Future Value Chains in the Computer Hardware Industry

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Abstract

Companies in the computer hardware industry can benefit by incorporating future business scenarios in their present decision-making processes. Any decision regarding strategic supply chain design is one such area where long-range planning can especially help. This is primarily because investments in new supply chains have a long return period, which also influence the chances of future success of a company. However, developing such long-range views of the whole industry is a challenging task, because of inherent uncertainties of the future and rapid changes in the computer industry itself. This paper takes a step towards achieving this goal by introducing several frameworks for the development of future scenarios and their analysis.

Thesis Supervisor: Dr. Larry Lapide
Title: Research Director, MIT Center for Transportation and Logistics

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To my beloved parents, Gour and Swapna Roy, and my loving wife, Kajal

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1 Introduction

The paper develops future scenarios of the computer industry and analyzes emerging competitive dynamics and supply chain strategies. The thesis starts by describing the present state of the computer hardware industry and the drivers behind its rapid growth in the past decade. It then introduces the concept of internal and external industry drivers, and describes their potential role in shaping the future of this industry. The future scenarios and their drivers are then presented using data collected through extensive research, and by applying basic concepts of system dynamics. Subsequently the thesis analyzes the different scenarios and predicts their competitive landscape and supply chain strategies. It finally summarizes the key findings and introduces a method for predicting and analyzing future scenarios. The primary goal of this thesis has been to provide the reader a systematic methodology for predicting the dynamics of the computer hardware industry as it evolves in the future.

1.1 Motivation

The motivation for the thesis stems from the Supply Chain 2020 initiative, one of the current research efforts by the Center for Transportation and Logistics at the Massachusetts Institute of Technology.

The premise of the Supply Chain 2020 research initiative is that corporations generally have short-term plans for adapting their current supply chains to fit their needs, while few corporations, if any at all, are able to develop long-term plans. The research initiative has been divided into two phases. The first phase comprises of researching nine different

industries and individual companies within those industries to profile their supply chain best practices, strategies, and external forces that drive them. The second phase, which builds on the first phase, aims at developing future scenarios and supply chains practices in different industries. As a research assistant with the group, I have been fortunate to get involved in both these phases of this multiyear research effort. In my research I have been focused on the computer hardware industry. This thesis, however, only refers to the second phase of my research. In the first phase, I profiled the supply chain strategy, models and systems of Dell and IBM, both known for their world-class supply chain practices. Interested readers can contact the Center for Transportation and Logistics at MIT to access my first phase working paper.

The second phase of my research is based on the key learnings from the first phase. In the first phase, after interviewing several senior executives from both Dell and IBM, we came to the conclusion that even though both the companies belong to the same industry, they differed significantly in their operating model and supply chain practices. Such a finding agreed with our research hypothesis, which is, effectiveness of a company's operating model and supply chain can only be judged in the context of its business strategy. Although both IBM and Dell operate in the same industry, their business strategies are very different from one another. IBM, for example, has moved away from being a hardware manufacturer to being a one-stop IT solutions provider. IBM's world-class integrated customer fulfillment processes and seamless coordination between different business units support their business strategy. On the other hand, Dell has largely remained focused on selling computers at the lowest price by constantly

squeezing cost out of its supply chain, supported by its direct sales to customers and efficient build-to-order manufacturing systems. Based on this learning, it became apparent that future supply chains in the computer industry would not be simply an extrapolation of present best practices, but rather be a function of the changing business environment and evolving competitive strategies of companies within the industry.

1.2 Approach

Niels Bohr had once said "Prediction is very difficult, especially for the future." Predicting the future of the computer industry and its supply chains is an even larger challenge, as it is widely known that the industry undergoes paradigm shift every few years. On the other hand, it would also be quite naïve for companies in this industry to completely ignore the future, as many of their present strategies have long-term implications.

We interviewed several executives and researchers of the computer industry to gather their perspectives on this issue. We consciously chose our interviewees from different players of the computer industry, such as leading computer OEMs, component suppliers, software & service providers, consulting companies, industry researchers and academicians to get a holistic perspective and different viewpoints on the future of the industry. The names of the interviewees who have agreed to be mentioned are included at the end of this section. The research also entailed extensive literature search on present and future trends in the computer industry and its supply chain practices. Even though our primary goal has been to evaluate the future of the computer hardware industry

consisting of personal computers and servers, we have included other segments such as software and services in our research, as they demonstrate strong influence on the hardware segment of the business.

The interviews indicated few strong developmental trends, which can be schematized as pairs of extreme scenarios for the personal computer and the server segments of the industry. The interviewees also identified macro drivers that indicate change towards one of the extreme scenarios. This is why we chose to adopt a scenario approach in predicting the future of the computer industry, where each scenario tells the story of one extreme future possibility. Moreover, such an approach is also congruent with the overarching Supply Chain 2020 project, which is using similar scenario planning methodologies for researching future supply chains. There are also several other benefits of a scenario approach. Firstly, instead of separately forecasting each and every element of the present, the scenario approach allows creation of holistic and meaningful stories of the future. Secondly, instead of a single point forecast, the scenario approach incorporates different possibilities and extreme situations that may arise in the future by developing multiple future scenarios. Finally, scenarios are like stories, which can be easily communicated to almost any audience. The thesis introduces a series of frameworks to evaluate the future scenarios, their competitive dynamics and meaningful supply chain strategies.

Names of Interviewees: Seshadri Subbanna (IBM), Brian Eck (IBM), Scott Ellis (Hewlett-Packard), Hans-Martin Schweizer (Infineon), Ray Homan (SAP), Raja Chandrashekar (i2), Douglas Neal (Computer Sciences Corporation), Jason Amaral

(Emeraldwise), Robert Parker (IDC), Bob Ferrari (Manufacturing Insights), Dean Strausl (Electronics Supply Chain Association) and Chris Terman (MIT).

1.3 Literature Review

There has not been much literature written on scenario planning and future supply chains in the computer hardware industry. However, a significant amount of work has been done separately in the areas of scenario planning, future supply chain management and future of the computer industry. In this section I highlight some of these works.

Scenario planning has been used in many contexts to predict the future. There are several publicly available scenarios, which were written by companies, researchers or futurists to plan for the future. However, most of these scenarios were not created with supply chain management issues in mind. In "The Art of the Long View" (Schwartz, 1996) Peter Schwartz introduces the concepts of scenario planning. The book describes various processes and tools for developing scenarios. "Inevitable Surprises" (Schwartz, 2003), published after the 9/11 attacks on the World Trade Center, describes different world scenarios covering topics such as politics, technology and ecology. The book describes what scenarios are and how they are constructed. (Wack, 1985), Pierre Wack gives important insights into scenario planning. These articles describe the way scenario planning evolved to include important elements such as incorporating consideration of target audience into the scenario building process. "Learning from the Future" (Fahey and Randall, 1998), provides different frameworks and useful examples of scenario planning. The book also highlights that future scenarios should be constructed to aid

objective decision-making, and states that scenario planning would not work if they were only used as gimmicks to predict the future. Publicly available Royal/Dutch Shell scenarios are also instrumental in the use and development of the field of scenario planning in the corporate world.

Supply chain management has emerged as a major field of study both in the scientific and business worlds. World-class companies have recognized the importance of superior supply chain management to gain competitive advantage. The first phase of the Supply Chain 2020 initiative concluded that excellent supply chains share at least four characteristics. Firstly, excellent supply chains support and enhance the business strategy, by being involved in the overall business design. Secondly, they are based on a clearly defined operating model that creates business value. Thirdly, they are measured on a balanced set of business-relevant objectives or metrics. Finally, excellent supply chains leverage a tailored set of business practices that support the operating models and operational objectives of companies.

Apart from such structural research on supply chain management, there has been significant work done on new practices and technologies that might shape future supply chains. Several researchers predict that new technologies would bring in sea change to the field of supply chain management. Radio Frequency Identification (RFID) is perhaps one such technology that has a lot of promise. Using active tags, RFID technology could virtually track every object in the supply chain in real-time. However, technology and infrastructure problems have so far delayed the adoption of RFID in a large scale. Many

researchers believe that the Internet is another technology that can potentially change the way information moves in the supply chain. Many companies have already adopted Internet websites for selling goods and services. However, the full potential of the Internet in improving supply chain processes is still to be adopted by most companies. Supply chain automation, intelligent transportation, supply chain risk management, advanced vendor contracts are some of the areas that may have a large impact in reshaping future supply chains.

The future of the computer industry has interested researchers, academicians and industry veterans for many years, especially due to rapid development and increasing dominance of computers on our daily lives. A multi year research initiative at MIT known as T-Party looked into the future of computing. According to researches in this group, in the future we would live in a distributed computing world where we would interact with a variety of systems and applications from various locations. Computer would become so fast and efficient that we would not care too much about which CPU is running in which machine, as long as we get our computing environment. Computers would become like hubs whose main job would be to manage the virtual computing environment of its distributed users. In the future we would not be required to carry computers with us wherever we go. Instead, would carry only portions of our computers that can plug and play with a variety of peripherals that are universally available. Some scientists suggest the earth will be wrapped in a "digital skin," transmitting signals over the Internet. Millions of sensors will probe and monitor highways, cities, forests, oceans and the atmosphere. Even though it is hard to say if such a world would actually exist in the future, one cannot deny that the

possibilities are also endless. Computers in the future may be very different from what we know of them today in terms of shape, size, form, usage and capability. As computers change, it may lead to significant changes in the competitive dynamics of the computer industry. "Clockspeed" (Fine, 1998), using several examples from the computer and other industries shows that the competitive dynamics of any industry is bound to change in the future, almost as a biological clock. The book indicates that the computer industry may again become vertically integrated as some players become more powerful at the cost of the others. Such a phenomenon might get accelerated with the rapid evolution of the underlying computer technology. Changing product, technology, customers and competitive dynamics could bring a sea change in supply chain management in this industry.

However, in spite of such a large body of research, there seems to be not enough work done in merging these three areas of research. This thesis aims at bridging this critical gap.

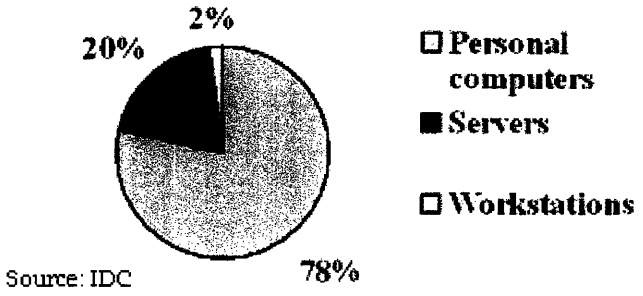
2 Computer Hardware Industry

For this thesis, the computer hardware industry is defined as the OEM manufacturers and sellers of finished computers, but does not include the component manufacturers that supply components to the OEMs. With this definition, the computer hardware industry can be segmented into three broad groups based on the nature of the final products, namely, the personal computers, the servers and the workstations. Since these three-product groups meet distinct customer needs and require different manufacturing and sales capabilities, firms in this industry often compete in each of these product groups separately. The personal computer segment, which is by far the largest segment, includes desktops, notebooks and other computer peripherals targeted towards both business and consumers. The server segment includes mainframes and supercomputers targeted towards businesses and high end research institutions. The workstation segment is comprised of high-end computers that are mainly used for engineering purposes.

2.1 Background

The size of the computer hardware industry was $247 billion in 2004, out of which the personal computers represented 78% of the total sales or $192 billion dollar in revenue, servers represented 20% of the sales or $49 billion dollar in revenue and workstations represented 2% of total sales or only $5 billion dollar in revenue (Fig.1). This clearly shows that the personal computer business is by far the largest segment in the whole industry. The following chapters discuss some of the important phenomenon of the personal computer and server segments of the computer industry.

Figure 1: Worldwide Sale of Computer Hardware $247 B in 2004



2.1.1 Personal Computer Industry

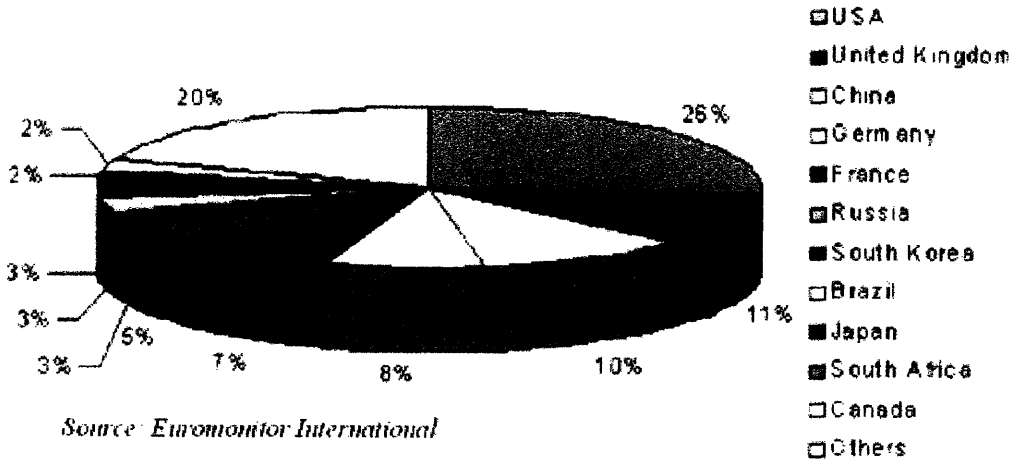
2.1.1.1 Growth

The personal computer segment, because of its large revenue share, is fiercely competitive. Due to lackluster demand from the corporate sector after 2001 because of the economic downturn and dot-com bust, the growth of this segment was primarily driven by consumer demand. Within the personal computer category, notebooks have driven the majority of the new sales because of aggressive price cuts and improved technology. In many cases, notebooks are replacing desktop sales as the notebooks have become comparable to desktops in terms of price and performance. Europe Middle East and Africa (EMEA) has surpassed the US in terms of growth rate of new notebook sales. EMEA is the fastest growing region in 2005 with PC shipment jumping by 20.2% over that of 2004 according to IDC. This has made companies invest in the operations of these growing geographies. In spite of this growth, the US remains the largest market for personal computers representing almost 40% of global sales by revenue.

2.1.1.2 Geographic Penetration

The sales of personal computers were restricted to the developed world for a long time. Though the trend is changing fast, statistics show that majority of the worldwide sales came from of a handful of countries. According to the data from Euromonitor, 70% of the worldwide retail sales of personal computers were restricted to only seven countries. The USA topped the list with 26% of total sales, followed by the UK (11%), China (10%), Germany (8%), France (7%), Russia (5%) and South Korea (3%) (Fig.2). The high computer penetration of China is a proof of its rapid growth and acts as a prelude for other developing countries to follow.

Figure 2: Worldwide Retail PC sales (in '000 units)



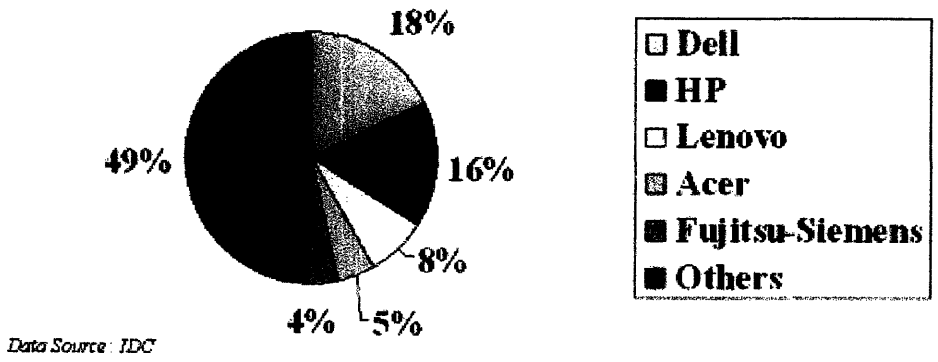
Source: Euromonitor International

2.1.1.3 Competition

Because of price pressures, the personal computer industry is fairly consolidated, with only five companies dominating nearly 51% of the total industry revenue. In 2005 Dell topped the market with 18% share of the total number of units shipped, closely followed

by HP with 16% and Lenovo with 6% of units shipped (Fig.3). The other two major players were Acer and Fijutsu - Siemens, which accounted for 5% and 4% of the market in unit shipped, respectively. Other than these handful of top competitors and a few other regional players, the rest of the market was highly fragmented.

Figure 3: Worldwide PC Shipment Market Share in 2005 (unit shipped)



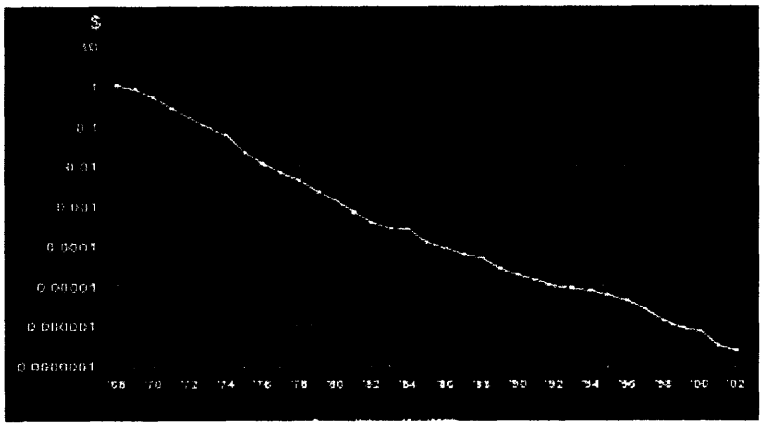
2.1.1.4 Growth Drivers

There are several avenues for growth for companies operating in the personal computer industry. The decreasing price of computers, increased penetration into low income group consumers, expansion into growing markets, market consolidation and diversification into related businesses are some of the high growth areas in this business. The following sections discuss each of these growth areas.

Reducing Price of Computers: Though there were several factors that drove the growth of the industry in the past, one of the most prominent reasons was the reducing price of computers that made them affordable to a wider range of consumers. Technological advancement made computers cheaper and faster. The decreasing price of transistors, which used to cost over $ 1 in the 1960s, cost only a millionth of a dollar in the 2000.

Such advancements show that even if a computer chip now contains a magnitude of times the number of transistors that it used to contain in the 1960s, the price of a chip would still be less in the order of magnitude (Fig.4).

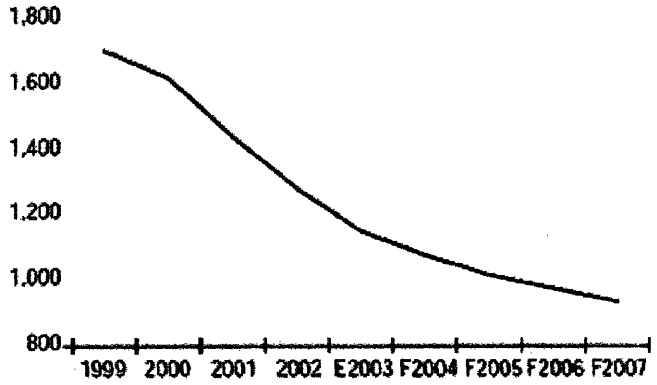
Figure 4: Average Transistor Price by Year



This downward trend in cost is visible in almost all other kinds of computer components that go into personal computers, servers and workstations, making computers more affordable. To give an example, the average price of a personal computer has fallen from $1,700 in 1999 to well below $1,000 in recent years (Fig 3.9). What magnifies this difference even more is that an average computer of 1999 can only be compared to a low-end computer of recent years, which would be even less expensive. This trend of reducing price has been exponential in the laptop segment. Until 2000 laptops were largely restricted to high-ranked executives in the corporate world because of their significant price premium. The limited computational power of laptops was another reason for its restricted use. But over the past few years the price of laptops has fallen drastically along with the increase in computational power. This has made laptops comparable to desktop computers and has attracted many new consumers. It is expected

that this downward trend of computer pricing will continue in the future and drive further user penetration.

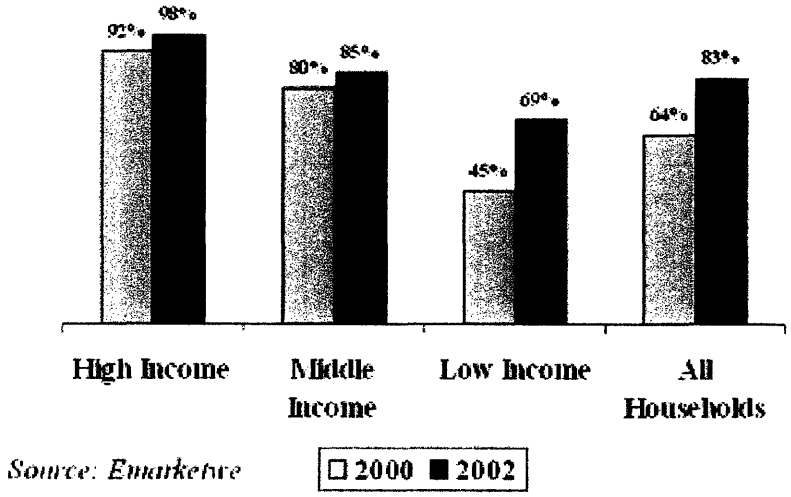
Figure 5: Average PC System Price (in Dollars)



E-Estimated. F-Forecast.
Source: IDC.

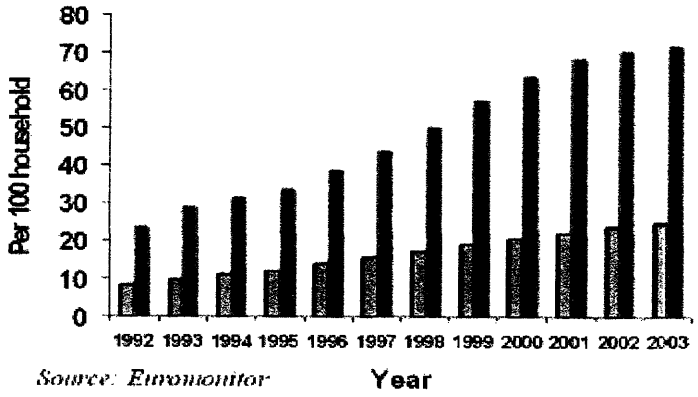
Increased Sales to Low-Income Groups / Small Businesses: Another growth area of computers is the increased sales to the low-income consumers group who traditionally could not afford a computer. The high and medium income group consumer market is almost saturated in most of the developed countries. For example, in the US nearly 98% of the high-income group and 85% of the middle income group had access to a personal computer in 2002. On the other hand, in the same time period only 70% of the low-income group had access to a personal computer (Fig.6). In developing countries, though there is still market potential in the high and medium income groups, there is lot of opportunity for growth in the low-income groups. Small businesses are another potential growth segment for increased sales of computers. Due to the ubiquitous use of computers and their decreasing prices, many small businesses have started to use computers for their daily operations.

Figure 6: Percent of US Household with PC, by Income in 2000& 2002



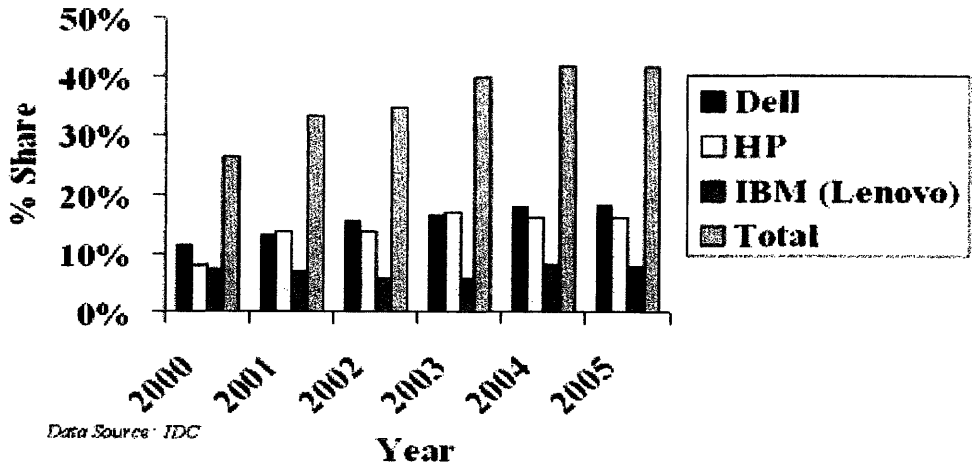
Geographic Penetration: Countries outside the US are catching up fast in terms of sales of computers. For example, only 24 out of 100 households residing outside the US own a personal computer (average of top 70 countries in terms of PC sales) compared to 70 out of 100 households inside the US (Fig.7). This shows significant market potential of personal computers in the developing countries in the near future. Many of the large companies such as IBM (Lenovo) are experiencing higher growth in countries outside the US.

Figure 7: Percentage of Household PC Penetration Worldwide



Market Consolidation: Through consolidation, companies have achieved economies of scale that have helped them to reduce computer prices, increase service offerings and provide better customer support. For personal computers, the total market shares of the top two vendors have progressively increased from 26%in 2000 to almost 41% in 2005 (Fig.8). Mergers and acquisitions between existing large companies have played a central role in consolidation. In 2001 HP and Compaq merged to overtake Dell in the US market. In 2004 Gateway and eMachines merged to overtake IBM in the US market. Also IBM sold off its shrinking PC business to Lenovo of China towards the end of 2004. This has made Dell and HP by far the largest companies in the PC industry.

Figure 8: PC Market Share of Top 3 Companies by Sales



2.1.2 Server Industry

2.1.2.1 Growth

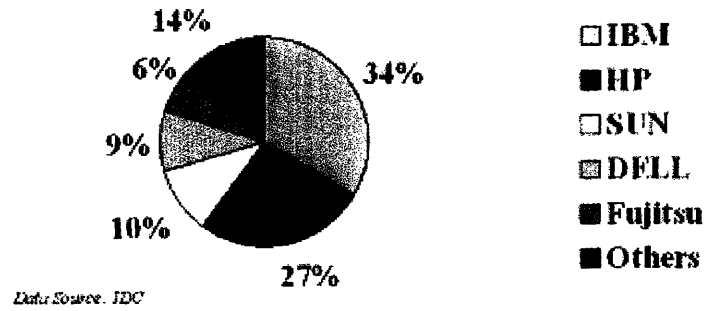
The server market plummeted after the dot com crash in 2001 when the market slid by nearly 17%. The market again recovered in 2003 with worldwide server revenues grew 3.2% to $46 billion and another 6.2% to $49 billion in 2004, according to IDC. The

server market can be subdivided into three categories based on usability and performance of servers, e.g. entry-level server, the midrange servers and the high-end servers. As the name suggests, the entry-level servers are used for light business applications mainly used by small and medium scale businesses. The increase in computational power of personal computers has made these entry-level servers vulnerable, which are often being replaced by high-end desktops. This has also created severe price competition in the entry-level server market. But the sales of these entry-level servers have been still substantial because of increased spending by small and medium scale businesses. The Midrange servers are typically higher-end systems running the Unix operating system managing a large number of transactions and data. High-end servers include supercomputers, mainframes, and other high-end servers. These servers are primarily used by large businesses and institutions. The market for high-end servers has been falling because of restrained IT spending and decreased R&D expenditure by large corporations and research institutions.

2.1.2.2 Competition

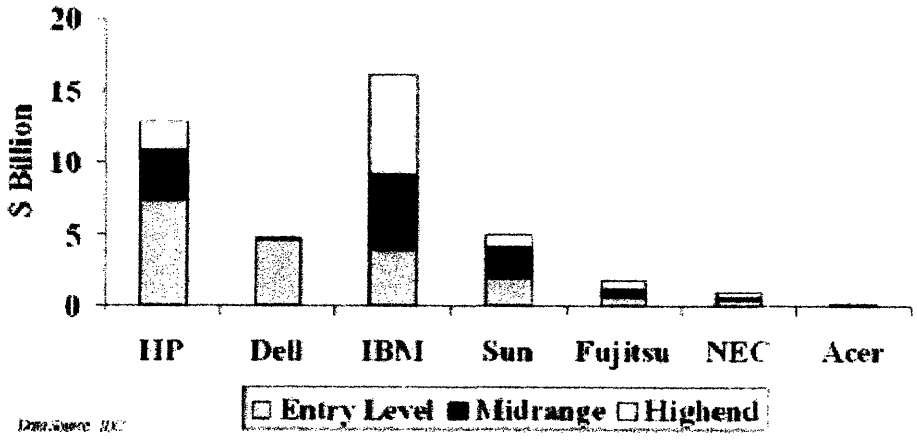
IBM being the largest player in the server market accounted for 33.3% of the total revenue of $ 49 billion in 2004. HP was the second largest player accounting for 26.6% of the total server revenue. These two companies collectively command nearly 60% of the total server market in 2004. The other big players are Sun Microsystems (10.5%), Dell (9.5%) and Fijutsu (5.9%) (Fig.9). Because of the high entry barrier of the server market, only five companies dominated nearly 86% of the total market share in 2004.

Figure 9: Worldwide Server Shipment Market Share in 2004 (by Revenue)



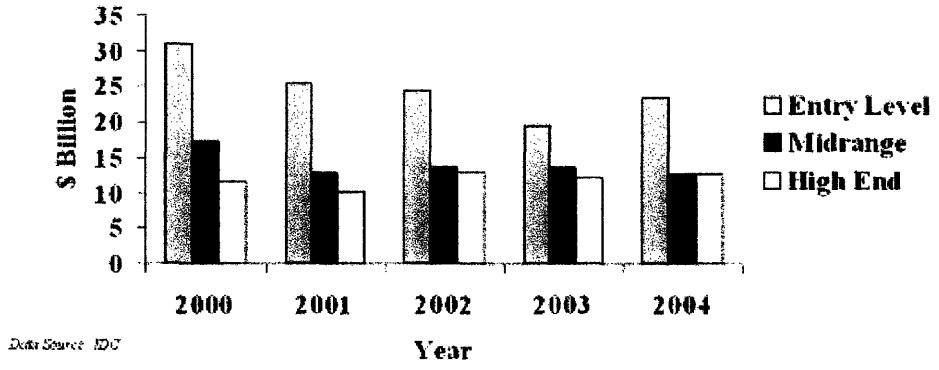
Although, HP and IBM are the main players in the Server market, they have very different strategies. IBM is focused on the high-end server segment, followed by the midrange, and has the least focus on the entry-level server segment. On the contrary, HP is mainly focused on the entry-level server segment, followed by midrange and least focused on the high-end server market segment. Their relative revenue from each of these segments reinforces that point (Fig.10). In 2004, IBM's revenue from entry-level, mid-range and high-end servers were $4 billion, $5.1 billion and $6.9 billion, respectively. On the other hand, in the same year HP's revenue from entry-level, mid-range and high-end servers were $7.4 billion, $3.5 billion and $1.9 billion respectively. Dell is more focused in the entry-level server segment with limited or no presence in the other two segments.

Figure 10: Server Revenue Share



The entry-level servers have also shown a downward trend in net sales between 2000 and 2003, with a little surge in 2004 (Fig.11). A possible reason for downward trend could be because of the increased computational power of personal computers that has slowly eaten up this segment. Many small businesses have found it much more cost effective to use high-end personal computers instead of servers for non-mission-critical and lighter applications. The market for midrange to high-end servers has remained stable in the same time period because of the worldwide economic slowdown. The majority of the revenue of the midrange and high-end servers has come from maintenance, upgrades and the scaling up of existing systems.

Figure 11: Trend in Server Revenue



Because personal computer and server businesses represent the lion's share of the computer hardware industry, in this paper we have focused our research on these two segments.

3 Predicting the Future

As we have seen in the past several decades, there are several drivers that affect businesses in the computer industry. In this chapter I describe some of the important drivers that have played an important role in shaping this industry in the past decade and presumably, would have an important impact in the future. These drivers have been summarized based on the data collected from literature survey and the interviews.

The drivers that play an important role can be divided into two broad groups, namely the 'internal drivers' and the 'external drivers'. The internal drivers emerge from within the industry whereas the external drivers emerge from a broader phenomenon that is outside the industry. Examples of a few internal drivers are changing consumer preference, new technology development and emerging technical standards. On the other hand, examples of a few external drivers are rapid globalization, rising income level in developing nations and new government regulations both within the United States and around the world.

Our research suggests that internal drivers perhaps play a more crucial role in the development of the computer industry. Development of new technology products and meeting changing consumer preference has been two key indicators of commercial success for companies in this industry. However, often it is very difficult to distinguish between the individual contributions of these two drivers in a given scenario. If one takes the example of iPods, which has been a large commercial success for Apple Computers in the recent past, it is hard to assert if iPod's innovative technology or latent consumer

demand for such devices was instrumental in its success. Consumer demands of computers are often fickle and unpredictable, which makes it hard to predict any latent demand. On the other hand, it is also difficult to predict if a new technology would find a large market or get lost in the oblivion. This is not to deny that both innovative technologies and consumer need are important, but it remains unclear if there is any charted prescription for commercial success in this industry.

New and emerging technical standards would also have a significant impact on the future of the industry. As computer technologies become more complex and computers proliferate into all aspects of human life, new standards would have to emerge to fuel the growth by developing interfaces between different computing devices. Companies that develop and lead this standard development would have a significant competitive advantage and play a crucial role in the development of the industry.

In the past, ambitious entrepreneurs working out of their small research lab, home garages or college dormitories have largely driven the computer industry. Bill Hewlett and Dave Packard starting Hewlett Packard Company from a small garage or Michael Dell founding Dell Computers from his university dormitory are great examples of such entrepreneurial spirit that has driven the industry for many decades. But with its increasing maturity, many external drivers have started to impact the industry. Hardware companies are increasingly procuring components from vendors located around the world and setting up their manufacturing facilities in low cost jurisdictions to become cost competitive. Only a few decades ago most of these companies were regional in nature,

having vendors, manufacturing facilities and customers located not too far from one another. But with the advent of global cooperation, friendly trade regulations and rapid development of transportation and information technologies, companies have globalized beyond anyone's imagination. Such a trend that was adopted by only a few in the beginning, have quickly become a norm for the rest of the industry. But gradually these globalized companies have become vulnerable to new external drivers beyond their control. As transportation networks have stretched across the globe, companies have become sensitive to the fluctuations of oil prices. Global corporations now not only have to be aware of the business drivers in the country where they are headquartered, but also in all those countries where they have business operations. Rising labor wage rate in China where many companies have their manufacturing facilities, weak intellectual property laws in India where they have their R&D labs, lack of regulations to protect customer information in Philippines where they have their call centers, or emerging green laws in the European Union where they have their customers are some of the common concerns of today's global corporations. With increasing globalization, some of the drivers could become critical in shaping the future of the computer industry.

Emerging new markets is another important driver that computer companies can no longer ignore. For many computer OEMs, the rate of growth of computer sales in the Asia Pacific region has exceeded that of the US in the last few years. According to a World Bank survey, the rate of GDP growth of the developing countries is expected to be much higher than that of the developed countries in the next few decades. Considering

the majority of world population lives in the developing countries, it is quite likely that some of these countries could soon become the largest computer markets in the world.

Emerging and new regulations can also have a significant impact on the future of the industry. One example being green laws enacted by the European Union that mandated compulsory banning of certain harmful material from electronics items and the compulsory take-back of items at the end of their useful lives. Such a regulation has large cost implications for the industry in terms of product redesign, re-tooling of manufacturing facilities and creating reverse logistics networks.

But, by what mechanism does the changing internal and external drivers impact the computer industry? My research indicates that there is no easy answer to this question. However, it seems that progressive companies innovate business models that leverage on the evolving drivers to gain competitive advantage. Success of such business models quickly makes it an industry norm, which in turn reinforces the drivers. For example, in the 1980s when computer components became standardized, Michael Dell started assembling and selling computers directly to his customers. Later when such a strategy turned out to be successful, it got copied by competition, further propelling standardization of computer components. In the 1990s with the advent of the Internet, Dell Computer started selling computers online. Such a model provided Dell Computer significant competitive leverage that later got adopted by the rest of the industry, further propelling the spread of Internet. In the last decade with the advent of efficient transportation modes and favorable trade regulations, many companies have set up

manufacturing facilities in low cost jurisdictions around the globe. Off shoring has now become of norm for the whole industry, which has propelled further innovation in transportation technologies and pushed for friendlier trade regulations. Similarly, new drivers would continue to manifest themselves into the future largely through new business models.

3.1 Common Axioms about Prediction

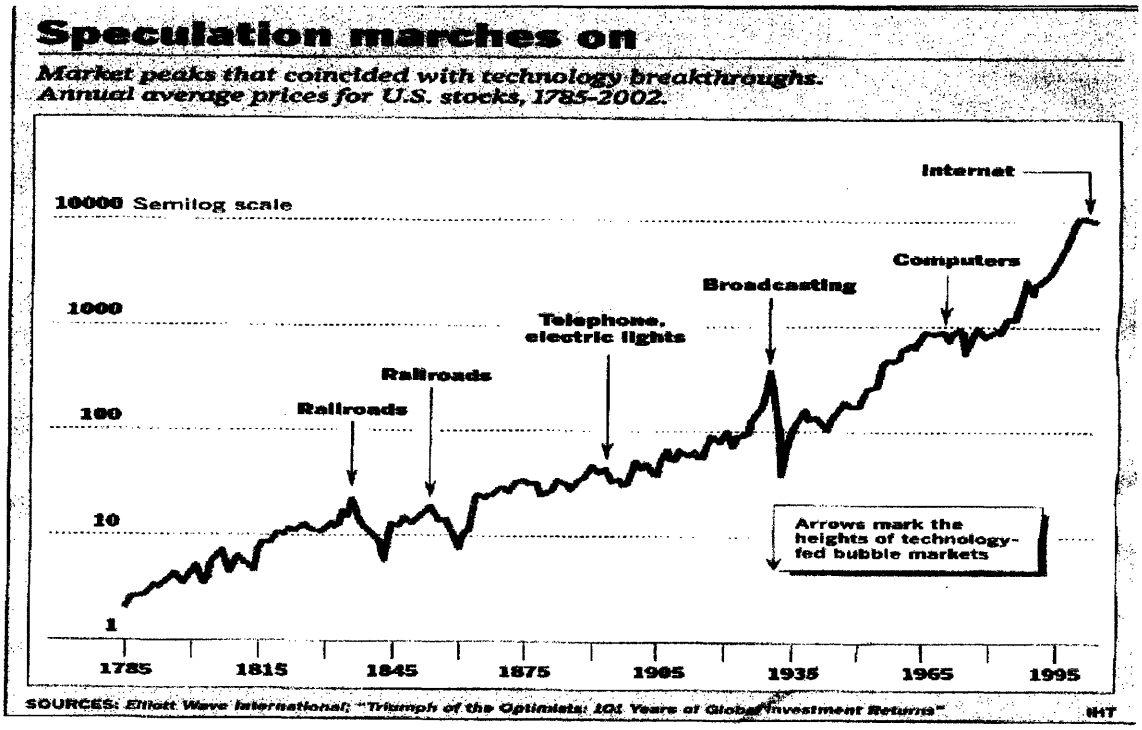
There are several pitfalls that are generic to any prediction. It would be worthwhile to keep in mind some of these pitfalls as the reader progresses through this paper.

Firstly, predicting the future is often erroneous because people's basic needs may change beyond anyone's imagination. There are numerous such examples in the history that can be quoted to prove this hypothesis. David Sarnoff's associates in response to his urging for investment in Radio in the 1920's said: "This wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?". In 1927, only few years before audio movies flooded the world, Harry M. Warner of Warner Bros said: "Who the hell wants to hear actors talk?". Ken Olsen, President, Chairman and Founder of Digital Equipment Corporation in 1977 said: "There is no reason for any individuals to have a computer in their home". As the examples suggest, if it is so difficult to even predict the future environment within which we would live, predicting future products and services is indeed a challenging task.

Secondly, the impact of new technologies are almost always over estimated. Between 1815 and 2000, almost all major technology breakthroughs were followed by market

hype and a subsequent correction. Starting with the introduction of railroads in the 1830s, telephone & electric light in the 1880s, broadcasting in 1930s, computers in 1960 and Internet in the 1990s, all of the technological breakthroughs followed a market hype and subsequent correction (See Fig.12). Quite surprisingly, several times the market has taken well over a decade to correct itself. It is quite possible that we may overestimate the role of a computer in the future. Many futurists presently describe the future as the age of ubiquitous computing where computers would become so intelligent that they would control every aspect of human life. In reality, ubiquitous computing era may turn out to be only a fraction of what is now being predicted.

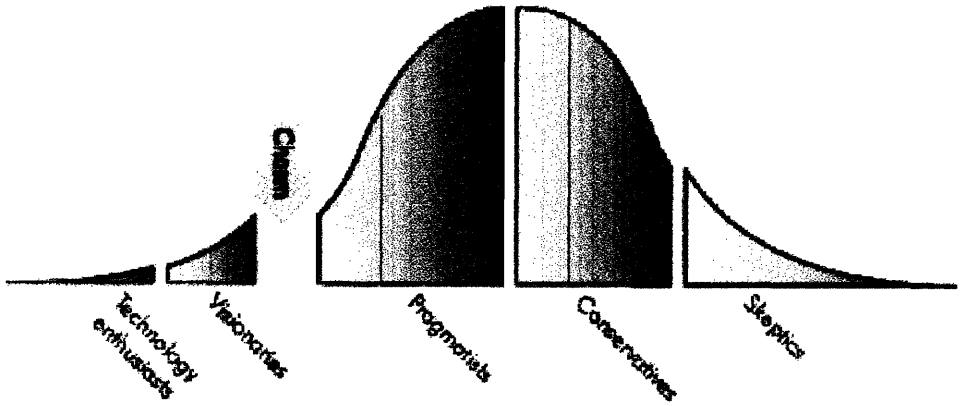
Figure 12:Market Hype Due to Technology Breakthroughs



Thirdly, new technology breakthroughs often take a long time before the masses adopt it. Research shows that historically many new technology adoptions have gone through five distinct phases (see Fig.13). Technology enthusiasts and visionaries adopt new

technologies more as their hobbies in the first two phases. Most technologies die in these phases, as they never make it to the third phase where they are adopted by the cautious pragmatists. Only when a technology succeeds with the pragmatists, it may eventually reach the conservatives in the fourth phase and the skeptics in the fifth phase. It often takes over several decades for any new technology to be adopted by the masses, if it at all makes the journey. There are several examples that support this hypothesis. One such examples is Radio Frequency Identification (RFID) technology. RFID was invented more than 50 years ago. But it has so far failed to live up to its promise, in theory, to track every item ever produced. Similarly, there are numerous other technologies that have been around for a long time without creating much impact. We can expect that future inventions might follow such a long adoption curve, limiting their immediate impact.

Figure 13: Technology Adoption Life Cycle



Source: Geoffrey A. Moore, *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*. HarperBusiness. 1999

4 Future Scenarios of the Computer Industry

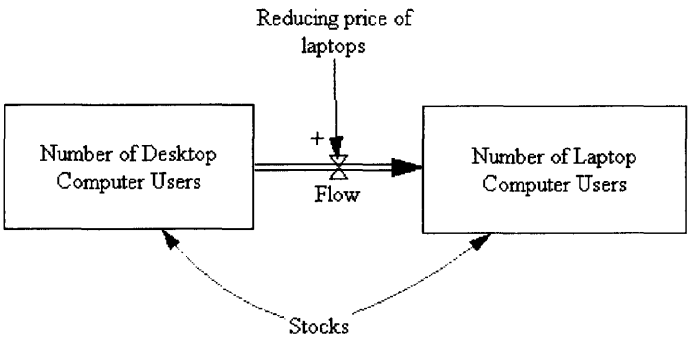
In this chapter I first provide a brief description of the field of systems dynamics, which is used for generating and describing future scenarios of the computer hardware industry. I then highlight important emerging trends from my research findings. Based on these trends and using basic concepts of systems dynamics, I then present few future scenarios of the personal computer and server industry segments.

4.1 Systems Dynamics

Professor Jay W. Forrester at MIT founded the field of System Dynamics in the early 1960s. At that time, he began applying what he had learned about systems during his work in electrical engineering to other fields. System dynamics relies on real world observations rather than on complex mathematical formulations to model any system, which distinguishes it from other fields of study. Because of its intuitiveness, systems dynamics has been applied in many fields of study including business, economics, public policy, and engineering over the past several decades. The use of stocks, flows and feedback loops to design any system is simple and provides a comprehensive method of analyzing a situation in a holistic way. A Stock, as it means, is a collection of any stuff. For example, a Stock can represent total number of desktop computer users or total number of laptop computer users in the computer industry. A Flow is like a pipeline that brings things into, or out of a Stock (See Fig 14). For example, there would be a flow from the desktop computer users stock to laptop computer users stock to represent those users who switch from using desktops to using laptops. One can draw links to Stocks or Flows to show the impact of other drivers of the system on stocks and flows. For

example, reducing the price of laptops would accelerate the flow of users from desktops to laptops. In this paper, I have used basic stock-flow diagrams to depict the emerging trends in the computer industry. Interested readers can refer to "Business Dynamics: Systems Thinking and Modeling for a Complex World" (J. Sterman , 2000) to learn advanced concepts of systems dynamics.

Figure 14: System Dynamics Stock-Flow



4.2 Trends and Future Scenarios in the PC Industry

Based on the interviews, the following key trends were identified in the personal computer segment.

Firstly, increasingly consumers are adopting smaller and more mobile computers for their day-to-day computing needs. Personal Digital Assistants such as Dell's Axim and HP's iPaq are getting popular with users because of their smaller size, increasing memory, faster processor, wireless connectivity and the availability of a variety of productivity, entertainment and GPRS applications. Microsoft's launch of handheld computers, pocket

computers, portable media centers in partnership with a variety of computer and electronics OEMs is an indication of potential future growth of such a trend.

Secondly, increasingly traditional phone users are adopting smart phones that can be used both as a cell phone and as a mini computer. The higher adoption of such devices is leading to the convergence of traditional computer and mobile communications industries. This puts the traditional computer OEMs and cell phone companies in a strange position, as both observe the other slowly cutting into their market space. One can expect such a trend to become more prominent in the future, changing the competitive dynamics of the industry

Thirdly, increasingly home and consumer electronics products such as television, music systems and even refrigerators are having computing capability. For example, high definition digital TVs, MP3 players, on demand movies, and streaming music are giving birth to new devices that are a hybrid of traditional home electronics and personal computers. Such a trend is an indication of possible convergence of the home electronics and computer industries. Digitization of information, new digital standards, strict IP laws, and high broadband penetrations are some of the key drivers that are driving this convergence. Similar to the communication industry, the home and consumer electronics industry holds new market opportunities as well as competitive threats for the traditional computer OEMs.

Figure 15: Stock Flow Diagram of the PC Industry Trends

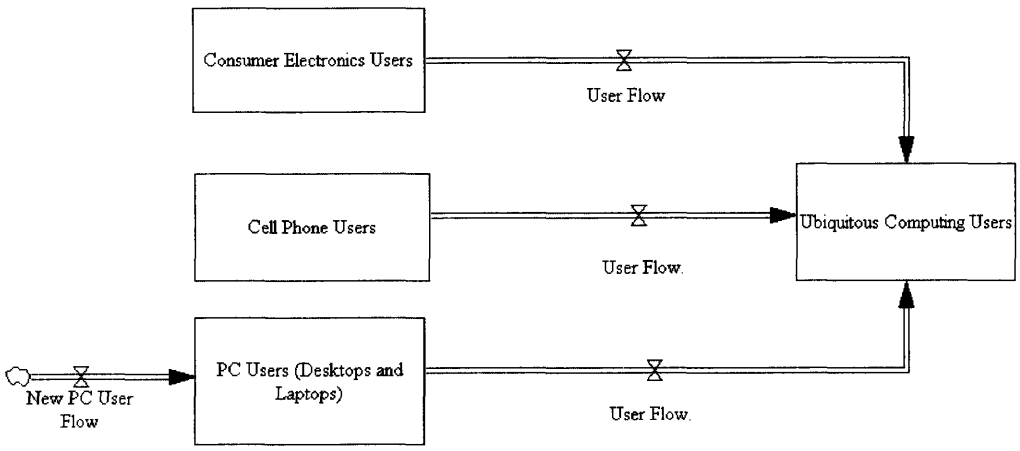
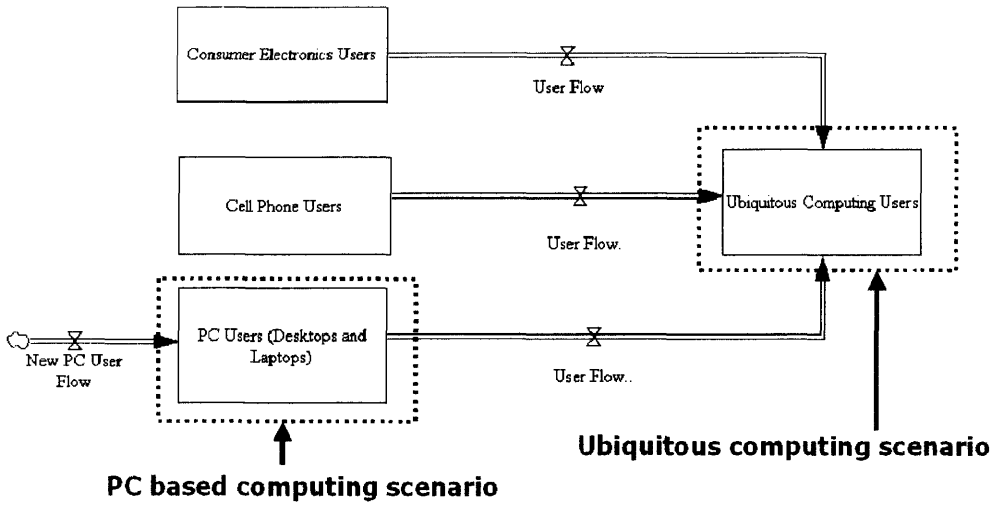


Fig.15 represents the dynamics of the personal computer industry through a stock-flow diagram. The consumers are divided into four stocks. The 'PC Users' stock represents the total number of present users of traditional desktops and laptops; the 'Cell Phone Users' stock represents the total number of users of traditional cell phones; the 'Consumer Electronics Users' stock represents the total number of users of traditional analogue electronics devices. Finally, the 'Ubiquitous Computing/Convergence Users' stock represents the total number of present users of mobile convergent devices. The flows represent the shift of users from one stock to the other. The flow into the 'PC Users' stock represents new user adoption of traditional desktops and laptops.

The above framework has been developed with the intention of capturing the dynamics of the personal computer market. The basic intention of the stock flow framework is to understand the possible future states of personal computer users and to analyze the drivers that affect the flow rates between the stocks.

The framework can be used to derive three possible future scenarios of the personal computer segment. The first scenario, which I call **'PC based computing'** scenario, assumes that most of the users remain in the 'PC Users' stock in the next 15 years. In this scenario the basic form of a computer does not change much, nor are there much changes in its use. However, supply-demand of computers may shift significantly because of changes in other industry drivers. The second scenario, which I call **'Ubiquitous computing'** scenario, assumes that the majority of the PC users migrate to the 'Ubiquitous Computing Users' stock. In this scenario the basic form of a computer changes drastically, so is its uses. The third scenario, which I call **'Both PC based and ubiquitous computing'** scenario, assumes that users would be distributed between the 'PC User' stock and the 'Ubiquitous Computing Users' stock. Both 'Ubiquitous computing scenario' and 'PC based ubiquitous computing scenario' assumes that some of the users also migrate from the 'Cell Phone Users' and 'Consumer Electronics Users' stocks to the 'Ubiquitous Computing/ Convergence Users' stock.

Figure 16: Extreme Scenarios of the future PC Industry



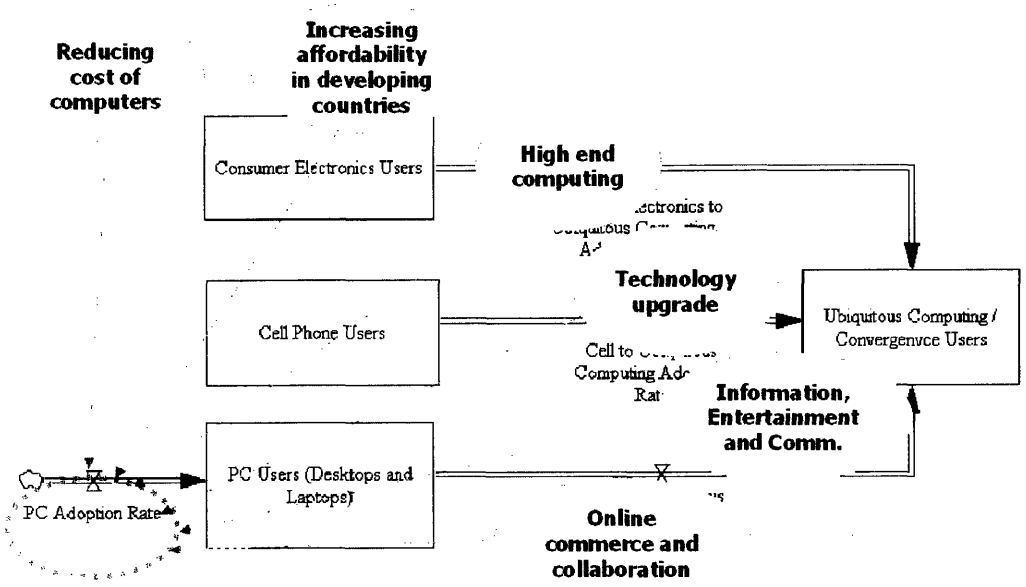
Though it is hard to predict which of these above scenarios would actually emerge in the by the year 2020, in this paper I have selected two of the extreme scenarios, namely the **'PC based computing'** scenario and **'Ubiquitous computing'** scenario, as boundary cases (see Fig. 16).

At this point, I would like to change gears and turn back to the internal and external drivers that I introduced in Chapter 3. If scenarios are the outcome, then the drivers are the cause. Hence, in the following section I will link the different drivers that impact the computer industry with future scenarios I just introduced. The drivers can also be conceived as sensors on the ground, whose relative strength would indicate which of the scenarios might emerge in the future

4.2.1 PC Based Computing Scenario

In this scenario I assume that the rate of new PC user adoption leading to the 'PC users' stock would become dominant by the year 2020. In this scenario, PCs become much more affordable because of reducing cost and new technological developments, new markets develop with the rise of average income in the developing world and a variety of new applications that drive the usage of PCs. The drivers identified as having the maximum impact in this scenario are 'reducing cost of computer', 'increasing affordability in developing countries', 'high end computing', 'technology upgrade', 'digital information, entertainment & communication' and 'online commerce and collaboration' (see Fig.17).

Figure 17: Drivers of the 'PC based computing' Scenario

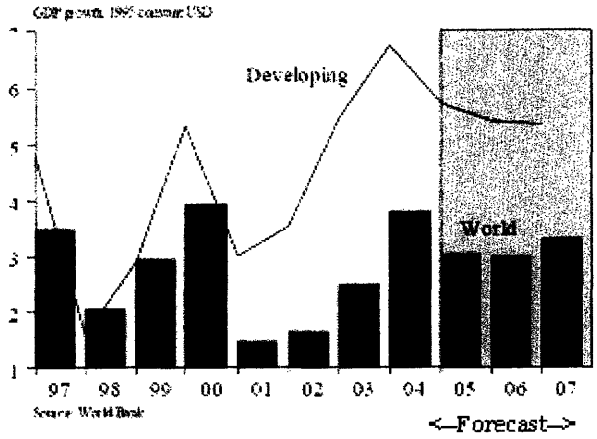


Reducing cost of PCs: Reducing cost of personal computers in the last decade has led to widespread adoption of PCs. Reducing component costs and increasing efficiency of computer manufacturing has primarily reinforced this trend. Further reduction in computer prices may still drive PC sales for decades to come. Consumers already having one PC might opt for a second or a third PC, just as many people maintain more than one car for their families. In the future we may see PCs installed in hotel rooms, airport terminals, airplanes, automobiles and other public or private areas as they become more affordable. Also, more and more people from low-income group would be able to afford computers, which still remains a large untapped market. Several computer OEMs have already started initiatives to address this opportunity. AMD has partnered with the MIT Media Lab to create a $100 laptop for school children in developing countries. AMD has also launched "50x15" initiative, a bold commitment to empower 50% of the world's

population with basic Internet access by the year 2015. Many other computer companies have launched similar initiatives to make computers affordable for the masses.

Increasing affordability in developing countries: The fast development of the developing world, especially China and India that resides nearly one third of world population, has the potential of becoming a large market of personal computers in the future. Increasing income level and purchasing power of the population living in the developing world has propelled multinational computer companies to start developing products specific to these markets. For example, Hewlett-Packard Company introduced a range of new products tailored to the fast growing Indian market, including a writing tablet that makes it easier to enter characters from two of India's national languages into a computer. Microsoft has also launched its operating system in local languages of developing countries. HP is also customizing its products for China and Russia in an attempt to adapt its products to countries with languages, economies and cultures that differ from the United States and Western Europe where they have their majority of customers. Dell is planning to increase its presence in India. Several other computer companies are eying the Asian markets and developing products and services to cater to the emerging market needs. Fig.18 shows how the GDP growth of the developing world is expected to be higher than that of the developed world for many years to come.

Figure 18: GDP Growth of Developing Countries



Increase in high-end computing: PCs are increasingly used for high-end applications, such as for playing high-end computer games, engineering and business applications. If consumers and business increasingly demand higher computing power for specialized uses, computer OEMs have to cater to that demand by producing high end PCs. Several computer component manufacturers and research labs are working on technologies that can power such high-end computers in the future. AMDs Athlon processor has broken the 1GHz speed barrier for personal computers. Intel has recently launched dual core processors for PCs that can handle heavy software applications. Such developments might lead to an increase in the popularity of high end PCs in the future.

Technology upgrade: Technology upgrade has been a major driver for PC adoption in the past decade. Regular upgrades of computer processor and operating systems have pushed customers to upgrade their PC in regular intervals. Upgrade cycles in the future may not be only limited to processors and operating systems, but could be driven by revolutionary new technologies developed and marketed by innovative companies. For example, Microsoft showcased its concept PC 'Athens' in 2005 that included next-

generation voice, video and text messaging systems. 'Athens' could transfer an incoming call to a cell phone enabled with Bluetooth wireless technology seamlessly to a PC when the user simply pressed an answer button on the keyboard. The PC used integrated speakers/microphone to manage the call audio, retrieve information about the caller such as communications history from the caller ID. Such new features developments would push users to purchase new PCs. Apart from user driven technologies, breakthrough technological innovations can create and drive new upgrade cycles. For example, new storage technologies might become increasingly popular with the explosion of digital information. New emerging technologies such as holographic or molecular data storage technologies may be used for developing next generation storage devices. Researchers believe that via holographic storage technologies one can store thousands of blocks of data each containing a million bits, within the volume of a sugar cube. According to the latest research it may possible to implement a memory subsystem to store vast amounts of data using molecules that store digital bits. Such technologies may quickly transform what personal computers are capable of doing today. In the future companies that can bring unique value to the consumers through revolutionary technologies might enjoy the same bargaining power that certain computer processor manufacturers and operating system producers enjoy today.

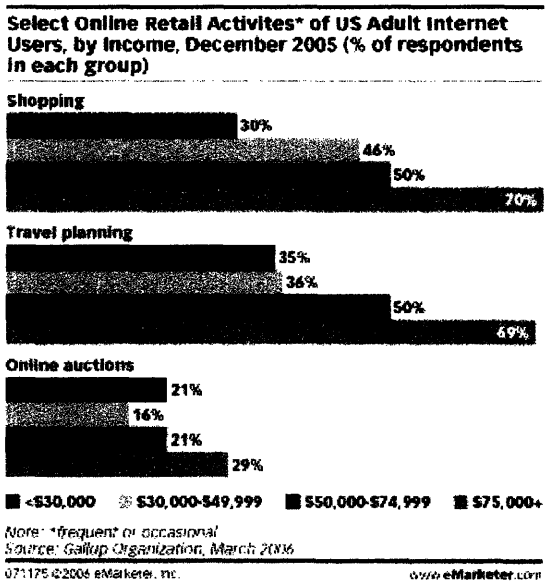
Digital information, entertainment & communication: More and more people are using personal computers for information, entertainment and communication purposes. People use computers for surfing websites, writing emails, listening to digital music and watching movies more than ever. But with the advent of broadband Internet, PCs now

have access to virtually an endless number of information and entertainment sources. Efficient web search engines provide relevant information in seconds by searching the entire web. One can use PCs to make Internet phone calls to any other PC around the globe or even to a traditional phone. One can listen to streaming music or catch the latest TV episode from their favorite website. Many large companies are already rushing to take part of this growing pie. Napster and Apple's iTune have attracted many music lovers online. Walt Disney is starting to broadcast its popular TV shows from its website for free. Yahoo, Time Warner's America Online, and others are readying their own online entertainment offerings. Intel is developing a new platform called Viiv that is trying to incorporate media sharing capabilities into at the hardware level. Skype and yahoo messenger are offering free audio and video chat. If these developments can set a trend, one can expect that more and more online information, entertainment and communications services will drive PC adoption.

Online commerce and collaboration: Online commerce has become an accepted phenomenon. Just the way consumers have started buying online goods and services from Amazon, Ebay and many other popular websites; businesses have increasingly participated in online sales, e-procurement and online collaboration with partners. According to a eMarketer survey, 70% of the respondents whose annual income is more than $75,000 shopped online in 2005 where as 30% of the respondents whose annual income is less than $30,000 shopped online in 2005. The data shows that online shopping gained popularity in certain income segments, with considerable growth opportunities in some other segments. Survey data on online travel planning and auctions also show

similar trends (FIG.19). Though many consumers have participated in online commerce, the percentage of online spent as compared to their total spent still remains low. If online commerce becomes increasingly popular in the future, it might become an important driver for increasing demand for personal computers, as more and more people turn to their PCs for their shopping or business needs.

Figure 19: US Online Activity



All the above drivers lead us to the 'PC based computing scenario' in the year 2020. However, not all these drivers may be equally significant in their impact. Also, new drivers may also emerge having an impact on the 'PC based computing scenario'. However, based on which drivers become dominant, one may be able to reasonably predict which scenario may emerge in the future.

4.2.2 Ubiquitous Computing Scenario

In this scenario PCs would change drastically in the future, with a majority of the PC users migrating to the 'Ubiquitous computing users' stock. This scenario is much more futuristic than the first scenario, in which the PC as a product does not change much.

Many futuristic, science fiction writers, progressive academicians have predicted a world of ubiquitous computing where computer terminals just might disappear altogether. They predict that computers are literally going to be absorbed by their surroundings and embedded in walls, carpets, toasters, and even in our own bodies.

Many scientists and futurists say that much of the basic infrastructure for ubiquitous computing already exists. Broadband Internet, faster processing power of computers and advances in wireless technology are some of the important ingredients of ubiquitous computing. For example, new technologies such as Wideband Code Division Multiple Access systems have radically increased the wireless data rates to download heavy content from the Internet in seconds.

People would use digital cash and credit, which will enable widespread use of networks for commercial purposes. Digital cash and smart cards can provide a platform for transferring funds and making purchases over the Internet, in stores, or at any variety of vending machines, ticket machines, and parking meters. Many of such systems are already in place, which might get transferred to the parts of the world where they do not exist. More over, people would use these systems more and more such that it becomes the status quo.

These developments collectively will emerge as an age of intelligent appliances, smart houses, more productive offices and many other smart applications. Computing rather than computers will take center stage as the hardware starts becoming less important to the users. But when computing devices begin to assist with the day-to-day chores of living, it would become more a part of human life than a passive device. Hence there would be a greater need for computers to be customized and personalized according to the users choice. Computers would also become smaller, more fashionable and easier to use.

Personal computers might disintegrate into different devices. Even if we have computers, it may not look like today's PCs. For example, new methods of communicating with a computer might replace keyboards, new visualizations technologies might replace traditional monitors, and CPUs can become so small that one can carry it around like a pen. Not only the hardware, new intelligent software programs can personalize user experiences, virtualized computing hardware, or even make all devices talk to each other.

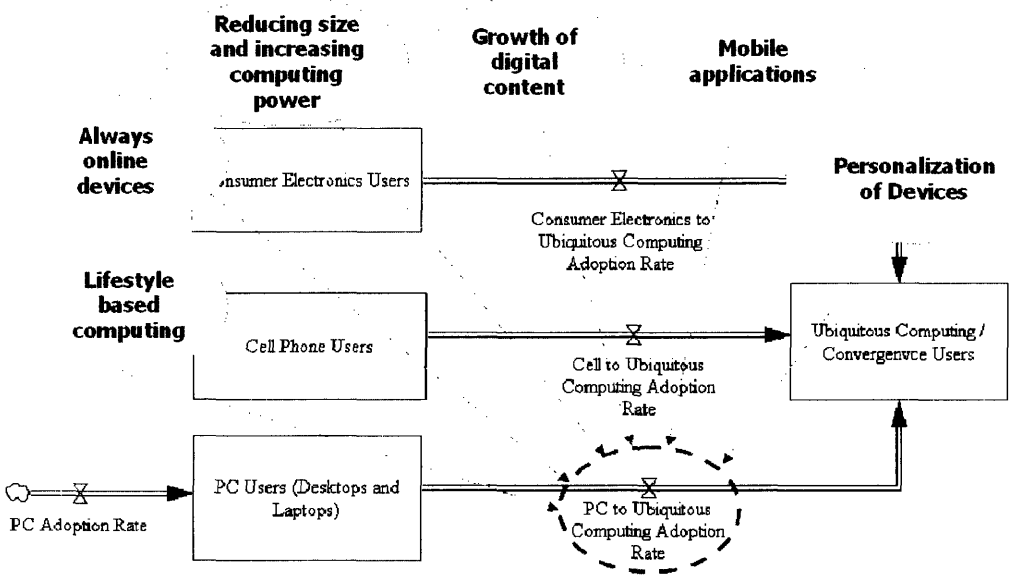
Though ubiquitous computing would bring lot of value to the consumers, it also has some vices. For example, threats to personal privacy, hacking, increasing network vulnerability and digital terrorism are some of the drivers that might limit its growth.

There are several drivers that might accelerate the adoption of the ubiquitous computing era; in this paper we have identified lifestyle based computing, the need for being always online, the reducing size and increasing computing power, an exponential increase in

digital content, new mobile applications and personalization of computers as some of the key drivers (see Fig.20). It is important to note that the drivers discussed in 'PCs based computing' scenario would also impact 'Ubiquitous computing' scenario. But in this section we focus only on those drivers that have an direct effect in the ubiquitous scenario. Further, the following sections would focus on the migration of users into the ubiquitous computing stock from the PC based computing stock.

Similarly, some of the drivers for accelerating 'Consumer Electronics to Ubiquitous Computing Adoption Rate' are high embedded computing, inter-operatibility of devices, high speed Internet penetration, popular applications such as demand video, interactive TV etc. However in this paper I only focus on the flow rate from the 'PC Users' stock to the 'Ubiquitous computing/convergence' stock and its related macro drivers. Interested readers can use the same principles to undertake similar analysis for the other two flow rates shown in the framework.

Figure 20: Drivers of the 'Ubiquitous computing' Scenario



Lifestyle based computing: Many consumers are demanding more fashionable computing devices as compared to today's functional PCs. As computers become ubiquitous, consumers would want them to suite their lifestyle. Apple's iPod is a good example of how innovative computing devices can quickly become popular if they are also fashionable. Similarly, users of a pocket PCs or smart phones want their phone to look good when they use them publicly. The popularity of Motorola Razor phone for its sleek looks is a good example of lifestyle-based items. Consumers are quickly moving away from the technology upgrade treadmill, and are realizing that one doesn't need the latest and greatest to do the most common tasks associated with desktop computing. The current trend in consumer demand is simpler, sleeker, smaller, and stylish, without sacrificing price, performance or expandability. Notebook computers are also trending towards thin, lightweight and attractive designs that are very portable and easy to use. In the future the computer business might become more like today's fashion businesses. For example, computers have to be customized according to region, demography, culture and lifestyle of their target customers. If George Washington University were doing extremely well in NCAA, there could be a demand for 6000 iPods with the logo of George Washington University on them. Such a demand might also collapse within few weeks if remains unmet. Companies that can quickly identify such trends and tailor their supply chain to meet that demand would be able to target such a growing segment of the personal computer market.

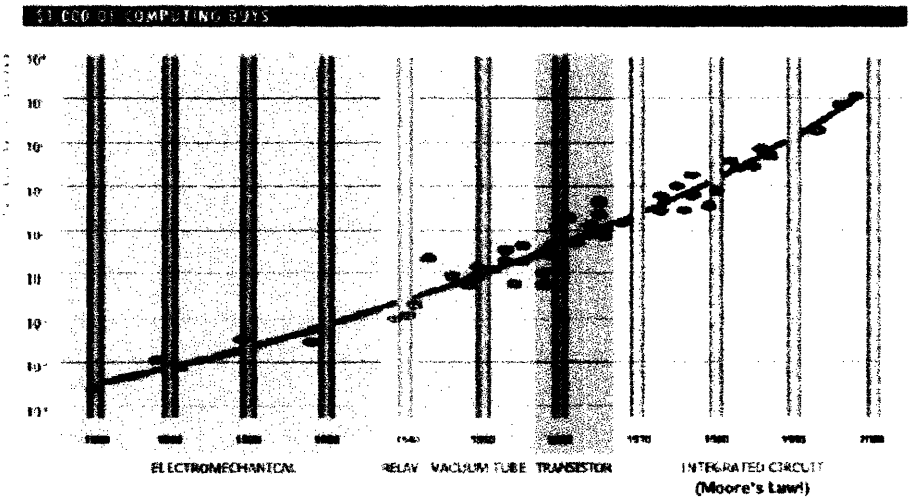
Always-online devices: New wireless broadband technologies have enabled computers to access high speed Internet from anywhere. Users can now access information, write

emails, message their buddies, make Internet phone calls, download or listen to streaming audio, view video and TV shows while on the go. Businesses are using these technologies to remain in constant contact with their field force, customers and trading partners. One can expect that such as trend may become even more prominent in the future, as many more applications are developed based on devices being always online. We might even see different devices talk to each other, automatically download upgrade information, send repair/maintenance requests when needed or get personalized upgrades based on user behavior. Always online devices can also be very lucrative for companies outside the computer industry. For example, location based advertisement has the potential to revolutionize the advertisement industry. Such a possibility has incentivized new players to deploy ambitious citywide free wireless service to the consumers for gaining control on such services. Google and EarthLink have teamed up to provide free wireless Internet service in the city of California in the US. Other big cities such as Chicago and Minneapolis are also trying to build citywide Wi-Fi services. If this business model becomes successful, many cities around the world would soon have ubiquitous Internet access and a proliferation of always-online devices.

Reducing size and increasing computing power: Computing power has followed Moore's law over four decades now, as the number of transistors on a chip has nearly doubled every two years. Moore's Law is actually not the first, but the fifth technology paradigm that has seen exponential growth, the previous four paradigms being electromechanical, relay, vacuums tube and transistors (see Fig.21). Each time one paradigm runs out of steam, another picks up the pace. If size of a transistor reduces to that of a molecule in a few years hindering further progress, new technological

breakthroughs such as quantum and DNA computing might lead us to the next paradigm of computing power.

Figure 21: Exponential Growth of Computing (1990-1998)



Source: Ray Kurzweil

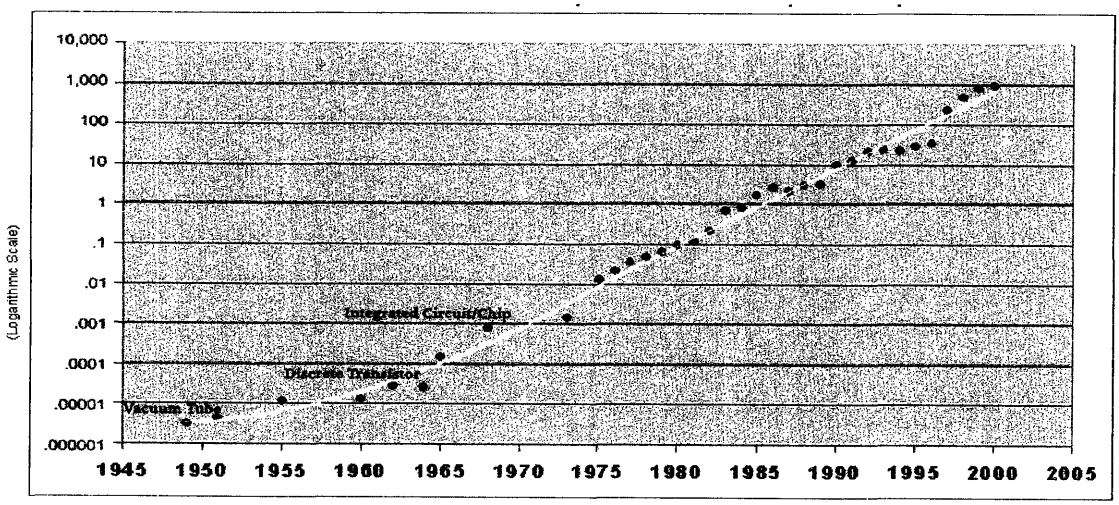
A quantum computer, in principle, can perform myriad operations in parallel, using only a single processing unit. This gives it the potential to be much more powerful than a classical computer of the same size. A DNA computer merges computing with molecular biology. The promise of DNA computing is massive parallelism such that with enough DNA, one can potentially solve huge problems by parallel search. If such technologies becomes commercially viable in the future, we would see increase in computing power of computers by several orders of magnitude. This might lead to more demand for personal computers for running high-end applications.

Mobile applications: Many new applications have come into existence that brings value to the ubiquitous computing world. Examples of such emerging applications are Apple

Computer's iTunes website that allow users to download music into their iPods, Google's mobile search allows users to efficiently search the Internet from their phones, Skype allows users to make Internet voice calls from their handheld, GPRS applications help users to track location and get direction. Such applications indicate a growing trend of more innovative applications that would fuel the ubiquitous computing era. New applications would leverage a variety of user devices, faster processing, higher storage, access to wireless Internet and popular digital content to add unique value to the consumers. Ubiquitous computing would drive more PC sales in the future if such a scenario materializes.

Exponential growth in digital content: Higher quality and negligible delivery cost of digital information have caused widespread digitization of information. Digital Movies, music, and pictures have filled our hard drives even though the memory size of the drives has continually increased. Boradband has enabled free distribution of digital content real-time to anywhere in the world. Independent producers like Mondo Media to big media companies like MTV has made the World Wide Web a sort of worldwide TV network. More and more companies are having all their information online, communication with their employees, customers and vendors over the Internet. Search engines have done an excellent job in producing the right kind of digital information to the user. The growth in digitization has been supported by the reduction of the cost of computer memory as shown in Fig.22. In the future we might see that many more parts of our human life getting digitized, spurring the growth of devices that can store and access a wide variety of digital content.

Figure 22: Random Access Memory in Kilobytes per Dollar



Source: Ray Kurzweil

Personalization: With computers becoming an integral part of our personal lives, personalization of computer hardware and software have become a major trend. Just like everyone has his or her unique eating, dressing or living habits, people also differ in their computing needs. Dell has used this driver to its advantage by allowing customers to customize his or her own computer while placing an order with Dell. Many computer companies have also provided many personalization options at a software level, in terms of choice of language, user interface etc. Several innovative companies have developed intelligent software that can dynamically change user options, features, and information content based on user behavior. Proliferation of such personalized devices can spur the growth of ubiquitous computing in the future.

Other than these six important drivers, there is one other driver that is worth mentioning.

Regulations and Internet security: Emergence of Internet security and privacy laws would be crucial for widespread adoption of ubiquitous computing. Loopholes in Internet

security and privacy can be a major bottleneck. South Korea is the world's most wired country, boasting the highest per capita rate of broadband Internet connections. It has been lately recognized that its high-tech prowess hasn't been matched by the development of a mature online society, creating a growing problem of what is known here as 'cyberviolence'. Complaints over such offenses more than doubled in 2005 to 8,406, according to the Korea Internet Safety Commission. The most complaints were for slander, which tripled to 3,933 cases in 2005. Other kinds of regulations, such as lack of international cooperation on Internet laws might complicate multinational companies to operate in different countries. When Google introduced their search engine in China, they had to filter their search results to comply with the Chinese Internet regulation. Google's move received a lot of controversy as liberals condemned Google's move. Lately when Apple computers planned to introduce its iTunes service in France, the French government mandated that Apple should make their music website accessible by any device if they want to operate in France. Apart from regulations, intellectual property laws have to be strengthened in many countries for maintaining digital rights and copyright laws. Some companies are also starting to handle security issues at the software or hardware level. For example, IBM Corporation is working on a method for injecting encryption capabilities into any machines' circuitry. That could mean enhanced security not only for users who keep sensitive data on portable devices, but also for content owners who can use encryption to lock down copyrighted material and prevent it from being freely disseminated

4.3 Trends and Future Scenarios in the Server Industry

The server industry segment has quite a different dynamics when compared to that of the PC segment. Though the server as a product may not change as much as a personal computer, the enterprise application industry that has traditionally driven the server industry is undergoing many changes. In this section we highlight two such emerging trends, namely On-demand applications and business process / IT outsourcing that are bringing many changes to the server hardware business.

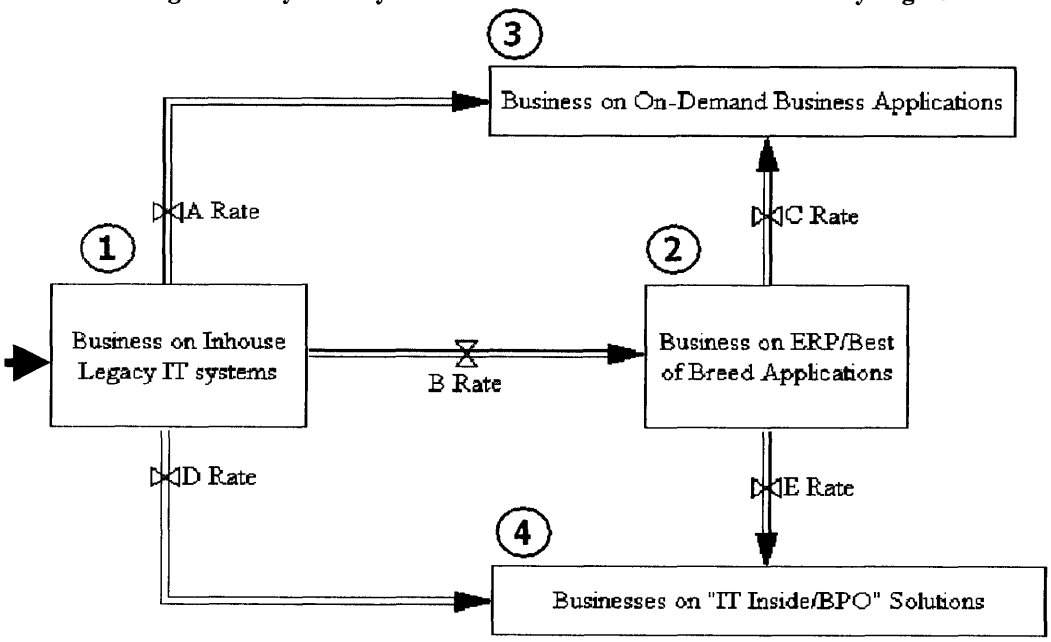
On-demand business applications are an emerging business model for enterprise software providers where software is sold as a service rather than as a product. In this model the software providers host the software centrally for multiple clients. The clients access the solution over secured Internet and pay on usage basis. Such a model has become increasingly popular with the businesses as their IT expenses become a variable rather than fixed cost. This helps them to better justify their IT investments as their return on investments becomes more visible. Success of salesforce.com, which is an on-demand CRM application provider, has pioneered the hosted application model. Such examples have pushed other vendors and customers to migrate into this new paradigm. Companies such as NetSuite and Salesnet, have also started providing online software services. Increasingly large enterprise software providers such as SAP and Oracle are working to shift to this on-demand model. In addition, vendors such as IBM, BEA, and TIBCO are offering middleware and integration products either for building on-demand applications, or as embedded infrastructure for application vendors. SAP's latest launch of SAP CRM is an indication of this trend.

Though it is an interesting business direction for the enterprise software providers, if such a trend materializes, it would potentially change the landscape for the server hardware industry. Firstly, the server OEMs would find that instead of individual businesses, a majority of their products would be procured by a handful of companies that host applications for those individual customers. Such a trend would transfer significant bargaining power in the hands of companies that host applications. These companies would demand better price for performance from the server OEMs. Secondly, the need for low-end servers might diminish as the application providers demand more powerful servers to cater to multiple clients from a single server. This could lead to a change in product mix for the server OEMs, as they would increasingly focus on high-end servers.

Business process/IT outsourcing is another growing trend where IT is being delivered to businesses as a service. Business Process Outsourcers (BPOs) and other business service providers such as FedEx for supply chain services and Hewitt for HR services outsource non-core business processes from their clients. Many businesses are ready to outsource their non-strategic processes, as service providers are able to provide similar or better service levels at a lower cost. With cost saving being a high priority for many businesses, such outsourced services are quickly gaining popularity. If this trend becomes dominant, it might have a high impact the Server hardware OEMs. Similar to the on-demand trend, the server OEMs would see consolidation of their customer base.

We have developed a framework to analyze the different future outcomes of the industry (see Fig.23). The framework uses a stock flow diagram of businesses that use enterprise applications, stock representing the states of the businesses and flow representing the migration from one state to the other. The framework groups today's enterprise software applications into four stocks -'Business on in-house legacy IT system', 'Business on ERP and best of breed solutions', 'Business on on-demand application' and 'Business on IT inside/BPO solutions'.

Figure 23: System Dynamics Framework of the Server Industry Segment



It is important to note that different part of a single business can be in different stocks at the same time. It is very common for large companies to have a few of their core processes on proprietary systems, such as an IBM mainframe or in-house developed software, and majority of their processes on ERP or best of breed solutions or even outsourced to external service providers. We assume that customers can remain in multiple stocks at the same time, but their presence in each of the stock might increase/decrease over time. One way to think about it is to allocate the fraction of IT

investments in each of the stocks, with their total always adding up to one. Even though in this paper we would restrict ourselves only to qualitative discussion using this framework, such an analogy might help the reader to understand the various arguments presented in this paper.

Though there can be several possible scenarios based on which stocks become large in the future, we have restricted ourselves to three important scenarios. The first scenario, which I name 'Decentralized server customers' scenario, assumes that majority of the businesses remain in stocks 1 & 2 leading to a decentralized large customer base for server OEMs. The second scenario, which we name 'Centralized server customers' assumes that majority of the businesses migrate to stocks 3 & 4 leading to a centralized small customer base for server OEMs. Finally the third scenario, which we name 'Part centralized and part decentralized server customers', assumes that that businesses remain evenly distributed among stocks 1,2,3 and 4 leading to a partly decentralized and partly centralized customer base for server OEMs.

Figure 24: Extreme Future Scenarios of the Server Industry

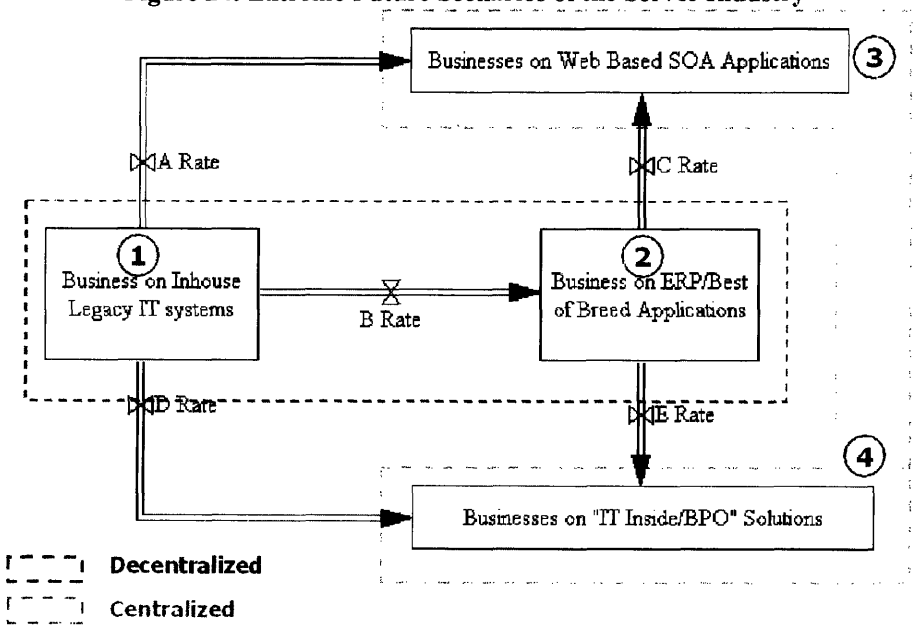
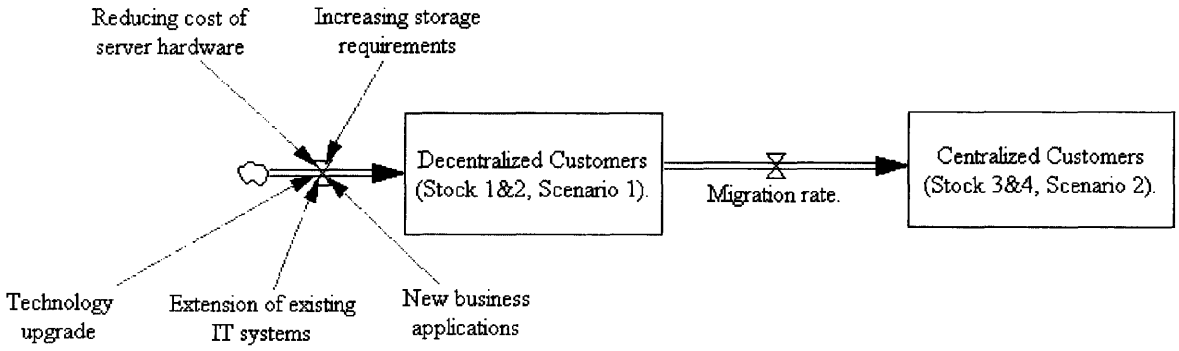


Fig.24 is a graphical representation of the two extreme scenarios, namely the decentralized server customers and the centralized server customers as boundary scenarios. Companies in the industry can decide on their individual strategies based on which boundary they become closer to in the future.

4.3.1 Decentralized Server Customers Scenario

In this scenario, business customers of servers remain decentralized like it is today, with little migration to centralized customers. Existing and new customers buy servers because of the reducing cost of server hardware, increasing storage requirements, technology upgrade, extension of existing IT systems and introduction of new business applications by software providers (see Fig. 25).

Figure 25: Drivers of the 'Decentralized Server Customers' Scenario



I now describe of some of the important drivers of the 'Decentralized customers' scenario.

Reducing Cost of Server Hardware: Similar to personal computers, cost of servers have also fallen in the past decade. If companies purchase more servers as the price of servers goes down, then keeping the cost low for the manufacturer becomes very important. Server OEMs (e.g. IBM, SUN, HP) and the component suppliers (e.g. Intel, EMC, IBM) that become the cost leader would succeed in this case. Businesses in developing countries that have not used enterprise IT systems might take advantage of more affordable servers to implement new systems.

Technology Upgrade: New server technologies both at the software and hardware level might lead to increased sales of server hardware. High end computing might drive sales of high-end servers. Life science, physical sciences, biotechnology and several other industries are increasingly demanding faster computing for advanced optimization, simulation, data analysis and other high-end work. Companies that manufacturer high-end server and components would take advantage if such a trend takes shape.

Extension of IT systems: Extension of present IT systems would drive server sales as more companies integrate internally with their employees and externally with their business partners. Even though for those companies that have heavily invested in their IT capability, continuously changing business environment would call for reinvesting in IT systems.

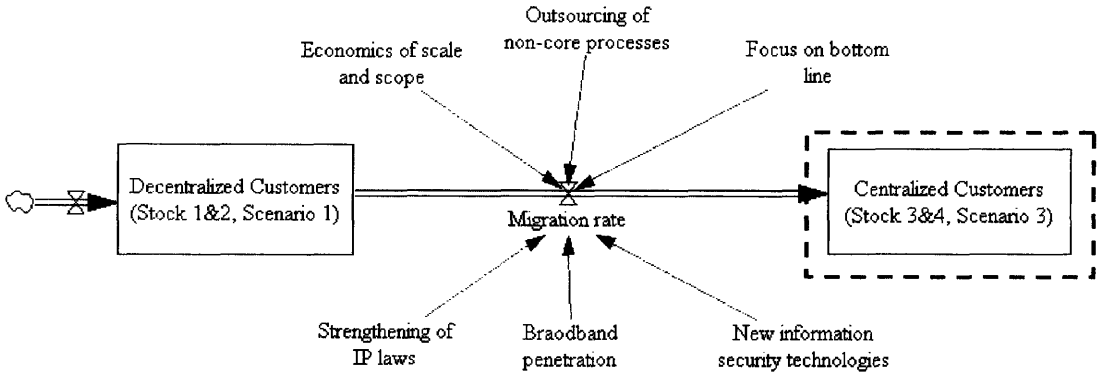
Increasing Storage Requirements: With the increase in digital content and transaction volume the need for storage systems might drive the need for storage server hardware.

New Business Applications: New business applications from software vendors would drive new IT investments and thus more server sales. SAP, i2, Oracle and best of breed application providers are constantly looking for new areas of enterprise application.

4.3.2 Centralized Server Customers Scenario

In this scenario, server hardware customers migrate from stock 1 & 2 to stock 3 & 4. Existing businesses either outsource their IT systems or procure applications on-demand driven by several drivers. Some of the drivers of this scenario are higher economics of scale, outsourcing of non-core processes, focus on bottom line, strengthening of IP laws, increased broadband penetration, and emergence of new information security technologies (see Fig.26).

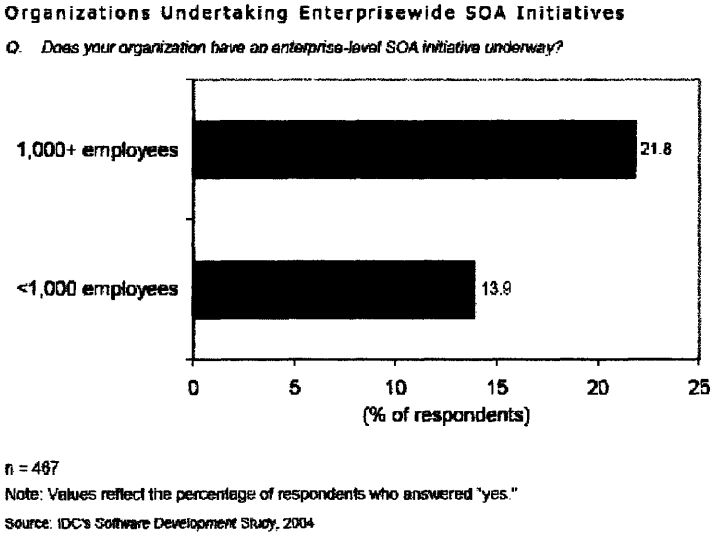
Figure 26: Drivers of the 'Centralized Server Customers' Scenario



Enterprise software vendors have started including support for service oriented architecture, modular design, extensive use of standards, and leveraging of virtual resource models to support centralized on-demand services. IDC conducted a survey among medium and large enterprises on their initiatives towards SOA. The study found

that a impressive 21.8 % of the companies who have more than 1000 employees, and 13.9% of the companies who have less than 1000 employees, have a enterprise level SOA initiative underway (see Fig.27). Such statistics strongly indicate a trend towards the 'Centralized server customer' scenario.

Figure 27: Adoption of SOA Architecture



I now describe some of the drivers of the 'Decentralized server customer' scenario.

Broadband penetration: As more and more businesses have access to high-speed broadband connection, it becomes possible to procure business applications, processing storage and storage space on demand. With accelerated broadband penetration, such a trend is bound to be dominant in the future.

Focus on bottom line: Many companies in developed countries are feeling the pressure to reduce cost from their business operations to remain competitive. Companies are constantly looking for ways to reduce their cost base without foregoing any strategic

advantage or exposing themselves to higher risk. Many companies have found that offloading their IT infrastructure to on-demand and outsourcing to service providers are effective ways to quickly reduce their total IT cost.

Economics of scale and scope: On-demand application providers and outsourcing service providers benefit from economics of scale and scope as they use the same hardware, software and staff across multiple clients. High economics of scale and scope help these companies to perform the same task at a much lower cost compared to their clients. Such cost advantage also gives their clients significant incentive to outsource business processes if they get past of the savings. Further, the service providers and their clients can quickly ride on the learning curve by transferring best practices from one client to the other.

New IT security technologies: Information security is a big concern for businesses as information leaves the premises of the company to the service provider, especially information that is critical for their business. Further, with the advent of several compliance regulations such as the Sarbanes-Oxley Act and Health Insurance Portability & Accountability Act, it is no longer a choice but is mandatory for companies to ensure information security and compliance. New information security technologies might mitigate such concern, further propelling companies to offload their IT assets to service providers.

Outsourcing of non-core processes: Non-core business processes hardly provide any competitive advantage to companies. This is why companies are increasingly outsourcing non-core business processes to third parties who can perform them much cheaply and efficiently. For example, increasingly we see companies outsource their logistics functions to third party logistics providers such as FedEx and UPS. Employee payment processing, accounting, and call center operations are other examples of business processes that companies often outsource to service providers in low cost jurisdictions. The service providers take complete control of these processes, which includes associated IT investments. Most traditional service providers such as UPS, FedEx, Hewitt Associates, Fidelity Employer Services, Mellon, First Data, ADP, Convergys, West, Quintiles Transnational, and many others are increasingly stressing IT capabilities as a strategic competency. In effect, these providers are increasingly getting into the IT solutions business.

Strengthening of IP laws: With stronger IP protection laws mandated by national and international governmental agencies, the risk of outsourcing/off-shoring of business processes and sensitive information would be mitigated.

4.4 Other Drivers Affecting the Computer Hardware Industry

Government funding: Decrease in US government funding in basic computer science research may tilt the innovation locus to other countries. In the US, IT research grew largely under DARPA and the National Science Foundation (NSF). Over the past four decades, the resulting research with the support of these two institutions has laid the foundation for the modern microprocessor, the Internet, the graphical user interface, and

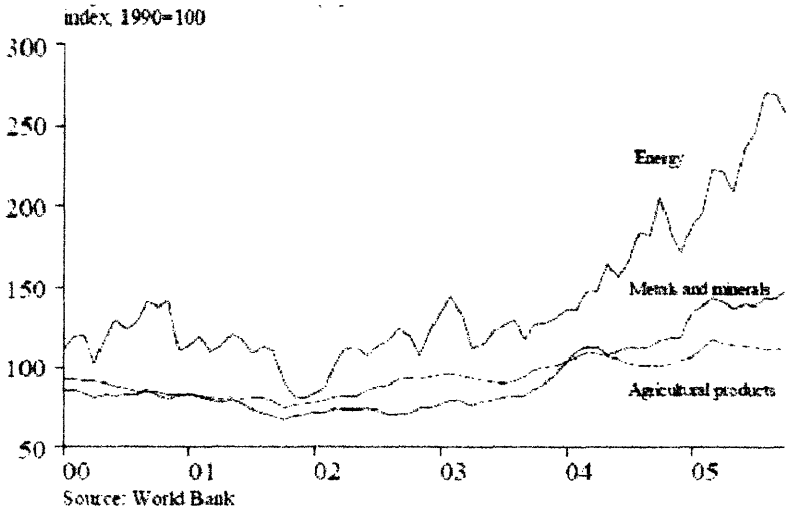
single-user workstations. Progressive research funded by these agencies has also launched entirely new fields of research such as computational science. Virtually every aspect of information technology and computer science that we know of today has some of their roots in federally sponsored research. A 2003 National Academies study provided 19 examples where such work ultimately led to billion-dollar industries, an economic benefit that reaffirms the importance of basic research for growth and prosperity of a nation. However, in the past three years, DARPA funding for IT research at universities has dropped by nearly half. Policy changes at the agency, including increased classification of research programs, and increased restrictions on the participation of noncitizens discourage university researchers to participate in federally funded research. The funding rate for competitive awards in the IT sector has also fallen significantly, discouraging the private sector to undertake risky fundamental research. Such a dip in research in harmful to the discipline and may threaten the position of the US as the research leader in the future.

Off-shoring: Off-shoring of manufacturing, R&D and support services has many benefits such as availability of cheaper labor, scarce business relevant skill-sets, tax benefits, easy access to raw materials among many others at the off-shored location. For this reason many companies have scrambled to offshore their non-critical and non-strategic processes to far off countries. However, with off-shoring now becoming an industry norm, its long term strategic advantage is now questionable. It is a common knowledge that labor wage rate in the developing and underdeveloped countries have continued to rise with the wake of off-shoring. Apart from rising costs, companies are

also facing high turnover of workforce at their off-shore locations. A part-time or full-time engineer in India or China, who works unseen in a virtual world, tend to have weak loyalties towards his or her employer in another part of the world. Unfortunately, such situations can lead to potential illegal sharing of a company's knowledge base and core intellectual property with a competitor. Underdeveloped intellectual property protection law in most of these countries is a hurdle for companies to guard themselves against such happenings. For larger companies, cost savings by off-shoring manufacturing, R&D and support services still remain compelling, even at a higher risk. But for the highly competitive and nimble software companies, however, the risks may quickly outweigh the cost savings given the possibility of losing any portion of their intellectual property, knowledge capital, or competitive edge.

Oil price: Mainly because of Middle East instability and repeated hurricane attacks at oil refineries in the US, oil prices have gone through the roof. But in spite of this historical price peak, many in the industry estimate that prices would sooner or later come down. Also, more dollars are now being put into research in energy efficiency and alternate fuel. However, even with the best possible efforts, bringing any fundamental change to solve the energy crisis would likely take a long time. Fig.28 shows how energy prices have increased at a much higher rate compared to metals, minerals and agricultural products.

Figure 28: Rising Energy Prices



Green laws: Many environmental, trade and governmental organizations have published reports on the fate and subsequent profound environmental effect of electronics products at the end of their useful life. Firstly, the higher rate of product innovation in this industry coupled with shrinking product life cycle has increased obsolescence rates considerably. This trend has made the electronics products the fastest growing segment of waste. Secondly, only a miniscule amount (5% - 15%) of this waste is recycled. Around 5% - 20% of the waste is deposited in landfills, incinerated or illegally dumped in the natural environment. The remaining of the waste (75%) is stored in attics, garages or warehouses. Thirdly, electronics goods contain various levels of lead, mercury, cadmium, and poly- brominated flame-retardants, which are known health hazards. According to data as of 2002, electronic waste accounted for 40% of lead and 70% of cadmium found in landfills. These toxic materials also gets mixed with underground water bodies, spreading to a wider area.

The government is definitely interested in reducing health hazards through tighter regulation. The government of individual countries would have to either finance system wide recycling effort by enforcing a recycling tax on electronics items sold or make the businesses responsible for financing their own recycling effort. Because of the exploding consumer base of electronics items and the complexity of reverse supply chains, financing and managing a system wide recycle effort would be a difficult task. The European Union and few states in the US have taken the later approach of regulating businesses to undertake recycling of their own products. For example, The European Union's Directive on Waste of Electrical and Electronics Equipment (WEEE) is the most prominent and extensive "take back" legislation enforced to date. The enforces mandatory take back of electronics items by the manufacturer at the end of their useful life. The legislation also creates incentive for "design for environment" processes that may reduce toxicity and improve re-cyclability of electronics products. This is a complicated issue, as manufacturers would ultimately pass on the extra cost to the consumer through higher prices for their products. On the other hand, lack of knowledge about harmful effects of electronics wastage would prevent most consumers from accepting the higher price. Further, because cost of recycling is only borne by the user of the product whereas the benefits are widespread, there is little incentive for the consumers to pay the extra price.

5 Analysis of Scenarios

In this chapter I evaluate the competitive dynamics of each of the scenarios described in Chapter 4 and predict what kind of supply chains might evolve in the future. Our research suggests that the competitive dynamics of a scenario largely depends on the drivers that drive those scenarios. To analyze the relationship between the different drivers and the competitive dynamics of a scenario, I now introduce a framework that I have used in our research.

5.1 Industry Power Matrix Framework

The basic hypothesis of the framework is that the bargaining power of the different players in the 'value chain' of the computer industry is directly proportional to the 'value' they create for their customers. The term 'Value chain' is used as the value-adding activities of different players in the industry that finally benefits the end customer. For example, in the personal computer industry segment, the operating systems providers such as Microsoft and Red Hat, component providers such as Intel and AMD and PC assemblers such Dell and HP are the different players in the value chain. The term 'value' to the end customer is used as tangible benefits that the customers are ready to pay for. For example, user friendly operating systems, faster processors or more sleaker laptop designs are some of the 'value' that the different players create for the end comsumers.

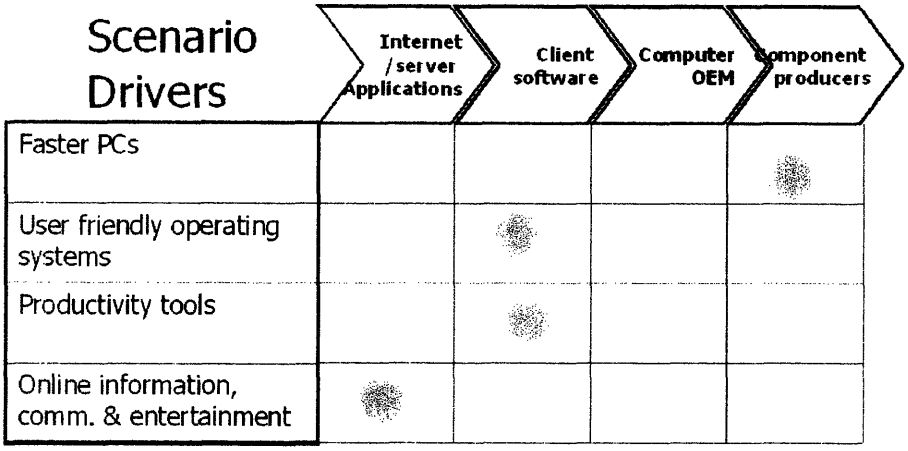
The industry drivers, value chain and competitive dynamics in the computer industry can be linked if one analyzes the history of the computer business. In the 1970s and the early

1980s the computer industry's structure was decidedly vertical. The three largest companies, IBM, Digital Equipment Corporation (DEC) and Hewlett-Packard produced most of the elements of the computers they sold, from the operating system and applications software to the peripherals and electronic hardware. Each company being a single entity dominated the end-to-end of the value chain. But in the 1970s IBM decided to outsource the operating systems and the processor of its PCs to two budding companies named Intel and Microsoft. Such moves led to the vertical disintegration of the computer industry. Increasingly Intel and Microsoft started controlling the user experience by developing faster processors and user-friendlier operating systems. This led to a power shift in the industry, as consumers valued Microsoft and Intel more than they valued IBM or Dell. The profit margin of the software producers and component manufacturers started climbing at the cost of the computer OEMs. The need for faster computers, user-friendly operating systems, and productivity tools were some of the drivers that caused such a shift of power in the industry's value chain.

With the advent of the Internet, the value chain of the whole industry has extended to include Internet application providers. As consumers are increasingly using computers for online information, entertainment and communication, there is an increasing power shift in the industry from the actual PC makers to the Internet players. Many of the computer users now see their monthly bill for broadband connection and membership charges for online services exceeding what they pay for their computers. In the cell phone industry, many service providers have started providing free cell phones with new service connections. In the future one might actually see the online service providers distributing

free computers with service registration. Fig. 29 shows an illustrative industry power matrix representing the relationship between the drivers, value chain and the competitive dynamics. The drivers are shown in the left hand column, and the industry value chain shown in the top. The green dots represent the dominating players in the industry value chain against each of the scenario drivers.

Figure 29: Illustrative Industry Power Matrix Framework



As consumers start buying PCs because of faster performance, the component suppliers who provide the technology gains power in the value chain as they become important in the consumer's buying decision. Similarly if consumers buy PCs because of user-friendly operating systems and software applications, then the software providers gain power in the value chain. Likewise in the future if consumers buy PCs for accessing online information, communication and entertainment, then companies that provide such data and applications would gain power. However, in reality a consumer's buying decision would be influenced by a variety of drivers. Also, the set of drivers may also vary based on demography of target customers.

In the future the value chain may change as new players join the industry, but depending on what matters to the end consumers, some of the players would become weak as others become powerful. This phenomenon might trigger vertical integration as powerful players start buying weaker players to increase their dominance and wean the majority of industry profits. Supply chains of companies would be dependent on its value chain, level of vertical integration and what matters most to the customer.

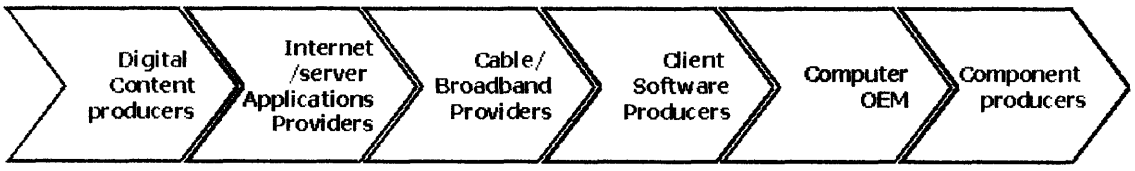
In the following sections I discuss the value chains and competitive dynamics of each of the four scenarios that were introduced in Chapter 4.

5.2 Personal Computer Industry

5.2.1 Industry Value Chain

The value chain of the personal computer industry is comprised of six players: the digital content providers, Internet/server-side application providers, broadband/cable providers, client software providers, computer OEMs and the computer component producers (See Fig.30).

Figure 30: Industry Value Chain of the PC Industry Segment



Digital content producers: This category of players create digital information and entertainment content that consumers access through their PCs. This category includes

companies that produce songs (e.g. Sony), movies (e.g. Time Warner), e-books, encyclopedias (e.g. Wikipedia), specialized information (e.g. webMD for health) and other kinds of digital content.

Internet / server applications providers: This category of companies control computer user's online experiences. The category includes companies that create search engines (e.g. Google), web portals (e.g. Yahoo), email applications (e.g. Hotmail), peer-to-peer file sharing software (e.g. Napster) and other kinds of online applications. This category also includes enterprise application providers (e.g. SAP, Oracle, Microsoft).

Cable/broadband providers: This category of companies includes the broadband service providers (e.g. Compact) and the Internet network backbone producers (e.g. Cisco) that connect individual PCs in millions of homes and offices to the Internet.

Client side software providers: This category of companies provides the operating systems (e.g. Microsoft, Linux, Apple), productivity tools (e.g. MS office, MS Outlook, MS word), and entertainment software (e.g. Windows media center) that control users experience of a PC.

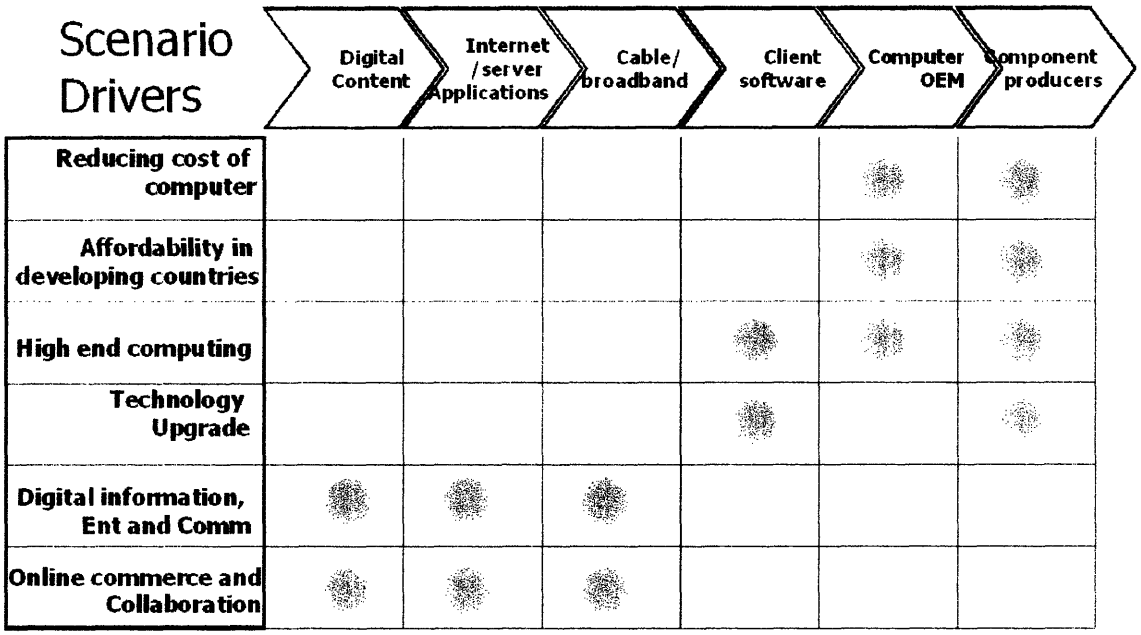
Computer OEMs: This category of companies provides personal computers. This category comprises of companies such as Dell, Apple, HP, Lenovo who manufacture and assemble the PCs. This category is our focus area in this research.

Component manufacturers: This category of companies produces computer components used by computer OEMs. This category comprises of companies such as Intel (for processors), EMC (for storage), nVidea (for graphics cards) and other component manufacturers.

5.2.2 Dynamics of the PC Based Computing Scenario

Fig.31 represents the power matrix of the PC based computing scenario.

Figure 31: Industry Power Matrix of the 'PC Based Computing' Scenario



As shown in Fig.31, if constantly reducing cost of computers becomes important in driving PC sales, as it is in the present, then computer OEMs and component producers may become important in the value chain. Dell for example, has used this driver to its advantage by becoming the cost leader in the industry. Intel has also used this driver to become dominant by reducing the cost of its processors through technology innovation. In the future companies that further drive down cost would become powerful should such

a driver become important. If computers become more affordable in developing countries because of rapid economic growth, the cost of computers would still play a large role in user adoption, making the computer OEMs dominant that cater to the developing markets with cheaper computers. Several Indian companies such as HCL are introducing computers that cost less than $200 to capture the vast rural markets. The $100 laptop project under One Laptop Per Child (OLPC) name at MIT is also banking on such a trend. HP, AMD and several other US companies are also developing more affordable computers.

If high end computing becomes popular, it would benefit high end application providers, OEMs and component producers that invest in faster PCs. Dell's recent (2006) acquisition of Alienware, a Miami based producer of high end computers is an example of such a trend. If technology upgrade drives demand for new personal computer, companies that invest in developing new technologies would become powerful in the value chain.

Delivery of digital information, entertainment and communication service may be a major driver of personal computer usage in the future. People are increasingly using computers for entertainment such as listening to online radio, songs, playing games or communicating with other people through email, online chatting software (e.g. yahoo messenger, ICQ, Google talk) or lately Internet calls (e.g. Skype). In the future what might matter to the consumers are the online services and not the physical computer itself. Hence consumers would be ready to pay more for the services and less for the

computer hardware, such as many consumers are spending more money on their broadband connection and other online services compared to regular hardware upgrades. If such a trend becomes prominent in the future, the computer OEMs might see a power shift in the industry towards the content, Internet connection and application providers.

Finally, online commerce and collaboration are increasingly important as more and more consumers are buying products and services online. Success of online merchants such as Ebay and Amazon are indicators of this growing trend. As more and more transactions become online; a good chunk of a consumer's time on a computer is spent on such services. Such a trend would shift the power more towards these online merchants.

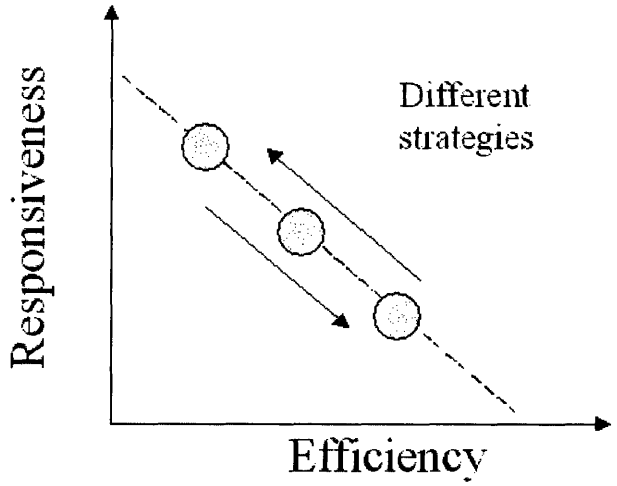
5.2.2.1 Supply Chain Strategy

Supply chain of a company supports its operating objectives and ultimately its business strategy. Hence, as the future unfolds, a company's operating model and its supply chain have to be suited to the new environment. In the 'PC based computing' scenario, world-class companies have to rethink their operating objectives to maintain competitive advantage. With reducing value of computer hardware to the end consumer, computers would become less differentiated and more like a commodity product. Also, with the emergence of new markets, companies would have to efficiently cater to the cost conscious customer base. As software and service become more important to the end users, traditional computers OEMs have to find out ways to integrate their supply chains with that of the software and service providers. With the advent of broadband and wireless, the process of delivering software and services may vastly change in the future.

Software and services could be delivered on-demand to the end consumer, shifting more leverage to the providers. Supply chains may become more distributed with the reduction of transaction costs in the future. It is important to note that the drivers in a future scenario only indicate industry standards for supply chain management and not company specific strategies and practices. Companies would choose their supply chain strategy based on their individual business strategy. For example, even if low cost computing becomes a significant driver in the future, some companies might choose to align themselves with a different driver, such as high-end or lifestyle based computing. Such strategic differences would call for different operating models and supply chain practices.

Predicting the individual business strategies and operating model of companies is almost impossible. Hence in this thesis I have outlined industry standards of supply chain management that might evolve under every scenario. Understanding of the industry standards under every scenario is important for companies to device a clear supply chain strategy. Our research indicates that different scenario drivers push companies to become either more efficiency or more responsiveness in their supply chain practices. For example, lower price of computers would push companies to become efficient by squeezing cost out of their supply chain. On the other hand, lifestyle based computing would push companies to be come responsive to the changing needs of the consumers. Also, for any company, the higher the supply chain efficiency, the lower the supply chain effectiveness and vice versa (see Fig 32).

Figure 32: Generic Supply Chain Strategy



In the future, companies would have to consciously choose one supply chain strategy over the other depending on their overall business strategy. They will invest in developing processes and systems that either makes them more efficient or more responsive. Table 1 lists the supply chain objectives and operating objectives against each driver of the 'PC based computing' scenario.

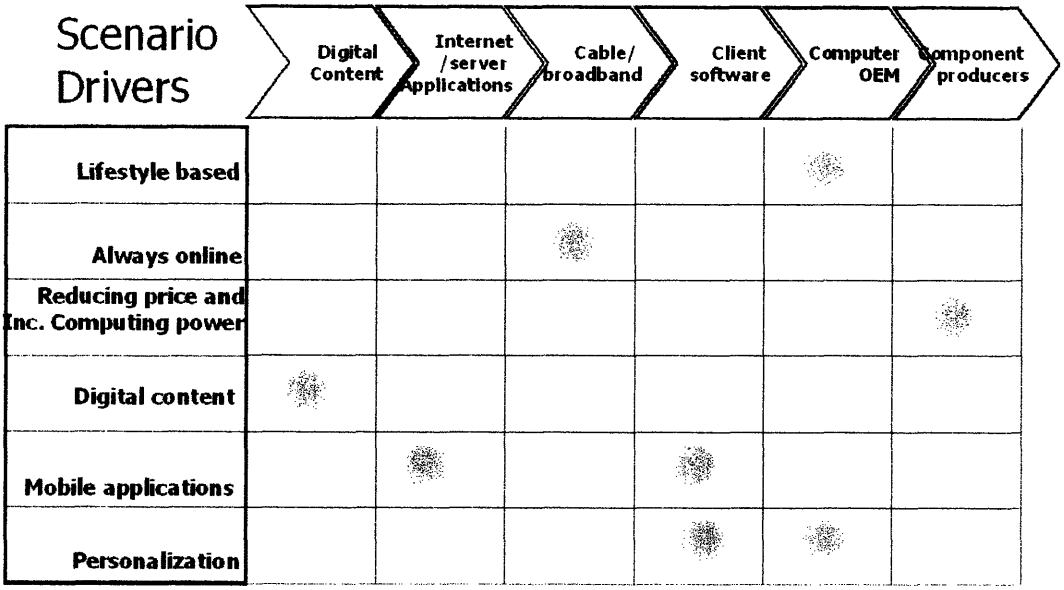
Table 1: Supply Chain Strategy of the 'PC Based Computing' Scenario

Scenario Drivers	Industry Operating Objective	Industry Supply Chain Standard
Reducing cost of Computer	Reduce cost	Efficiency
Increasing Affordability in developing countries	Increase market reach and reduce cost	Efficiency
High end computing	Specialization	Responsiveness
Technology upgrade	Focus on R&D	Responsiveness
Digital information, entertainment and communication	Integrate with service partners and reduce cost	Efficiency
Online commerce and collaboration	Integrate with service partners and reduce cost	Efficiency

5.2.3 Dynamics of the Ubiquitous Computing Scenario

Similar to the 'PC based computing' scenario, Fig.33 represents the power matrix of the 'Ubiquitous computing' scenario. The drivers are shown in the left hand column, and the industry value chain shown in the top. The green dots represent the dominating players in the industry value chain against each of the macro drivers.

Figure 33: Industry Power Matrix of the 'Ubiquitous Computing' Scenario



If computing becomes lifestyle based, then the form factor of the products become important for the customers. Computer OEMs would have to innovate products that suite the specific lifestyle of the users, and those who can, would gain power in the value chain. If always online becomes a key value proposition for consumers, companies that provide broadband services to a variety of devices would become the key player in the industry value chain. If reducing size and increasing computing power becomes one of the key value propositions for consumers, then the component makers who are the technology drivers would emerge as the key players. If, availability of digital information, real-time or otherwise, becomes important to the users then companies that

provide such content would emerge as key players. If new mobile applications such as email/GPRS/location based services become the key value propositions to the users, then the server /client side software vendors would emerge as key players in the industry. Finally, if consumers adopt to ubiquitous computing because it would enable them to personalize their user experience with intelligent interfaces, then the computer OEMs and software companies that provide such personalized interfaces would become dominant in the value chain.

5.2.3.1 Supply Chain Strategy

The supply chain strategies in the 'Ubiquitous computing' scenario can be represented as it has been done for the PC based computing scenario. With the computer as a product changing drastically, supply chains may undergo significant changes. New technology development along with shrinking size of computers would make computer-manufacturing processes much more automated. Such a phenomenon might make it easier to manufacture computers closer to the consumer, reversing the wave of off-shoring of manufacturing. Further, reducing size of computers would change the transportation cost economics, as increasing value density would make them cheaper to transport. Also, computers become much more lifestyle based, consumers might demand lot more customization in computers to suite their individual lifestyles. This would make computer supply chains similar to fashion businesses. As people prefer to buy fashion items from a store, in the future computers might again be sold through physical stores, reversing the online sales trend. Supply chain strategies of companies would however depend on which of the drivers become dominant in the future (see Table 2).

Table 2: Supply Chain Strategy of the 'Ubiquitous Computing' Scenario

Scenario Drivers	Industry Operating Objective	Industry Supply Chain Standard
Lifestyle based	Focus on design, Fast inventory turn	Responsiveness
Always online	Integrate with service partners and reduce cost	Efficiency
Reducing size and more computing power	Focus on product development, reduce cost	Efficiency
Digital content	Integrate with service partners and reduce cost	Efficiency
Mobile application	Integrate with service partners and reduce cost	Efficiency
Personalization	Focus on customization	Responsiveness

It is again important to note that companies may use different and innovate strategies to gain competitive advantage in a given scenario, which may deviate from the ones mentioned in the table.

5.2.4 Vertical Integration

Shifting power among the different plays in the industry might lead to vertical integration of the industry. Some of the dominant players may try to encroach the playing field of others or buy them to further increase their dominance. Some of these fights are already emerging. For example, as Google becomes more powerful in the value chain, it would challenge some of the existing players. As consumers spend more time in the Internet, Google might try to provide online applications to users that directly challenge

Microsoft's position in PC business. Google or Comcast one day might start distributing free PCs with its service registration, just as we now get free cell phones while registering with a new service plan. Dominant players might start buying weaker players to get strategic advantage, leading to vertical integration. Even though there is no clear sign of such a happening in the near future, but considering the speed at which changes happen in the computer industry, such kind of possibilities cannot be ignored. Professor Charlie Fine of the MIT Sloan School of Management calls it the clockspeed of an industry, which indicates the speed at which an industry goes through from vertical integration to disintegration and back to vertical integration. Professor Charlie Fine through his groundbreaking research across several industries has shown such a phenomenon does exist. In his book "The Clock Speed", he has described how companies in an industry go through a double helix phenomenon in one such cycle. The computer industry, which started vertically integrated a few decades ago, is now disintegrated. There is a possibility that in some point in the future, maybe by 2020, the industry may become again vertically integrated. Such a phenomenon can result from the power shift in the industry based on which of the drivers become dominant in the future.

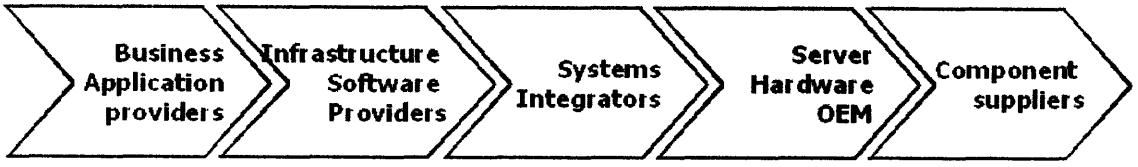
5.3 Server Industry

5.3.1 Industry Value Chain

The value chain in the server industry segments is different in the decentralized and centralized scenarios.

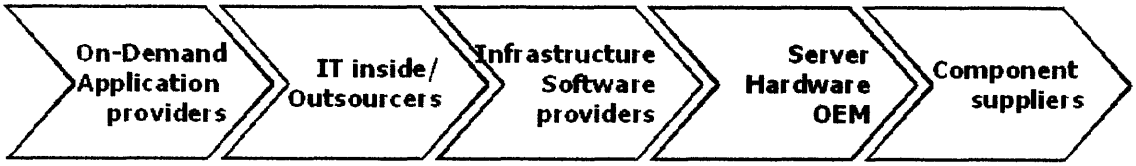
The value chain of the server industry in the 'Decentralized server customer' scenario would comprise of five players, namely, the business application providers, infrastructure software providers, systems integrators, server hardware OEMs and component suppliers (see Fig.34).

Figure 34: Industry Value Chain of the 'Decentralized Server Customers' Scenario



The value chain of the server industry in the 'Centralized server customer' scenario would include on-demand application providers and, IT inside/outsourcers replacing the business application providers and infrastructure software providers (see Fig 35).

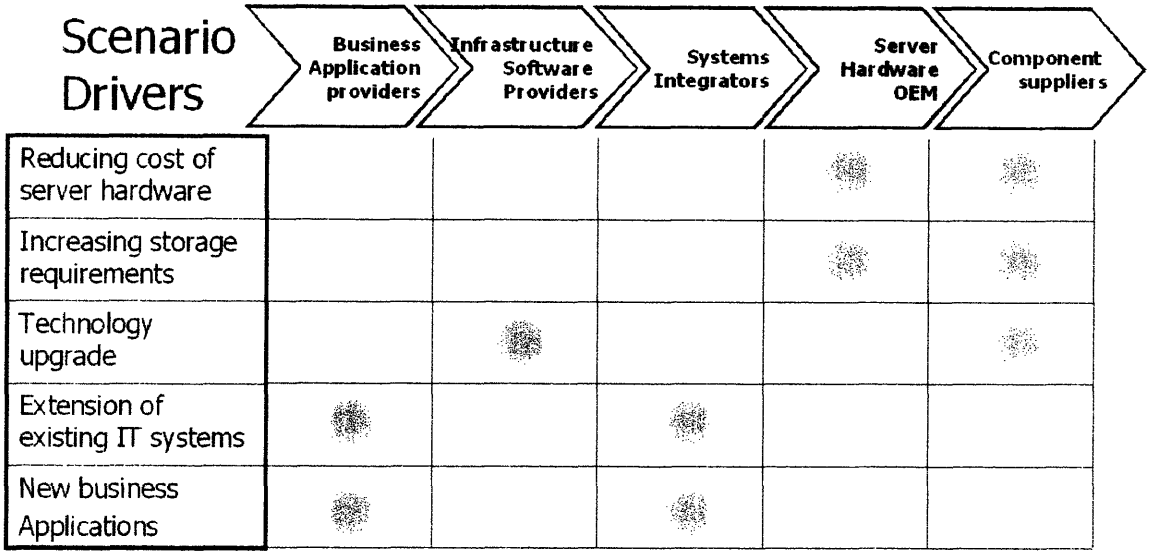
Figure 35: Industry Value Chain of the 'Centralized Server Customers' Scenario



5.3.2 Dynamics of the Decentralized Server Customers Scenario

Fig.36 represents the power matrix of the decentralized server customer scenario. The drivers are shown in the left hand column, and the industry value chain shown in the top. The green dots represent the dominating players in the industry value chain against each of the macro drivers.

Figure 36: Industry Power Matrix of the 'Decentralized Server Customers' Scenario



From Fig.36 we notice that for few macro drivers becoming dominant, the 'server hardware OEMs would drive the value chain, and for the rest, other players might drive the value chain.

5.3.2.1 Supply Chain Strategy

Similar to the PC based scenarios, the supply chain objectives of companies, operating objectives and macro drivers are presented in Table 3.

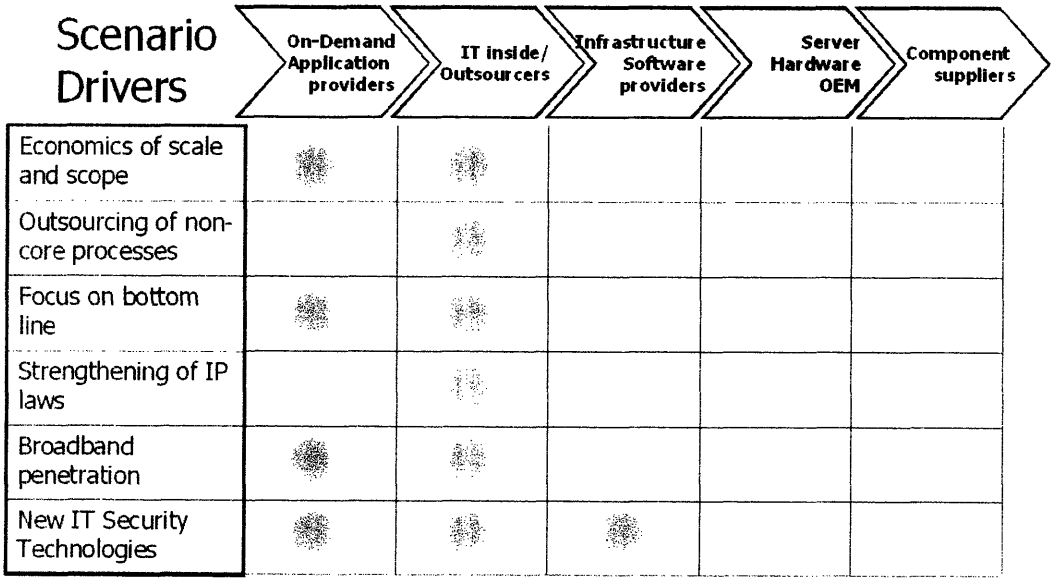
Table 3: Supply Chain Strategy of the 'Decentralized Server Customers' Scenario

Scenario Drivers	Industry Operating Objective	Industry Supply Chain Standard
Reducing cost of server hardware	Reduce cost	Efficiency
Increasing storage requirements	Work closely with storage vendor	Efficiency
Technology upgrade	Work closely with component manufacturers & software providers, integrate with R&D	Efficiency
Extension of existing IT systems	Work closely with system integrators & business application providers	Efficiency
New business Applications	Work closely with business application providers & system integrators	Efficiency

5.3.3 Dynamics of the Centralized Server Customers Scenario

Fig.37 represents the power matrix of the 'Centralized server customer' scenario. The drivers are shown in the left hand column, and the industry value chain shown in the top. The green dots represent the dominating players in the industry value chain against each of the macro drivers.

Figure 37: Industry Power Matrix of the 'Centralized Server Customers' Scenario



If economies of scale and scope derived from the centralization of systems become the main driver, then companies that provide On-Demand Applications, and IT Inside/Outsourcers solutions become dominant in the value chain. If outsourcing non-core business processes becomes the main driver, companies providing IT inside/outsourcing solutions would become dominant in the value chain. It strengthening of IP laws protect companies information, they would be more comfortable to outsource their information systems. Thus companies that provide outsourcing services would flourish and dominate the value chain. If broadband penetration enable business access solutions over high speed Internets, then companies that use broadband to provide their solutions, such as the application providers and outsourced service providers would dominate the value chain.

From Fig.37 we notice that the 'Centralized server customer' scenario is quite unfavorable to the 'Server Hardware OEMs' as majority of the value in the industry is driven by the 'on-demand application providers' and 'IT inside/outsourcers'. But larger and fewer service providers would demand high end servers that can support multiple client applications, provide faster computation and store large amounts of data.

5.3.3.1 Supply Chain Strategy

The supply chains objectives of companies, operation objectives and macro drivers are presented in Table 4.

Table 4: Supply Chain Strategy of the 'Centralized Server Customers' Scenario

Scenario Drivers	Industry Operating Objective	Industry Supply Chain Objective
Economics of scale and scope	Reduce cost by centralizing operation	Efficiency
Outsourcing of non-core processes	Reduce cost by making appropriate make/buy decision	Efficiency
Focus on bottom line	Reduce cost	Efficiency
Strengthening of IP laws	Integrate with companies to manage their data	Responsiveness
Broadband penetration	Provide on-demand services	Responsiveness
New IT Security Technologies	Access on-demand or Outsource more critical processes and information	Efficiency/Responsiveness

5.3.4 Vertical Integration

The server industry might undergo vertical integration in the future. Infrastructure software players such as CA, BMC, Microsoft and Novell are re-architecting their products that supports the dynamism of on-demand service oriented architecture. Recent examples that support the dynamic infrastructure platform include Symantec's acquisition of VERITAS and CA's acquisition of Netegrity. If on-demand becomes a dominant trend in the future, one can expect that the software providers that align themselves to this trend would gain power in the value chain. On the other hand major systems vendors such as IBM or HP may partner with independent software suppliers or develop their own stack of software. For example, in support of this dynamic

infrastructure platform vision, HP and IBM have bought many companies in the past few years. Depending on the extent and lucrativeness of the on-demand / outsourced business in the future, some of these players would gain power and dominate the value chain. On the other hand, some systems providers such as Dell have stayed out of the software business for the most part, with its success leveraging on the success of software and components providers. In the long run such companies could be marginalized if they remains so heavily focused toward the hardware side of the business. Infrastructure providers that are at the edges of computer systems business such as Cisco and EMC may broaden their presence in the infrastructure space to avoid being marginalized by infrastructure platform leaders. Notably both these companies are moving up the value chain to the information and application space. Such dynamics in the computer server industry may lead to vertical integration and disintegration of the whole industry in the future.

6 Conclusion

In this chapter I summarize the methodology followed in our research. I hope this would help the reader in similar other scenario planning exercises. In our research, we went through four distinct phases in analyzing the future of the computer hardware business. Table 5 lists the four phases along with primary data sources used in each phase.

Table 5: Four Phases of Our Research

Phase No.	Activity	Primary data sources
1	Scenario Generation	Interviews, literature search
2	Identification of drivers (for each scenario)	Interviews, literature search
3	Industry value chain and power matrix (for each scenario)	Interviews
4	Industry Supply Chains (for each scenario)	Interviews

Scenario Generation: In this phase we developed the future scenarios for the personal computer and server industry segments. In our experience, generating future scenarios is perhaps the most challenging part of the entire research as it involves filtering through endless future possibilities to create only a handful of meaningful scenarios. To tackle this issue, we focused our research effort on identifying the important dynamics of the industry that could have a large impact on its future. We interviewed several industry veterans on various important aspects of the computer industry such as emerging product, technology, supply chain innovation, the new uses of computers, new markets and regulations to understand and filter the key dynamics. At first what started as open-ended discussions, slowly started to take shape as different dynamics emerged. Analysis of the

of the interview responses pointed us towards a few trends in the industry that could have a large impact in the future. We further filtered through these trends by analyzing the extent of impact and by counting the number of interviewees mentioning about them. Our main purpose was to generate extreme future scenarios from these trends that also have a sizable impact on the computer businesses. Basic stock-flow diagrams from Systems Dynamics helped us in visualizing these trends and in generating extreme outcomes from them. In the personal computer industry, rapid convergence of personal computers and other electronics devices led us to the 'PC based computing' and 'Ubiquitous computing' scenarios. On the other hand in the server industry, growing popularity of on-demand applications and increasing outsourcing of IT infrastructure led us to the 'Decentralized server customer' and 'Centralized server customer' scenarios. Our experience tells us that generating future scenarios of an industry is a highly adaptive process where one needs to deal with uncertainty. However, one can limit the risk of going completely off-track by involving different stakeholders of the industry in the scenario development process early on.

Identification of drivers: Once we generated the scenarios, we started questioning what might cause these scenarios to emerge. Study of different industry drivers made us realize that there is a co-relation between industry drivers and the future scenarios, such that, as one or more of these drivers become dominant in the future, we get closer to one scenario over the other. Hence, we identified the different drivers of the computer industry and linked them with the future scenarios. In total, we identified approximately six drivers for each of the four future scenarios we generated in the first phase. The drivers were

selected based on the responses of the interviewees and literature survey. However, because of limited time and boarder scope, we restricted ourselves only to a few drivers for each scenario. For further focused research on this topic, we recommend that one needs to ensure that the drivers are mutually exclusive but collectively exhaustive as far as possible.

Industry value chain and power matrix: Scenarios and drivers provided us useful information about the future, but they are of little help without knowing what strategies companies should follow to become competitive in the future environment. The industry power matrix framework helped us to bridge this crucial gap by linking the drivers of each scenario with relative power of different players in the industry value chain. For example, few drivers for the 'Ubiquitous computing' scenario are lifestyle based computing, always online devices and new mobile applications. However, each of these drivers would have a different effect on the competitive power of each of the players in the value chain. If consumers decide to buy computers because of their stylist designs, the computer OEMs that create better computer designs would dominate the value chain. On the other hand if consumers decide to buy computers because of new software applications, then software companies who provide those applications would dominate. The power matrix helped us to understand if a driver helps or threatens the competitive position of any particular player in the value chain. Collectively, the framework also provides useful information about competitive dynamics, potential integration and disintegration between players and the need for new capability development of different players.

Industry Supply Chains: The scenario drivers also indicated supply chain capabilities that might become industry standards in the future. In this phase we linked the industry drivers with the industry operating objectives and supply chain standards. However, individual companies would have to develop their own set of capabilities based on their individual business strategies. For example, in the 'Ubiquitous computing' scenario, if a computer OEM wishes to leverage on lifestyle based computing, it has to design a supply chain that is responsive to the changing user lifestyles. On the other hand, if a computer OEM wishes to leverage on increasing demand for faster computing power, it has to design a supply chain that can efficiently collaborate with innovative component suppliers.

Table 6 summarizes the four scenarios, drivers and competitive dynamics that are presented in this paper. Companies can use such information for identifying potential future areas of concern, ongoing monitoring of drivers and devising competitive and supply chain strategies. However, such illustrations are outside the scope of this thesis.

Table 6: Summary of Research on Scenarios, Drivers, Competitive Dynamics and Supply Chain Strategies

List of Scenarios	Sr. No.	List of Drivers (Internal & External)	OEM Power (from Industry Power Matrix)	Industry Operating Objectives	Industry Supply Chain Objective
PC Based Computing Scenario	1	Reducing cost of computer	Up	Reduce cost	Efficiency
	2	Affordability in developing countries	Up	Increase market reach and reduce cost	Efficiency
	3	High end computing	Up	Specialization	Responsiveness
	4	Technology upgrade	Down	Focus on R&D	Responsiveness
	5	Digital information, entertainment and communication	Down	Integrate with service partners and reduce cost	Efficiency
	6	Online commerce and collaboration	Down	Integrate with service partners and reduce cost	Efficiency

Ubiquitous Computing Scenario	7	Lifestyle based	Up	Focus on design, Fast inventory turn	Responsiveness
	8	Always online	Down	Integrate with service partners and reduce cost	Efficiency
	9	Reducing size and increasing computing power	Down	Focus on product development, reduce cost	Efficiency
	10	Digital content	Down	Integrate with service partners and reduce cost	Efficiency
	11	Mobile applications	Down	Integrate with service partners and reduce cost	Efficiency
	12	Personalization of devices	Up	Focus on customization	Responsiveness
Decentralized Server Customers	13	Reducing cost of server hardware	Up	Reduce cost	Efficiency
	14	Increasing storage requirements	Up	Work closely with storage vendor	Efficiency
	15	Technology upgrade	Down	Work closely with component manufacturers & software providers, integrate with R&D	Efficiency
	16	Extension of existing IT systems	Down	Work closely with system integrators & business application providers	Efficiency
	17	New business Applications	Down	Work closely with business application providers & system integrators	Efficiency
Centralized Server Customers	18	Economics of scale and scope	Down	Reduce cost by centralizing operation	Efficiency
	19	Outsourcing of non-core processes	Down	Reduce cost by making appropriate make/buy decision	Efficiency
	20	Focus on bottom line	Down	Reduce cost	Efficiency
	21	Strengthening of IP laws	Down	Integrate with companies to manage their data	Responsiveness
	22	Broadband penetration	Down	Provide on-demand services	Responsiveness
	23	New information security technologies	Down	Access on-demand or Outsource more critical processes and information	Efficiency/ Responsiveness

I now introduce a scenario analysis methodology developed by Dr. Mahender Singh at MIT as part of the Supply Chain 2020 research initiative. In my belief, the methodology is very useful as it provides companies with actionable strategies to counter the implications of different future scenarios. The methodology divides implications of the different future scenarios into robust implications and contingent implications.

Robust implications imply predictable impact of a future scenario. Companies can counter such implications by developing appropriate strategies in advance. These

strategies can be classified into three groups, namely, 'No Brainers', 'No Regrets' and 'No Gainers'. 'No Brainers', as the name suggests, represents those strategies that clearly benefit a company in all future scenarios, and thus, should be implemented without hesitation. 'No Regrets' represents those strategies that clearly benefits a company in few of the future scenarios, but may not have any impact on the rest. Such strategies can be implemented without regret, as they can only provide upsides to a company. 'No Gainers' represents those strategies that are clearly not beneficial to a company under any circumstances, and thus, should not be implemented at all.

Contingent implications imply either partially predictable or unpredictable impact for a future scenario. Companies can counter contingent implications using strategies that are more adaptive in nature. These strategies can be classified into three groups, namely 'Detailed Review', 'Risk Management' and 'Sensors on the Ground'. 'Detailed Review' represents those strategies that require in-depth study of each future scenario on an ongoing basis before making any decision. 'Risk Management' represents those strategies that limit the negative impact by guarding the key risk factors. 'Sensors on the Ground' represents those strategies that identify and monitor the drivers that lead to different future scenarios. In this thesis I have largely used 'Sensors on the Ground' strategy for analyzing implications of the different future scenarios. Interested readers can try to use other strategies for analyzing the future of the computer business.

I conclude by summarizing a few basic observations from our research. Firstly, it is almost certain that the future scenarios and competitive dynamics in the computer

industry would be substantially different from that of the present. Companies would need to adopt a different set of strategies to win over future customers, ward off competition and collaborate with trading partners. Companies who fail to anticipate such future changes in advance would likely face severe competitive threats from their smarter counterparts. Secondly, many of the present decisions that companies make may have long-term negative implications. Any present investment that has a long return period should be scrutinized in the context of the future. A scenario approach to evaluate return on investment can be useful in this respect. Thirdly, even though the future is unpredictable, several strategies can be adopted to extract useful information about the future, and act accordingly.

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