Chapter 6

THE INTERNET

AND THE PRODUCTION NETWORK OF DELL COMPUTER

"We are not experts in the technology we buy. We are experts in the technology of logistics and supply chain integration."

Richard L. Hunter, Dell Computer

"The Internet offered a logical extension of our direct model,...we used Internet browsers to essentially give the same information to our customers and suppliers -- bringing them literally inside our business. This became the key to what I call a virtually integrated organization..."
Michael Dell

From Custom Direct to Internet Direct

On the walls of a stairwell near the entry to the Dell Computer Corporation, Morton Tofper Manufacturing Center in Austin, formerly known as Parmer North 2, hang two large arrangements of picture frames, aligned row upon row, each frame encasing a patent awarded to the world's largest PC firm. Embedded in this display is a story with an unmistakable aim. Represented in each frame is an idea. On the basis of merit -- and a property right conferred by government -- each of these ideas has ascended to a privileged status reserved for the phenomenon known as *innovation.* The "wall of patents" as it is referred to by Dell, is a metaphor intended to convey Dell's story as an innovative firm.

Dell Computer has emerged as one of the most innovative firms of the current period on the basis of a business model with three elegantly simple, but ultimately powerful concepts. One concept revolves around the practice of selling *direct,* absent intermediaries, from the manufacturer to a final customer. The second idea involves the notion of *customization* for the specific needs of end users, and building customized products in high volume. The final concept centers on Dell's response to the Internet revolution and its use of the Internet in reorganizing not only its system of direct sales but, more significantly the procurement and assembly operations underlying mass customization. By grafting its system of custom direct sales onto the Internet infrastructure, Dell has transformed these activities, creating what is arguably the most innovative and efficient procurement, production, and distribution network ever built.[1]

The innovative advance made by Dell in deploying Internet communication as the foundation of its production network, is a *process* innovation. Although to some extent, the Internet has enabled Dell to create a new product -- a PC custom-configured through Internet communication -- it is the process of organizing flows of materials and information within its network, from customer order to procurement, production and delivery, by means of Internet communication, that defines the innovation at the Firm. As Richard Hunter, director of manufacturing and supply chain management at Dell, insists: "We are not experts in the technology we buy. We are experts in the technology of supply chain integration. We have created this expertise with the Internet at its core " (Hunter, Interview 7/18/01).[2]

Although it manufactures computers, Dell accumulates profit as a logistics firm. It is an organization of knowledge and routines extracting surplus not from production, but by managing the movement of product and information flows along a globally-dispersed network of companies engaged in the various operations of producing and marketing finished PCs. In this role as a logistics company, Dell's most revered accomplishment consists in the degree to which it is able to balance supply and demand of product flows among the firms in this global commodity chain. "Supply and demand balancing," insists Hunter, "is one of the most important core competencies at Dell" (Hunter, 5/24/01). The key to this core competency in material balancing, however, lies in Dell's capacity to process Internet information flows that the PC maker uses to manage the "external capabilities" of other firms. This mastery over material balance flows and Internet information flows has enabled Dell to create a production network, differentiated from the networks of its competitors by the degree to which it has

[1] There is a vast literature supporting this claim. From a journalistic perspective see Rocks (2000); Perman (2000), McWilliams (1997), Dodge (1998), and *Business Week* (August 28, 2000: 90). From the supply chain literature see especially Lee (2000), and from a scholarly perspective see Kenney and Curry (1999; 2000a; 2000b), Kraemer et al. (1999), and Kraemer and Dedrick, (2001).

[2] It should be emphasized that others in the industry are far more caustic in making this same point. "Dell doesn't make computers," says Scott McNealy, CEO of Sun Microsystems. "They're not in the PC business any more than Safeway is in the food manufacturing business" (quoted in *Business Week*, September 24, 2001). In this sense, Dell fits a paradigm described as "The Computerless Computer Company," taking advantage of the technical capabilities of other firms (Rapport and Halevi, 1991).

succeeded in accomplishing a singular aim: accelerating speed and compressing time in the movement of materials as they pass through the adjacent steps of customer order, procurement, production, and final product delivery (Kenney and Curry, 1999).

The most visible benchmark of this core competency in material balancing focuses on levels of inventory maintained by Dell and its network partners. In 1994 when Dell launched its Internet strategy, the Firm carried an average of 32 days supply of inventory in its procurement and production chain. By 1997, as Dell began to deploy the Internet more fully in its supply chain operations, the figure had shrunk to thirteen days. In mid-2002, Dell was carrying four days inventory while at the same time, Compaq, the firm Dell surpassed in becoming the world's largest PC maker, held six weeks of inventory (Cook, Interview of May 17, 2002; Business Week, June 17, 2002).

In order to achieve this level of balance in demand and supply conditions, Dell has had to complement its Internet-based logistics activity with a different type of organizational relationship between itself and the other firms in its network. While this form of organization shares the *dis*-integrated, interfirm structure of the production networks organized by other PC makers, it differs in the degree to which the operations of Dell, and its relatively-small number of partner firms are *functionally* integrated by means of Internet communications. Dell refers to the structure of its network deriving from these collaborative relationships between formally separate firms as *virtual* integration.

Although nominally separate, Dell and the firms comprising its virtually-integrated network, do not produce finished PCs on the basis of arms-length interactions mediated through markets and the price system. On the contrary, Dell organizes highly structured relationships of collaboration between itself and its networks partners on the basis of its power to manage and control these other firms. The PC maker deploys an organizing principle in the way it structures these interfirm relationships, described by Coase as "conscious power or *planning*" (Coase, 1937), by Williamson as the principle of *Hierarchies* (Williamson, 1975), and by Chandler as *The Visible Hand* (1977). Far from a revolution in production that is reverting to market coordination within interfirm networks, the experience of Dell reveals how the hierarchical, conscious power of the Visible Hand is not only compatible with interfirm networks. Such mechanisms of control, typically, associated with vertical integration, are in fact integral to Dell in securing the collaboration from its network partners necessary to organize its high-velocity supply, production, and distribution chain, and build custom-configured PCs in high volume on a just-in-time basis.[3]

The Internet plays a vital technical role in reinforcing Dell's capacity to control these collaborative relationships between itself and its network partners.[4] The Internet has provided Dell with a technology to create its own Web-based communications protocols as the foundation for collaboration with suppliers and logistics partners. Based upon the balance of power between Dell and these firms, the latter have little choice but to accept these Web-based protocols and integrate their operations around them if they want to remain within the PC maker's network. Dell, in effect, has successfully exploited the Internet infrastructure to impose a technology-based system of collaboration on suppliers and logistics providers as terms for entry into its network. In this way, Internet technology has enabled Dell to secure the benefits of organizational control associated with actual integration without its costs.

Dell's production network, with its operational attributes of time compression in material balancing, and its organizational attributes of virtual integration, is also creating a distinct geographical pattern of economic activity. This pattern is marked by the interplay of two spatial tendencies operating simultaneously within its network, the tendencies of spread, and concentration. On the one hand, Dell's production network is a geographically extended collection of nodes. Long distances separate the different regions where Dell has located its build-to-order operations. Long distances also separate Dell's build-to-order operations from the locations of its key suppliers. This tendency of geographical spread is marked by the coordination of geographically-extended, long-distance flows of product and information connecting dispersed nodal points in Dell's network. On the other hand, however, Dell's network operates on the basis of critical relationships of spatial proximity between certain nodes. Dell itself is the agent in creating these relationships, most notably in its requirements on suppliers to maintain either factories, or supply "hubs" within twenty minutes driving distance of Dell assembly sites. In this way,

[3] This chapter takes issue with views of interfirm production networks as examples of ascendant market forces. Dell -- and many other firms with highly efficient supply chains -- suggests the opposite.

[4] I am indebted to Navi Radjou of Forrester Research for emphasizing this point to me in a personal communication.

Dell is not only influencing the location patterns of firms in the regional localities where it operates. Dell is providing a compelling picture of how its Internet-based, build-to-order innovation is concentrating and shaping the geography of economic activity within regions, while defining processes of economic globalization as they actually occur on the ground.

This Internet-driven, virtually-integrated, and globally-organized production network has enabled Dell to become the world's largest, and arguably most competitive, PC maker. Perhaps more importantly, virtually every major PC firm has attempted to imitate elements of Dell's Internet-based business system. As Robert Cihra, computer analyst for ING Barings prophetically affirmed just prior to the announced merger of Hewlett Packard and Compaq, "the Number one issue on the mind of virtually every major PC vendor is defense against Dell, and for Compaq, IBM and HP, 'Dell' has truly become a four letter word" (Cihra, personal communication 8/20/01). How Dell ascended to this position is the subject of this chapter.

This chapter profiles the key operational, organizational, and geographical elements of Dell's Internet-based procurement, production, and distribution network.[5] In organizing this profile, this chapter focuses on a recent supply chain integration project implemented at Dell known as *DSi2*. This project, while touted by Dell as "the single biggest change in the Dell business system" (Hunter, Interview 6/5/01), is actually the culmination of an ongoing process of experimentation with the Internet that began in the mid-1990s and is still continuing (Dell Interview of 8/24/01).

The chapter is organized historically. Within this historical organization, however, are several key themes that tell a contemporary story of evolutionary economic change, and trace the route from the Internet revolution, to innovation and territorial transformation. How the structure of the PC industry came into being; how Dell's early business model challenged the competitive foundations of the industry; how Dell used the Internet to transform its original business model and create a uniquely-innovative production and distribution network; how, in assuming a position of competitive superiority and diffusing

[5] It should be noted that these elements are constantly in flux. In language strikingly similar to the innovation literature, one Dell engineer walking me through the factory floor of the Topfer Manufacturing Center in Austin, insisted that the Company is in involved in an "ongoing learning process" in an effort to improve its pull material to order business system. As a consequence, some of the process details described in the chapter may have changed slightly. The emphasis in this chapter is the thematic meaning of these elements.

among other firms, this network has changed the PC industry; and how the operational, organizational, and geographical characteristics of this network are redefining the structures of the global economy, are the contours of the Dell story that follows.

Competition and the PC Value Chain Before Dell

When Dell Computer began operations in 1984, the PC industry, though still very young, had already developed an industrial structure with clearly defined terms of entry and competition, and a dominant system of value creation and profit making. It was these attributes that would provide Dell with opportunities for innovation on the basis of a very different vision of how to compete and make profit. In order to grasp both the initial phase of innovation at Dell when the PC maker developed its custom direct business model, and the second phase of innovation when the firm adapted this business model to the Internet, it is essential to identify the salient attributes of the industry as it evolved since the commercialization of the personal computer.

IBM and the PC

The development of the personal computer as a product with a mass market and an industry based on volume production, begins when IBM introduced its PC in August, 1981 (Dedrick and Kraemer, 1998: 50). Although IBM was far from the first firm to produce personal computers, its presence in the PC market changed the industry. Moreover its entry defined the fundamental pathway of competition for other firms. In the process, as it came to dominate the industry, IBM also created the environment for eventual transformation of PC production and selling.

IBM's decision to produce personal computers came in the wake of a changing market environment. By 1980, demand for PCs had outstripped supply. The catalyst for this imbalance was business demand. As more and more businesses began to use PCs, IBM recognized that it was failing to capitalize on a lucrative market opportunity with sales already approaching $500 million (Dedrick and Kraemer, 1998: 51). Equally significant, IBM had concerns that increased business use of PCs would threaten its position as a supplier of larger computers to its corporate customers. The Company aimed to defend its mainframe business by convincing its corporate customers that the PC was an integral part of the total computing infrastructure while expanding its PC market with other business and non-business users.

In July of 1980, when IBM made the decision to enter the PC business, the world's largest computer firm committed to bringing a product to the market within one year. The strategy pursued by IBM to achieve this aim -- a strategy of outsourcing and marketing its product through existing independent retail channels -- was decisive in shaping the development of a production and selling system for the PC that would dominate the way the PC was built and marketed for the next two decades. While this production and selling system proved enormously successful for IBM, and while it emerged as the competitive standard for other firms, the IBM system embodied inefficiencies that Dell would exploit in entering the industry, and challenging the production and marketing standards on which the industry was based.

When IBM decided in July of 1980 to get into the PC market, the manager assigned to lead the program, William Lowe, provided a sobering assessment of what had to be done: "The only way to get into the PC business," explained Lowe, "was to go out and buy part of a computer company or buy both the CPU and software...because we can't do this within the culture of IBM" (quoted in Langlois, 1992: 21). Consequently, IBM gave Lowe autonomy to build the product independently as a start-up firm with IBM acting as a venture capitalist.

With a 12-month deadline to bring a PC to market, the start-up had a mandate to outsource technology and components from existing firms when necessary, enabling it to avoid IBM's traditional business model of using its own internally-developed technology. When IBM departments voiced opposition to this approach, Philip Estridge, who had succeeded Lowe as project manager, told them to submit bids for components much like independent firms. Although some internal sourcing occurred in this open bidding system namely for keyboards and circuit boards, the main sources of supply were firms outside of IBM. Disc drives were provided by Tandon; Zenith furnished power supplies; Epson from Japan made printers; SCI Systems, a contract manufacturer based in Alabama, stuffed the circuit boards;

and China Picture Tube, part of the Taiwanese electronics firm, Tatung, made the monitors. The computer was assembled in Boca Raton, Florida from these components.

For its distribution strategy, IBM decided to market its PC primarily through retail computer outlets rather than through its own sales agents. It even solicited input from the largest dealer, ComputerLand, on how best to accomplish this aim and established a set of criteria for any dealer that wanted to sell the IBM PC. Dealers were required to attend a training program at IBM and agree to a minimum sales quota. The firm was able to impose these standards on dealers because demand was so strong that an excess number of retail outlets wanted to become IBM dealers. In pursuing this marketing strategy through independent retailers rather than relying on its own sales organization, IBM essentially elevated the role of distribution in the overall value chain for the PC.

On both the production side and distribution side, the IBM PC was a striking example of reliance on "external capabilities" to build a product and bring it to market (Langlois, 1992).

This reliance on outside firms resulted from two decisions made by IBM regarding the microprocessor and the operating system software that had an enormous impact on the development of the industry.[6] In shopping for a microprocessor, IBM decided to use a 16-bit processor from Intel, the 8088, rather than the 8-bit processors used in existing PCs. Although this processor did use 8-bit external buses for which there existed a complement of support chips, the decision meant that the IBM PC could not use existing operating systems linked to 8-bit processors. Consistent with its strategy to use the market for necessary technology, IBM turned to the small Seattle-based software company active in the earlier phase of the PC industry, Microsoft, for the operating system. Microsoft, in turn, purchased a system from another local software supplier, made some small modifications to it, and sold it to IBM. The product was known as PC-DOS. In a decision with extraordinary implications, IBM allowed Microsoft to license the operating system to other PC makers as MS-DOS without having to share royalties. In purchasing the microprocessor from Intel, and allowing Microsoft to license the operating system, IBM effectively ceded control of the two most critical elements of the PC architecture. The IBM

[6] The following two paragraphs rely on Dedrick and Kraemer (1998: 51-53) and Langlois (1992).

PC had essentially evolved on the basis of an *open* and largely *modular* architecture, and a global sourcing system for that architecture.[7]

Despite the fact that IBM had lost control over the architecture of its PC, and despite the fact that there was very little technological advance in the product, the IBM personal computer was hugely successful. Demand for the PC exceeded its own sales forecasts by 500 percent as the 13,533 units shipped during the final months of 1981 were far short of supplying the large backlog of orders (Langlois, 1992: 23). By 1983, the firm had captured 26% of the PC market with roughly 750,000 units shipped. From a position as a relatively late entrant, IBM catapulted to a position just behind Commodore as the world's second largest PC maker.

Table VI-1
The Early PC Market in the U.S.

Year	Units Sold	$ Value (millions)
1976	17,450	$36.0
1977	41,000	$74.5
1978	120,700	$223.8
1979	181,200	$302.5
1980	246,000	$495.0
1981	380,000	$936.9
1982	792,400	$2,002.3
1983	1,764,000	$4,718.0

Source: Steffens, 1994: 90-126, 167.

[7] There is an extensive literature on IBM's decision to create an open architecture and the role of Intel and Microsoft in the evolution of the PC. Among the more informative, see Chposky and Leonis (1988) and Ferguson and Morris (1994), as well as Dedrick and Kraemer (1998) and Steffens (1994).

Large Firms, Suppliers and Clones

Three critical developments followed from IBM's success that affected the competitive structure and the development trajectory of the PC industry.

Firstly, IBM's entry compelled other large companies from the office products and consumer electronics industries to enter the PC marketplace. These entrants included such firms as Xerox, Hewlett Packard, Texas Instruments, Zenith, DEC, and Wang Laboratories. This group also consisted of numerous foreign firms, among them NEC, Sanyo, Hitachi, Toshiba, and Fujitsu from Japan, and Philips and Olivetti from Europe. Nevertheless, these firms exhibited widely varying levels of success. NEC, HP, Toshiba, Fujitsu, and Olivetti were able to gain between four and nine percent of the U.S. market for differently priced PCs (Steffens, 1994: 177). Other firms, most notably Xerox were surprising failures in the PC market. Despite the qualified success of some of these large firms, however, by the beginning of 1984, IBM, Apple, and Tandy still dominated the PC market in the U.S.

Secondly, the growing demand for the product, coupled with the PC's nonproprietary and modular architecture, created an enormous market opportunity for suppliers of components, peripherals, and parts. An entire industry of specialized suppliers emerged to exploit these opportunities linked to the fortunes of the IBM PC. Firms most notably in Taiwan, but also in Singapore and South Korea, entered this market and became skilled producers of these components.[8] In addition, IBM, in launching its PC on the basis of high volume production, provided many of these component vendors with opportunities to scale their operations from the outset. As a consequence, these firms were able to develop production efficiencies and cost advantages very early after entry into the industry. "IBM put its suppliers into the high-volume business," and in the process "so bore their start-up and learning costs" (Ferguson and Morris, 1994: 52). This pattern was especially true of East Asian suppliers such as Taiwan's Tatung which IBM helped to achieve the volumes necessary to supply the PC maker's expanding market

[8] Taiwanese firms tended to be smaller start-ups. By 1979 these companies in Taiwan were already fabricating components for central processing units (CPUs) and had successfully produced Apple II clones by 1981 (Bae, 1998: 148). Firms in Singapore and Korea by contrast tended to be larger firms. The industry in Singapore grew as a result of investment by American electronics producers while the Korean industry emerged within the large Korean *Chaebol* which had benefitted from the transfer of technology from earlier investment by Japanese electronics producers (Callon, 1995; Bae, 1998).

(Dedrick and Kraemer, 1998: 52). By the mid-1980s, Singapore and South Korea, along with Taiwan had emerged as major world centers of production for the industry. Firms in the region were both Asian firms and the foreign operations of U.S. based companies.

Table VI-2

Computer Hardware Production in E. Asia
($ millions)

	Taiwan	Singapore	S. Korea
1980	$80	--	$9
1981	$110	--	$31
1982	$170	$147	$47
1983	$430	$530	$207
1984	$1.040	$1,066	$428
1985	$1,260	$1,194	$579
1986	$1,739	$1,914	$880
1987	$2,890	$2,928	$1,459
1988	$4,001	$4,503	$2,431
1989	$5,046	$5,368	$3,180
1990	$5,886	$6,974	$3,073

Source: Dedrick and Kraemer, 1998: 321; Bae, 1998: 79, 148.
Singapore Economic Development Board.

Finally, and perhaps even most significantly, demand for the PC which IBM was not able to supply until eighteen months after it introduced the product, created an enormous market opportunity for other producers to clone IBM's machine. The expanding supply base along with the open architecture of the PC, provided these clonemakers with possibilities to copy the PC. Nevertheless, one hurdle remained before clonemakers could produce a PC. IBM's input/output system software known as BIOS, which enabled the PC to transmit and receive data, somehow had to be duplicated. This problem, however, proved far from insurmountable. Firms such as Compaq, among others, successfully reverse-engineered the BIOS specs in a way that insulated them from copyright and patent infringement regulations. Because of the market in components that had developed from IBM's reliance on external capabilities, all that the clonemakers needed to duplicate the PC was to buy the 8088 microprocessors from Intel, the MS-DOS from Microsoft, and the remaining hardware components from the expanding base of supplier firms. Furthermore, the interests of clonemakers actually converged with those of Intel and Microsoft whose fortunes were dependent more on an expansion in the number of PCs than any one-way relationship with IBM. By 1983, Compaq was the largest among nearly one hundred clonemakers that emerged in the wake of the IBM PC's success. Two years later this upstart was fifth largest firm in the PC industry and ascending rapidly. Hundreds of other companies would soon follow supported by a base of specialized suppliers numbering in the thousands (Dedrick and Kraemer, 1998: 56).

Open Standards and Modularity

IBM's decision to outsource most components of the PC, and relinquish control over the microprocessor and operating system, created a product architecture based on relatively open standards that had three enduring impacts on the nature of competition in the industry. In the first place, open standards for PC components enabled the PC to become an increasingly modular product. Secondly, in what is perhaps a paradox, this attribute of modularity -- the ability of PCs to be assembled from standardized components "much like Legos" -- provided the foundations for PCs to be custom-produced in high volume (Langlois, 2001: 26).[9] Thirdly, and perhaps most decisively, modularity and standardization diminished the role of technology as an element of competition in the PC industry, and elevated the role of efficiency in procurement, production and distribution of the product. Modularity, in effect, was the critical precondition of Dell Computer's business model.

The modular character of the PC diverged dramatically from the era of central computing. During the period of central computing, mainframes and minicomputers produced by firms such as IBM

[9] Langlois points out, however, that customization achieved through modularity and standardization did not originate with PCs or the Internet economy. The idea of offering slightly differentiated product models based on a set of underlying mass produced components was already recognized as a business model by Alfred Marshall (1920: 141).

or DEC had been proprietary “closed systems.” The architectures of these systems were largely incompatible with those produced by other vendors. As a result, firms producing mainframes and minicomputers tended to be highly integrated. Because these systems were closed and proprietary, firms building them had to produce components in-house, and scale the production of these components sufficiently to achieve cost-efficient, internal scale economies. Nevertheless, this integration did not include *all* computer components. Mainframe and minicomputer firms integrated vertically with respect to components of high value to reduce their risk, and increase their control over production of computer systems.

The openness of the IBM PC, by contrast, meant that standards for interoperability between different components were defined by firms more or less publicly and collectively. Such agreement by firms on standards is basically “unsponsored,” arising *de facto* in a competitive environment and is distinct from standards agreements that are negotiated and implemented by statute or political authority (David, 1987; David and Greenstein, 1990). As a result of this market-driven process of agreement, third-party vendors could design and build components on the basis of publicly-defined standards that would operate together as a system. This openness enabled different hardware and software firms to produce compatible and interchangeable components that could be integrated into the PC as a *system* created by the efforts of numerous separate firms.

Assembled from components available in the market produced by a variety of firms, the IBM PC enabled a base of suppliers and imitators to proliferate. Although the microprocessor and operating system markets became virtual monopolies dominated by two firms, Intel and Microsoft, the remaining hardware segments of the industry evolved into highly specialized, extremely competitive businesses producing standardized modular components. Driven by standardization and modularity established by IBM protocols, production of these components by the mid-1980s had already become a *dis*-integrated global activity marked by the emergence of a large concentration of producers in East Asia. The personal computer was, in effect, a product of globally-organized interfirm production networks in which both innovative capacity and productive capacity had migrated to new areas of the world.

These networks were characterized by specialized core competencies among assemblers and component vendors. Unlike the system of mainframe computer production, coordination of the production system for personal computers moved from inside, to outside the boundaries of the firm (Langlois, 1990; 1992). The model for this industry was one of horizontal partnerships and away from vertical integration which created an entirely new set of management challenges for PC builders. Products built by different companies were virtually identical in terms of technology. These attributes of the production system evolved largely from the impact of IBM's entry into the industry, and the legacy of choices made by IBM at the outset.

From the outset, design and production of these standardized, modular components evolved on the basis of the relationship between three basic elements comprising personal computer systems: 1) semiconductor and microprocessor families, 2) operating and I/O systems, and 3) applications software (Steffens, 1994: 121). Changes in any one of these elements created incentives for changes in the others. As these elements evolved, the result was a transformation in the hardware architecture in which these elements were housed.

While all three elements were critical in promoting ongoing changes in the PC, the dominant driver in transforming the personal computer was the continuous improvement in semiconductor and microprocessor technology. Known as Moore's Law, these advances doubled the number of transistors packed into microprocessors every 12-18 months and forced the costs as a measure of performance for computing to plummet. From 1982-1998, the estimated cost per million instructions per second fell by a factor of 500 (Rowen, 2000: 194). Such changes in performance and cost resulted in average annual rates of decline in prices for microprocessors per transistor of 35 percent from 1985-96, while for memory chips over the same period, the decline was 20 percent (Kenney and Curry, 1999: 11). This pattern of change enabled Intel, with a dominant position in the market for microprocessors, to set the key standards for the ongoing changes in PC hardware (Dedrick and Kraemer, 1998: 73). Other components, however, most notably hard disk drives, developed along a similar trajectory. The average annual rate of decline in the price per megabyte of storage for hard drives from 1980-89 was 30 percent. Such expansion in the capabilities of computer components compelled PC hardware firms to develop new generations of personal computers at regular, and ever-shorter intervals (Steffens, 1994: 151). As PC firms developed new products, however, the price for these products typically declined between 20-41 percent per annum over the life of each new PC model (Berndt and Griliches, 1993; Kenney and Curry, 1999: 12).

As a product in a state of ongoing technological change, yet evolving along a pathway of modularity and standardization, the PC was susceptible to competitive pressures deriving not only from technology but also from the interplay of two fundamental variables, *price* and *time* (Kenney and Curry, 1999). As soon as a new product iteration came to market, it was under constant downward price pressure, its value shrinking with the passage of time in anticipation of the next wave of new processing technology and application software. With technological change a constant, and with price and time emerging more as the defining elements of the market environment for the PC, terms of competition for PC makers actually shifted away from technology to a very different aspect of the PC value chain.

As product performance became increasingly standardized within the supply base and from one PC company to the next, and as product differentiation became difficult to sustain, *distribution* emerged as a primary competitive factor within the PC value chain (Steffens, 1994: 259). This emphasis on distribution, in turn, would eventually elevate the role of logistics as a competitive variable in producing and selling PCs. Again, the legacy of IBM was a critical factor in this shift in the way that it established competitive standards of the indirect channel.

The Indirect Channel

As early as 1983, PC makers began to adopt IBM's emphasis on the professional retailer as the preferred channel of distribution. In order to attract customers, especially from the business market, computer firms had to ensure that their sales channels had the same standards as those of the industry leader (Steffens, 1994: 197). This indirect channel, created in the image of IBM, also represented a route to legitimacy for clonemakers, notably Compaq.

This decision by IBM to use professional retailers as its primary distribution channel, and the influence of IBM on the rest of the industry, changed the way many PC makers deployed resources. PC firms made investments in relationships with resellers and dealers, and in marketing activities to support these relationships, on the assumption that wholesale and retail outlets provided manufacturers with better access to nationwide sales. These firms, in effect, owing to the influence of IBM, veered away from the earlier bias on technology, and toward a new emphasis on marketing and distribution activity (Steffens, 1994: 197; 269).

In 1983, the structure of the U.S. personal computer market reflected eight identifiable channels of distribution and sales to end users (Steffens, 1994: 160). These channels included 1) office products dealers, 2) value added resellers and systems houses, 3) manufacturers' own office products stores, 4) wholesalers, 5) mass merchandisers, 6) mail orders, 7) computer specialty dealers, and 8) direct sales primarily by the sales forces of larger PC makers such as IBM. Of these, computer specialty dealers were overwhelmingly dominant. Direct sales accounted for the second largest distribution channel but these sales were largely the result of IBM and other large PC vendors working directly with their largest business accounts. Even by 1987, with Dell and Gateway already selling direct, specialty computer dealers still accounted for 56% of total shipments while collectively the various indirect channels accounted for 80-90% of all PC sales (Steffens, 1994: 260).

By 1984, this indirect channel of selling computers through intermediaries emerged as the dominant route of distribution from manufacturers to final customers, and was a defining element in establishing terms of competition in the industry. Firms, in order to compete, had to rely on, and contend with these intermediaries. While there was value added to the PC by these entities as the product circulated from the manufacturer to the customer – the so-called "gains of trade" resulting from what geographers term, a change in location -- there was also the inefficiency of an excess number of actors in this process. As a consequence, the idea of capturing the value created by intermediaries in the PC production and distribution chain, presented a compelling entrepreneurial opportunity for PC firms.

Entrepreneurial Opportunity

In order to capture the value created from intermediation in the PC value chain, the entrepreneurial firm was presented with an opportunity to reconceptualize and transform the relationships between four key elements lying at the core of the indirect system of distribution. These four elements consisted of: 1) forecasting market demand; 2) building according to demand forecasts; 3) "pushing" finished inventory from the factory into the distribution and sales channel; and 4) waiting for customers to make purchases.

While these attributes functioned together in creating a production and distribution system, PC firms were completely reliant in this system on accurate forecasting of future demand. They were therefore vulnerable to the carrying charges from excess inventories when forecasts went awry and goods went unsold. At the same time, they were susceptible to missed opportunities when forecasts underestimated the market. Even with the best demand projections, however, the indirect push system of production was beset with perhaps an inherent and intractable problem for the PC manufacturer -- the need to purchase and hold inventories of components and subassemblies in order to build finished systems and fill quotas for distribution outlets. Such challenges are not unique to the personal computer industry. They are symptomatic of all industrial activities that rely on demand forecasting, and the sale of finished goods through intermediaries. There are good reasons, however, why the indirect channel of distribution was particularly well-suited as a target for competitive challenge in the PC industry.

Driven by incessant advances in processor technology and software applications, along with resultant shortened product life cycles, the PC is susceptible to ongoing downward price pressure as it circulates through the various stages of the value chain. Once assembled, the PC is constantly losing value because the components in it depreciate as time passes in anticipation of the next wave of technical improvements in those components. These two characteristics -- constant technical improvements coupled with simultaneous downward pressure on PC prices -- give the personal computer a perishable-like quality, similar to industries such as fashion and even food (Kraemer et al., 1999: 3; Kenney and Curry, 2000: 5).[10]

This perishable-like quality and the depreciation in value of the product over time exposes PC firms to an especially vexing problem -- the problem of *inventory*. If the product is held for any

[10] The recent development by Intel of a two gigahertz chip provides a powerful example of this phenomenon. As soon as it released this chip in late August, 2001 at a price of $562, Intel reduced the price of its existing 1.8 gigahertz chips, selling for $562 in July, to $256 (Gaither, 8/28/2001: C4). Such examples have compelled Stan Shih, CEO of Acer Computer, to liken PCs to fresh vegetables while similarly Michael Dell refers to PC components as "having the shelf life of lettuce."

appreciable length of time in inventory, it is depreciating in value. Such a problem becomes increasingly acute for the PC maker at the stages in the value chain where the product moves from the final assembly point through the channel and eventually into the hands of the customer. Frequently, the period of time between final assembly and sale to the customer ranged from 3-4 months. During this time, the components in the PC, most notably the central processing unit, hard disk drives, and DRAMs would depreciate in value such that the selling price, by the time the system was actually purchased, would have to be lowered. This increment of time in the channel, in effect, represented a sizeable loss of value for the PC maker. For this reason, competition in the PC industry as early as the mid-1980s began to evolve in the direction of two related factors -- speed and time (Kenney and Curry, 1999).[11] Such a shift created an opportunity for innovation focusing on the logistics of building the PC, and distributing the product to the final customer. Any strategy for decreasing the holding period of time in inventory at each step in the value chain, especially between final assembly and sale, and accelerating the speed at which the build process and final marketing occurred, held enormous potential as a business model in the industry.

What enabled such a business model to emerge as viable by 1984 was the way in which the industry had evolved since the IBM PC, and the attributes of the PC stemming from this history. Firstly, the industry was already organized on the basis of decentralized and globalized subcontractors. Virtually all computer makers had access to, and were subcontracting from this supply base located primarily in East Asia, Japan, and the U.S. Secondly, the PC components produced by this supply base had evolved into highly modular and increasingly standardized items. With uniform design, engineering, and technology, components were easily accessible to PC makers. Differences in the product from one firm to the next, whether branded or cloned, had narrowed so dramatically that, with the exception of Apple, design, technology and engineering were of secondary importance as terms of competition in the industry. What differentiated these products were brand names. Nevertheless, even the IBM brand failed to stem the ascendancy of clones, most notably Compaq, but also the non-branded clones.

[11] Kenney and Curry (1999) refer to the more recent manifestations of this phenomenon in the PC industry but the importance of speed and time was already established in the industry by the mid-1980s.

In effect, the PC had become a standardized commodity. It was built from components purchased from an accessible base of suppliers, and distributed through a channel of actors that functioned on principles of demand forecasting, and accepted the accumulation of inventory as inevitable. Admittedly, the process required enormous logistical coordination across distance to build the product from this existing base of firms, and market the product successfully through the existing distribution channel. Yet, in evolving with an increasing emphasis on logistics and distribution, the PC industry was vulnerable to change from a business model challenging the principles upon which the prevailing system of logistics and distribution was organized. That challenge would emerge in 1984.

Genesis of Dell

A single core concept served as the inspiration for Dell Computer: "Sell computers directly to the end customer. Eliminate the resellers' markup and pass those savings on to the customer" (Dell and Fredman, 1999: 12).[12] The target of Dell's business model was thus not the technology of the PC, but instead the industry's indirect channel of distribution. A different relationship with the customer provided the underlying foundation for this business model. This relationship was the source of innovation at Dell and the catalyst for transformation in the Company's logistics oriented production and distribution system.

Custom Direct

Michael Dell began his business in late 1983 by upgrading IBM personal computers from his dorm at the University of Texas, and selling the customized PCs directly to businesses anxious to purchase the reconfigured machines at prices far lower than existing computer outlets. In Dell's own words, the superiority of these two notions -- direct selling and customization -- was obvious. What was less clear to Dell was the reason why existing computer firms were not producing and marketing their products in this way.

[12] Information in the following three paragraphs taken from Dell and Fredman, 1999: 10-15.

Dell achieved several advantages from customized producing and direct selling. The most decisive advantage derived from the elimination of links in the PC value chain. Such disintermediation not only enabled Dell to capture that portion of the value taken by PC wholesalers in the process of distribution. For Dell, eliminating intermediaries was a critical path to compressing time in the cycle of PC production and distribution itself, and capturing greater levels of value by increasing the velocity of moving products from order through final sale. Secondly, the relationships with final customers built through direct selling provided Dell with a platform for one of the most important sources of sales in the industry, repeat sales. Because the technology of the PC was changing so rapidly, and because the product life of the PC was so short, customers buying a machine at any given moment were the best prospects for future sales. Furthermore, by eliminating product in the channel, Dell was in a position to offer its customers the latest technology without having to send products through a lengthy distribution process. Thirdly, in producing PCs only after receiving orders, Dell avoided the inventory problems associated with faulty demand forecasting. Finally, in purchasing components and building finished systems only after receiving orders and payment from customers, Dell was able to carry a *negative cash conversion cycle.* It took possession of the customer's money before paying its suppliers, thereby funding its own operating expenses.

Excess inventory held by distributors of certain PC makers provided Dell with an early source of low-priced PCs from which the firm could turn a profit. Especially important was the "IBM gray market" consisting of unsold PCs at certain dealers. "We would buy these stripped-down computers," admitted Dell, "and sell them for a profit" (Dell and Fredman, 1999: 14). In addition, Dell's fledgling firm capitalized on another fortuitous opportunity to seed the business. An open bidding process in the State of Texas for PC hardware enabled Dell to compete for public contracts with more established firms. In winning several of these bids, Dell obtained a source of revenue to supplement its base of individual sales and began to grow rapidly.

By early 1984, Dell was selling $50,000 - $80,000 per month to customers in the Austin area. In May, Dell incorporated the firm as "PCs Limited." By the beginning of the following year the Company was building computers under its own, PCs Limited, brand name.

Three attributes of the industry enabled Dell to enter the industry relatively easily and build computers under its own brand. Firstly, the burgeoning base of PC suppliers, both in the U.S. and in East Asia, is what provided Dell with access to the technology and engineering necessary to build the product (Dell and Fredman, 1999: 23-24). Second was the fact that many of these components had become so technologically standardized and modular that assembly into finished PCs had become a relatively low-skill activity requiring limited investment in training a highly-skilled workforce. Finally, related to the modular nature of PC components, Dell was able to exploit new technologies in "chip sets" that combined the roughly 200 semiconductor chips required to make an Intel 286-based PC, into five application-specific integrated circuits (ASICs). This modification in semiconductor design simplified PC design. As a result, Dell was able to employ an engineer in the Austin area, Jay Bell, to design a 286-based PC. The firm had its own product with technology as good as any other company. It had a brand name. Perhaps most importantly, PCs Limited had a uniquely-competitive business model for selling its product.

While other firms had to forecast the product configurations and quantities demanded by customers, and accept the consequences of inaccurate forecasting, Dell took a different route to reaching its customers. It knew the configurations and quantities to build because its customers told them and Dell produced only from orders received. The Company did not stock the reseller and retail channel. Dell also made a critical decision on the type of customer it wanted to reach most -- corporate customers. Although the corporate market was difficult to sell as a start-up, Dell hired an aggressive sales force with the aim of securing such accounts. Ironically, it was a technical breakthrough that enhanced its credibility as a formidable competitor in the PC industry and facilitated its ability to reach this market.

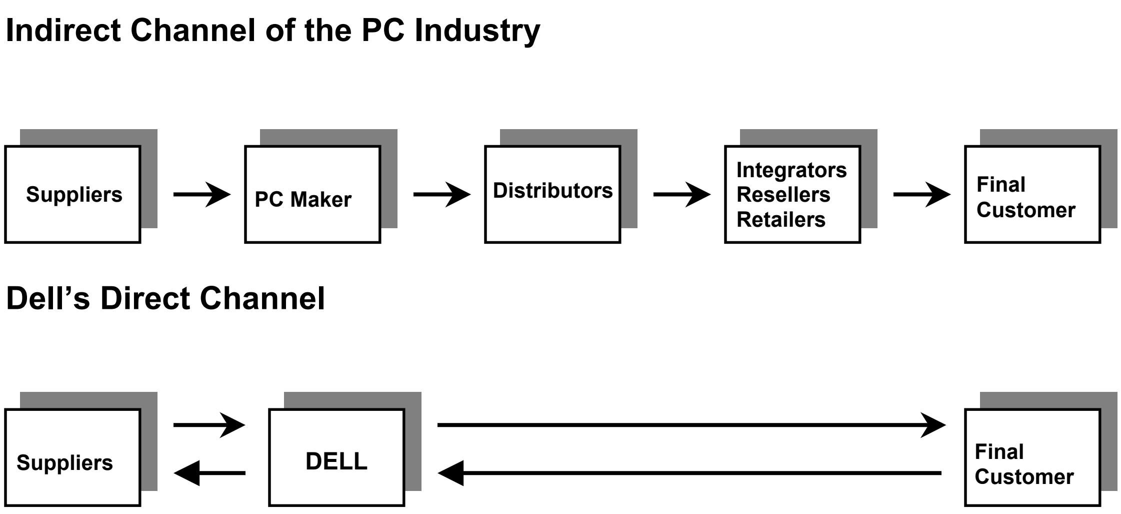
At the end of 1985 and beginning of 1986, Dell made a decision to try and build the world's fastest PC. At the time, IBM was building a six megahertz machine with an Intel 286 processor priced at \$3995. Dell aimed at designing a twelve megahertz 286 PC. In early 1986, the Company successfully built and tested a twelve megahertz PC running on a 286 processor. It priced this breakthrough product at \$1995. In March, 1986, Dell took the product to Comdex, the largest computer show in the world, which landed PC's Limited on the cover of *PC Week.* Subsequently, Martin Marietta, Burlington Northern, and

Price Waterhouse bought systems from Dell's company. By February, 1987, 85% of the output from PC's Limited was being sold to the business market (Lewis, February 2, 1987).

With its mostly-corporate accounts, Dell created what is termed, "a closed loop" relationship with its customers that the PC maker exploited as a source of outreach to secure new sales. Owing to the ongoing breakthroughs in processing speed that made the PC such an ephemeral product, coupled with the interests of firms in upgrading equipment to take advantage of these improvements, Dell's closed loop with its customers created an ideal marketing channel to potential new demand. Nearly two-thirds of its revenues were coming from existing, mostly corporate customers (Economist, March 2, 1991).

Figure VI-1

SCHEMATIC OUTLINE OF PC CHANNELS



Source: Adapted from Kraemer et al. (1999): 5-6; Reprinted with permission.

Using the telephone and the fax as the communications infrastructure for its direct channel with customers, PCs Limited grew impressively during its early years. Between its initial year and its second year, Dell's firm increased sales almost tenfold growing from $650,000 in 1984, to $6.2 million in 1985. Rapid expansion continued during the remainder of the 1980s. In 1988, PCs Limited generated a market capitalization of $34.2 million through an initial offering of its common stock. The stock split during the first year of public operations and continued to split in the years thereafter. By the end of the decade, Dell Computer as the Company was now renamed, had generated sales of $258 million. Foreign sales accounted for 15% of this total. Despite predictions that its business model would fail, Dell was generating nearly $400 million in revenues by 1990 and had become the 20th largest PC firm in the world.

Table VI-3

Early Sales and Profit of Dell Computer ($ millions)

Year*	1985	1986	1987	1988	1989	1990
Net Sales	$6.2	$33.7	$69.5	$159.0	$257.8	$388.5
Net Profit	$.3	$.7	$2.2	$9.4	$14.4	$5.1

* Fiscal Year
Source: Dell Computer Corporation, 1989 Form 10-K, Item 6, p. 23.
Dell Computer Corporation, 1991 Form 10-K, Item 6. p. 16.

Table VI-4

Rankings of PC Firms by PC Revenues (1990)

Rank	Firm	Rank	Firm
1	IBM	11	Intel
2	Apple	12	Tandy
3	NEC	13	Acer
4	Compaq	14	Hitachi
5	Toshiba	15	Siemens / Nixdorf
6	Olivetti	16	AT&T
7	Fujitsu	17	Seiko Epson
8	Packard Bell	18	Hewlett-Packard
9	Groupe Bull	19	Unisys
10	Commodore	**20**	**Dell Computer**

Source: Steffens, 1994: 335; Dedrick and Kraemer, 1998: 57. Pinella, 1991: 42.

This rapid growth, however, came with certain costs. In emerging among the twenty largest PC firms, Dell experienced its first setback in 1990 as profits fell for the first time from $14 million the previous year to $5 million. Ironically, this drop in profitability occurred as a result of problems with component inventory. While inventory can be an asset against the risk of supply shortages, it is also a liability in the PC industry when component costs are constantly dropping and the value of such inventory is continually diminishing. With sales expanding dramatically, Dell found it more difficult to keep in balance the two elements of its business model -- low inventory and mass customization -- that in other business systems are generally irreconcilable. Volume in Dell's build-to-order, direct system had thus reached a certain threshold where parts for orders had to be stored revealing the vulnerability of the Company's business model in a high volume setting. In addition to high volumes, these problems were traceable to the geography confronted by Dell in organizing supply chain operations for its system of mass customization. Long-distance linkages between suppliers, located primarily in East Asia but also Mexico and the U.S., and assembly in Austin characterized the geography of this network. Problems in coordinating the transport of these components over distance, and accounting for the variation in component delivery lead times from suppliers, conspired to push up inventory levels. Numerous separate warehouses in Austin where these components were stored before assembly exacerbated the complexities of the different lead time delivery schedules. "To our stunned belief," writes Dell about the period around 1990, "we had quickly become known as the company with the inventory problem" (Dell and Fredman, 1999: 37).

MAP VI-I

Tactical Shift

Dell attempted to adjust to these inventory problems after 1990 as well as expand its market share by implementing two related and perhaps surprising modifications in its custom direct business system. Firstly, Dell began to use a key actor in the indirect channel, value-added resellers (VARs), to reach certain business customers and initiated a number of indirect channel programs as part of this strategy (Aragon, July 20, 1998). Secondly, Dell supplemented this approach to partnering with the VARs with an extensive program to market its computers through large retailers. The Firm negotiated deals with computer superstore, CompUSA; big box retailer, Price Club; office supply franchise, Staples; and the electronics chain, Circuit City. These stores agreed to sell Dell PCs at the Company's own mail-order prices.

Indeed, as a result of these moves, Dell's sales continued to expand. By 1994 the Firm had generated annual revenues of just under $3 billion. Furthermore, with a world market share of 2.4%, Dell had ascended into the ranks of the world's largest PC firms. Shipping over a million units, it now occupied the position of the world's tenth largest PC maker.

Table VI-5

Computer Firms
Ranked by World Market Share (1994)

Rank	Firm	Units (000s)	% Share
1	Compaq	4,799	10.0%
2	Apple	3,957	8.3%
3	IBM	3,937	8.2%
4	Packard Bell	2,473	5.2%
5	NEC	1,941	4.1%
6	Hewlett-Packard	1,903	4.0%
7	Acer	1,451	3.0%
8	Toshiba	1,442	3.0%
9	Fujitsu	1,441	3.0%
10	**Dell**	**1,152**	**2.4%**

Source: Gartner Group / Dataquest.

Nevertheless, this period of growth and ascendancy into the top ranks of PC firms, also marked a negative milestone in the Company's brief history. Although Dell's sales had expanded impressively, and although by 1994 it had become even more of a presence in the world PC industry, the Company was not able to sell profitably through the intermediaries of the indirect channel. Its cost of sales rose dramatically, consuming profitability. Whereas in fiscal year 1991, Dell's cost of sales were 66 percent of its total sales, by fiscal year 1994 the figure had risen to 85 percent (Dell Computer, 1994 Form 10-K: Item 6, pp. 13-14). Furthermore, its tactical shift into the indirect channel, through it expanded sales, exacerbated its difficulties with component procurement and excess inventories.

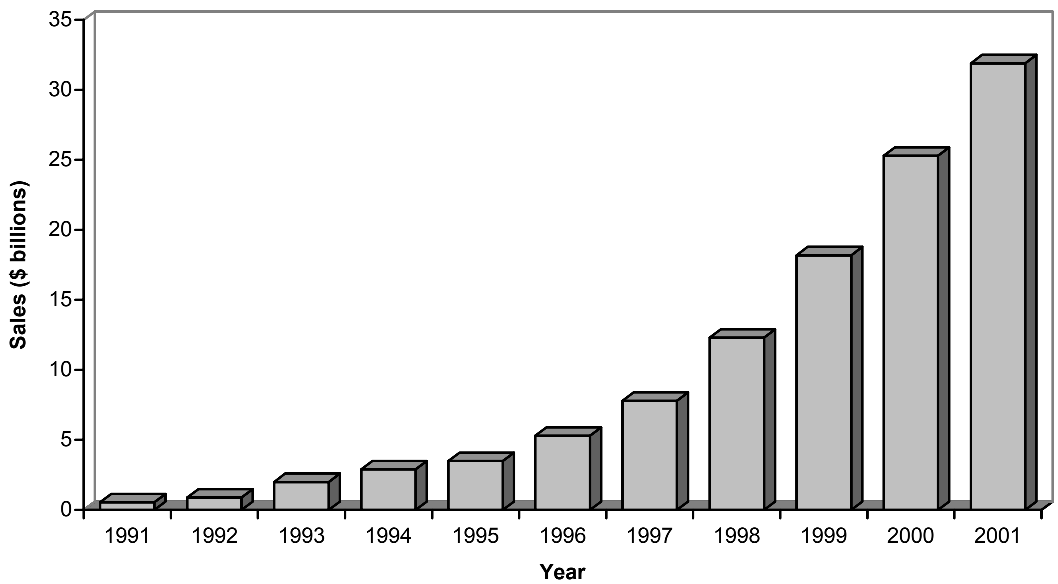
As a result, Dell suffered its first quarterly loss during this period. For its fiscal year ending on January 30, 1994 Dell reported a net loss of $35.8 million on its $2.9 billion in sales, the first and only annual loss, to date, reported by Dell (Dell Computer Corporation, 1994 10K: Item 6). Rising costs linked to larger-than-expected inventories in its procurement chain, a failed program with VARs, and too much product in the retail channel, created the first significant crisis at the Company (Wood, 1993; Aragon, July 20, 1998).

Consequently, in early 1994, Dell made two critical strategic decisions. Firstly, the Company decided to abandon its experiment with resellers, and concentrate on its origins as a direct seller. Secondly, and perhaps more significantly, Dell began to experiment in adapting its custom-direct business model to an entirely new communications infrastructure -- the Internet.

The Internet

Dell's Internet-driven production and distribution network has taken shape in two overlapping, and still-ongoing phases. In the first phase, Dell used the Internet to transform its system of selling and order intake with its customers, enabling the PC maker to become one of the early pioneers of Internet commerce. Phase two consists of Dell's deployment of the Internet to reorganize its procurement planning and the logistics of assembly and product delivery. Its aim in this second phase is to link its Internet-based system of order intake with customers, to an Internet-enabled process of procurement, production, and distribution with suppliers and logistics providers. What has occurred alongside this deployment of the Internet is an extraordinarily sharp acceleration in revenue growth. From 1994-2001 sales increased at Dell almost ten times, demarcating this period of sales growth from the period preceding it.

Chart VI-1
Growth of Dell Prior to, and During Internet Period



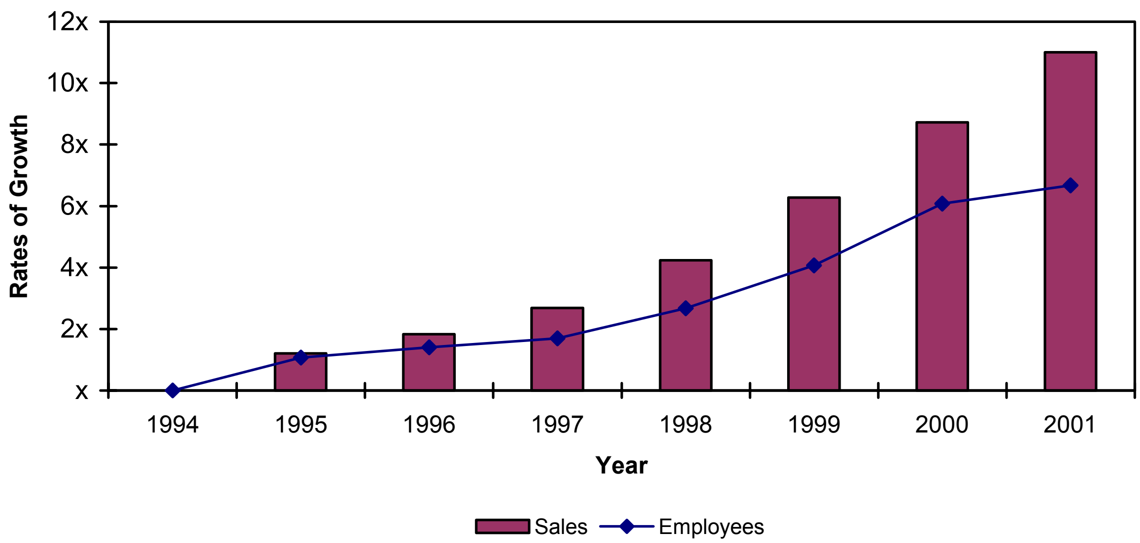
Source: Dell Computer Coorporation, 1992 Form 10K; 1996 Form 10K; 2001 Form 10K

In addition to sales growth, this integration around the Internet has recast Dell in three profound ways. Operationally, Dell has used the Internet to create more rapid cycles in its system of pulling components from suppliers than in previous years. In a build-to-order environment where PC systems are produced and delivered at rates that match the rate of sales, Dell has been forced to implement these compressed cycles because of its explosive revenue growth after 1994 (Albers, 2000: 3). In this sense, sales growth and time compression in procurement and assembly have been mutually reinforcing.

Organizationally, in extending the Internet backward into its supply chain, Dell has created a new form of business enterprise with its interfirm partners to manage the more rapid cycles in its build-to-order system. This form of enterprise relies on strategically organized relationships, not markets, as a basis of collaboration. Finally, Dell has created a distinct form of territorial organization in the places where it has established its build-to-order operation. In these places, physical proximity between supply sources and assembly sites, strategically crafted by Dell, has resulted in a set of territorial relationships between operations and actors that are shaping the contours of a new generation of industrial districts.   These industrial districts, in turn, are helping define the actual character of global production ensembles in the contemporary economy.

While these attributes have emerged most sharply in the period following implementation of the DSi2 project, they actually began to take shape alongside the initial experiments by the Company in online selling, and deployment of the Web in supply chain management and enterprise resource planning.

Chart VI-2
Comparative Growth Rates of Dell Sales and Employment



Note: 1994 Sales and Employment = 0
Source: Dell Computer Corporation, 1996 Form 10K; 2001 Form 10K

Table VI-6

Sales and Employment Growth of Dell during Internet Period

	1994	1995	1996	1997	1998	1999	2000	2001	2001/1994
Sales ($ billions)	2.9	3.5	5.3	7.8	12.3	18.2	25.3	31.9	**11x**
Employees (000s)	6.0	6.4	8.4	10.4	16.0	24.4	36.5	35.0	**5.9x**

Source: Dell Computer Corporation, 1996 Form 10K
Dell Computer Corporation, 2001 Form 10K.

Online Selling

Dell had a decided advantage over other PC firms in selling its products over the Internet. Unlike the indirect channel of its competitors, Dell's direct sales path was far more easily adaptable to the direct linkages between manufacturers and customers, and the phenomenon of disintermediation characteristic of Internet selling. In effect, the emerging system of Internet selling represented a logical extension of Dell's direct business system. Unlike its competitors, Dell did not confront the problem of alienating channel partners through direct Internet sales, and was thus not impeded by the legacy of the indirect selling system.

As a consequence, Dell was one of the first large manufacturers to set up a website in 1994. The following year, customers were able to configure systems and obtain price quotes from Dell.com. By June, 1996, Dell was the first firm in the PC industry to sell systems over the Internet. Within three months, Dell had become one of the largest Internet Commerce firms. At a time when Amazon.com was selling $15 million worth of books per quarter, Dell by the end of 1996 was already selling PCs over the Internet at a rate of roughly $90 million per quarter or six times the sales volume of Amazon. Six years later, Dell was the largest online retailer of goods accounting for 22% of all Internet retail sales (Tedeschi, July 22, 2002: C6).

In expanding its Internet sales as well as increasing its total sales, Dell admittedly benefited from a virtuous circle created by the relationship between the Internet and the PC. The expansion of the Internet as a communications revolution created a corresponding surge in demand for PCs as the device of choice for access to the Web. While the entire PC industry prospered from this relationship, Dell as an online seller by 1996, profited from this innovation in two ways. It was able to take advantage of the increasing interest for Internet access not only as a demand stimulant for its own PCs. Dell used the Internet infrastructure itself as a means of scaling its system of order intake and innovating its sales system to meet this surge in demand.

Table VI-7

Daily Internet Sales of Dell Computer

	1996	1997	1998	1999	2000	2001
Daily Sales ($ millions) *	1	3	11	20	40	50
% of Total Sales *	7%	14%	32%	40%	50%	57%

* end of year totals
Source: www.Dell.com, Speech Archive of Michael Dell.

Nevertheless, while this transition to online selling had an enormous impact in lowering Dell's administrative costs per order from roughly $50 to $5, this innovation represented a relatively small portion of the overall operation. Beyond order intake on the front end of the value chain, however, lies a more complex set of operations and relationships between Dell and its suppliers. It is these relationships, and the integration of these relationships with the customer, that would become the focus for the second phase of Dell's Internet innovation. [13]

[13] This notion of Dell's "second web revolution" taken from Rocks (2000). A similar idea is also expressed in Boulton et al. (2000: 8).

Beginnings of the 'Second Web Revolution'

By extending the Internet from the point of sale into procurement, production, and enterprise resource planning, Dell's "second web revolution," represents a more far-reaching set of transformations at the Company than the Internet innovations focused on sales. In this second phase, the Company has become an innovator in the realm of business-to-business Internet commerce. Dell refers to this type of Internet activity linking itself to its customers, suppliers, and logistics partners, as *e-commerce*. As a logical extension of Internet-driven efficiencies in the process of order intake and sales, the second phase of Internet deployment at Dell represents the continuation of a single overriding concern at the Firm -- diminishing the inefficiencies in the value chain associated with *time.*[14] This concern with time, in turn, compelled the Company to focus on ways of using Internet communication to enhance perhaps the most critical core competence at the Company – balancing demand and supply in a build-to-order environment. This effort at using the Internet to eliminate more of the unproductive time from the process of demand and supply balancing while operating in a build-to-order environment, is what drove Dell's Web experiment upstream into supply chain management and enterprise resource planning. This initial effort at integrating the Internet into the procurement and build processes was dubbed by Dell as the Genesis Project.

Launched in 1994, Genesis aimed at creating a standardized system of data management for all aspects of the Dell operation using the Web as an information and communications infrastructure. Procurement planning, production schedules, order intake, product delivery, and accounting along with the logistics linking these activities, were to share this common information platform. The project, however, did have a clear and measurable performance goal. The objective of the project was to reduce the inventory problems that had emerged at Dell during the previous four-year period.

Central to the project was a Web-based information system for enterprise resource planning designed by the software firm, SAP. The SAP / R3 platform was intended to provide enterprise resource planners at Dell with the capacity to identify how the impacts of an order ripple throughout the entire

[14] The idea of time compression as a management strategy at Dell and the PC industry taken from Kenney and Curry (1999).

operation. It aim was to create simulations as orders occurred for balancing procurement levels, coordinating production schedules, and adjusting financial balance sheets. It represented one of the early efforts at extending the Internet from the point of sale with the customer backward to Dell's suppliers and forward through assembly and delivery.

Two problems emerged with this project (King, 1997). Firstly, the SAP system had difficulty accommodating Dell's regional organizational structure adopted in 1995, especially the multiple assembly sites. Secondly, the project did not appear sufficiently scalable to handle the growth rate of transactions within the Company (Koncaba, Interview of 7/27/01). Genesis had been conceived in 1994 when Dell was a $3 billion firm. By the time Dell actually abandoned the still-unfinished effort in 1997, its sales volumes had quadrupled to roughly $12 billion. Furthermore Dell had already concluded that the R/3 architecture, with its large centralized database, was incompatible with one of Dell's important new aims. Dell was committed to run its ERP system on its own servers, which could not accommodate R/3. According to Jerry Gregoire, chief information officer at Dell in 1997, "having a full SAP suite and all of these tightly integrated applications going into the company at the same time didn't make as much business sense as it did before" (quoted in King, 1997).

Nevertheless, one critical achievement emerged from this early effort at integrating the Internet into procurement and production. From 1994 until cancellation of the project in 1997, Dell did succeed in accomplishing its primary goal of decreasing inventory. By 1997, Dell had once again assumed leadership on this metric within the PC industry. The Company was also growing faster than its competitors in the PC industry. By 1997 Dell had become the third largest PC firm in the world surpassing such firms as Apple and Hewlett Packard.

Despite cancellation of the SAP project, Dell would continue its experiments with the Internet and enterprise resource planning over the course of the next two years. During this period, Dell (along with Cisco Systems) became known as the Company with the most advanced Internet-based system for supply chain management. Nevertheless, as Michael Dell admits, these early efforts at Web-based supply chain management were still very much a process of experimentation in trying to create Internet links between Dell and its suppliers (Dell and Fredman, 1999: 190). Furthermore, the Company confronted the problem of trying to standardize competing, and not always compatible, information and communications platforms in terms of phones, faxes, and the Web. By the end of 1999, Dell had decided to embark on a far more ambitious project for integrating the Internet into its operation.

Table VI-8

Days Supply of Inventory at Dell and Compaq

	1994	1995	1996	1997	1998	1999	2000	2001
# Days Supply of Inventory **@ Dell Computer**	32	21	16	13	8	6	5	4
# Days Supply of Inventory **@ Compaq**	67	59	44	32	29	31	36	42

Source: Dell Computer Corporation, 10-K Reports various years; Compaq Computer, 10-K Reports various years; Robert Cihra, The PC Industry, ING Barings Furman Selz, 1998; Business Week, June 17, 2002, p. 77.

Table VI –9

Computer Firms
Ranked by World Market Share (**1997**)

Rank	Firm	Units (000s)	% Share
1	Compaq	10,596	13.1%
2	IBM	6,958	8.6%
3	**Dell**	**4,464**	**5.5%**
4	Hewlett Packard	4,297	5.3%
5	Packard Bell / NEC	4,116	5.1%
6	Gateway	3,261	3.7%
7	Apple	3,070	3.4%

Source: Gartner Group / Dataquest.

Dell's i2 Internet Production Network

Dell embarked on the DSi2 project with the idea of building its business "with the Internet at its core" (Hunter, Interview of 5/24/01). In this sense, the aim of the project was similar to the aim of its earlier experiments with the Internet and supply chain management. The goal of DSi2 is to enable Dell's demand and supply planning, parts procurement, build-to-order production schedules, customer order intake, and product delivery processes to operate on a single but flexible Internet-based information platform. In practice, this aim sought to transition aspects of these operations still being conducted through the phone, fax and even email, onto the Web. In addition, this project was designed to get all of Dell's geographical regions to use this common Web-based information and communications system. Perhaps most importantly, the project reflected an effort to link itself more systematically with its supply chain and logistics partners. Although Dell developed some of its own proprietary software for the program, it turned to the supply chain firm of i2 to provide the overall architecture for the PC maker's Web-based information system. The DSi2 project that emerged from this joint effort, is characterized by the PC maker as "one of the single biggest changes in the Dell business system" (Hunter, Interview of 5/24/01).

The DSi2 initiative utilizes Web-based communication to address what is arguably the most formidable challenge to Dell in its build-to-order business model -- the challenge of supply and demand balancing in an environment of fluctuating customer orders over time. Although supply and demand balancing confronts all manufacturers, most companies address this problem primarily through inventory management. If orders spike upward at any one time, firms rely on inventory to balance the fluctuation. Dell, however, has rejected this approach as incompatible with its build-to-order system. Instead of storing inventory, Dell relies on what is called "burst capacity" to deal with ever-fluctuating demand (Albers, 2000: 23, 29).[15] This strategy relies upon a small amount of unused capacity within the procurement and production process as a safeguard against large increases in demand at any one moment. When demand climbs, this unused capacity gets deployed. Such burst capacity, however, in the context of build-to-order, has to include the entire procurement and assembly process, which means that it must

[15] Information on burst capacity and its role in the Dell business system taken from Albers (2000).

extend back into the supply base and throughout the entire network of the Company. DSi2 represents a new set of planning and logistical innovations by Dell to increase the efficiency of burst capacity and the achieve a more favorable balance of supply and demand within its just-in-time procurement and assembly system.

The DSi2 project has two principal elements. The first element consists of what Dell calls, *Global Supply Planning*. The second element is *Demand Fulfillment*. The first element, as its name implies, focuses on planning processes. The second is concerned with the execution and logistics of moving parts, semi-finished, and finished goods through the Dell procurement, production, and distribution network. This separation of planning from execution is one of the single biggest changes implemented by the DSi2 project (Cook, Interview of 6/14/01).

Operations: Global Supply Planning

Global supply planning involves two types of planning processes. On the one hand, global supply planning involves the creation and management of data and information used to forecast general demand parameters for components. Secondly, and perhaps more significantly, global supply planning refers to a system of information exchange between Dell and its component suppliers to coordinate the process of ordering and procurement of these components by Dell from parts suppliers. The innovative advance made by Dell in this process hinges on the way the PC maker has deployed Web-driven communication, configured through the i2 modules as well as its own software, to create an automated procurement system in which Dell is more functionally integrated with its parts suppliers and logistics providers.

This integration with suppliers through the Internet has resulted in a more centralized and standardized process for procurement planning. Global supply planning centralizes Dell's inbound planning activity in the Company's worldwide procurement organization in Austin. At the same time, however, the global supply planning process creates "a single system of record" for procurement at all six of Dell's regionally decentralized operations (Koncabaa, Interview of 6/12/01; Kelly, Interview of

5/4/01). This centralized planning system for what is essentially a regionally decentralized production system is one of the innovations made by Dell facilitated by the Internet.

Despite the emphasis made by Dell on differences between its business model and those based on forecasting, and disclaimers about its own forecasting abilities, Dell does employ a type of strategic forecasting in its global supply planning process. These forecasts of unit demand and component requirements are the first step in creating a system of *material balances* at Dell. This system aims at equalizing supply and demand of parts within Dell's build-to-order environment and is central in the overall system of supply and demand balancing at the Company. Thus, contrary to perception, "forecasting is critical" in Dell's Web-driven, just-in-time producing and selling system (Hunter, Interview of 4/17/01). Although Dell does not pre-build products on the basis of forecasts, unlike its competitors that sell machines through the indirect channel, absent forecasts, there would be no viable foundation from which to launch its build-to-order, just-in-time, pull system. In addition, strategic forecasting is crucial because some of Dell's primary suppliers maintain lead times of 8-12 weeks for production and delivery of components. Forecasting these cycles enables the Company to position material in its supply chain so that it can be procured and pulled into the build process as needed. Nevertheless, the Company does not orient its business around this element. **"**We are not a great Company at forecasting because we do not build our business model around forecasting," insists Lance St. Clair, director of supply chain and materials management for Dell. "We are a pioneer in using the Internet for e-commerce with our customers and suppliers to balance demand and supply in the movement of components through the supply chain and production system" (St. Clair, Interview of 6/20/01; 1/10/02).

Consequently, the DSi2 global supply planning system at Dell begins with 12-month "Master Production Plans." These forecasts tell operations departments how much business to expect in the next 12-month period (Inbound Supply Chain Manager, Interview of 4/19/01). These forecasts, however, are continually updated as market conditions change.

Forecasts for Master Production Plans are generated from the interplay of two sources. One source is historical data. For the Master Production Plan, historical trends are disaggregated according to three main categories: 1) products (desktops, notebooks, servers, etc.); 2) market regions (Americas, Asia Pacific, Europe, etc.); and 3) customers (large-scale *relationship* customers serviced by salespersons, or smaller *transactional* customers). Because the Company grew so rapidly from 1994-2000, however, historical trends in these categories do not always convey accurate estimates of future demand. Furthermore, the marked slowdown in demand for PCs starting in 2001has raised additional questions on the use of historical trends as future indicators. This potential shortfall in historical data makes the second source of information for long-term forecasts equally, if not more valuable.

This second source derives from the purchasing plans of its largest relationship customers. Dell is able to obtain this information on upcoming purchases from the customized “premier” websites created by Dell for customers that transact $1 million annually, and from information secured by salespersons working with these large accounts. This information, not captured in historical trends, enables Dell’s largest accounts to participate in a direct way in forecasting future demand for materials.

The Master Production Plans generated from historical data and information supplied by large accounts, are transformed into materials requirements. Through the i2 module known as “Supply Chain Planner,” these material requirements are further refined into a broad-based “material requirements plan” (MRP). This MRP is one of the principal outputs of the global supply planning process.

The material requirements plan divides a projected level of output into a matrix of different components, automated for Dell by the i2 “Tradematrix” module. In certain ways, this matrix resembles a transactions table in what is known in regional science as input/output analysis. It provides Dell with the material requirements by component type for a certain level of final demand.[16]

Suppliers collaborate in this forecasting process through an extranet called Valuechain.dell.com. Through this portal, component producers are able to verify Dell’s material requirements for the duration of Master Production Plans. Suppliers then commit to these requirements, and take responsibility to

[16] Paradoxically, the planning and forecasting system at Dell possesses some of the attributes characteristic of the central planning system in the former USSR. In the Soviet planning system, forecasts of aggregate final demand were broken down into requirements by industry sector. The “Plan” functioned as a system of *material balances* within and between these various sectors. In the Dell system, forecasts of final demand are broken down into requirements by component type. Other differences are equally critical. In Soviet planning, output targets were rigid and inflexible and became ends in themselves. At Dell, forecasting is undergoing ongoing modification in real time as output targets and supply requirements are constantly being rebalanced as conditions change.

produce parts as needed over the 12-month period of the Master Production Plan. In this way, parts producers confirm supply and delivery of Dell's component demand. Through Internet communication, suppliers in effect, provide information necessary for completion of the Master Production Plan, which is constantly in flux as a forecasting tool as conditions in the build-to-order environment change.

With the material requirements of the Master Production Plan as strategic parameters, the global supply planning process assumes its innovative character by creating procurement cycles matched to the fluctuations in customer orders in real time. Through an on-line tracking system for components, Dell is able to respond to changes in its material requirements, and alert its suppliers of its new requirements. This tracking system, configured through a combination of i2 tools, generates what is called an "exception action report." Created automatically over the Web, this report alerts procurement planners at Dell of an "exception" in one or more parts necessary to fulfill demand in that moment. Where an exception exists, a purchase by Dell becomes necessary. Through the "Supply Chain Planner" module of i2, the parts procurement planner/buyer at Dell is able to set up a requisition, get it approved, convert the requisition to a purchase order, and send the order to the supplier. The supplier receives an on-line notification of the purchase order via Valuechain.dell.com. The supplier, in turn, is able to respond to the notification and commit to the new order requirement, which is then received by the procurement planner/buyer at Dell.

The advantage of this innovation is that it transfers the ordering process for parts to what Dell calls an "exception basis" away from spreadsheets, and onto the Internet (St. Clair, Interview of 5/24/01). In the period just before DSi2, certain aspects of this process were executed over the Internet while others were undertaken by more conventional methods such as faxes and phone calls. By mid-2001, however, roughly one year after initial implementation of the program, almost 90% of Dell's purchases from suppliers were occurring through Web-based interactions (Hunter, Interview of 6/20/01). As a result of the direct relationship with its customers, coupled with the advent of Internet communication, Dell has created a new type of connection between the process of customer order intake, and the process of components procurement from its suppliers. Forged on the basis of a new communications infrastructure, this link represents on ongoing search by Dell for ever-greater levels of balance between demand and supply in a build-to-order, demand pull environment.

Operations: Demand Fulfillment

Demand fulfillment in Dell's Internet direct business model refers to the execution of how supplies are delivered to Dell's production sites for assembly into finished products. The core element of demand fulfillment consists of "pulling material to order" every two hours into Dell factories. Customer orders released to the factory floor for configuration into finished PC systems provide the input that initiates these material pulls. Dell schedules these orders to be built in two-hour cycles and pulls only those components required to fulfill orders for the given two-hour period. According to Lance St. Clair, demand fulfillment, with its emphasis on pulling material to order, is "the rocket science of the Dell supply chain system" (St. Clair, Interview of 5/24/01; 1/10/02).

A critical intermediate step, however, precedes this process of pulling materials into Dell's assembly factories. This step consists of storing and staging components in sufficient quantities so that they can actually be pulled into the assembly process on a just-in-time basis. This staging process focuses on planning and executing the movement of components between two of the primary nodes in Dell's network: 1) supplier factories located long distances from Dell assembly sites; and 2) supply logistics centers (SLCs) located in each of the six regional locales where Dell operates assembly plants.

This staging activity is essentially a system for collapsing distance between the location of component supplies, and the location of the assembly process. Such collapse of distance, in turn, plays a crucial role in enabling Dell to manage the compressed time cycles for pulling material into production on a just-in-time basis. In this way, physical proximity between supplies and assembly activity, and time compression in the just-in-time pull system are mutually reinforcing.

The reason why this staging process occupies a position of such centrality in the Dell network stems from geography. Long distances separate the locations where components are produced, and the locations of Dell's assembly sites. In Dell's just-in-time, build-to-order environment, there is simply no way of eliminating the friction of geography when distance separates sources of supply and the activity of assembling supplies into finished products. In effect, the storing and staging of supplies by Dell is a response to the problem of risk. The greatest risk faced by Dell in its business system is not only access to component supplies. The risk confronting Dell is access to supplies within specific parameters of time in a manner consistent with its build-to-order pull system. Consequently, what Dell is seeking through the staging and storing process is control over the risks it encounters in securing access to sources of supply. It is, in effect, an attempt to seek a substitute for inventory as a mitigation against the risk of access to component supplies.

Although numerous primary and second tier suppliers have established factories in the locations where Dell operates its assembly plants (see "Organization" and "Territorialization" below), a varying percentage of components at each assembly site -- sometimes most of the components at sites such as Ireland or Brazil -- are supplied from factories located at great distances from Dell's assembly centers. Such suppliers are required by Dell to operate through SLCs located adjacent to Dell's assembly sites. In these SLCs, component vendors store parts as inventory. In general, Dell requires parts suppliers to maintain ten working days or two weeks supply of inventory at SLCs (Cook, 6/14/01). Consequently, there *is* inventory in the procurement, production and distribution network of Dell although compared to other PC makers, this level of inventory is relatively small. As explained more fully below, however, it is component suppliers that are the bearers of these inventory costs.

The operational costs of the SLCs are assumed by suppliers and third party logistics providers (3PLs) as part of an emerging trend in supply chain management known as vendor managed inventory or VMI. Dell is one of the pioneering firms in this area. Third party logistics providers involved in VMI for Dell include BAX, Menlo Logistics, Ryder, IEC, and Eagle Logistics. Suppliers negotiate contracts for operation and management of supply logistics centers directly with 3PLs and pay what is called "pallet in/out charges" to 3PLs for storage of component inventory (Cook, Interview of 6/12/01). While Dell closely monitors the ability of 3PL-managed supply logistics centers to provide the required services to Dell factories, the operation of SLCs is conducted independently of Dell (Kelly, Interview of 5/4/01). Nevertheless, this relationship between Dell and the SLCs is far from what would qualify as a market transaction between independent agents. In Austin, for example, the SLC built by Dell and leased to

Eagle, is directly adjacent to the Morton Topfer Manufacturing Center where Dell assembles finished goods. Such an arrangement represents a strategy by Dell for simultaneously contracting out and passing certain costs onto other parties, while retaining necessary control over an essential element in its operation.

The staging process for the storage of inventory at SLCs begins when suppliers commit to the procurement order from Dell through the ValueChain portal. In making such commitments, suppliers take responsibility to position and store components in the Supply Logistics Centers if they do not have a factory adjacent to the Dell assembly site.[17] As part of their management contracts with Dell, Supply Logistics Centers are obligated to operate on the same Web-based i2 communications platform that Dell uses for global supply planning and demand fulfillment. In this way, SLCs are part of a three-way planning and fulfillment conversation taking place with Dell and suppliers on the same information infrastructure. Through ValueChain and the i2 tools, SLCs transmit information to Dell factories every hour on the ever-changing inventory of components storied in them and commit to material requests from Dell. At the same time, SLCs communicate with supplier factories on components needed to replenish inventories. The general principle of this replenishment system at SLCs is supply and demand balancing while the specific requirements hinge on ten days' supply.

As orders from customers are received from the Dell.com website or by phone, and as they are queued and cleared by the credit department, they are downloaded to factories every twenty seconds and simultaneously transformed into a matrix of material requirements (Hunter, Interview of 5/24/01). From this matrix of required components, the "Factory Planner" module of i2 creates a 2-hour production schedule that organizes the "kitting" of parts for assembly as per order, and a build schedule for orders in the 2-hour window. At the same time, the schedule from Factory Planner is converted to a different output within the i2 suite called "Rhythm Collaboration Planner" which sends an automated feed to the SLCs on the components needed in the Dell assembly site for the upcoming 2-hour build schedule. Third party logistics providers managing the SLCs are given 1.5 hours to deliver the required parts to the dock

[17] Suppliers that maintain factory operations in proximity to Dell assembly sites do not use the SLCs but are obligated to supply factory sites on the same replenishment schedules as the SLCs. The most notable supplier to Dell that does not participate in the SLC system is Intel, which uses its own logistics centers to ship to its customers.

at Dell's factory. It is because of this 1.5-hour window that proximity between Dell and supply logistics centers is so critical. Dell unloads these parts in thirty minutes. For the next two hours, assembly workers configure components into finished machines. The entire cycle from order clearance to finished product is four hours. Only when material is needed within a 2-hour period is it actually pulled into the Dell assembly site.

By pulling material to order over a Web-based communications infrastructure, Dell's demand fulfillment system represents an innovation with an enormous operations cost benefit for Dell. In the first place, because the dominant cost driver for Dell is the cost of goods procured externally from component producers, any advantage Dell can secure in terms of procurement costs will greatly affect its margins.[18] Dell pays prices to its suppliers for these components *after* they enter Dell assembly plants from the SLCs. In the interim time period between Dell's procurement order, and final delivery of parts to Dell following the staging of components in SLCs, suppliers assume the costs of falling component prices. Consequently, in an environment where the component costs are the primary drivers of total costs, and where the value of these components is falling over time at a rate of roughly 1% per week, Dell has an interest in securing these components at the last possible moment before they are assembled into finished machines. The SLC system enables Dell to accomplish this aim. When Dell assembles these components and ships the finished systems directly to the customer generally within 5-7 days, these components have a limited window of time in which to drop in value. The SLC system therefore provides a buffer to variability in demand and supply. It also shields Dell from the loss of value associated with PCs as perishable goods.

Furthermore, this pull material-to-order system represents a solution to one of the most intractable problems with a just-in-time, mass customization business model -- the problem of balancing customer choice and volume production with low levels of inventory. Even if the ten-day supply of components typically stored at SLCs is added to the inventory levels at Dell's own operations, inventory in the Dell network is extremely low compared to its competitors. According to one of Dell's largest suppliers that

[18] In fiscal year 2001 when Dell's total sales amounted to $32 billion, its material costs accounted for $26 billion, which emphasizes how small the gross margins are in the PC business.

also supplies other PC firms, Dell operates what is probably the most efficient supply chain and inventory system in the industry (Interview Supplier #1).[19] At the core of this balance in supply and demand is the transmission and processing of information from the customer, through Dell, and throughout the supply chain. "The Internet at Dell extends from our customers to our suppliers," observes Lance St. Clair. "The use of the Internet and e-commerce represent ultimate customer choice, and the ability to scale and deliver those choices to the customer without inventory" (St. Clair, Interview of 6/20/01; 2/10/02).

This highly innovative system for balancing supply and demand and reducing inventory, however, is not without contradictions and conflict. In a certain sense, Dell's mission with suppliers -- ensuring continuity of supply -- undercuts the aim in supply chain management, which is the reduction of inventory throughout the entire procurement and production process. "They [Dell] are much more focused on making sure they have continuity of supply than the other PC customers we serve," insists one of Dell's largest suppliers (Interview with Supplier # 2, July 2, 2002). This hedge against risk imposes certain limits on how far Dell is able to compress inventory levels in its build-to-order system. "It just isn't possible to make this a totally efficient world," concedes another of Dell's suppliers. "The way that Dell balances this contradiction is by passing the inventory problem to suppliers" (Interview with Supplier # 3, June 24, 2002). One of the outcomes of this emphasis on continuity of supply, however, is that component producers push their own suppliers for greater "asset velocity" meaning faster inventory turnover, thereby enhancing efficiency in the entire value chain, not just the efficiency for Dell. Nevertheless, Dell provides suppliers with very clear expectations on the levels of inventory required in SLCs, and when inventory passes to control and ownership of Dell.

How Dell has been able to assume this power in its relationships with suppliers, and create what is the most innovative and efficient procurement, production, and distribution network is the story of how the PC maker has fashioned a new type of business organization.

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[19] At the same time, however, this supplier also suggests that Dell's innovations in supply chain management are being copied by other PC makers. While these firms do not execute as well as Dell, this supplier insists that Dell's advantage in inventory management is narrowing (see "Diffusion" below).

Organization: The *Virtually*-Integrated Firm

When Dell began implementation of its global supply planning and demand fulfillment system, the PC maker faced a difficult problem with its component vendors. In order for its DSi2 innovation to function, it had to ensure that its suppliers adopt the same Web-based planning and execution system being developed by Dell. This requirement meant that firms aiming to supply Dell had to operate on the same communications platform as Dell and develop the same interactive capabilities on the Web and the same standards of interoperability with the PC maker (Radjou, Interview of 8/6/01).[20] Component vendors and logistics providers therefore had to make investments in their own information systems compatible with Dell's i2 system as a precondition to supplying and interacting with Dell. Such investment, however, was far more than a technological imperative. Convincing suppliers to operate on the same information and communications infrastructure as Dell, was a first step in creating a new type of business organization. Dell refers to the form of enterprise it has created from these technical and organizational imperatives, as the virtually integrated firm (Magreta, 1998).

The aim of Dell, in establishing such an organization and requiring suppliers to operate on this common Web-based communications platform, was to move away from market-oriented transactions for procurement, and toward interactions with parts vendors based on *relationships*.[21] Michael Dell describes this phenomenon as replacing "the traditional 'bid-buy' cycle, with a relationship based on communication and ongoing information sharing" (Dell and Fredman, 1999: 180). What Dell seeks to gain in replacing market-oriented bids for parts contracts by suppliers with transactions undertaken through relationships, is leverage over risk in its high-speed, Internet-driven procurement, production and distribution network.

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[20] In speaking of these requirements on suppliers to make technology investments compatible with the systems at Dell, CEO Michael Dell makes reference to the virtues of market power. "Dell in the U.S. is 50 percent larger than its nearest competitor and growing four times as fast," he says. "Suppliers have a choice: Supply Dell, or lose market share. Let's face reality. If my largest customer had a new requirement, I'd listen to them" (quoted in Perman, 2001).

[21] There is an extensive literature on the idea that relationships between economic actors are in fact the *precondition* rather than the outcome of market activity between such actors. See especially the pathbreaking article of Granovetter, (1985) as well as derivative pieces on trust by Sabel (1989; 1993). The early notion that the Internet and Internet commerce would eliminate the role of relationships in market transactions, and create more purely market-oriented interactions among firms, is contradicted by Dell. The Dell case reveals that in its build-to-order business model, relationships, not market-transactions, are more critical than ever.

Just as the mitigation of risk in component procurement is the aim of Dell's 10-day replenishment system of supply at SLCs, so too is the mitigation of supply disruptions in procurement the motivation for Dell to pursue relational, as opposed to market-based transactions with its parts vendors. Dell, in effect, has concluded that markets pose more risk of supply disruptions than relationship-based contracting. As a consequence, Dell is reticent to confront the risks of contracting with suppliers and logistics partners through the market and the price system. Virtual integration is thus an interfirm network responding to risk with a governance structure based upon non-market forms of administrative coordination.

In this sense, the reliance of Dell on administered relationships to link the adjacent operations in its network is similar to the dependence of vertically-integrated firms in the late nineteenth century on administrative controls to organize their procurement and production systems. In much the same way that vertical integration coupled with administrative planning represented a response to the risk of managing complex procurement, production and distribution systems without disruption, so too does the virtually-integrated enterprise of Dell confront similar types of risk by deploying similar control mechanisms. The difference is that whereas manufacturing firms in the early mass production age tended to exert such control through mechanisms of administrative planning in concert with ownership of assets, Dell exerts control through mechanisms of administrative planning in combination with assets owned by different firms. Although the asset structures of the two types of networks are different -- vertically-integrated firms invariably owned the assets in their network while Dell does not -- the forms of control through administrative planning, and the rejection of market-based interactions to accomplish operational objectives are fundamentally similar.

Thus, the idea that market forces are emerging as the mechanism of governance in interfirm production networks, is far removed from the experience of the virtually-integrated, interfirm network coordinated by Dell. While the proliferation of the interfirm network as an organizational phenomenon is undeniable in the current period, the virtually-integrated enterprise of Dell tells a far more revealing story about interfirm networking than the focus on its structural characteristics *per se*. The story of virtual integration pioneered by Dell is instead one of how power is exercised within networks of firms, and how the exercise of such power mobilizes resources within the network for innovation and profit. Not only are relationships of administrative control compatible with interfirm networks. Such non-market relationships, in the case of Dell, are essential in enabling these networks to function in an innovative way.

In this sense, the virtually integrated organization of Dell and the vertically integrated organization of the 19th century share fundamental control objectives not sustainable through markets. What has emerged from Dell's effort to replace market coordination with coordination by conscious control, is a new type of innovative interfirm business organization. This organization, however, is still one that relies on prerogatives of power for pursuit of profit and competitiveness.

This orientation toward functional integration with suppliers and logistics providers has resulted in the creation of a business model for interfirm Internet commerce with non-market characteristics that lies at the core of Dell's procurement system. This business-to-business form of Internet commerce, referred to by Dell as e-commerce, is far different than the market-oriented auction models used by other large manufacturing firms, and the Internet exchanges established by intermediaries such as VerticalNet or FreeMarkets.com for such large manufacturers (Chapter 5). In these auction and marketplace models, companies such as General Electric and Boeing, or Web intermediaries have used the Internet to expand the number of suppliers bidding on parts orders, in an effort to force suppliers into a race to the lowest price. The primary idea in these models, in effect, is to use Internet technology to broaden the number of participants bidding on supplies, and to use this enlarged base of competing firms to drive down procurement costs through pricing.

Dell, by contrast, has generally rejected this auction-like, free market approach to Internet commerce. While it has experimented with the FreeMarkets exchange for low volume, highly standardized supplies, its concerns about quality and ongoing capacity have precluded the PC maker from using Internet commerce as an auction mechanism for procurement of supplies. "Auctions and exchanges have fueled the thinking that price is everything," insists Richard Hunter, "but there is more to procurement of materials than just price" (quoted in Sheridan, 2001). Hunter goes on to comment how "strong relationships" that create "common processes" are also critical to driving down procurement costs. Instead of auctions, Dell has oriented its approach to commerce on the Internet toward establishing consciously coordinated relationships with the firms in its network. In using the Internet as the basis for these relationships, Dell has extended the idea of the closed loop with its customers, creating what in effect is an Internet-based closed loop with its suppliers. In this closed loop transactions, even over the Internet, occur not through arms-length, market-oriented interactions. Instead they take place on the basis of coordinated relationships that are the key to mobilizing resources from both outside and within the enterprise in the search for efficiency.

The relationship imperatives of virtual integration have had profound consequences on the supply base itself. In the first place, virtual integration, requiring such close collaboration with component producers, has forced Dell to consolidate its supply base, a trend that actually started in 1994. As a consequence, Dell, which at one time worked with over 200 first-tier suppliers, now has a core group of 30-35 primary suppliers. This small group provides close to 80% of the “material spend” for components used in Dell’s products (Hunter, Interview of 4/17/01). An additional twenty suppliers bring the total to roughly 95% of Dell’s raw material costs. This relatively small supply base, and the relationships stemming from it, are the foundations for the virtually-integrated organizational structure to which Dell aspires.

The power relationship between Dell and its suppliers and logistics partners, along with Internet technology play complementary roles in the establishment of this virtually-integrated organization. Dell has made it clear to its component vendors that if they want to supply Dell, they must submit to its technical requirements structured around the idea of virtual integration. “As a market leader in every aspect of the PC supply chain, Dell has the bargaining power to structure these supplier relationships in order to sustain its build to order model,” insists Nigel Johnson of the Eclipse Group, a supply chain management consultant in Silicon Valley (Johnson, Interview of 4/24/01). Component vendors themselves are candid in the way this system of relationship-building gets constructed. “Dell has a significant amount of power with its suppliers based on the current and future business levels they offer,” argues one of Dell’s large suppliers. “They know it and they use it.” Nevertheless, this supplier is quick to add that the pressure from Dell on continuity of supply enables it to push its own suppliers for greater velocity in the delivery of materials. Furthermore, Dell gives a clear accounting of what it expect from vendors. "One aspect that I like about Dell," says this supplier, "there is clear delineation on control and ownership [of inventory]." As a result, this vendor is able to supply Dell with greater velocity than other PC customers (Interview with Supplier # 2, July 2, 2002).

One important way that Dell has used its leverage in these supply chain relationships occurred in the aftermath of the Taiwan earthquake of 1997. As a result of supply disruptions with its Taiwanese vendors following this event, Dell initiated what it called the Supply Assurance Program. Its aim was to ensure that Dell would never be shut down by supply bottlenecks or shortages. Suppliers were obliged to endorse this program through agreements with Dell. "Dell dragged us over the coals to make certain that we knew about the risks in our own supply chain," admits one of Dell's suppliers, "but they did not impose upon us a set of best practices to correct it." Instead, this supplier worked with the vendors in its own supply chain to become more efficient. The outcome, however, was somewhat of a puzzle reflecting the at times divergent interests of Dell and its vendors. "As a result," concedes this supplier, "we actually increased our available inventory so that Dell's own supply chain system will not suffer even in an event as catastrophic as the Taiwan earthquake"(Interview with supplier # 3, July 24, 2002).

Perhaps the most obvious way that Dell has been able to prevail upon its supply base is the requirement on component producers to stock SLCs with ten days supply of inventory. According to a major supplier, "reduction in inventory levels at SLCs is the single biggest issue facing suppliers." This supplier insists that in the current period with the exception of Intel and Microsoft, "Dell's suppliers are bleeding." For this reason, components producers have been trying to negotiate with Dell to reduce the ten-day requirement to five days. "Dell has resisted," explains this supplier, "because they do not want the risk" (Interview with Supplier # 1, 4/26/02). In this regard, power and risk avoidance are complementary.

For Dell, relationships, crafted on the basis of power and planning, are the foundation of the virtually-integrated network enterprise. This form of organization seeks other firms to operate functionally as units of Dell's own operation. In this way, virtual integration aims at capturing the benefits of vertical integration -- control over the adjacent operations required to build, market, and support a product -- but without the asset requirements and expertise needed for such a comprehensive approach to competing. “We want to take advantage of the benefits deriving from vertical integration,” admits Richard Hunter, “but the problem with vertical integration is that we have to become experts at many different product and process technologies. We want those advantages at Dell, but we want them *virtually* through Internet communication” (Hunter, Interview of 5/24/01).

This form of organization, and the structures of control that enable it to function in an innovative way, have had profound impacts on the geography of Dell’s network.

Territorialization: Geography and the Dell Network

Forms of business organization are inherently spatial (Walker, 1988: 385). Business organizations create economic territory in the way they coordinate and manage the assets, activities, and actors within the networks in which they procure, produce, and sell. In this process of territorial formation, business organizations play two essential roles. They have a technical role in applying appropriate technology -- that is, ways of getting things done -- to coordinate spatially-dispersed operations in producing and selling a product. Business organizations also have a social role in coordinating interactions occurring over distance within and between firms that are integral in this process of producing and selling. Business organizations therefore create economic territory by managing the technical and social forces that connect the facilities, processes, and actors involved in producing and selling.

In managing these technical processes and social entities, Dell has fashioned an organization with a geography emerging from three basic sources. On the one hand, this geography derives from the locations of the principal network *nodes,* and the territorial configuration of these assets. Secondly, Dell’s organization assumes its geographical character from the *flows* of product and information circulating between these facilities, and the territorial routes created by the patterns of these operational activities. Thirdly, this geography consists of the organizational *relationships* and relations of *power* between Dell and the firms in its virtually integrated enterprise. Such relationships determine how assets are distributed across space, and how they operate in the spaces where they are distributed.

Dell's innovations in global supply planning and demand fulfillment have enabled the Company to reconfigure the geography of its production network in three fundamental ways.

Firstly, Internet communication has provided Dell with a more centralized form of control not only over global supply planning, but also over the execution of fulfillment activities across its regionally decentralized network. What has resulted from this more centralized form of control is a more standardized set of fulfillment systems at each of the locations where Dell concentrates its operations. The Company has created what it calls a "copy-exact approach" of the pull-material-to-order system in each of its regional locations (Cook, Interview of 6/14/01). This "copy-exact" approach standardizes the logistics of the Dell fulfillment system across space.

Secondly, far from diminishing barriers of distance in procurement and production, the Internet-driven planning and execution systems created by Dell have intensified the need for certain relationships of spatial proximity between nodes in Dell's network. Thus, while Internet communication has provided Dell with an infrastructure for managing the logistics of planning and execution in its globally-spread procurement, production and distribution system, the velocity requirements, and the supply and demand balancing requirements of its Web-driven business model have placed an even greater premium on proximity between Dell and its suppliers and logistics partners. Such relationships are what enable the PC maker to manage the flows of materials in its just-in-time, pull material-to-order business system.

Thirdly, Dell has assumed an active role in shaping the geography of its network by influencing the location decisions of its network partners. The PC maker has prevailed upon firms in its network to establish operations -- either factories, or more commonly the replenishment operations of supply logistics centers -- adjacent to the locations where it has chosen to organize its just-in-time, custom-build assembly activity. By controlling the locations of its network partners, and by configuring relationships of proximity in these locales, Dell has actually shaped its own place-based external economies of scale. As it creates these external economies and reshapes local landscapes where the key nodes in its network operate, Dell is helping fashion the industrial districts of contemporary globalization in which tendencies of geographical spread and spatial concentration co-exist (Storper, 1997).

The Geography of Assembly

The locations of Dell's assembly facilities are the primary drivers of the global and regional geography in Dell's production network. The six assembly plants in the network are spread across the four continents of North America, South America, Europe and Asia. Generally, each facility configures products for customers in a specific geographical area. These areas approximate the division of the world by Dell into four market regions: 1) the Americas (both North and South); 2) Europe (which encompasses Africa and the Middle East); 3) China; and 4) Asia-Pacific. Assembly sites in Austin and Nashville service customers in North America. Eldorado do Sul in Brazil is responsible for South American customers. The facility in Limerick, Ireland builds PCs for Europe, Africa, and the Middle East. Xiamen, located directly across the strait from Taiwan, services China while the Asia Pacific assembly center in Penang, Malaysia services the rest of Asia. Customer orders are automatically routed over the Web to the configuration center that services the region where the customer is located. In this way, the assembly sites of Dell are global in their geographical reach, and regionally decentralized.

The locations chosen by Dell for expanding assembly operations beyond the Company's origins in Austin, reveal a pattern with several common themes.

The most important characteristic of the expansion sites in Limerick, Penang, Xiamen, and Eldorado do Sul, is that all of these places possessed *existing* concentrations of computer-related firms resulting in large part from government policy. Penang, Malaysia, is perhaps the best example of this phenomenon.

MAP VI-II

Penang was the beneficiary of government policy in the late 1960s to attract foreign transnational corporations to Malaysia through a program of high technology targeting supported by the creation of "Free Trade Zones." By the early 1970s, Penang emerged as a top electronics-producing region in Malaysia. Intel, AMD, Motorola, National Semiconductor, Siemens, and Hewlett Packard established operations in Penang's Bayan Lepas Free Trade Zone during this period that created employment for 12,000 workers in Penang in 1971-72 (Kahaner, 1996). During the 1980s, a second wave of investment, this time including Japanese and Taiwanese firms, made Penang one of the most important centers of the electronics industry in Asia (Rasiah, 2000). By 1992, Penang had over 76,000 electronics workers with semiconductors and disk drives the most important industry sectors (Kahaner, 1996). When Dell began operations in Penang in 1995-96, the city-region had close to 100,000 employees in 148 electronics factories (Kahaner, 1996; Penang Development Corporation). Dell was now part of a computer-related cluster of companies many of which were major suppliers to Dell such as Acer, Iomega, Komag, Seagate, Quantum, and Sony. This pattern, similar in Dell's other chosen locations, reveals the importance of pre-existing concentrations of electronics firms, including suppliers, in influencing the location decision of Dell.

In this sense, the locations selected by Dell conform broadly to the preferences of firms for proximity to other firms in the same industry. First observed systematically by Alfred Marshall, these agglomeration economies include access to specialized suppliers, a "constant market for skill," and an environment enabling the spillover of technical knowledge (Marshall, 1890: 267-277). Such external economies of scale are now commonly attributed as drivers of high technology concentrations.

Yet, while Dell has taken advantage of existing agglomeration economies in these locations, it has also contributed in recasting these places as high technology concentrations by its own location decisions. In this sense, the location pattern of Dell exhibits what has been described as *cumulative causation*, or similarly, historical *path dependence*.[22] In Limerick, for example, Dell began operations in 1992 with 184 employees. At the beginning of 2001, however, Dell employed 5000 workers at its

[22] On cumulative causation see especially Myrdal (1957) and Hirschman (1958), while on path dependence as it relates to industrial location see especially Arthur (1988). The similarity in these theories derives from the fact that both attribute location decisions in the present to the agglomerations inherited from the past.

Limerick complex. This figure made Dell one of the largest high technology employers in the Limerick region.[23] Through such location choices, however, Dell has not only reinforced the high technology character of these places. In bringing its pull-to-order business model to the Limerick region, it has succeeded in configuring a new set of activities upon the local landscape and in the process, changing the nature of the place itself.

A second characteristic of Dell's location pattern focuses on direct incentives. While Dell receives certain indirect benefits from the external economies where it has established its assembly locations, the PC maker has successfully secured a variety of financial incentives from government in each of its assembly locations outside the U.S. According to the PC maker along with local development officials, such incentives played a role in influencing its location decision (Robertson, Interview of 6/27/01; Wong, Interview of 5/24/01; Tobin, Interview of 2/6/01). In the case of Penang and Xiamen, Dell operates in government-created incentive zones, which provide the PC maker with exemptions from import and export taxes along with other material benefits.[24] In the case of Limerick and Eldorado, Dell has similarly managed to secure incentives from local, regional, and even national authorities. Nevertheless, as is generally the case with such programs, it is inconclusive whether such incentives actually influence location decisions, or whether companies make such decisions on the basis of other factors and then simply collect what government offers.

Another characteristic of these locations is that while they all represent formidable concentrations of electronics firms, within this category they all share features as the world's "Second Tier" of high technology cities (Markusen et al., 1999). With the possible exception of Penang, these cities are one level below the concentrations of high technology found in places such as Silicon Valley, Boston, Singapore, or the area around Taipei. Dell is part of this growth trend that is extending electronics development to selected places outside of these first tier electronics concentrations in creating newer high technology industrial districts.

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[23] Employment figures for Dell Limerick furnished to the author by representatives of the Shannon Development Corporation, and the Limerick Development Corporation.

[24] The Bayan Lepas Free Trade Zone in Penang emerged from the Free Trade Zone Act of 1971 while Xiamen was one of four Special Economic Zones (SEZs) along with Shenzhen, Shuhai, and Shantou created by China in 1979.

Finally, Dell has shown a preference for locations near its most critical material supplier, Intel. The world's largest semiconductor manufacturer operates a production, testing, and supply center in Penang roughly five minutes drive from Dell's facility. Intel also operates similar facilities in Ireland and China, with relatively easy access to Dell's configuration centers there. This pattern conforms to Dell's preoccupation with avoiding supply disruptions, and using proximity as a remedy for such risk.

Dell, in effect, has taken advantage of existing high technology concentrations in making location decisions for its assembly operations. Its locations also reveal an effort to maintain physical proximity to its most critical material supplier, Intel. In following these trends, Dell itself has emerged as an actor in reshaping the agglomeration economies where it has located into the world's new generation of high technology industrial districts. This role of Dell in reshaping the places where it assembles PCs is more readily apparent in the way it participates in the geography of supply.

The Geography of Supply

In addition to assembly sites, Dell's network also assumes its territorial configuration of spread and concentration from a geography of supply. This geography derives from the interplay of two sources. Firstly, Dell's geography of supply is a product of historically conditioned, but constantly evolving location choices of supplier firms in siting their factories for component production. Secondly, this geography is the result of the decision-making power exercised by Dell to influence the locations of supplier facilities in order to optimize advantages of physical proximity in its build-to-order production system. The interplay of these two sources producing this geography is one of structure and agency in which Dell is the agent reshaping a structure to accommodate its operational objectives.

Supplier factories creating this structure are spread throughout the world but have distinct geographical concentrations. East Asia, Mexico, and the U.S. are the largest concentrations where components are produced.[25] Suppliers from these areas are themselves frequently part of subcontracting

[25] Recently, Dell, motivated primarily by a search for lower costs, has started to procure an expanding share of low-end components from Eastern Europe produced by electronics firms operating in the Czech Republic and Hungary, (Williams, Interview of 8/30/01).

relationships in which the lead supplier firm, and the firm (or firms) actually producing the components or subassemblies of the components, are different entities based in different countries. This phenomenon of cross border production networks is common across a range of different PC supplies (Cohen and Borrus, 1997; Borrus et al., 2000; Saxenian, 1999). It includes highly standardized components such as disk drives, to semiconductors in which chipmakers in Silicon Valley typically subcontract fabrication and assembly to chip foundries in Taiwan who in turn, subcontract portions of this work to other specialty firms in different parts of Asia, or increasingly China or even to their own subsidiaries in these areas. These networks of ever-shifting contracting relationships reflect the influence of two major trends.

On the one hand, this phenomenon of networking in which work gets subcontracted and disperses to other locations, reveals the impact of what is called the "product cycle." Originally developed by the economist, Simon Kuznets (1930) to explain business cycles, product cycle theory insists that the life of products passes through stages. This focus on stages was later given a more geographical orientation by Raymond Vernon (1966) and Ann Markusen (1985), who argued that stages in the life of products correspond to shifts in the location where such goods are produced. As products mature and become more standardized, production requirements for such goods become more routine. In this process of maturation and standardization, the production skills of firms from areas formerly unable to produce such goods, eventually match the more easily-mastered production requirements of goods in the more mature phase. What differentiates these newer entrants, however, is their low wage and low cost structure. As a consequence, firms originally making such products, subcontract production to these newer firms outside the location of origin to take advantage of their low costs. [26] Thus, from product cycle theory, the geographical spread of firms producing PC components in network-like subcontracting relationships reflects an evolutionary stage in the development of the PC. As the components of the PC assume standardized formats, production of these goods is able to spread to lower wage producers.

[26] Markusen makes an original contribution to product cycle theory by shifting the argument to declining *profit* margins as the product becomes standardized to account for spatial dispersion. This insight on "profit cycles" is particularly appropriate in describing the PC industry.

On the other hand, however, there is a second major variant of this story about contracting and networking that supplements the emphasis in product cycle theory on low wages and geographical spread. This second approach shifts the focus from costs to capabilities. In this approach, cross border networks of companies and subcontracting aim at exploiting a diverse array of technological knowledge that is spreading outside the U.S. At the same time, these networks are taking advantage of increasingly specialized skills and technical knowledge that are concentrating within and among particular firms located in specific geographical localities (Borrus et al., 2000: 2; Saxenian, 1999). From this perspective, the geography of supply associated with subcontracting relationships is marked by the spread of capabilities to a new generation of firms that concentrate into new skill-based and knowledge-based regions. The process is one of creating new high technology industrial districts.

In effect, both product cycle theory and cross border production network theory provide essential pieces of the story driving the pattern of spread and concentration in the geography of supply. One piece focuses on the search for low costs; the other focuses on the search for skill. The geography of Dell's supplier network is part of this dual phenomenon. This search by Dell for costs and skills is what has given its supplier network its structural focus on the three primary regional nodes in East Asia, Mexico and the U.S.

Within East Asia, firms in Taiwan, Singapore, Malaysia, Korea, Japan, and China supply most of Dell's components. The companies producing components for Dell in these places are Asian firms such as the Taiwanese firms of Compal, Quanta, and Acer, and the South Korean firm of Samsung. Asian firms producing for Dell also include such companies as Taiwan Semiconductor Manufacturing Company (TSMC) that is the primary foundry for Dell's graphic chip supplier, NVIDIA. Dell's suppliers in this region are also the East Asian subsidiaries of mostly-American, but also Japanese, European and now increasingly Taiwanese-based transnational electronics producers. Because of the standardization and modularity of the components in the PC, all of these companies are resorting to outsourcing PC component production to low wage areas. In this process of migration to lower cost areas, Malaysia and especially China are emerging as the locations of choice for fabrication of PC components.

In addition to the East Asia region, the border area of Mexico is also an important center where production of components takes place. Invariably the same firms outsourcing production from subsidiaries in Asia are also sourcing production for PC components from their own border operations in Mexico. The Japanese firm Sony, for example, makes flat panel displays for Dell at its Malaysian subsidiary while also supplying Dell from a plant in Mexico. Samsung of Korea supplies Dell's LCD monitors by outsourcing from the same locations.

The U.S. is notable as the primary location for the two firms producing the two most critical components of the PC, the operating software supplied by Microsoft, and the microprocessor and related semiconductor components supplied by Intel. Microsoft is in many ways a special case not only because of the dominant control it exerts over the operating software, but also because it is not really a material supplier. What it supplies Dell is intellectual, rather than material property. Intel, in this sense, is far different since the intellectual property it produces is embedded in a physical product. Most design, development, and wafer production of Intel chips occurs at facilities in the U.S. A significant amount of this same work, however, occurs outside the U.S. in Malaysia, Israel and Ireland. Low-wage assembly and testing is often subcontracted by Intel to firms such as ASE of Taiwan which in turn, sources some of its work from facilities in Penang, Malaysia and increasingly, Shenzhen, China. In this way, chip production is a prime example of networking and subcontracting.

Alongside this structural pattern in the geography of Dell's supply base, however, is the role played by Dell in shaping the location behavior of its component vendors to accommodate its requirements for proximity to sources of supply for its build-to-order system.

In much the same way that Dell compelled its vendors to operate on the same Web-driven i2 information platform, so too has the PC maker elevated "location" as a condition for entry into its supply network. This process has taken two forms. On the one hand, as noted above, Dell has compelled suppliers to operate through the SLC system (see above) which is the approach generally taken by Dell to address the need for proximity in its business model. Nevertheless, Dell has supplemented this approach by convincing certain suppliers to locate factory operations in the locations of its assembly plants. In pursuing this strategy, the Company approached a number of its primary suppliers and requested that they service Dell in each of its regional assembly locations.[27] In Penang, for example, Dell prevailed upon two of its contract manufacturers for motherboards, SCI and Jabil Circuit, to set up factory operations close to the Dell assembly facility (Wong, Interview of 10/2/01). While it may be that suppliers have good reason to establish operations close to Dell, and may very well follow Dell in these locations to benefit from the same economies of proximity, it is also true, as Michael Dell reveals, that suppliers and Dell engage in "discussion" about such location decisions. In this way, at the very least, structure *and* agency -- the objective forces pulling suppliers toward Dell, and the actions taken by Dell to encourage such movement -- are factors in accounting for the decisions of suppliers to locate near Dell. Consequently, whether forcing suppliers to operate through SLCs, or compelling vendors to establish factory sites near Dell assembly centers, the motivation for Dell is the same. It is to use proximity as a solution to the logistical challenges of material balancing in its just-in-time, pull system of production, and as a remedy for the risks of supply disruptions. Dell's assembly sites and these supply sites, both factories and SLCs, are thus linked organizationally, technologically, and spatially. On the basis of these linkages, Dell has actually created more heavily concentrated bases of supply where it assembles PCs.[28]

Where Dell is surrounding itself with suppliers and supply hubs, and organizing specific types of relationships between these entities and its assembly operations, it is playing a role in transforming the economic geography of those places. The PC maker is creating a set of fundamentally similar production complexes across space. "All of these factory complexes are set up much the same way," says a Dell senior manager of global supply chain strategies. "We want consistency across the globe." As it standardizes the logistics of the fulfillment system in each of these places, the copy-exact approach used by Dell for its pull material to order model creates roughly equivalent spatial arrangements between

[27] Michael Dell describes how the PC maker went to its suppliers insisting they develop "the capability to service Dell around the world." According to Dell, this insistence worked. "A vendor who started with us in Ireland knew we were building a manufacturing center in Malaysia, so it set up a plant next to our plant in Penang and then another in China. When we decided to expand operations in Round Rock, Texas, the same company added a plant there. Next stop: Brazil" (Quoted in Dell and Fredman, 1999: 178).

[28] The extent to which Dell is able to draw on supplies produced locally, however, varies in each location. In Penang, local suppliers provide roughly 70% of Dell's component needs while in Limerick and Eldorado, Brazil the percentage is much lower ranging from 25 to 50 percent.

supplier facilities and assembly complexes. According to Daryl Robertson, Vice President of Dell Latin America and General Manager of Dell in Brazil: "We execute the same business model everywhere. It's like McDonalds. While there is some local customization of production systems, we want to offer the same basic menu of products and services to our customers worldwide" (Robertson, Interview of 6/27/2001; Interview of 3/12/2002). In employing this "McDonald's type" approach, Dell is creating a factory system that is reinforcing the idea of globalization as an essentially homogenizing force. It is creating these uniform places as part of a pattern of spread and concentration. As the PC maker selects locations around the globe for nodes in its network to cluster, and as it organizes the operations of these facilities within its locations of choice, Dell has assumed the role of agent in crafting the territorial features of the contemporary regional economic world.

MAP VI-III

Diffusion of Dell's Production Network

The efficiencies of Dell's Internet-driven business model and production network have driven other firms in the PC industry into a pattern of imitation that Schumpeter characterized as the second element in the innovation process, the element of *adaptive* response (chapter 2). This adaptive response of firms to the business models of more innovative companies is what actually completes the transformation of entire industries and entire economies, and is part of what Schumpeter described as "creative destruction." Together, the creative response of innovative firms, and adaptive imitation by competitors, are what drive the development of economies. There are few better contemporary examples of this innovation and diffusion process than the impact of Dell Computer on the personal computer industry.

Dell's Final Ascent

The motivation for this process of imitation derived from Dell's ascent to the very top rank of the PC industry while at the same time, Dell's Internet-driven business system provided competitors with a model to emulate. From 1996-2000, Dell's growth rate in units shipped was as much as four times the industry average and far exceeded Compaq, its principle competitor (Table VI-11). As the largest firm in the industry during this period, Compaq had good reason to be especially wary of Dell although all PC firms were compelled to respond to Dell's efficiency advantages (Kirkpatrick, Feb.17, 1997; Kirkpatrick, Sept. 8, 1997; Aragon, July 20, 1998). As a $2.9 billion company in 1994, Dell was a respectable competitor. As Dell began its seemingly irrepressible rise from 1994-2001, however, every action of the Company, from Internet selling to reorganization of the entire procurement, production and distribution system, became a source of intense scrutiny by the rest of the industry.[29] Other firms began to experiment with elements of Dell's business model. This adaptive process of experimentation began to reshape the PC industry much in Dell's own image and likeness.

[29] "Now Everyone in PCs Wants to Be Like Mike: Michael Dell, That is" (Kirkpatrick, Sept. 8, 1997).

Table VI -10

% Increases in PC Shipments
(Year on Year)

Firm	96-97	97-98	98-99	99-00
Dell	**62%**	**65%**	**51%**	**27%**
Compaq	42%	21%	17%	8%
PC Industry	16%	15%	22%	15%

Source: IDC Press Release January, 2001.
Gartner Dataquest Press releases.

Table VI -11

Computer Firms
Ranked by U.S. Market Share (2001)

Rank	Firm	% World Share	% U.S. Share
1	**Dell**	**13.4%**	**24.0%**
2	Compaq	12.1%	12.7%
3	Hewlett Packard	6.9%	9.4%
4	Gateway	3.2%	7.6%
5	IBM	7.2%	6.1%
6	Apple	4.1%	4.8%

Source: IDC Press Release July 30, 2001.

In Dell's Own Image and Likeness

The adaptive response of firms to Dell had two primary components. The first component of this response was Internet selling. Almost two years after Dell began to sell its PCs over the Internet, Compaq, IBM, and HP also initiated Web sales of personal computers directly to customers, although unlike Dell, the initial target market for this effort was primarily consumer sales. A steady stream of press releases in 1998 along with print ads in major media, especially from Compaq and IBM, announced this Internet sales effort.

While it is true that the phenomenon of Internet selling was pushing firms throughout the economy to experiment with Internet-generated sales, it is difficult to imagine that these firms were oblivious to the success of Dell's Internet sales and were therefore being driven into emulating, at least in part, aspects of the Company's Internet-driven business model.

Nevertheless, Internet sales posed an almost intractable dilemma for competitors of Dell that sold systems through the indirect channel (Kenny and Curry: 2000a: 19). By marketing PC systems directly to customers over the Internet, Compaq and other purveyors of the indirect sales channel would be in direct competition with the very distributors and resellers upon whom they depended for the overwhelming bulk of their sales. This contradiction lies at the core of Compaq's problem in trying to develop an Internet direct system of sales. When in 1998 Compaq made one of its frequent announcements of plans to sell direct to some of its corporate accounts, and direct through the Web to consumers, its channel partners, grasping the contradictory position of Compaq in direct selling, reacted with both hostility and skepticism. While Compaq's resellers were unreceptive to the idea, at the same time, consensus among them was that Compaq would be forced "to sell 100 percent through the channel" (Hayes and Connolly, 1998). Alternatively, Compaq and the other indirect firms could continue to avoid the Internet as a sales channel. Realistically, however, they could not simply allow Dell to dominate Internet sales and gain market share at their expense. As a result, Compaq, HP, and IBM in 1997-98 began cautious approaches to Internet selling.

What these firms did initiate as part of this Internet orientation that was more far-reaching, was to combine Internet sales with a build-to-order business model. Although inspired by Dell, this build-to-order business model was different from that pioneered by Dell. It was created specifically for the indirect channel. This new custom build system was called *channel assembly*.

Channel assembly represented a joint effort by indirect PC firms and their largest distributors such as Ingram Micro and Tech Data, to respond to Dell by developing their own "pull" system for assembling PC systems.[30] This response was essentially a compromise aimed at enabling indirect vendors to adopt an Internet selling system without alienating their channel partners. In the traditional indirect selling system, assemblers such as Compaq would make as many computers as their demand forecasts projected, and ship them to distributors for final marketing. They would then hope that the forecasts were accurate and the distributors would be able to sell them. In this indirect system, distributors, although serving as the customers of the PC makers, had a potentially antagonistic relationship with the PC firms. Ownership rights to the end user were often zealously guarded by distributors and resellers. As a result, PC makers and their indirect distributors maintained more of a market relationship with the other.

Channel assembly aimed to change this process firstly by creating a different type of relationship between the PC maker and the distributor, and secondly by dividing the assembly of the PC into two phases (Kenney and Curry, 2000a: 22). In the first phase, the components of the PC box that decreased in value more slowly than the other parts would be assembled by the PC firm. During the second phase, the components most susceptible to price decline -- DRAMS, microprocessors, and hard disk drives -- would be added to the box by the distributors when orders were actually received.

Examples of the program at IBM and Compaq reveal how the influence of Dell has shaped the industry. IBM initiated its Authorized Assembler Program (AAP) in 1997. Perhaps not surprisingly, it recruited an executive from Dell, Steve Martson, to manage the program. Compaq began the Configuration Partner Program of its Optimized Distribution Model (ODM) during the same year. As part of this program, Compaq, for example, reduced the number of its primary distribution partners in the U.S. from thirty-nine to just four (Kenney and Curry, 2000a: 23). The motivation for this reduction was to work better with fewer channel partners.

These changes in the indirect system of assembly, and the accompanying shifts in the relationships between PC makers and distributors, resulted in systems of procurement, production and distribution with geographical consequences that in many ways resembled the network geography of Dell.

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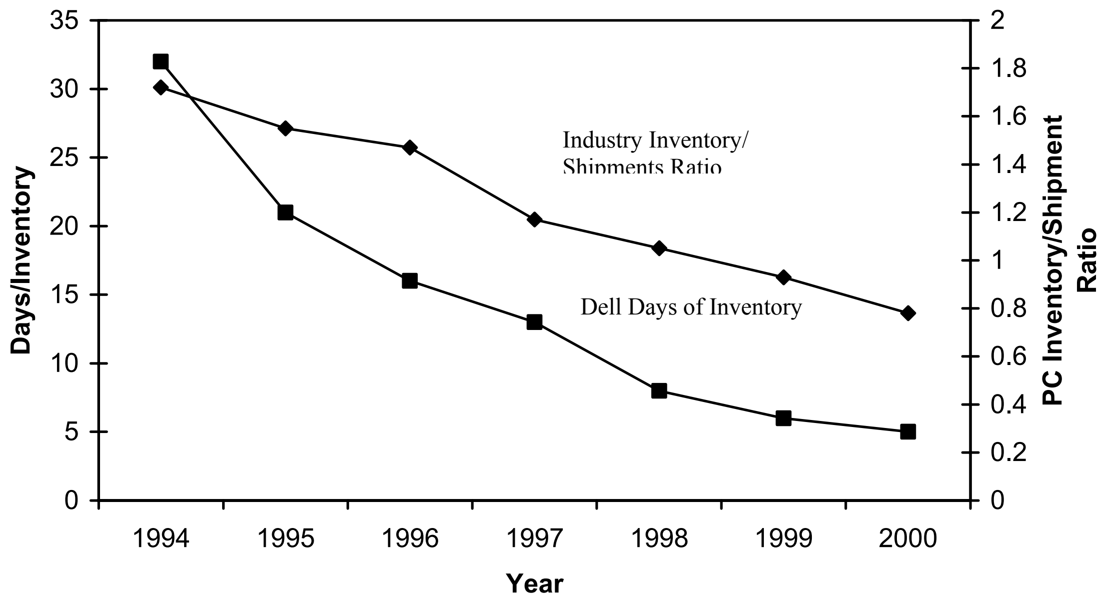
30 "In my experience," says Tony Ibarguen, president of distributor Tech Data Corp., "we've never had a rallying cry like the one we've had in the past year on supply chain costs that was motivated by Dell's success" (Quoted in Aragon, July 20, 1998).

In the first place, channel assembly resulted in distributors establishing final configuration centers adjacent to the factory locations of PC makers in a program known as *co-location.* In this way, PCs assembled during the first phase of channel assembly by the personal computer maker could be more easily and more quickly transported to distributors for the second and final phase of the custom configuration. Secondly, the PC firms have essentially imitated Dell's model of having components stored as inventory in warehouses located adjacent to configuration centers. "All of the major PC makers have followed Dell in using the SLC system of storing parts next to assembly facilities," says one of Dell's suppliers that also supplies other firms (Supplier # 1, Interview of April 26, 2002). IBM has compelled its suppliers to establish replenishment services centers (RSCs) near the IBM's fulfillment centers. These RSCs, much like the supply logistics centers (SLCs) of Dell, are either individually owned or leased by suppliers, or managed by third party logistics providers. Similarly, Compaq is using third party logistics provider, CSX in Houston to operate and manage a parts warehouse next to Compaq's main campus. In effect, just as proximity emerged as a critical strategic element in Dell's business system, so too has proximity emerged as an essential element in the evolving business systems of Dell's competitors.

These changes did indeed make PC firms more efficient. Inventory levels throughout the industry assumed a downward trend similar to the trend at industry leader, Dell.

Chart VI-3
Inventory of Dell and Inventory/Shipments Ratio of PC Industry



Source: Dell Computer Corporation, 10-K Reports various years; Compaq Computer, 10K Reports various years; Robert Cihra, The PC Industry, ING Barings Furman Selz, 1998; U.S. Department of Commerce, Office of Information Technologies *Computer Industry Indicators: 1992-2000.*

Data for Chart VI-3

	1994	1995	1996	1997	1998	1999	2000
# Days Supply of Inventory @ Dell Computer	32	21	16	13	8	6	5
PC Industry Inventory / Shipment Ratio	1.72	1.55	1.47	1.17	1.05	0.93	0.78

Source: Dell Computer Corporation, 10-K Reports various years; U.S. Department of Commerce, Office of Information Technologies *Computer Industry Indicators: 1992-2000.*

These levels of inventory reduction and enhancement of efficiency throughout the industry -- improvements driven fundamentally by Dell -- have also contributed to a much steeper series of prices declines for computers during the Internet period. Again, Dell as the most efficient and most dominant firm in the industry has played a critical role as the so-called "King of Cutthroat Pricing," in helping drive this trend (Business Week, Sept. 24, 2001: 92). From the second quarter of 1987 until the third quarter of 1994 price declines for computers revealed a trend of a 12.1 percent decline annually. By contrast, from the fourth quarter of 1994 through the fourth quarter of 1999 the trend decline for computers was more than twice as rapid amounting to 26.2 percent (Department of Commerce, 2000: 2).

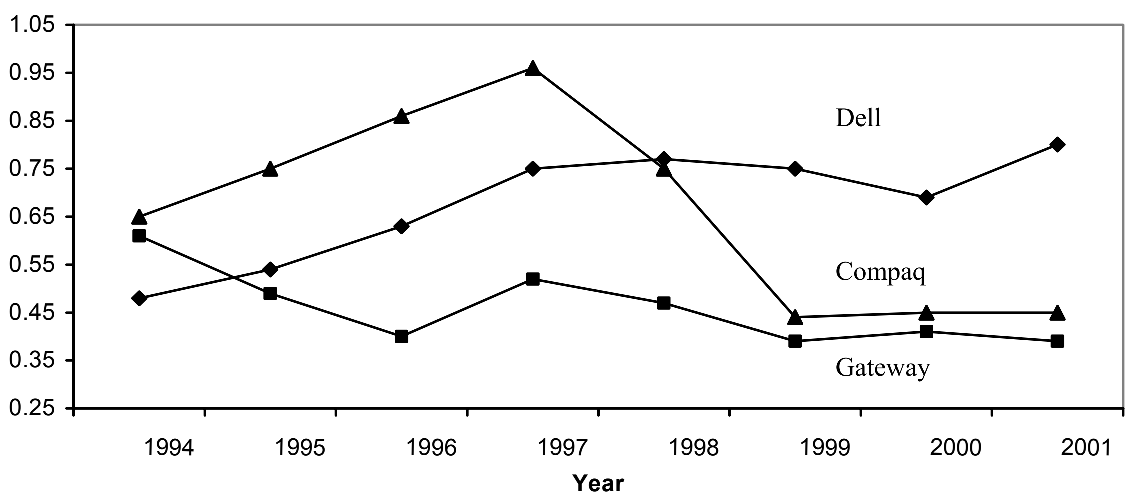
Chart VI-4

Price Declines of Computers

(Log Scale: Index 1987 = 100)

Nevertheless, as the rest of the industry tries to follow what Dell has accomplished, these firms are not always equally successful in duplicating Dell's results. Many of these other PC companies, in experimenting with new strategies such as channel assembly in the case of IBM and Compaq, or even complementing a direct sales model with retail stores as is the case with Gateway, have encountered new and perhaps unanticipated difficulties. In the first place, these firms face ongoing challenges in grafting elements of Dell's Internet direct model onto their own existing business models. In the parlance of the industry, Dell's competitors face the problems associated with the "legacies" of their own business systems. Secondly, and perhaps more importantly, none of these firms appear to have the same capacity for execution of the Dell system as Dell itself. As a consequence, while Dell has forced its competitors into a process of adaptive response, it has retained decided competitive advantages over these firms. Although they now more closely resemble Dell, they are not necessarily as efficient, productive or competitive as Dell.

Chart VI-5
Productivity Index During Internet Period*



*   Measured by sales per employee
Source: Hoovers Online Company Profiles

Data for Chart VI-5*

	1994	1995	1996	1997	1998	1999	2000	2001
Dell	.48	.54	.63	.75	.77	.75	.69	.80
Gateway	.61	.49	.40	.52	.47	.39	.41	.39
Compaq	.65	.75	.86	.96	.75	.44	.45	.45

* Measured by sales per employee
Source: Hoovers Online Company Profiles

Dell, in effect, has forced competitors such as IBM and Compaq to overhaul the procurement and production logistics of a once-dominant producing and selling system. Through its competitive ascent, it has imposed its standards upon an entire industry. In the process, Dell has forced the industry to change. It has succeeded in defining the terms of competition in the personal computer industry, reinforcing the shift in those terms away from the product, and toward the issue of costs and systems of logistics. Although these changes have resulted in the entire industry becoming more efficient, such transformations have enabled Dell, as the most efficient company, to emerge as the most competitive. Indeed, it is hardly an exaggeration to say that Dell has succeeded in remaking the PC industry in its own image and likeness. Others are trying to find ways to catch up.

APPENDIX

INTERVIEWS AND INTERVIEWEES

Access to interview subjects for this project occurred in two ways. In the first place, I assembled an informal network of individuals in the journalistic and business world who provided me with referrals to specific Dell individuals. Secondly I employed an approach inspired by Dell itself. I went *direct*.

From journalistic and business literature on Dell, I assembled a list of interview subjects relevant to the issue areas of my project. I then contacted these individuals through email and explained what I was trying to do. Most of these individuals were extremely interested in trying to help me understand the Dell business system.

From these contacts, interviews for this project assumed three forms: 1) Face-to-face, 2) phone, and 3) email. I also toured first-hand the Morton Topfer manufacturing facility and the supply logistics center adjacent to this facility in Austin.

There was no set questionnaire for the interviews. As I learned more about the Dell business model over the course of the interview process, which lasted roughly eight months, my questions evolved and changed. In putting the Dell story together while conducting these interviews, I asked questions about particular elements as they emerged in my analysis. The goal was to get a sufficient amount of first-hand information to create a coherent story of how the Company operates what is arguably the most innovative production and distribution network in the industry.

Dell Interviewees

Lance St. Clair, Director of Supply Chain and Materials Management Systems

Stephen Cook, AFC Senior Process Engineering Manager

Richard L. Hunter, Vice President, Americas Manufacturing and Supply Chain Management

Laury Johnson, Senior Manager, Logistics, Compliance and Procurement, Dell Brazil

Gregory Kelly, Senior Manger, Dell Nashville Materials and Logistics

Victor Koncaba, Senior Logistics Manager and Information Systems Architect

Eric Michlowitz, Director of Supply Chain e-business

Dan O'Donnell, Procurement Manager, Dell Europe

Daryl Robertson, Vice President and General Manager, Dell Latin America

Rosan Sison, General Manager, Dell Philipines

Anna Belle Williams, Senior Manager, Worldwide Procurement

Simon Wong, General Manager, Dell Asia Pacific

Senior Logistics Manager for the Americas

Inbound Supply Chain Manager

Former Dell Executive

Other Interviewees

Robert Cihra, ING Barings

Nigel Johnson, Eclipse Group (now with Brocade Communications)

Robert Persuit, SJ Consulting

Navi Radjou, Forrester Research

Richard Tobin, Limerick Corporation

Interview with Supplier firm #1

Interview with Supplier firm # 2

Interview with Supplier firm # 3