markus and Tanis' (2000) ERP life cycle model, Nah et al. (2001) were able to categorize the success factors into the various phases of the ERP life cycle. The four phases and their accompanying critical success factors are shown in Figure 4:

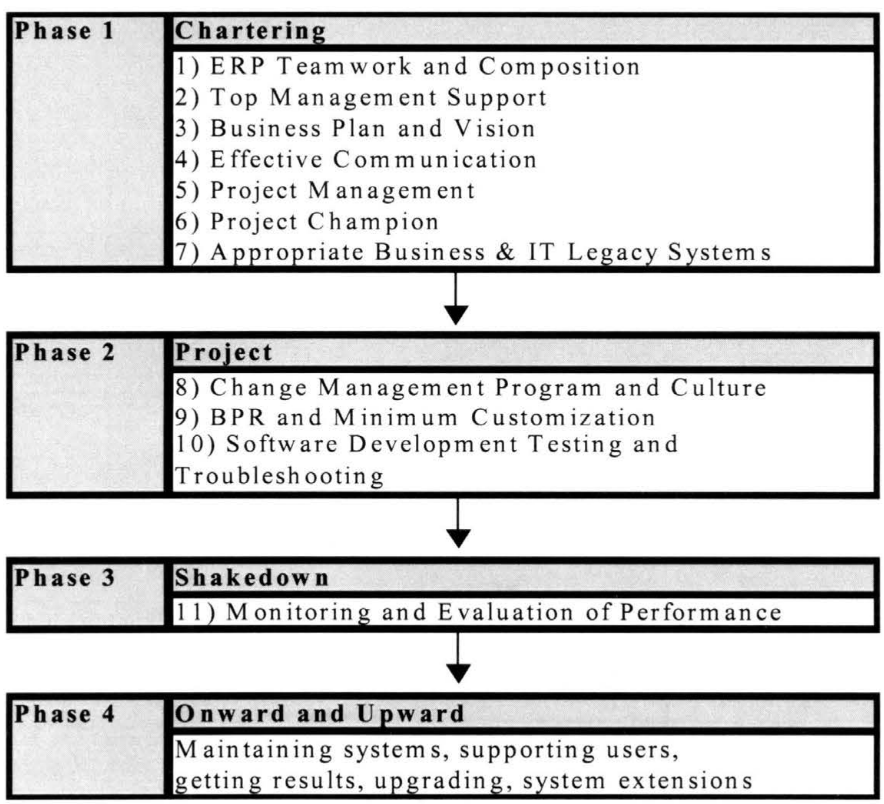

Figure 4: Critical Factors of Successful Implementation of an ERP System

For the interested reader Nah et al.'s (2001) article on "Critical Factors for Successful Implementation of Enterprise Systems" provides a more detailed explanation of all 11 success factors and how they relate to their appropriate phases in the life cycle. Only a few of the more important factors will be discussed in this paper. The first factor, which is highly important, is top management support. When implementing an ERP system, management must be prepared to be in it for the long haul. This requires providing assistance to those employees who still have their regular job duties in addition to implementation, such as encouraging and reinforcing employees continuously and allocating the proper amount of resources to get the job done right (Barker & Frolick, 2003). In "ERP Implementation Failure: A Case Study," Barker and Frolick noted one example of the detrimental effects of not allocating the proper amount of resources.

> Trying to minimize setup costs and reduce expenses, the company overlooked many of the planning team's recommendations regarding the project. This ERP implementation created high turnover and communication problems, which led to the termination of key people and animosity among employees. All of these factors, in turn, led to a system that was grossly underused, and in the beginning, a hindrance to the overall business (Barker & Frolick, 2003, p. 44).

The second factor that is highly important is effective communication. In Barker and Frolick's study, a lack of communication ended up turning into a great resistance to change. The authors advise that effective communication should involve keeping employees that are not involved in the implementation apprised of relevant information, encouraging employees to make suggestions and ask questions, convincing employees of the benefits, and keeping a steady and clear channel of communication open (Barker & Frolick, 2003).

The last factor discussed here is change management program and culture. Nah et al. recommend a heavy investment in training in order to foster a culture that is favorable to success. Employees should be involved in the design and implementation process (Nah et al., 2001). An adaptive culture that promotes the acceptance of new technologies should be encouraged to reduce any resistance to change by the employees.

Aladwani (2001) identified the sources of resistance to change and recommended a solution for the problem of resistance to change. The two sources of resistance that Aladwani identified are perceived risk and habit. Perceived risk is a perception of one's own risk in a decision to accept an ERP system and habit is the routine practices that one does (Aladwani, 2001). Aladwani's recommendation to overcome resistance is a three-phase approach that includes knowledge formulation, strategy implementation, and status evaluation. Knowledge formulation, the first phase, consists of identifying and evaluating the attitudes of users and influential groups. The second phase, strategy implementation, builds upon the results of the first phase by using the knowledge of the users to conceive strategies that conquer the resistance. Again, a key component of the strategy implementation phase is effective communication. In addition to the earlier mentioned recommendations, Aladwani suggests gaining the endorsement of well-known individuals and opinion leaders and carefully timing the introduction of the new system. A rule of implementation should be to introduce the system only when a positive attitude has been built and sustained about the introduction of the system. The third and final phase, status evaluation, is the continuous process of monitoring and evaluating the change management strategies (Aladwani, 2001).

ERP: *Contributions*

Cutting cycle times and reducing inventory are among some of the benefits of adopting an ERP system (Gupta, 2000). The adoption of ERP in the manufacturing industry has decreased inventories up to 35 percent (Gupta, 2000). These benefits are a direct result of the increased scope of an ERP system over an MRP. "Thus, a key difference between MRP II and ERP is that while MRP II has traditionally focused on the planning and scheduling of internal resources, ERP strives to plan and schedule supplier resources as well, based on the dynamic customer demands and schedules" (Chen, 2001, p. 376). The harmful results of the Bullwhip Effect are also minimized as inventory variability stabilizes with the implementation of an ERP system.

When done correctly, ERP can increase employee satisfaction by eliminating the redundancy of day-to-day activities (Barker & Frolick, 2003). Barker and Frolick also note that the improved employee satisfaction resulting from ERP will encourage employees to stay with the company longer, thereby creating a competitive advantage for the company through lower turnover and training costs. Gupta (2000) also identified the following benefits to ERP: ease of use, integration of all functions already established, online communication between suppliers and customers, customization is an option, improved decision making due to availability of timely and appropriate information, improved process times, feasibility of administering prae facto control on the operations, Internet interface is an option and planning inaccuracies are reduced (Gupta, 2000).

ERP: *Limitations and Problems*

Despite the benefits mentioned above, a semi-annual survey administered by A.T. Kearney Company revealed that the percentage of CEO's satisfied with their ERP efforts fell to 10% in 2000 from 62% in 1996 (Willis & Willis-Brown, 2002). One problem that has been the cause of much of this disappointment has been the excessive costs of ERP implementation and management's view that taking shortcuts is an alternative to complete implementation. Willis and Willis-Brown specify that the source of many of management's shortcuts are obtaining a generic ERP system that only meets a fraction of the company's needs, depending too heavily on in house experts and inadequate knowledge. Another problem cited by Willis and Willis-Brown is the lack of user-friendly systems and the employee's view that it takes an expert to work the system (Willis & Willis-Brown, 2002).

Gupta describes the disadvantages of ERP as a high organizational resistance to change, a long time to achieve the changeover causing cost overruns, data errors carried throughout the system and excessive costs and time for maintenance (Gupta, 2000). "Almost every ERP project director is confronted with problems, such as late orders, billing errors, and inaccurate inventory records after implementation" (Willis & Willis-Brown, 2002, p. 36). The first step to overcoming these problems is the realization that the journey doesn't end upon completion, but rather begins (Willis & Willis-Brown, 2002). To compare the limitations and problems of ERP to the other systems of the traditional supply chain refer to Table 2: Contributions and Limitations of The Traditional Supply Chain.

Table 2: Contributions and Limitations of The Traditional Supply Chain

System	Contributions	Limitations	Selected References
JIT		Non-targeted functions may be harmed; cultural resistance to change; lack of top management commitment	(Vokurka & Lummus, 2000)
	Cut down production time; higher earnings and cash flow per share		(Boyd, 2001)
	Reduced risk of obsolescence; Reduced response times	Involves entire business; disconnect between theory and practice	(Beard & Butler, 2000)
	Eliminates waste; improved internal and external qualities; improved labor productivity and employee behavior	Organizational support a must	(Chong et al., 2001)
		Implementation problems for small-sized firms	(Temponi & Pandya, 1995)
EDI	Decreased document handling; secure telecommunication links; reduced logistics cost; real-time information	High implementation and operations cost; difficulty in maintaining and updating standards; one-way communication	(Witte et al., 2003)
	First method of e-commerce; linked trading partners; employees more focused on value-added job responsibilities	Charged by bit sent across network; implementation requires experts; continuous upgrading	(Williams & Frolick, 2001)
	No human intervention		(Sawabini, 2001)
	Greater productivity; reduced cost of operations		(Sriram et al., 2000)
	More accurate information quicker; reduces redundant data entry		(Bhatt, 2001)
		Lack of universal standards	(Pawar & Driva, 2000)
ERP	Connects suppliers and customers; makes data available for variety of purposes; cuts cycle and reduces inventory; customization an option	Organizational resistance to change; long time to achieve changeover; data errors carried throughout the system	(Gupta, 2000)
	Generate and access information in real time	Excessive cost; lack of user friendly systems; employees believe expert is required to work system; all projects problem-laden	(Willis & Willis-Brown, 2002)
	Increased employee satisfaction	Requires extensive planning and organization; extensive resources needed; resistance to change	(Barker & Frolick, 2003)
		Top management support required	(Nah et. al, 2001)
	Bullwhip effect minimized		(Chen, 2001)

CHAPTER IV

THE E-SUPPLY CHAIN

The e-supply chain refers to the developments that were brought on by the introduction of the Internet, web technology and agents. These developments changed the dynamics of the supply chain and, along the way, forced every business to adapt to the new era of the e-supply chain. The term disintermediation began to gain popularity as companies began to eliminate their middleman and sell directly to the end consumer more quickly and cheaply.

Internet

One of the developments brought on by the introduction of the Internet was a shift in the supply chain. In the traditional supply chain, manufacturers had to sell their products to wholesalers who, in turn, would turn around and sell those products to retailers, who would ultimately sell those products to the end consumer. Before the Internet, manufacturers had no choice but to pursue a distribution strategy such as the one mentioned above, due to the increased costs of setting up stores over a large geographical area to sell directly to the end consumer. The emergence of the Internet provided all manufacturers, large and small, the ability to sell directly to the end consumer without paying incredible amounts for overhead. Bypassing the middleman also translated into reduced savings for the end consumer by eliminating the additional markups of unnecessary stages in the chain. One example of these cost savings was found in a study done by Brynjolfsson and Smith who found that prices for homogenous items, such as books and CDs, were on average 9-16% lower in e-outlets in the late 90s compared to their traditional brick and mortar counterparts (as cited in Johnson & Whang, 2002).

Internet: *Contributions*

Throughout this section, contributions of the Internet to the supply chain will be highlighted and the problems that companies faced when implementing Internet technology will be noted. In the book *Jack Welch Speaks*, Jack Welch says,

> Phrases like: 'If it ain't broke don't fix it,'or 'Don't be a solution in search of a problem,'or 'Don't break up a winning team.' We all use these over and over – a dismissal of someone trying to change something that's going just fine. But, in truth, the wisdom may lie in changing the institution while it's still winning – reinvigorating a business in fact while it's making more money than anyone ever dreamed it could make (as cited in Lowe, 1998, p.95).

When the Internet took off, Jack Welch, CEO of General Electric, told his employees to convert every process in the organization to E-Business, a strategic move that would ultimately create a new competitive advantage for GE. For GE, the proof is in the pudding in that they have already achieved significant benefits from converting to an e-business platform. GE's trading process network (TPN) does one billion dollars worth of business in one year with 1,400 suppliers around the world (Graham & Hardaker, 2000). TPN revolutionized the time-consuming and rigorous contract bidding process that was in place prior to converting to an e-business platform, allowing GE to conduct business at net speed (Graham & Hardaker, 2000). The above quote from Jack Welch is important for those companies that have successfully taken advantage of Internet technology. They share one common theme: the cultures of those companies have been adaptive and creative. Williams et al. make this observation when they note that the primary distinction between the electronic supply chain and the traditional supply chain is one of adaptability; the e-supply chain is dynamic in nature, changing concurrently with trends, consumer preferences, and competitive pressures (Williams et al., 2002).

Williams and Frolick also note that the barrier of cost to implementing EDI has been brought down by the Internet. "Operating in an eSC context only requires a free Web browser, a $500 computer and $14.95 month/Internet access" (Williams & Frolick, 2001, p.710). The research of Williams & Frolick (2001) also indicates that the value of strategic partnerships and alliances have changed. No longer do companies maintain strategic alliances for their relative cost savings because they can now increase their access to suppliers exponentially via the Internet.

Large corporations such as GE were not the only ones to take advantage of the efficiencies created by changing to an e-business platform. Small- and medium-sized businesses probably received the biggest benefits of the introduction of the Internet by allowing them to achieve the same efficiencies and cost savings as their larger competitors (Rao, Metts, & Monge, 2003). In addition, research shows that those small to medium sized businesses that utilize the Internet earn higher revenues. Statistics such as these have fueled the trend towards increased IT and telecommunications spending in small to medium sized businesses (Rao et al., 2003). SMEs (small- to medium-sized enterprises) are described as the lifeblood of the economy due to the crucial role they share in bringing innovative products and ideas to market, providing an entry for workers into mainstream America, and enabling millions to achieve the dream of economic growth (Rao et al., 2003).

The e-revolution has brought down the barriers of distance, cost, and time and transformed the traditional supply chain into a ubiquitous channel that is not only connected to the other links in the chain, but interconnected with every other player in the world. "The Gartner Group expects some $6 trillion in global B2B transactions to be made online in 2004 - predictions that are backed by emerging evidence of the real savings that can be made in such transactions" (Coltman, Devinney, Latukefu, & Midgley, 2001, p.61).

Despite statistics such as this, some evidence suggests the supply chain aspect of e-business has been neglected (Cagliano, Caniato, & Spina, 2003). In the article, "E-business strategy: How companies are shaping their supply chain through the Internet", the author's research into the extent of adoption by European manufacturing firms along the supply chain revealed the following results. First, the most frequent approach for those companies adopting the Internet has been for sales and customer care. However, their research also showed that there was a higher payoff for those companies that were fully integrated with the Internet compared to those who only used it for sales. Secondly, the author's research shows that those companies that have adopted the Internet in limited areas are seeking to expand its use through the company's operations. Third, those companies that have used the Internet extensively in the supply chain have formed close collaborative relationships with their partners. The results of this research tell us two things: first, the Internet has traditionally been implemented in a stair-step fashion and second, the implementation of the Internet increases communication throughout the chain (Cagliano et al., 2003). However, with the introduction of any new technology, an opening in the market is created for the creation of those companies that tailor to the new technology. Up to this point, this paper has focused how already existing companies have implemented the Internet. At this point, the focus will shift to those companies that were created solely around the technology of the Internet.

Internet: *A New Focus*

Kozmo is one company that contributed to the e-revolution. Kozmo's major contribution was adapting the supply chain to the customer (Wu, 2001). Kozmo's business model was to let the customer know immediately what was or was not in stock and to deliver the product to the customer's front door, all within an hour. This was a tremendous difference from the sixty-six weeks it took to move an apparel product from raw material to the customer at the onset of the supply chain (Lummus & Vokurka, 1999).

One valuable lesson learned by the Kozmo business model was the power of collaboration.

> The idea behind Kozmo Direct was that in order to control costs, companies must collaborate. Think of the savings if only one truck was pulling up to each little store every day, instead of four. Kozmo Direct hoped to help companies like Nabisco, Pepsi, Frito-Lay and Haagen-Dazs collaborate and become more efficient (Wu, 2001. p.47).

As Wu mentions, their plans were quite ambitious, but Kozmo's ambition is soon to become the standard as technology continues to evolve.

Controlling costs isn't the only motivation for companies to collaborate. Scholars speculate that product customization will be a defining characteristic of the new twenty-first century business model. Lancioni, Schau, and Smith (2003) discuss in their article how participants in all stages of the chain can now collaborate more efficiently to allow for increased customization in their products and processes.

Internet: *Limitations and Problems*

The contributions of the Internet haven't come without their fair share of limitations, though. By analyzing case studies, Barnes, Hinton, and Mieczkowska (2003) determined the following emerging issues:

1) Investment in e-commerce is primarily technology driven
2) Investments in e-commerce are tending to automate, rather than re-design existing processes
3) E-operations are run as a discrete set of processes
4) There is a lack of formal performance measurement in e-commerce
5) Legacy systems and a lack of industry standards are major encumbrances to information systems integration.

The first issue stems from the fact that many companies are not embracing the Internet for the opportunities that it provides, but rather out of fear that they will be left behind by those competitors utilizing the technology. The trend towards automation rather than re-design is limiting the success of implementation by not attacking the inefficiencies that are created through the use of the technology. Issue three, the separation of e-operations from the rest of the business, creates problems because the Internet should not be viewed as a standalone component to a business but, instead, as a tool that can enhance all aspects of the business. A lack of performance measures in e-commerce is also impairing the organization's ability to determine whether they are performing adequately. The fifth issue that Barnes et al. discuss is the lack of industry standards. Just as companies implementing EDI were plagued with the problem of suppliers and partners operating on different standards, the Internet's lack of standards has reduced its integration along the supply chain (Barnes et al., 2003).

Johnson and Whang conclude that, while companies are conducting more operations over the Internet, they are generating more data that give them the opportunity to "take real time data and make dynamic decisions" (Johnson & Whang, 2002, p. 421). The increased pressure to make real time decisions is culminating in the emergence of new technologies to help facilitate the dynamic decision making process. The next section will explore the contributions and limitations of one of those technologies, agents.

Agents

In a recent Harvard Business Review panel, Chris Gopal was asked, "What are the priorities today (for supply chain management)?" His response was,

> Another current priority is getting the tools we need to create an adaptive and responsive supply chain strategy-which is important because most supply chain strategies start down the road to being obsolete almost as soon as they are published. Creating an adaptive strategy starts with modeling the supply chain and doing scenario planning" (Scott, Burt, Copacino, & Gopal, 2003, p. 66).

Agents provide an opportunity to both model the supply chain and create an adaptive and responsive supply chain strategy in real time.

Depending on the tasks they perform and the ways in which they are implemented, an agent can be defined in a variety of ways (Julka et al., 2002). While the definition of an agent in the literature is obscure, there is an agreement among scholars on the key attributes of agents. An article from the May/June 2003 *Supply Chain*

Management Review identifies the key attributes of agents as being autonomous, social, adaptive and mobile. 'Autonomous' means that no human intervention is required for the agent to make a decision. However, pre-determined decision levels can be set to establish exactly what level of authority the agent will have. The 'social' attribute of agents refers to their ability not only to communicate with other agents, but also with humans. 'Adaptive' means that the agent can change its behavior on the basis of experience. 'Mobile' implies that the agent can move across computer networks while representing various users in different tasks. While mobility is not a requirement for agents, it has its benefits in assuring stability, information retrieval, and affecting the dynamic deployment of software or code (Greis, Olin, & Dasarda, 2003).

Agents communicate among themselves by way of messages. A unique name serves as an agent's address and enables communication between agents regardless of location (Julka et al., 2002). Transmission of messages is accomplished by hosts. When it is created, each agent is assigned a host that serves as an agent's "post office" delivering messages between agents (Julka et al., 2002). An agent's permission to send messages can either be programmed to allow delivery within its environment, outside of its environment or both; an environment being defined here as a group of agents (Julka et al., 2002). This type of architecture allows agents the ability to work on several tasks simultaneously (Julka et al., 2002).

Agents: *Contributions*

Previous research has focused on the use of agents in modeling various supply chain problems such as inventory management, demand forecasting, and distribution systems, while recent attention has turned to the complete supply chain structure (Julka et al., 2002). The authors examine the use of a multi-agent approach to modeling all entities in the supply chain. The authors' review of the literature identified several contributions of multi-agent modeling in the supply chain. A few of the contributions have ranged from matching demand and supply, analyzing reengineering options for a company, and resource scheduling (Julka et al., 2002).

The use of agents in modeling the supply chain is still a relatively new idea; however, the contributions to date have been copious. Procter & Gamble's use of agent-based modeling has already saved the company $300 million annually on an investment of less than 1% of that. P&G's use of agent-based modeling has had such a dramatic effect on the company they now refer to their supply chain as a "supply network" (Anthes, 2003).

> Their work is a real-world example of what mathematicians call 'agent-based modeling of complex, adaptive systems' a discipline pioneered by BiosGroup and other mostly Santa Fe-area companies, laboratories and think tanks. The idea is that many systems that are enormously complex overall are, in fact, made up of semiautonomous local 'agents' acting on a few simple rules. By modeling and changing the agents' behavior, one can understand and optimize the entire system (Anthes, 2003, p. 26).

Agents: *Limitations and Problems*

From Nissen's (2001) review of the literature concerning agents, he identified four factors that contribute to the limitations of agents in the supply chain:

1. Knowledge engineering : the capture and formalization of knowledge for use by a knowledge based system

2. Design inexperience : since development remains a nascent discipline, little design guidance specific to agent development exists at present
3. Message congestion: more agents result in more frequent number of messages sent between them
4. Third-party collaboration: heterogeneous agents may have difficulty in communicating and coordinating to perform tasks

The limitation of knowledge engineers results from the fact that many of the engineers of agents have no knowledge of the supply chain, just as many of the supply chain practitioners have no knowledge of agents. This results in a lack of intelligent communication concerning the area. Design experience is related to the fact that there have been no specific standards set for the design and use of agents due to the newness of the field. Message congestion is the direct result of too many agents sending messages, thereby slowing down the system because of the bandwidth, processing speed, and the time it takes for an agent to decipher which messages are important. Finally, the fact that the field of agents is still in its infancy has led to a lack of third-party collaboration among the architectures, languages, ontologies and protocols of the agents. This has exacerbated all of the above limitations of agents and is a major concern for their use in the supply chain, limiting their use to only a single supply chain application (Nissen, 2001).

The following table, Table 3: Contributions and Limitations of The E-Supply Chain, compares the contributions and limitations of the Internet and Agents.

Table 3: Contributions and Limitations of The E-Supply Chain

System	Contributions	Limitations	Selected References
Internet	Cost savings		(Johnson & Whang, 2002)
	Reduced time & easier bidding process	Changing values	(Graham, 2000)
	Adaptability		(Williams & Frolick, 2001)
	Ability for SMEs to achieve the same efficiencies as larger competitors		(Weller, 2000)
	Increased communication	Supply chain aspect of e-business has been neglected	(Cagliano et al., 2003)
	One-hour delivery Immediate inventory recognition		(Wu, 2001)
Agents	Real time decision making	Emerging issues	(Johnson & Whang, 2002)
	Attributes are autonomous, social, adaptive, and mobile		(Barnes, 2003) (Greis, et al, 2003)
	Can work on tasks simultaneously; supply chain modeling		(Julka et al., 2002)
	Companies' use of agents; optimization of entire supply chain		(Anthes, 2003)
		Knowledge engineering; design inexperience; message congestion; third party collaboration	(Nissen, 2001)

CHAPTER V

SUPPLY NETWORK TOOLS

The "supply network" refers to the interconnected state of organizations cooperating to achieve their individual goals while realizing their impact on the whole system. Supply network tools consist of the most evolved information systems that have the potential for mimicking the human decision-making process. These tools have the power to replace humans in certain processes while creating a more efficient and reliable mechanism for process control. Supply network tools have been a major contributor to the evolution of the supply network. The major information systems of this era are Fuzzy Logic, Neural Networks and Genetic Algorithms. Figure 3 in Chapter II demonstrates how every organization in The Supply Network is ultimately affected by each other's actions compared to that of The Traditional Supply Chain.

The supply network tools mentioned in this section are not a recent innovation, however. Their use only really began to catch on when the power of information systems had developed to a stage that would facilitate their use. Another name for Supply Network Tools are "Evolutionary Systems". This name was given for several reasons. First, as was previously mentioned, these systems are the most evolved information systems to date and have the power for emulating the human decision-making process. Secondly, the systems in this section were not developed through a process of trial and error, but by way of observation and modeling of certain biological processes.

Fuzzy logic is modeled after the human decision making process; neural networks are modeled from the function of the brain; and genetic algorithms are modeled after the process of natural selection and evolution. These systems were developed in theory many years before their use, but it was the advancement of information systems that allowed their applications to become prevalent. In Figure 5: Timeline of Evolutionary Systems Development, the origin of the theory of evolutionary systems and the dates that their applications began appearing are on the left side. On the right side of the timeline are the dates of key advancements in information systems. Notice how the applications of these theories developed after key advancements in information systems.

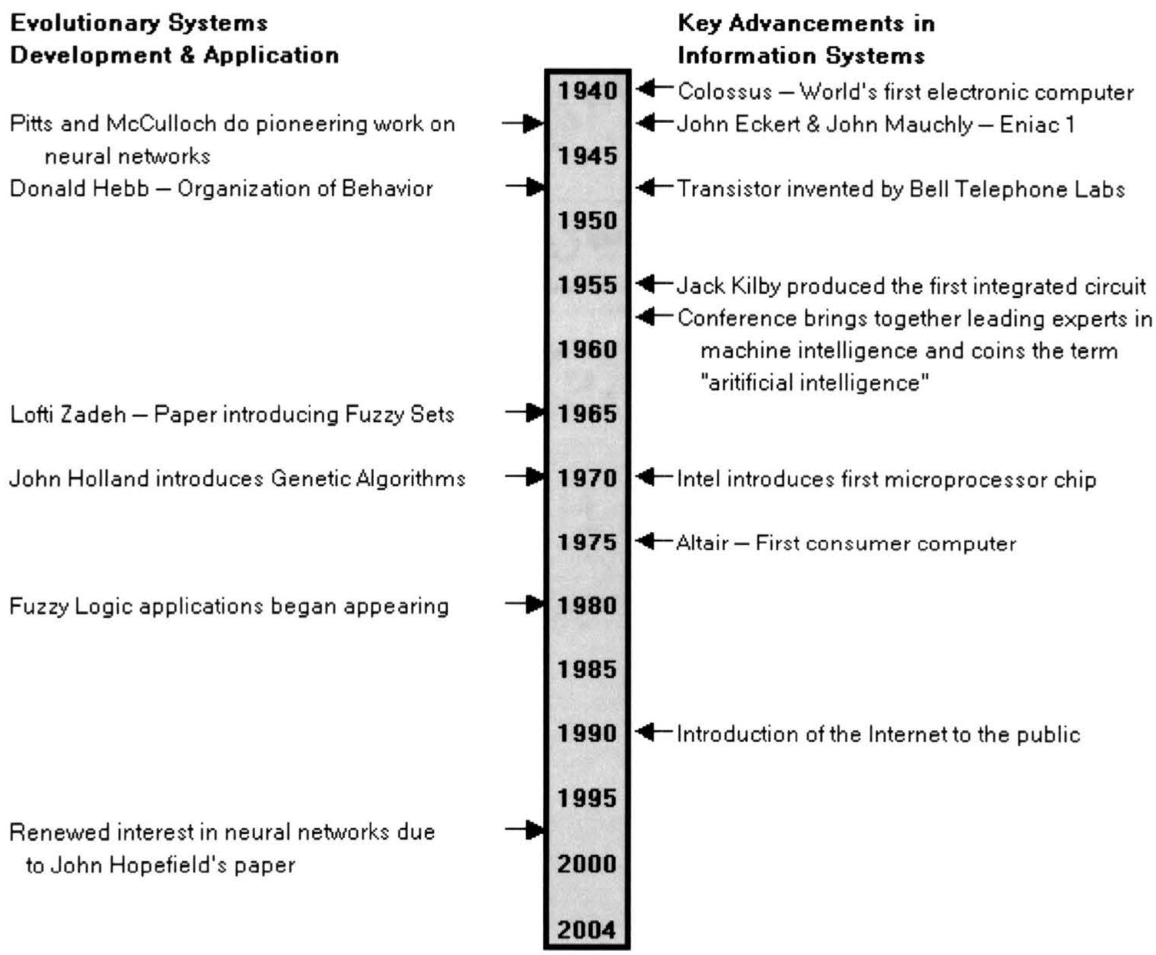

Figure 5: Timeline of Evolutionary Systems Development

Fuzzy Logic

Fuzzy logic is a problem-solving control system methodology that captures the way a human would make a decision, only much quicker. Introduced in 1965 by Lofti Zadeh (1965), in his paper on Fuzzy Sets, fuzzy logic works by allowing a partial set membership such as a gray area rather than a precise black or white, or a right or wrong. By using a series of 'IF, THEN' statements, fuzzy logic provides an easy way to arrive at a definitive answer even if the data are vague, ambiguous, or missing (Zadeh, 1965).

Using fuzzy logic we can begin to answer some of the perennial questions that have perplexed philosophers for some time. For example, take the clichéd question, "Is the glass half full or half empty?" (Kosko, 1993)

Since Socrates' time, people have debated over which group of membership the glass would fall in, either empty or full. Fuzzy logic tells us, though, that the glass is 50% full and 50% empty; therefore, the glass has a membership in both sets of 50% (Kosko, 1993). Nearly 20 years after its introduction, fuzzy logic finally started to catch on in the 1980's. However, American firms chose not to pursue the idea as aggressively as their Japanese and European counterparts and subsequently fell behind in the use of its applications.

Fuzzy Logic: *Contributions*

One method for monitoring supply chain performance was developed by Lau, Pang, and Wong at the Hong Kong Polytechnic University. The methodology assumes that strategic alliances have already been formed on the basis of the mutual needs of the parties involved. The model analyzes the weighted average of the past performance of defect rates and delivery times in order to forecast the quantity of the next order (Lau, Pang, & Wong, 2002).

Lee and Padmanabhan (1997) found that information sharing could significantly minimize the consequences of the Bullwhip Effect. Knowing this, Shore and Venkatachalam developed a fuzzy logic model for selecting suppliers based on their information sharing and infrastructure capability. Shore and Venkatachalam used Hofstede's 1980 research into collaboration behavior and the willingness of an organization to share data to help develop their model. Shore and Venkatachalam conclude that fuzzy logic is a useful tool for solving supply chain evaluation problems (Shore & Venkatachalam, 2003).

Chan and Qi (2003) advocate the use of a performance measure based on the holistic performance of the supply chain. Instead of taking the traditional approach of focusing on financials, profit orientation and local optimization, Chan and Qi base their performance measure on the performances of the chain as a whole, considering all business aspects involved in the supply chain. Inherent in fuzzy logic's contributions are certain drawbacks. Next, some of the limitations and problems of fuzzy logic will be examined.

Fuzzy Logic: *Limitations and Problems*

One limitation of fuzzy logic has been the requirement of experts to develop and monitor the systems. Lau et al. (2002) note that experts are usually required to generate the rules of the systems, as well as monitor and adjust the rules at the beginning of implementation. This limitation alone has resulted in making fuzzy logic a costly alternative for a company. In addition, fuzzy logic gives up a certain degree of accuracy and reliability to work as a rule-based system. Another limitation faced by fuzzy logic is the need for more sophisticated models as the phenomenon being modeled grows in complexity. Lau et al. (2002) gave the example of a competitor forming a supply chain alliance with one of your partners; while this is a very important point to consider, it may not be represented in the model.

Neural Networks

Like fuzzy logic, neural networks are not a new phenomenon, but the widespread use of them has only caught on in the last 10 years. Neural networks actually predate the original computer, though people's interest wasn't really sparked until Rosenblatt developed the famous "Perceptron" in 1958 (Kay, 2001). Neural networks mimic the brain in the way it processes information, but at a much smaller scale through the use of a large number of interconnected neurons that learn by example.

Neural networks have a highly connected, nonlinear structure that aids in identifying patterns through a process of learning (Thieme, Song & Calantone, 2000). Neural networks, depending on their structure, are typically made up of several layers connected by weighted links. The nodes, as they are referred to, represent the neurons of the brain while the weighted links represent the synapses. Just as the brain learns through a process of adjustment to the synapses, so does the neural network. This adjustment takes place by training a neural net on a reliable set of inputs and outputs. Examples must be chosen with great care because the user has no way of knowing how the neural network arrives at the conclusion that it does. Below is a simple diagram displaying a neuron and its weighted links.

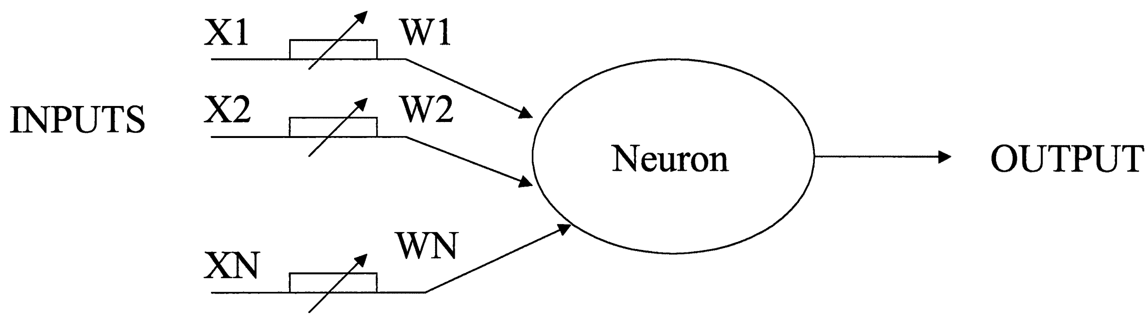

Figure 6: The Neuron and Weighted Links

(Retrieved March 18, 2004, from http://www.doc.ic.ac.uk/~nd/surprise_96/journal/vol4/cs11/report.html#What%20is%20a%20Neural%20Network)

Before exploring the contributions of neural networks some of the terminology will be discussed. Generalization is a term used to describe how accurately a neural network identifies inputs not used in the training process. Therefore, one set of inputs is used for training and another for evaluating. A prerequisite to good network generalization is the right amount of learning, any less or any more can result in underlearning or overlearning. Underlearning results when the number of nodes and weights of a network are less than what is required for the particular model, while overlearning is a result of too many nodes and weights. The number of nodes and weights in a network directly affects the system's variance and bias. 'Variance' is used in this instance as the sensitivity of a network to its training data and 'bias' is the difference between the actual output obtained from a set of inputs and the average output of the network over every feasible data set (Thieme et al., 2000). Now that the reader has an idea of how a neural network functions, some of its contributions to the supply chain will be noted.

Neural Networks: *Contributions*

One contribution made to the supply chain by neural networks has been their improved ability to forecast retail sales (Chu & Zhang, 2003). Central to the profitability of any retail business operation is the ability to accurately forecast the demand for your product in order to carry the inventory when needed and replenish it in a timely manner. Traditional linear models, such as time series regression and exponential smoothing, have been used for these purposes in the past. One disadvantage of the previous models has been the assumptions that are required for their use. By manipulating the data to meet the assumptions, we are in fact changing the very thing that we are trying to measure. It is amazing that we are still making these mistakes three quarters of a century after Werner Heisenberg developed his Uncertainty Principle. This provides one of the lures of the neural network over traditional linear regression, which is the reduced number of assumptions that have to be met to analyze the data. Another lure is that a neural network can work with missing data. Chu and Zhang's (2003) research concluded that nonlinear models, specifically neural networks, are the preferred approach for modeling retail sales movement (Chu & Zhang, 2003).

Thieme et al. (2000) found neural networks to be a very useful tool in the development of new products. The patterns that are learned from prior projects allow an experienced product manager in the new product development process to ultimately lead the product to success or failure. The artificial neural network (ANN) developed by the authors ended up outperforming the traditional methods of k-nearest neighbor, logistic regression, ordinary least squares (OLS) regression, and discriminant analysis in the prediction of success of a new product. The authors' ANN correctly predicted success 96.7% of the time out of a sample of 212 new product development projects. Through a case study, the authors' research found that one company could have achieved a total cost savings of $462 million through the use of the ANN proposed in the article. Contributions, such as the previous cost savings, have clearly been noted in the literature; however, the significant limitations of neural networks discussed have caused a conundrum for any manager considering using the technology (Thieme et al., 2000). The next section will be an investigation of some of these limitations.

Neural Networks: *Limitations and Problems*

In the article, "Artificial Neural Network Decision Support Systems for new Product Development Project Selection," the authors note that rules based on the extensive experience of experts have not been developed because of the intricate relationships involved in the development process. This again indicates that there has been a disconnect between theory and practice in the application of neural networks. In addition, the incredible predictive powers of neural networks have come at the cost of diminished explanatory power. Thieme et al. (2000) note that thus far there has been no model developed that is superior in respect to both predictive ability and explanatory power.

Neural network's ability to handle ambiguous and missing data makes them a very flexible tool for analyzing data. However, in order to exploit the full power of this flexibility, careful focus should be paid to the learning process. A firm that believes that they can just gather data, create a generic network structure, and train with a generic algorithm are in for a rude awakening (Thieme et al., 2000).

Genetic Algorithms

Developed in the 1970's by John Holland at the University of Michigan, genetic algorithms have become a very useful tool in optimization problems (Holland, 1975). When John Holland began his research in the 60's, he set out to improve our understanding of the natural adaptation process and design artificial systems having properties similar to natural systems. First, one must represent a solution to the problem, known as a genome or chromosome; from there the genetic algorithm creates a population of solutions, mutating and crossing over until it finds the optimal solution to the problem. Genetic algorithms are advantageous in that it is not necessary to know much about the problem to find a solution. However, Kim and Kim's (2002) research indicates that the inclusion of certain specific knowledge may improve the performance of GA (Kim & Kim, 2002). Therefore, for those who require better results, it is recommended that they include certain specific knowledge. One of the optimization problems that has gained interest over the years has been production scheduling. Kim and Kim (2002) apply optimization to a two-machine flow shop to find the shortest completion time. Their article provides a good place to begin research into GA by providing a framework for walking beginners through the process of developing a GA and identifying the inherent limitations in its use (Kim & Kim, 2002). Some of these contributions and limitations are discussed below.

Genetic Algorithms: *Contributions*

GA has been proven to be an effective search procedure, particularly in those areas in which the search is very intricate. Another area of contributions to the supply chain by genetic algorithms has been in forecasting. Jeong, Jung, and Park (2000) use a computerized causal forecasting system for efficiently forecasting the various performance indices involved in the supply chain. The purpose of their study was to develop a general causal forecasting model that would be applicable to all of the forecasting problems in the supply chain. In setting out to do this, Jeong et al. were concerned with the issue of premature convergence (will be discussed later in the limitations section). To overcome the problem of premature convergence, they introduced a measure of diversity of each population, Population Diversity Index (PDI), since it has been shown that a decrease of population diversity is directly correlated to premature convergence. Results from a case study indicate that the use of PDI is effective in minimizing premature convergence. The results also show that a GA based method of forecasting produces more accurate results than regression analysis. This is due in part to the fact that the GA based method reflects recent data intensively, while regression analysis gives equal weights to all of the historical data (Jeong., Jung, & Park, 2000).

Zhou, Min, and Gen's (2003) GA designed for the bi-objective warehouse allocation problem has been proven successful and thereby provides a framework to obtain solutions for warehouse allocation problems with multiple objectives by modifying the proposed algorithm. In spite of these contributions limitations and problems do exist.

Genetic Algorithms: *Limitations and Problems*

One of those limitations is the requirement of an expert who understands the information. "Since the threshold value and the amount of information in the population are crucial for the efficiency of the GA, an expert who understands the information and the purpose of selection is required for each generation of GA procedure" (Kim & Kim, 2002, p. 160).

Another disadvantage of their use is probable 'premature convergence'. Premature convergence occurs when the search process stops at a local optimum before it has searched a sufficient area of the solution space. Kim and Kim (2002) recommend using a hybrid search method or pursuing new techniques to jump out of premature convergence.

Zhou et al. identified another limitation of GA. "Although GA aims to produce global optimal solutions efficiently, its population size cannot be infinite. Thus, its final solution can be biased due to finite sampling of potential solutions" (Zhou, Min & Gen, 2003, p.36).

Refer to Table 4: Contributions and Limitations of Supply Network Tools below to examine the similarities and differences between the limitations and contributions of supply network tools.

Table 4: Contributions and Limitations of Supply Network Tools

System	Contributions	Limitations	Selected References
Fuzzy Logic	Monitor supply chain performance	Expert required; Complex model required	(Lau et al., 2002)
	Supplier selection		(Shore & Venkatachalam, 2003)
	Performance measurement method		(Chan & Qi 2003)
Neural Networks	Improved ability to forecast sales	Expert required	(Chu & Zhang, 2003)
Genetic Algorithms	Production scheduling; effective search procedure	Expert required; premature convergence	(Kim & Kim, 2002)
	Forecasting; improvement upon regression analysis		(Jeong, et.al, 2000)
	Warehouse allocation	Finite population	(Zhou et al., 2002)

CHAPTER VI

CONCLUSION

In this section, the support obtained for the stated hypotheses through the literature review will be documented. Each hypothesis will be analyzed for how well it is supported according to the findings. The following table lists the hypotheses from the first section, introduction, that will be analyzed.

Table 5: Hypotheses

H1	Advancements in information systems have led to a concurrent evolution in the supply chain.
H2	Lack of understanding of opportunities in the supply chain may have limited the use of information systems in the supply chain.
H3	The impact of the contributions of information systems on the supply chain has been significant.

Hypothesis 1

Advancements in information systems have led to a concurrent evolution in the supply chain. At this point, the figures in Chapter II showing the stages of the supply chain's evolution should have a whole new meaning to the engaged reader who has observed the advancements of both the supply chain and information systems in the literature review. Referring to Figure 1, we can see the characteristics of both vertical integration and the traditional supply chain. At the time of vertical integration, the use of information systems for the purpose of moving raw materials through to finished products were so minute that they could have been considered nonexistent.

Another important characteristic of vertical integration from Figure 1 is the way that companies dealt with each other, which was in an arm's length manner compared to the cooperative relationships of the traditional supply chain. Cooperative relationships were not just an option for companies implementing JIT, EDI and ERP, but rather a necessity. To recall one quote from the JIT section concerning implementation, "Setting up a JIT system, however, involves the entire business, from suppliers to production to customers-even to administrative aspects such as accounting" (Beard & Butler, 2000, p.61). In the EDI section it was explained that the maximum benefit of EDI is obtained through a high level of EDI embeddedness. The concept of embeddedness is that the structure and quality of social ties between firms shape their economic action (Chatfield & Yetton, 2000). Therefore, a high level of EDI embeddedness is associated with cooperative relationships. In addition, a quote from the ERP section describes the type of cooperation that is required for its implementation,

> Thus, a key difference between MRP II and ERP is that while MRP II has traditionally focused on the planning and scheduling of internal resources, ERP strives to plan and schedule supplier resources as well, based on the dynamic customer demands and schedules" (Chen, 2001, p. 376).

From these examples we can see how the introduction of Interorganizational Systems such as JIT, EDI and ERP influenced companies interactions with each other. In addition, the significant contributions made by these systems mandated their use for those companies that strived to stay competitive and, in doing so, helped evolve vertical integration into the traditional supply chain.

Figure 2 shows a very sizable difference between the traditional supply chain and the e-supply chain. The emergence of the Internet created an outlet that provided all manufacturers, large and small, the ability to sell directly to the end consumer, thereby eliminating the need for a middleman in some cases. In essence, Internet technology changed the structure of the supply chain. By eliminating the middleman and serving as a platform for a faster, more dynamic form of communication, the Internet affected not only companies, but consumers who demanded more from their companies. The terms "net speed" and "mass customization" are synonymous with what consumers demanded during the e-era. In Table 2, Contributions and Limitations of the E-Supply Chain, we can see that immediate inventory recognition and one-hour delivery are just a couple of the contributions of the Internet. These contributions, though, are what give the e-supply chain its characteristic of operating in real time. Once again, in this instance, it is important to see how these advancements in information systems worked to evolve the traditional supply chain into the e-supply chain.

The emergence of the e-supply chain brought with it new tools to help manage its distinguishing real time characteristic. One of the tools developed for this purpose was agents. Referring to Table 2, note that agents facilitated real time decision making, worked on multiple tasks simultaneously while being autonomous, social, adaptive and mobile. The contributions of agents to the supply chain began to change many people's view of their supply chain. Recall that P&G's use of agent-based modeling has had such a dramatic effect on the company that they now refer to their supply chain as a "supply network".

Here the supply network was born and with it came the characteristics seen in Figure 3, collaboration, prediction and the use of evolutionary systems. Whereas cooperative relationships were defining characteristics of the traditional supply chain collaboration is now the norm due to the paradigm shift mentioned in the Bullwhip section. In order to create a strategy for success, it is necessary to consider how the position interacts with the whole system and how actions influence the outcomes of the other variables in the system. A holistic focus is pervasive throughout the supply network and, referring to Table 3, The Contributions and Limitations of Supply Network Tools, it is apparent that the tools embody this holistic focus. Contributions of fuzzy logic have helped to monitor supply chain performance and assisted in supplier selection. Neural networks have improved the ability to forecast retail sales and predict successful new products. Genetic algorithms have improved production scheduling and warehouse allocation.

The holistic focused supply network of today is very different from the traditional supply chain of just two decades ago. The traditional supply chain was linear, cumbersome, simplistic and slow to react compared to the supply network of today that is dynamic, nonlinear, intricate and responds in real time. The previously cited advancements in information systems and their effects on the supply chain provides support for the first hypothesis. *H1: Advancements in information systems have led to a concurrent evolution in the supply chain.*

Hypothesis 2

Lack of understanding of opportunities in the supply chain may have limited the use of information systems in the supply chain. Visionaries such as Henry Ford whose implementation of a JIT system cut production time from 21 days to 4 days in 1921 and reduced the cost of a Model T from $850 to $290 not only understood the opportunities but embraced them (Boyd, 2001). However, visionaries such as Henry Ford have been the minority in a business world characterized by a wait and see attitude. It wasn't until over sixty years later that companies really felt the pressure to adapt the JIT philosophy that Henry Ford adopted in 1921. As a result, many of those companies didn't survive throughout those sixty years.

From the literature review, the main reason that was identified as a cause for the lack of understanding opportunities was a natural resistance to change. It is no surprise to find that one of the causes of a lack of understanding of opportunities in the supply chain is a natural resistance to change, given that one of the causes of resistance is ineffective communication (Barker & Frolick, 2003). As Barker and Frolick point out, effective communication consists of keeping those employees who are not involved in the implementation apprised of relevant information, encouraging employees to make suggestions and ask questions, convincing employees of the benefits and keeping a steady and clear channel of communication open. In addition, Barker and Frolick (2003) recommend involving employees in the design and implementation process, investing heavily in training and creating an adaptive company culture to overcome resistance.

Advancements in information systems have evolved the supply chain and forced every company that wants to stay competitive to adapt. The key word here is "forced", by not embracing change and moving with it rather than following it, companies have limited the use and effectiveness of information systems in the supply chain. Those visionaries who embraced and mastered change not only adapted but also reaped the maximum benefits from the fruits of their labor.

The wait and see attitude and halfhearted approach to implementation of most information systems are a consequence of management's lack of understanding of the opportunities of these systems. Recall that Barnes et al. (2003), by analyzing case studies, determined that the number one emerging issue of the Internet is that it is primarily technology driven. This issue stems from the fact that many companies aren't embracing the Internet for the opportunities that it provides, but rather out of fear that they will be left behind by those competitors utilizing the technology. From looking at Table 2, it is notable that several authors have cited the importance of organizational support for the successful implementation of any new information system. However, the halfhearted approach as mentioned above in the Internet example is doomed to failure from the beginning. A lack of understanding of opportunities is one reason for a halfhearted approach to organizational support. For, if management was aware of the tremendous cost savings and efficiencies obtained from the adoption of information systems, common sense tells us that they would be rushing to hop on the information systems bandwagon. The above documented findings from the literature review provide support for the second hypothesis. *H2: Lack of understanding of opportunities in the supply chain may have limited the use of information systems in the supply chain.*

Hypothesis 3

After reviewing the literature, the research shows that information systems have not only worked to evolve the supply chain but have made very significant contributions along the way. Throughout this section, support for the third hypothesis will be examined by documenting the contributions found in the literature review. Hypothesis 3*: The impact of the contributions of information systems on the supply chain has been significant.* To begin, the contributions of information systems to the traditional supply chain will be discussed. From looking at the table below, one can see that these systems eliminated waste and reduced inventory, which thereby reduced the risk of obsolescence. Employee productivity and satisfaction were increased as a result of such contributions as reducing redundant data entry, decreased document handling and greater accuracy. Suppliers and customers are connected through secure telecommunication links with the ability to generate and access information in real time.

Table 6: Contributions of Information Systems to The Traditional Supply Chain

JIT	EDI	ERP
➢ Cut in production time ➢ Reduced response time ➢ Eliminates waste ➢ Reduced risk of obsolescence ➢ Improved labor productivity and employee behavior	➢ Decreased document handling ➢ Secure telecommunication links ➢ Reduced logistics cost ➢ Real time information ➢ No human intervention ➢ Greater accuracy ➢ Reduces redundant data entry	➢ Reduces inventory ➢ Connects suppliers and customers ➢ Generate and access information in real time ➢ Increased employee satisfaction ➢ Bullwhip effect minimized

Looking at the contributions of information systems to the e-supply chain, it is important to note that the Internet reduced costs and time, increased communication and abilities for SMEs. The Internet also created an environment of adaptability, while allowing for immediate inventory recognition and one-hour delivery. Agents provide real time decision making while working on multiple tasks simultaneously. The ability of agents to model the supply chain has allowed practices to be optimized, all the while being autonomous, social, adaptive and mobile. This is summarized below in Table 7.

Table 7: Contributions of Information Systems to the E-Supply Chain

Internet	Agents
➢ Cost savings ➢ Reduced time and easier bidding process ➢ Adaptability ➢ Increased communication ➢ Increased abilities for SMEs ➢ One hour delivery ➢ Immediate inventory recognition	➢ Real time decision making ➢ Autonomous, social, adaptive and mobile ➢ Can work on tasks simultaneously ➢ ➢ Supply chain modeling ➢ Optimization of entire supply chain

The contributions of supply network tools have enabled companies to monitor the supply chain's performance, assist in supplier selection and improve forecasting. Neural networks have been able to successfully predict new product development projects, while genetic algorithms have worked to solve the eternal supply chain problems of production scheduling and warehouse allocation. These contributions are summarized in Table 8 below.

Table 8: Contributions of Information Systems as Supply Network Tools

Fuzzy Logic	Neural Networks	Genetic Algorithms
➢ Monitor supply chain performance ➢ Supplier selection ➢ Performance measurement method	➢ Improved ability to forecast sales ➢ Successful prediction in new product development	➢ Production scheduling ➢ Forecasting ➢ Warehouse allocation

As was mentioned previously, the significance of some of these contributions were impressive. As indicated by Williams and Frolick (2001), RJR Nabisco lowered their cost of processing a paper-based purchase order from $70 to less than a dollar via EDI, Graham (2000) also indicated that GE revolutionized their rigorous and time consuming contract bidding process by converting to the Internet and now does over one billion dollars worth of business with 1,400 suppliers around the world, and P&G's investment into agents has already saved the company $300 million annually according to Anthes (2003). These are just a few of the contributions cited from the literature; indeed there are many more contributions out there. These contributions provide support for the third hypothesis. *H3: The impact of the contributions of information systems on the supply chain has been significant.*

From looking at the timeline in Chapter V, one can see that the supply chain has come a long way since Henry Ford's day. However, the potential to go even farther is there. The data suggest that contributions of cost savings, efficiencies, and improved employee morale and productivity are just a few of the many benefits of implementing information systems. Some companies never achieve these benefits because a major deterrent to implementing information systems is resistance to change. The supply network today now has the characteristics of being dynamic, nonlinear, intricate, and responsive in real time compared to the backward-looking, inefficient, and slow-to-react supply chains of the past. In the future, the supply network will continue to change, and how companies respond to that change and overcome resistance will contribute to their effectiveness.

Supply Chain Management in the Future

Several areas for future research for the role of information systems in the supply chain are identified.

- Communication to overcome resistance to change
- Adaptive cultures to overcome resistance to change
- Globalization
- Mass customization

As Aladwani (2001) and Barker and Frolick (2003) pointed out, one solution to resistance to change is communication. It is important to communicate not only what the new technology does, but how employees can benefit from it. Given that resistance to change is the biggest barrier to implementing information systems, it is worth examining other tools to help alleviate this resistance.

Another area of future research has to do with creating adaptive cultures to overcome resistance (Nah et al., 2001). This issue will become even more important in the future since new technologies are being developed at a much quicker pace than they were in the past. This is attributable to the fact that, as a society, we have reached the part on our technology curve where we are growing exponentially.

To understand the magnitude of where we are as a society in terms of growth, there is an analogy from an issue of T*he Economist* that was published in the mid 90's. If you take a regular sheet of paper and fold it in half and continue to do so, at 7 folds it would be as thick as a notebook. When it reaches 17 folds it will be taller than the house you live in. But here it begins to get really interesting: an additional 3 folds and it is a quarter of the way up the Sears tower. At 50 folds, it has reached the sun; at 80 folds, it is 12,000 light years away; at 100 folds, it is the approximate size of the universe, 12 billion light years.

Two specific areas were also identified as areas of potential future research. The two areas, globalization and mass customization, were identified due to the direct correlation that they have with advancements in information systems. Mattson (2003) defines globalization as a process by which an already highly internationalized firm increases its integration of activities and resources between different geographic markets. Nothing has contributed more to this process of globalization than the e-revolution. The Internet has brought down the barriers of distance, time and cost that once stood in the way of firms partnering or doing business with companies in foreign territories.

Until recently, mass production has been the norm, but due to the impact of globalization and the Internet, a movement has started towards mass customization. The emergence of the technologies of the Internet and agents has not only made mass customization possible but consumers are beginning to demand it. We have already begun to see these shifts in a wide range of industries, some even notorious for their mass production, i.e., the fast food industry and their new shift towards "Made Your Way".

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