Information-based Manufacturing in the Informational Age

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Abstract
The customer of the 1990's demands products and services that are fast, right, cheap, and easy. Manufacturing organizations have adopted information-based manufacturing strategy that incorporates information technology to maintain and deliver information required for knowing what, when, and how to make economical products. This strategy is explored within the context of the New Economy as it is manifest in the areas of globalism, informationalism, and customer dominated markets.

(Information Technology, Informational Society, Logistics, Networks, Mass Customization, Zero Latency Enterprise)

1.0 Introduction

Customers expect products and services that are available on demand, exhibit high levels of quality and reliability, are fairly priced, and are easy to use. These expectations reduce to the adjectives fast, right, cheap, and easy. Manufacturing organizations have adopted an information-based manufacturing strategy that incorporates information technology to maintain and deliver information required for knowing what, when, and how to make economical products. More than technology, information-based manufacturing also includes related issues such as connectivity, the ability to coordinate and integrate, and a practical implementation strategy to provide the capability to adapt and react to customer demands.

Information-based manufacturing is better understood when placed within the larger context of the "New Economy". This economy, a development of the Informational Age, is global in reach, sustained by social and financial networks, and enabled by information technology. Since the resource constraints of the previous Industrial Age no longer pertain, its principles are not readily intuitive. Former competitors now collaborate as members of standards committees. Once monolithic hierarchical organizations devolve into distributed units that compete with each other. The previously passive customer has assumed a dominant role in the buyer-seller relationship that changes production practices from build-to-stock to build-to-order. All of these changes unthinkable during the industrial age are required to thrive in the information age.

Although Alvin Toffler popularized the concept of the transition from the industrial age to the information age in the 1970's best seller *The Third Wave,* the socio-economic effect of this transition remains to be fully understood. The link between the concept of the information age and the New Economy can be explained as follows: "Information is not the foundation of the 'New Economy,' for information is not an economic offering. […] Only when companies constitute it in the form of information *services* - or informational *goods* and informing *experiences* - do they create economic value. Economic offerings, not forms of intelligence, comprise the substance of buying and selling." (Pine & Gilmore 1999) In short, information has become an output of, as well as an input to, economic production.

Networks play a definitive role in the information age and the related New Economy. This organization structure became prevalent with the rise of digital technology and the emergence globalism at the end of the Cold War period. These events coincided with customer domination of markets as supply and demand came into balance after the recovery from World War II. These three phenomena set the stage for radical change in commerce and especially for manufacturing. Information-based manufacturing provides an organized response to the challenges presented by these three radical changes.

The remainder of this paper is organized as follows: The role of networks in the New Economy is discussed in Section 2.0. The effect of the customer domination upon markets and the producer response with mass customization and the zero latency strategies is explained in Section 3.0. Some John Deere experiences are sketched in Section 4.0. A short summary follows in Section 5.0

2.0 The Network Society

In the abstract, networks are a set of interconnected arcs and nodes. A node is the point where two nodes intersect. Physical examples or networks include fishnets, spider webs, and geodesic domes. However, the concept of network has become more general with the rise of information technology. For example, the notion of a financial network now includes the communication backbone as well as the power and influence associated with financial transactions. Networks are open systems that are able to expand and integrate new nodes as long as communication can be established and maintained.

Global networks of capital, management, and information exemplify the New Economy. The impact of networks upon organizations, technology, and the general economy are essential to an understanding of the need for information-based manufacturing.

2.1 Networked Enterprise

At the end of the Industrial Age, declining multinational corporations faced the threat of global competition. Their response to this challenge was limited to refinement of the basic assumptions of mass production and related infrastructure rather adopting fundamental change. Examples of these refinements included adoption of automated production, flexible production, labor-management collaboration, and the outsourcing of nonessential work. Continuing cost pressures prompted them to use inter-firm networks, partnerships, and alliances to accomplish nonessential elements of production, standards development, and general research and development activities. The horizontal model emerged with decentralized operating units that could act autonomously, even to the point of competing against each other, albeit within a common or enterprise strategy. (Castells 1967)

The horizontal corporation model incorporates a dynamic and strategically planned network of self-programmed, self-directed units that operate upon basic principles of decentralization, participation, and coordination. It incorporates flexible means to enable the autonomous units to thrive but manages the interface of the units with the enterprise in real time. The networked enterprise model extends the previous networking relationship of the horizontal corporation model beyond suppliers to include arrangements with other producers, linkages to the customer, and agreements with standards bodies and R&D communities. For example, the electronic and automobile industries are organized around the five types of networks shown in Table 1. (Castells 1996)

Type	Definitions
Supplier	Subcontractor, original equipment manufacturer (OEM), and original design manufacturer (ODM) arrangements between client and supplier of intermediate production inputs.
Producer	Co-production arrangements that enable competing producers to pool their production capabilities, financial, and human resources in order to broaden their production portfolios and geographic coverage.
Customer	Forward linkages of manufacturing companies with distributors, marketing channels, value-added resellers and end users, either in the major export markets or in domestic markets.
Standards Coalitions	Agreements with the explicit purpose of locking-in as many firms as possible into their proprietary product of interface standards.
Research & Technology Development	Agreements that facilitate the acquisition of product design and production technology, enable joint production and process development, and permit generic scientific knowledge and R&D to be shared.

Table 1: Five types of networks in the electronic and automotive industries. (Castells 1996)

In the aeronautical industry, McDonald Douglas Aerospace has built a highly effective networked enterprise in conjunction with AeroTech Service Group in St. Louis. McDonald Douglas production processes require rapid consultation on product designs with hundreds of partners distributed across the world. However, network security issues blocked all but the simplest data exchange. AeroTech provides a ready solution. McDonald Douglas transmits the data to AeroTech, a secure third party who transmits it to the appropriate party, and avoids the cost of establishing secure communications with hundreds of partners. This relationship also facilitates electronic bidding, coordinates schedules, and provides the capability to operate software in remote locations from a central site. (Upton and McAfee 1996)

Multinational enterprises exist as nodes within complex global networks rather than retaining their previous identity as monolithic structures. They retain market dominance because entry into these strategic networks requires either considerable resources (financial, technological, market share) or an alliance with a major member of the network. They retain their national identity even though the networks they comprise transcended national boundaries, identities, and interests. By their very nature, they depend upon membership this a complex, changing structure of interlocked border-crossing networks to wield the power of wealth and technology in the global economy. (Castells 1996)

2.2 Information Technology

Both globalization and innovation in Information Technology motivated the adoption of the network business model as the fundamental organizational structure of the New Economy. The performance of network technology took a quantum leap in the early 1990's due to the convergence of three trends: (1) digitalization of the telecommunications network; (2) development of broadband transmission; and (3) increased performance of distributed computation that paralleled breakthroughs in microelectronics, operating systems, and programming languages. These innovations enabled the development of fully interactive, computer-based, flexible processes of management, production, and distribution that involved simultaneous cooperation among internal divisions as well as external firms. Information technology advisory service The GartnerGroup Inc. states that " … IT is now the global language of business…" (Pucciarelli, Claps, Morello, Magee 1999)

Cooperation and networking enable firms (and operating units within firms) to share the capital costs of industrial production and innovation flourishes through collaboration and sharing of resources. Outside the network, the cost to merely survive consumes the majority of resources, which stifles creativity and innovation. Industrial firms engaged in the transition to the informational economy depend upon the infrastructure and architecture of the informational society to enhance their products and processes. (Castells 1996)

Information Technology accelerates the rate of socioeconomic change via a feedback loop between the designer's intended uses of technology and the user's appropriation for other purposes. Take the Internet as an example. At its inception, its designers created it to convey valuable information among academics. However, non-academic users appropriated it and converted it into a communications media for the masses. This new role was incorporated into its structure through design changes and, later, through a change in definition with the advent of the World Wide Web and web browsers.

2.3 Economics

The joint development of technology and related infrastructure in the areas of communications and transportation created an integrated network environment that enabled producers to market, produce, sell, and deliver their products and services to progressively smaller market segments. British economist Geoff Mulgan describes the co-evolutionary development of transportation and communications networks this way, "Throughout the twentieth century physical mobility and communications grew in tandem rather than as substitutes. The spread of the telephone accompanied that of commuter railways and trams, the radio accompanied the spread of cars and airplanes, the television that of motorways and jets, and everywhere the graphs of traffic movement move in parallel with the graphs of communication usage." (Mulgan 1998)

The development of two complementary industrial revolutions helps explain this co-evolutionary development. The first revolution started in the last third of the eighteenth century, characterized by new technologies such as the steam engine, the spinning jenny, Cort's process in metallurgy, and, more broadly the replacement of hand-tools by machines. The second revolution, about 100 years later, featured the development of electricity, the internal combustion engine, science-based chemicals, efficient steel casting, and the beginning of communications technologies, with the diffusion of the telegraph and the invention of the telephone. These two industrial revolutions diffused throughout the world economic system and penetrated the whole social fabric. The results of these combined revolutions provided the necessary power to produce, distribute, and market goods and services that in turn freed humans for intellectual pursuits that amplified the revolutions. (Castells 1996, pages 34-35)

2.3.1 Economics of Information

Information Technology enabled human communication to progress dramatically over the last century. The trade-off between richness (bandwidth, customization, and interactivity) and reach (size of audience) produces a degree of hyper connectivity sustainable only by networks. (Evans and Wurster 1997) A networked organization forms when transaction costs are shared among partners. A hierarchy forms when transaction costs are minimized within a single organization. Thus, the value chain of a hierarchical organization may fragment (devolve) to gain competitive advantage as membership in a network becomes available. In hierarchies, capital intensive assets such as a mobile sales force, a system of dealers, a chain of stores, or a delivery fleet formed barriers to entry for competition. The Internet and digital distribution channels make these same organizational assets liabilities. For instance, banks conduct much of their business with ATM machines located away from their branch offices in shopping malls and grocery stores.

The advantages of business networks are numerous. As a member of a network of firms, a firm can: (van Alstyne 1997)

- Trade with other members for goods that it produces less efficiently
- Generate economies of scale through sales to a larger external market
- Create economies of scope through complementary products of other members
- Lower their fixed costs with highly efficient variable costs of network partners.

The flexibility of labor processes and labor markets induced by the network enterprise, and enabled by Information Technology, profoundly affects the social components of production that have been received from the industrial society. Information Technology allows work to be decentralized and coordinated in real time, whether it is between floors of the same building or between continents. (Castells 1996) At the personal level, people with more disposable income than time are contracting for personal services and creating new business opportunities outside of corporations. New franchised services emerge almost weekly. Mothers Matter (a maternal support service), Savory Cooking (visiting chefs that prepare a week of dinners for the freezer), and Tidy Lawn (a "pooper-scoopers" service) are representative examples. (Armour 1998) Francis Swain, the technology manager of Dorr Farms, envisions another new service business within the agriculture industry, “My dream is not to farm but to own the information company that farmers hook up to for information on logistics, crop data…" (Ferder 1998)

2.3.2 Economic Models

In the face of global competition, vertically integrated hierarchical organizations reorganized into a complex web of networks. New economic principles and models of competition occur as a natural consequence of these new structural forms.

Increasing Returns

The Industrial Age fostered an economy of diminishing returns and mass production. In this environment, products were perceived as “congealed resources with a little added knowledge”. Supply constraints, rising costs, and diminishing profits associated with a static state of equilibrium ultimately stifle return on investment. Increased volume played a significant role in cost control and empirical studies supported the existence of the learning curve, a sigmoid shaped function that equates declining costs and volume.

The Informational Age has fostered an economy of increasing returns and mass customization. (Arthur 1996) In this environment products are typically perceived as “congealed knowledge with few added resources”. Since information has become the product, a firm that has earned a dominant market share can easily continue to gain market share. The increasing return model and the logic of networks are closely linked:

· Development costs dominate production costs. Thus, unit production cost falls as sales volume increases (e.g., a pharmaceutical).

· Networks of users produce sales volumes that make a product the *de facto* industry standard (e.g., the Windows operating system).

· Extensive training, a prerequisite for productive use, raises the customer's switching costs. (e.g., single source provider of an airline fleet).

New Forms of Competition and Cooperation

Conventional economics assumes the existence of established, mature markets with fixed structure and people that act as if they were stimulus-response machines. Under these assumtions, sellers and buyers can optimize production and consumption. However, real world economic behavior is much more dynamic than this. Firms may compete directly for customers but still cooperate on industry-wide issues such as technical standards. This “co-opetition” sacrifices a degree of self-interest but gain by improving the total industry performance. The game-theoretic formulation of the networked economy has four types of members - supplier, customer, competitor or complementor (firms that cooperate to add value). Firms assume one of these four role dynamically depending upon their willingness-to-pay for products and services: (Brandenburger and Nalebuff 1996)

· Complementors (competitors) *with respect to a common customer* if the willingness-to-pay for buying from both is larger (smaller) than the willingness-to-pay for buying from A alone plus the willingness-to-pay for buying from B alone.

· Complementors (competitors) *with respect to a common supplier* if the opportunity cost of supplying both is larger (smaller) than the opportunity cost of supplying A alone plus the willingness-to-pay for supplying B alone.

3.0 Customer-dominated Markets

Business networks undergo a continual redefinition of organizational goals, purposes, and processes driven by market intelligence of the needs and preferences of individual customers. Mass customization, providing customers with specialized products at an acceptable cost, is a key strategy for addressing the rising power of the customer. Through product tailoring and differentiation, Mass Customization for niche markets enables firms to limit direct competition and charge full price to the consumer. Niche marketing reduces the secondary markets potential for products. Cooperation via the network model enables firms to obtain economies of scope by bundling complementary products. (van Alstyne 1997)

The rise of mass customization makes it imperative to link rate of production and rate of demand to ensure a rapid, economical response to changing market needs. To achieve efficiency across the enterprise, manufacturers have become agile to reduce inventory volume while remaining responsive to customer needs. These strategies have been instituted in the areas of inbound logistics, production, and outbound logistics. Each of these responses incorporates one or more elements of information-based manufacturing.

3.1 Mass Customization

Mass production developed in the United States for the manufacture of pocket watches in the early 19th century and for firearms in the mid-19th century. This experience laid the groundwork for the automobile assembly line at the beginning of the 20th century. The remark attributed to Henry Ford; "You can choose any color of car you want, so long as it is black" typifies the producer-centric mentality of mass production of the car as a utilitarian product. By the early 1920's economies of scale made it possible for General Motors to adopt a new business model centered on the automobile not as a utility but as a social statement and expression of personal identity. This transition was an early triumph of market segmentation and precise product positioning over mass production and the advantages of incumbency. This approach, as subsequently adopted by other corporations, retained the producer-centric perspective by creating apparent customer choice in relatively unimportant items; the real choices made by the producer were obscured and made to appear relatively insignificant. (Dickson 1974) By the 1980's, an increasingly competitive and over crowded marketplace forced firms to begin to respond to customer needs and desires. Some firms adopted a strategy of product proliferation with frequent new product introductions and line extensions intended to attract and retain customers. Consultant Joe Pine articulates the customer demand for mass customization when he says, "…customers do not want a choice; they just want what they want." (Pine 1992). Pine adds, "Anything you can digitize, you can customize, because once it is embedded in a computer system you can customize it." (Pine 1998)

3.1.1 Know the Customer

Successful mass customization requires an appropriate product design motivated by a deep and profound understanding of suppliers, internal operations, and customers. MIT design expert Eric von Hipple explains that, "The economies of mass customized production are achievable if and as a custom design falls within the preexisting capability and degrees of freedom built into a given" solution space of the configurable product. (von Hipple 1998) A continuum of customization can be established from pure standardization (or mass production) to pure customization (or craft production) in design, fabrication, assembly, and distribution. Most firms that embrace mass customization today operate near the middle of this continuum in the "customized standardization" mode that incorporates standardized design and fabrication with customized assembly and distribution. (Lampel and Mintzberg 1996)

Traditional market segmentation takes a one-size-fits-all approach product view by averaging costs and profits within and across the various groups. This producer-centric approach ignores the relative value that the customer places on service offerings. On the other hand, segmenting customers by their service needs enables a firm to develop a portfolio of products and services tailored to various segments. By focusing upon solutions driven by customer value, firms can realize price advantage for their goods and services without incurring added cost. In the New

Economy, bundling products with flexible service offerings has become the preferred way to tailor products.

3.1.2 Modular Design

Although mass customization strategies vary across industry, product, and customer, they all require an appropriate product design. To obtain the requisite economy of scope, firms have adopted the use of modular design to fulfill customer preferences with a vital few changeable features while maintaining many more standard features. Designers achieve the required degree of modularity by partitioning information into a set of design rules that define the common platform and the interchangeable modules. Modularity is beneficial only if this partition into platform and modules is precise, unambiguous, and complete. (Baldwin and Clark 1997)

Modular products are difficult to design. Engineering details that may appear to be of little consequence may assume a consequential role in a modular design. For instance, a flange needed to mount modular components on an engine might be eliminated to reduce weight and cost if its function in modular design were not considered early in the design process. Without a fully integrated program of project management, time saved in parallel development of independent modules may be lost during the final system integration. However when properly executed, families of products derived from a single platform of common product structures, technologies, and production processes economically fill the needs of multiple market segments. Successful companies recognize and respond to market opportunities quickly with these derivative products rather than new product designs. This strategy has special appeal in global markets. (Meyer and Lehnerd 1997)

3.2 Zero Latency

A typical supply-chain pipeline contains many opportunities to reduce product throughput time, lead-time, and stock-outs. Zero-latency strategies reduce these delays or eliminate non-value-added activities. These strategies take advantage of IT to obtain instant awareness and appropriate response to trigger events occurring at bottlenecks anywhere across an entire enterprise. Traditional online transaction processing applications provide an element of zero-latency in the sense that application updates are immediately visible to end users of that application. However, the ability to instantaneously link disparate, geographically dispersed application systems distinguishes a zero-latency enterprise from zero-latency applications. (Enslow and Schulte 1998)

For zero latency strategies to be effective, data flow, planning cycles, and rate of production must be synchronized. Accelerating information flow can be a competitive weapon only if firms also have the appropriate business policies, processes, and product offerings in place. Planning and execution cycles must be tightly linked by an event driven system that is capable of real time execution in order to support a zero latency strategy.

3.2.1 Inbound Logistics

No single zero-latency inbound logistics strategy exists for all firms. Functional products require efficiency obtained by predictable delivery volumes and continual improvement as the key to cost control. Fashion or technology products require responsiveness to guarantee availability and rapid response to changes in demand levels as the key to price realization. (Fisher 1997) Beyond this division, firms must design their own network of producers and suppliers to support their own strategic needs. Perhaps information, used to enhance coordination and reduce uncertainty, could substitute for inventory. (Strader, Lin, and Shaw 1998)

For instance, cross-dock strategies change with the addition of information. Opportunistic cross docking uses visible orders in the work queue to switch shipments between carriers.

Planned cross docking uses real-time visibility to current inbound/outbound events to deliver specific loads to a planned shipping or staging location for consolidation with other loads.

3.2.2 Production

Demand Flow Technology® (DFT) is rapidly emerging as a useful zero-latency strategy in discrete manufacturing. It replaces the producer-centric principles of mass production with a process-oriented customer focus. Based upon Toyota production methods such as Just-in-Time and kanban, DFT enables the efficient execution of a sequence of assembly tasks that are dictated by a flat bill of material with production paced by actual demand. The typical flow line consists of a single assembly line supported by one or more linked synchronous feeder lines, and a number of adjacent asynchronous machine cells. (Costanza 1994) Like all pull processes, the depletion of finished goods inventory triggers production in a flexible and reactive way along the entire production cycle. Economies obtain as inventory remains in its most flexible and economical state, as raw material, when rates of production and demand are synchronized. DFT requires purposeful assembly line design to ensure economical operation and nearly perfect quality levels for smooth operation. As material flows from one workstation to the next, built-in quality procedures prescribe quality checks of the work performed during the prior operation. This direct linkage reduces the number of defects that can build up in the system and provides instant feedback to the problem operation should a defect occur.

3.2.3 Outbound Logistics

Zero-latency outbound logistics strategies depend upon the visibility to orders and shipments rather than the parameters and constants of legacy systems such as wholesaler lead-time, echelon level inventory control policies, and retail order patterns. In-transit visibility enables third-party logistics companies to merge in-transit orders for configure-to-order manufacturers. Distributors consolidate demand forecast for a group of customers and delay final allocation of the goods pending their arrival at a regional cross-docking facility. In-transit visibility and knowledge of a product bill-of-material also facilitate light assembly and packaging within the warehouse to enable firms to meet demand while minimizing the number of stock keeping units and total inventory on hand. Final assembly of configure-to-order components can also be accomplished in warehouses. However, visibility alone is not a panacea. In a capacitated supply chain single, assuming that the retailer operates with a (s,S) replenishment policy, the sharing of demand information has the most benefit when both the difference (S-s) and the demand variance are moderate and, in addition, the supplier has moderate to high capacity. (Gavirneni, Kapuscinski and Tayur 1999)

4.0 A Company in Transition

Founded in the agrarian age, Deere & Company is the only agricultural machine manufacturer to remain intact during industry consolidation. Now it faces an equally challenging transition from the industrial age to the informational age as indicated by this analysis in an industry magazine, "Deere & Co. takes a practical approach to technology, both in the field and in the enterprise. Whether it's designing tractors with global positioning technology to help farmers determine their position while working acres of crops or finding new ways for its employees to collaborate regardless of geographic location, Deere equips customers and users with the technology they need to do their jobs." (Hicks 1999) In response to globalism, Deere & Company has initiated steps to become a process centered organization that will present a common face to the customer across geographic and product lines.

To accommodate customer-dominated markets, Deere & Company has embraced the concept of zero latency enterprise by focusing upon obtaining efficiencies and economies in four processes - customer acquisition, order fulfillment, product delivery, and product support. Their approach to product design, originally intended to facilitate a configure-to-order strategy, has been adapted to support a build-to-order strategy for Mass Customization. Manufacturing strategies such as a genetic algorithm based assembly line sequencing system enables them to meet customer expectations for product variety, availability, and quality. This system has also been expanded into an order management system. An innovative hub logistics strategy supports the move to flow manufacturing.

4.1 Order Management Systems

Efficient sequencing of orders can mean the difference between meeting and missing a planter order delivery date. An efficient assembly sequence balances production performance with metrics of productivity, efficiency, quality, and cycle time while controlling cost. Non-manufacturing constraints such as customer service policies, market-planning goals, order fill priorities, product distribution, and other business strategies may also be included. The assembly line sequence is generated daily by commercial software that incorporates a proprietary genetic algorithm for automatic sequencing of customer orders and an intelligent graphical user interface for manual sequencing and sequence repair. An efficient constraint computation engine enables the software to compute a fitness value for each sequence evaluated in the search. (Fulkerson 1997)

As delivery increasingly becomes a component of product, production strategies require integration between their sales force and their logistics planning systems to enable sellers to commit to accurate delivery dates at the moment of sale. (DeSisto and Enslow 1998) Capable-To-Promise (CTP) order management systems check each order against the entire set of constraints to determine the factory's capacity, expressed in terms of machines, material, labor, and logistics, to commit to deliver the order by a requested delivery date. With a CTP system, a seller (or buyer) can check an order for configuration accuracy, query the factory for a desired or best-available delivery date, and then reserve a position in the actual production schedule. All of these steps occur within seconds. The constraints used for assembly line sequencing pertain to order management systems as well. In a capacity constrained factory, customer preference, product profitability, or inventory costs may be used to prioritize orders. In a factory with unconstrained capacity, orders may be moved ahead to use uncommitted resources and to free future resources.

4.2 Logistics

Deere & Company utilizes a spoke and hub strategy for physical distribution of service parts, attachments, and wholegoods. (Brinkley 1991) This strategy controls freight costs across the enterprise by use of dedicated carriers and a network of depots, factories, and suppliers. A single facility designated as the hub, which is owned and operated by a third party logistics provider, furnishes efficient, economical, and timely distribution of goods that can not be shipped directly to dealers by the producer.

Each night, at least one truck leaves from a node bound for the hub. A node may be a depot, factory, service parts center, or distribution center. Factories that ship directly to dealers on an order prioritization basis use zero latency strategies including cross-docking and load consolidation. Major suppliers of raw materials and components have adopted these zero latency strategies as well. The hub receives, unloads, sorts, and stores inventory in designated locations according to dealer pool codes and outbound shipping destination. According to a weekly schedule, the hub builds and ships outbound loads to dealers by pool code and ship day. Critical inventory is picked and shipped in less than full loads (LTL) when required. Depot stock orders are shipped direct to the dealer. Service parts may be shipped direct to the dealer or to a regional carrier break terminal where the truck is unloaded, the shipment deconsolidated, and the shipment made to dealers via third party shippers.

5.0 Summary

The transformation from an industrial economy to an informational economy began in the 1970's. The combination of rapid advances in digital technology and globalism gave rise to a new organizational structure, the networked enterprise. Its structure, a complex web of enterprises, embedded into a multiplicity of institutional/cultural environments forms the global economy. (Castells 1996) A similar shift from the supplier to the customer began at approximately the same time as, " Highly competitive markets and abundant information have placed the customer at the center of the business universe." (Slywotzky and Morrison 1997)

Elements of the industrial and informational economies exist simultaneously in a complex relationship. Many forms of commercial activity previously performed in the industrial society remain essentially unchanged except for an additional information component. In the informational economy people devote more of their skills to processing symbols than to processing materials. Their operating rules and system logic agree sufficiently to allow industrial companies to continue to operate but new Informational related rules pertain for them as well. (Castells 1996)

The transition from an agrarian society to an industrial society exhibited many of the same tensions. Two hundred years ago fully 90 percent of Americans were engaged in agriculture while today only 3 percent are similarly engaged. Agriculture didn't disappear, it became industrialized which increased productivity, and in turn produced societal changes that caused the shift from agricultural to industrial employment. In a similar manner, manufacturing has not disappeared but is becoming "informationalized". (Blitz 1999) The combination of Informationalism and globalism complicates this current transition. New York Times columnist Thomas Friedman explains, "… globalization involves the inexorable integration of markets, nation-states, and technologies to a degree never witnessed before--in a way that is enabling individuals, corporations, and nation-states to reach around the world farther, faster, deeper, and cheaper than ever before, and in a way that is also producing a powerful backlash from those brutalized or left behind by this new system." He goes on to link globalization and technology by saying, "Globalization has its own defining technologies: computerization, miniaturization, digitization, satellite communications, fiber optics, and the Internet. And these technologies helped to create the defining perspective of globalization." (Friedman 1999)

Information-based manufacturing originated from early accounting systems and electronic data interchange (EDI) designed to link internal and external processes and partners by transactions much like digital paper. However, the networked enterprise with its web imbedded within a web structure requires true collaboration over distributed locations rather than a simple exchange of transitions. This form of collaboration requires a virtual factory environment that possesses a high degree of functionality, ability to deal with all levels of IT sophistication, and a system relationship that is easy to enter and leave. Many companies have perfected elements of the virtual factory but few companies have exhibited the fully function environment required. (Upton and McAfee 1996) This is the hope and challenge of information-based manufacturing.

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