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THESIS COVER PAGE

A STUDY OF COMPUTER OBSOLESCENCE AND ITS IMPACT

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THESIS APPROVAL PAGE

This is to certify that the thesis prepared by Jeff Whitley, entitled “A Study of Computer Obsolescence and Its Impact”, has been approved by this committee as satisfactory completion of the thesis requirement for the degree of Master of Science in Computer Science.

Chair, Thesis Committee — Date

Committee Member — Date

Committee Member — Date

Dean, College of Graduate Education and Research — Date

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ABSTRACT

A STUDY OF COMPUTER OBSOLESCENCE AND ITS IMPACT

Jeff A. Whitley

Computer hardware and software technology has grown at a near exponential rate in recent years. The more frequently this technology is upgraded, the more computer obsolescence occurs causing manufactured waste and user frustration. To analyze the effects of this obsolescence phenomenon on the computer user, surveys were distributed to students and employees. Opinions of possible ways to alleviate obsolescence were also examined. Interestingly, participants were generally not negatively affected by computer obsolescence. However, there was considerable support for various methods of assuaging the computer obsolescence pace. Obsolescence taxonomy and impact models were demonstrated to provide an overview of the hardware, software, and humanistic aspects of the obsolescence paradigm. Finally, possible ways to ease the negative effects of computer obsolescence were presented, which included computer recycling, emerging Internet technologies, object-oriented software development, and the use of smaller, Internet-linked computing devices.

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INTRODUCTION

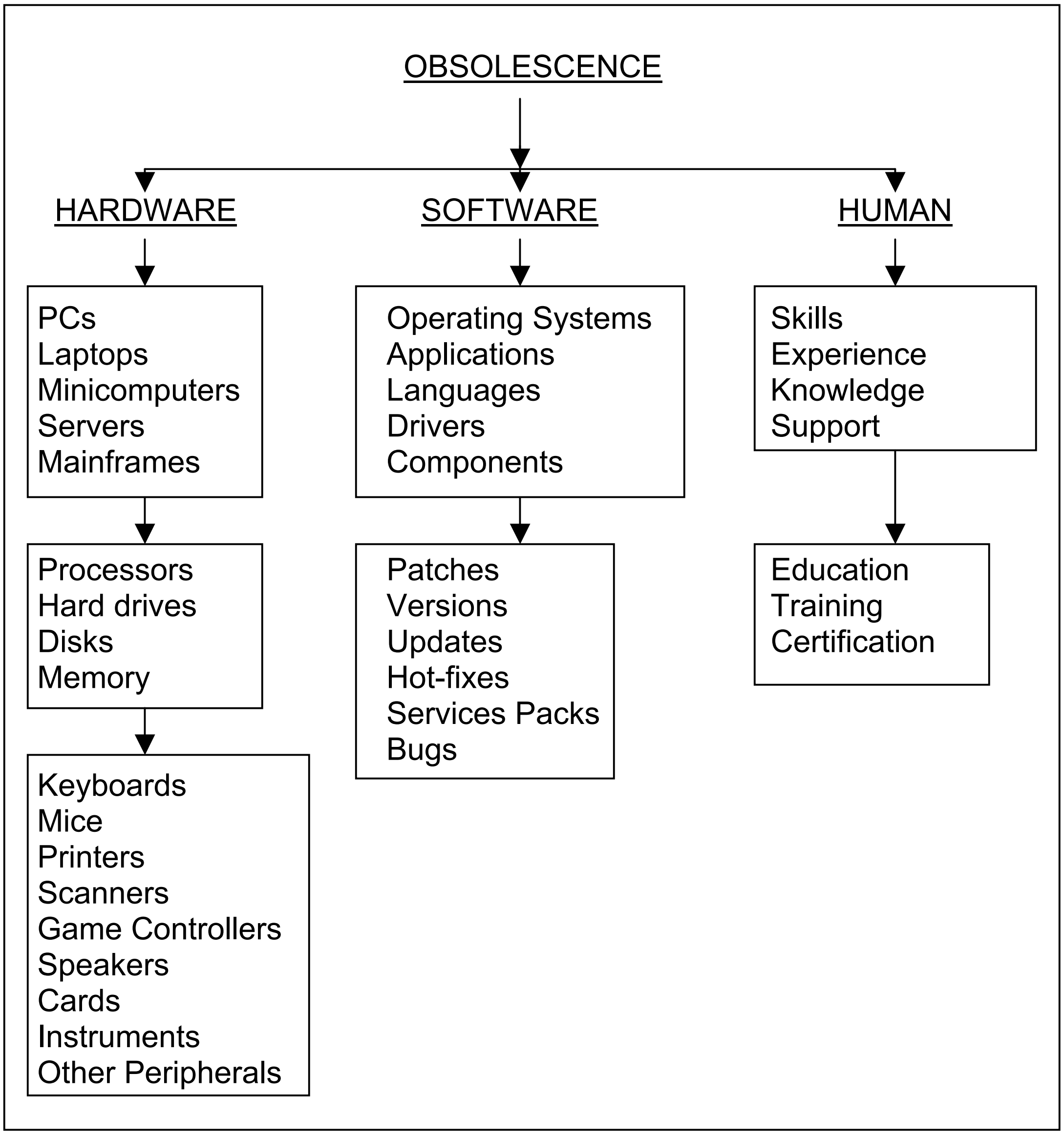
Problem Overview

Since computers first became popular for public use in the 1970's, computer hardware, operating system, and software application technology has grown at a near exponential rate. As computer technology improves and becomes more efficient, robust, functional, and user-friendly, the computer user is forced to make decisions about upgrading his or her computer system, operating system, and/or application version all too often. This "forced" obsolescence has a profound effect on the individual from the standpoints of either being at the cutting edge of technology at all times or having the ability to use an application that one is perfectly happy and comfortable with for a long time even though the application, operating system, and hardware platform the application runs on are outdated and no longer supported. This can be seen as both a benefit and a nuisance for users, depending upon their particular point of view, but it definitely presents a problem for most individuals either way. Computer obsolescence produces a great waste of resources, creates an environmental threat, and generates frustration and unnecessary costs for users. There is a significant need for change as the technology keeps improving and expanding at home and in the workplace.

Obsolescence, as expressed in this paper, is an abstract term. Purely, it means that something has gone into disuse, either because of becoming outmoded or because it is damaged or too old to perform what it was intended for. However, obsolescence is more than that, because of the rapid pace of technology “improvements” in recent years and because of marketing pressure from software and hardware manufacturers on the consumer to keep up with the latest technology. Obsolescence affects all types of computers, including laptops, servers, and most importantly, personal computers (PCs). It impinges upon computer components and peripherals such as processors, memory, printers, and scanners. Obsolescence also has an effect on all computer software available including operating systems, applications, and smaller software components. Its direct affect can be seen with the multitude of software versions and upgrades available. Finally, computer obsolescence even causes a “human obsolescence” in the form of skills and knowledge of computer hardware and software becoming obsolescent. The increasing quantity of training and certifications available for people to learn new hardware and software further illustrates the extent of the obsolescence paradigm. Based upon these facts, a computer obsolescence classification can be structured, based upon the three main tiers of computer obsolescence: hardware, software, and human. This taxonomy is illustrated in Figure 1.

Figure 1

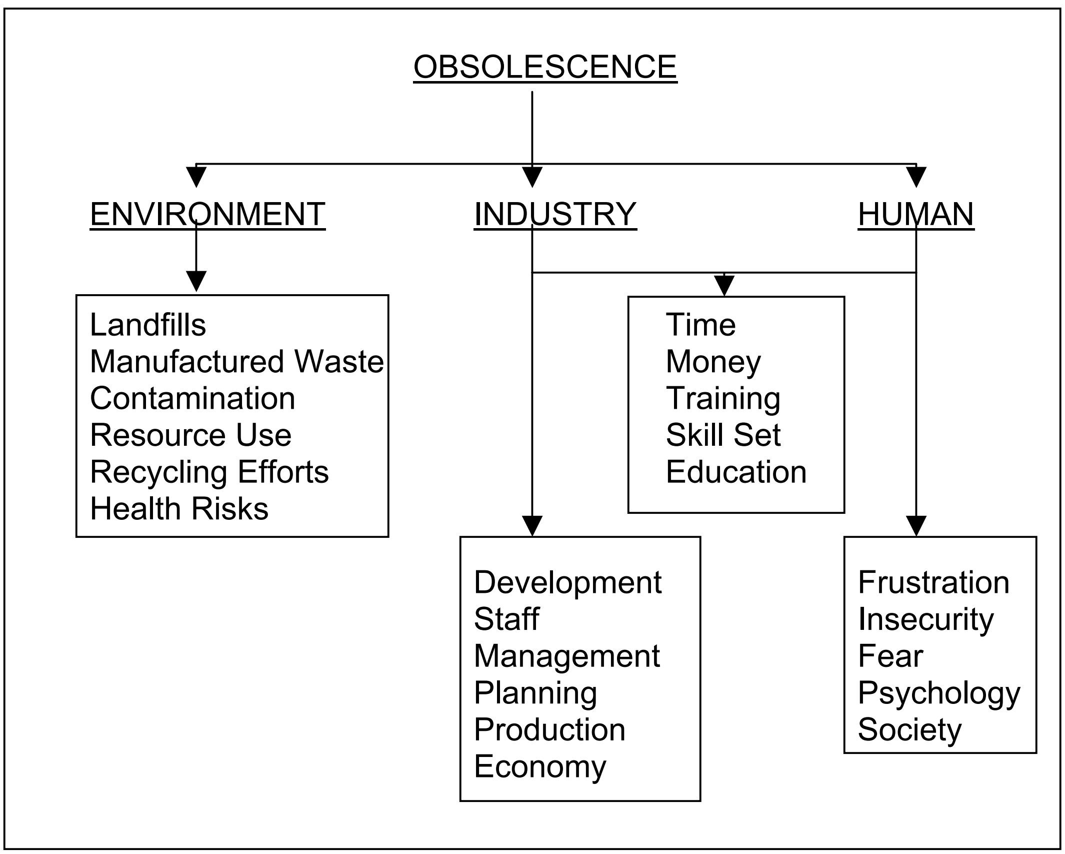
<u>Computer Obsolescence Taxonomy</u>



Computer obsolescence has a three-tier impact affecting the environment, industry, and humans. Obsolescence impacts our environment by polluting the planet with the dangerous chemicals in the form of manufactured waste of obsolescent computer hardware. The industry must plan for obsolescence either by promoting it with quick development of competing products or by dealing with its affects with proper resource and training management. People are impacted by obsolescence with wasted time and money along with the frustration of learning and adapting to ever-changing computer technologies. The world's economy and society have even been forever revolutionized by this rapid technology age. Figure 2 categorizes the overall impact of computer obsolescence.

Figure 2

Computer Obsolescence Impact



It is basically an industry notion that the computer consumer should stay away from obsolescence and keep buying new products to keep up with technology. This is an excellent marketing ploy, since most computer users actually believe this is a necessity. Moreover, the software and hardware companies promote this by not supporting technology that is out of date. To illustrate this phenomenon, suppose there is a problem with an older version of an application, and the user calls the application's technical support group to report it. The support personnel tell the user that that version is no longer supported and that they must upgrade their application to correct the problem. Some upgrades can make the application look totally different, even though it fundamentally functions in the same manner. This is daunting to users who then have to re-learn how to use the application. Consequently, instead of spending fifteen minutes trying to fix a small problem, the user has to spend days re-learning a completely new and revamped application. To complicate the basic problem even further, the new version of the application may require a newer operating system to run on, which means the user has to purchase and learn a new operating system as well, which, in turn, may cause some of the user's other applications to not function correctly or at all. However, it does not stop there. To further compound the problem, the new operating system and application may be too complex, large, or fast for the hardware that is running it, which means the user may have to purchase more memory, a larger hard drive, a faster processor, or a whole new computer system. In this example, for a simple application problem, the user has to spend money and time purchasing, configuring, and learning a new computer system, operating system, and application version. This is an extreme example, but it illustrates how the application, operating system, and hardware are intertwined to make the computer obsolescence paradigm both a complex and expensive problem.

Overall, the obsolescence phenomenon is spread throughout the industries, governments, and homes all over the world. Users are frustrated and insecure, the time and skills of technology professionals is wasted, and more and more training is required to keep up with the changes obsolescence causes. The trend now is that software costs are skyrocketing while hardware costs are going down. Over the past 20 years, hardware costs have been reduced by one-half every two years while the density and speed of hardware has doubled. Applications are becoming more communication intensive and less computation intensive. They seem to appear and disappear so rapidly, they are rarely fully understood by users. Word processing software, spreadsheet software, database software, and web-browsing software go through so many releases that analysts even have a difficult time tracking the changes. The trend is for manufacturers to continue to release new hardware and software products endlessly making things more obsolete without significantly extending the life of existing products (Karne & Bradley, 1996).

Currently, multimedia data and the Internet are promoting computer obsolescence. Computer processors must become faster and faster to be able to handle today's multimedia data. In addition, faster processors are required to search, transmit, and manage complex data quickly over a network, in particular, over the Internet. Current PC-based computer systems are environment sensitive, vendor-sensitive, and not application based. Because of this race between hardware and software, information technology is promoting obsolescence and wastefulness. Socially and culturally speaking, there exists a fear of learning new technology, as time and energy need to be spent on re-training and re-learning new applications and operating systems. Obsolescence affects the productivity of hardware and software developers, educators, computer-using professionals, and the average computer user. In fact, technology professionals with more than five years of experience are even becoming obsolete unless they are constantly re-trained.

Aaron Weiss indicates that it can be said that the computer's obsolescence mirrors that of automobiles. People know obsolescence exists, but they still tend to purchase a new car every three to four years even though the initial purchase could have remained useful for over a decade. It is now socially accepted that computers are obsolete almost immediately even though the newest computers perform 90% of the same tasks that old computers do acceptably. It is really splitting hairs when the difference between launching an application on a new machine in two seconds versus launching the same application on an older machine in eight seconds costs $2000. The industry has convinced and forced the computer user to buy overpowered machines on the basic notion of "progress". Consumers are strung along with minor improvements in each subsystem: CPU speeds increase, RAM access times decrease, or cache memory becomes integrated even though, in reality, there is little or no benefit in noticeable speed. Weiss goes on to say that computer users are a part of a big psychological experiment to keep them hooked on the latest and the greatest that they must have to keep up with the currently used technology. Interestingly, each time a new computer is purchased, the consumer is actually buying 80% of the same components he or she already has all over again (Weiss, 1998).

Bryan Pfaffenberger states that hardware and software industries work together to guarantee computer recycling at a far too high of a rate. It seems that whenever hardware manufacturers come out with more powerful chips, software publishers come out with more bloated, feature-rich, yet performance-poor programs that use the full extent of the new chips. "Software publishers are much more interested in bringing out products with marketable features than they are in creating products that run acceptably on older hardware" (Pfaffenberger, 2001).

It is important to think back to when home computers first arrived and consider the context in which computers evolved and how the obsolescence problem grew. Rebecca Day remarks that early computers were expensive, clunky, slow, and monitors had poor resolution. Yet they gradually evolved to be multimedia "edutainment" machines. Computers can still crunch numbers, write words, and play games, but now they let you watch television, answer the phone, and browse the Internet. They have become a common household appliance like the television, however it is an appliance that needs frequent replacement. Computer advancements used to be driven by the need to improve productivity at the work place, but now they are driven by home users' wants, such as processor speed, video and stereo capabilities, and web access. People now want, and believe they need, more RAM, faster processor speeds, faster Internet connection speeds times, better software performance, higher multimedia resolution, and more disk space to store the latest and greatest applications. To some degree, how often an upgrade is required really depends upon the user. If someone is only using a computer for word processing and e-mail, the need to upgrade is not great and that computer could be sufficient for up to five years. However, if playing graphic-intensive games is the objective of the computer user, then the user should expect to upgrade every one to three years to maintain performance by keeping up with the latest technology.

Day also notes that the market fosters obsolescence by discontinuing and not supporting older technology, such as older application versions, the 5 ¼" disk, and eventually, the 3 ½" disk. The keyboard, mouse, and monitor have been fairly stable and immune to the obsolescence problem by themselves, but since new computer systems usually include a keyboard, mouse, and monitor, they are needlessly discarded and become indirectly affected by the obsolescence problem. New peripherals can wreak havoc on different areas of the computer, and can cause some users to be weary of upgrades. Due to the high rate of hardware advancement and replacement, plug-and-play hardware is becoming a necessity in order to help alleviate this problem. As computers are becoming more and more sophisticated, software and hardware incompatibilities increase and can lead to increased consumer confusion. It used to be that to install a new peripheral on a computer, the case of the computer had to be opened, the new board added, switches or jumpers may have had to be configured, and the software driver had to be loaded. Now, with Universal Serial Bus (USB) and Firewire connections, computer systems are able recognize and configure the new device automatically. Even though this makes the computer easier to deal with, it is another aspect to add to the hardware obsolescence problem since non-USB and non-Firewire peripherals are now obsolete (Day, 1995).

To further illustrate the essence and complexity of the obsolescence paradigm, its three main parts will be examined, the hardware, software, and human aspects. Hardware obsolescence matters to be focused upon include the environmental problem “old” computers cause, the costs incurred with new hardware purchases, and the rate at which hardware “improves” and is released to the public. Software obsolescence topics illustrated include the unnecessary variety of computer languages used to write the diversity of operating systems and software applications, and the rate at which new versions are released. Specific examples of human obsolescence issues at home and at the workplace are also provided. Finally, user perspectives of the obsolescence paradigm and proposed solutions of lessening the obsolescence affects will be examined. This is an all-encompassing problem that affects everyone in this computer age.

Hardware Aspects

Computer hardware obsolescence is at the heart of the obsolescence paradigm. It embodies a significant environmental issue with all of the obsolescent computer parts needing disposal, especially personal computers. As new hardware is released, we are forced to discard the old hardware because of incompatibility issues created by the new hardware technology. This results in a waste of manufacturing resources and money. In Figure 3, major computer hardware releases are shown. This figure is presented to illustrate the shear magnitude of the hardware obsolescence rate, particularly in recent years. A popularly referenced law, stated in 1975 by Gordon Moore, co-founder of Intel, was even spawned from the high rate of obsolescence. Moore's Law states computer chips get twice as fast every 18 months. He meant that the data density of the number of transistors per square inch on integrated circuits doubles every 18 months (Sterling, 2000). Particularly in the past decade, the rate at which technology is made more complex and sold goes alarmingly beyond Moore's Law. Not only the competing types of hardware shown, which in and of itself produces compatibility issues and is another problematic paradigm, but the rate at which the same type of hardware is improved is mind-boggling.

Figure 3

Chronology of Major Computer Hardware Releases

1950 – First Floppy disk
1957 – First Dot Matrix printer
1964 – First minicomputer
1965 – First Mouse
1970 – First RAM chip, Intel 1103 with 1 K-bit of memory
1971 – First microprocessor, Intel 108-kHz 4004 4-bit microprocessor
1972 – Intel 200 kHz, 8008 8-bit microprocessor
1973 – Computer with first elements of the modern GUI, Xerox PARC
1974 – Intel 2 MHz, 8080 8-bit microprocessor
MITS Altair 8800 computer with 8080 processor
Motorola 6800 8-bit microprocessor
1975 – MITS Altair 8800 with 1 KB memory
First laser printer
1976 – Apple I
Intel 5 MHz 8085 processor
Zilog 2.5 MHz Z80 processor
1977 – Apple II with 6502 CPU & 4 KB RAM
Radio Shack TRS-80 microcomputer with Z80 CPU & tape cassette
1978 – Intel 4.77 MHz 8086 8 MHz microprocessor
Epson MX-80 dot matrix printer
Atari 400 and 800 computers with 6502 CPU
1979 – Apple II+ with 48 KB RAM
Commodore Pet with 1 MHz 6502 processor, 8 KB RAM, cassette deck, & 9” monochrome monitor
First Compact disc
68000 16-bit microprocessor by Motorola for Apple and Atari
Intel 4.77 MHz 8088 8 MHz microprocessor
1980 – Perq graphical workstation
Apple III, one of first multiprocessing desktop PCs - with 2 MHz 6502A processor, 128 KB RAM & 5 ¼” floppy drive
Hewlett-Packard HP-85 with 16 KB RAM & cassette tape Recorder
Radio Shack TRS-80 computer – w/Motorola 4 KB 6809E processor
1981 – First system with Windows, Icons, Menus and Pointing device (WIMP) GUI - Xerox Star
IBM 5150 PC with 4.77 MHz Intel 8088 processor, 64KB RAM, & 5 ¼ floppy drive
Commodore VIC-20 with 5 KB RAM & 6502A processor
IBM 8087 math coprocessor
1982 – Intel 286 microprocessor with 20 MHz & 16 MB RAM
Commodore 64 with 6510 processor & 64 KB RAM
IBM double-sided 320 KB floppy disk drives
First IBM PC clone – MPC by Columbia Data Products

Chronology of Major Computer Hardware Releases (continued)

1983 – First personal computer with GUI interface - Apple Lisa with 5 MHz 68000 processor, 1 MB RAM & 12" B/W monitor
Apple IIe with 10 MB hard drive, 64 KB RAM, 1 MHz 6502 processor and 140 KB 5 ¼" floppy drive
Apple III+
IBM PC/Jr. with Intel 8088 processor & 64 MB RAM
IBM XT with 8086 processor, 10 MB hard disk, 128 KB RAM, one floppy drive, monochrome monitor, & printer
Atari 800XL and 1200XL with 64 MB RAM
Frankin Ace 1200 - Apple II clone with 28 KB RAM &143 KB floppy
Microsoft Mouse
Coleco Adam computer with Zilog Z80A processor & 80 KB RAM
Iomega Bernoulli storage device
Syquest's SyQuest storage device

1984 – First Macintosh with 68000 processor, 128 KB RAM & 7.83 MHz
Apple Lisa 2
Apple IIc with 1 MHz 65C02A processor &128 KB RAM
Apple III discontinued
First Laserjet printer, by Hewlett-Packard
Motorola 16 MHz 68020 processor

1985 – Apple Lisa changed to Macintosh XL
Apple IIe enhanced
Intel 386 microprocessor with 33 MHz and up to 4 GB memory
CD-ROM by Phillips
Enhanced Graphics Adapter (EGA)
Postscript used by Apple Laserwriter printer
Commodore 128 personal computer
Atari 520ST
Commodore Amiga 1000 with Motorola 68000 CPU, 256 KB RAM & 880 KB 3 ½" drive

1986 – Apple IIGS with 1 MHz 65816 processor
First Intel 386 PC – Deskpro 386 by Compaq
Commodore 64C

1987 – Apple MacSE and Mac II with Plug & Play slots, multiple monitor support, and 32-bit color; Mac II with 16 MHz Motorola 68020 processor, 1 MB RAM & 40 MB hard drive; MacSE with 8 MHz 68000 processor, 1 MB RAM & 20 MB hard drive
Apple IIe extended
IBM PS/2 Systems on 8086, 80286, and 80386 processors with 3 ½" "microfloppies"
Video Graphics Array (VGA)
AD-LIB sound card
Commodore Amiga 2000
Motorola 68030 processor

Chronology of Major Computer Hardware Releases (continued)

1988 – Apple IIc+
Macintosh IIx based on Motorola 68030 processor with 16 MHz, 128 MB RAM, & 80 MB hard drive
NeXT Computer with 25 MHz 68030 processor, 8 MB RAM, 250 MB optical disk drive, math coprocessor, digital processor for real time sound, fax modem, & a 17" monitor
Intel 16 MHz 80386SX processor
1989 – Remaining 2,700 Apple Lisa models trashed at Logan landfill
Intel 486 DX 25 MHz microprocessor
Macintosh SE/30 with 68030 processor, Macintosh IIcx & 25 MHz IIci
CD-I by Phillips and Sony
Sound Blaster sound card
1990 – Super Video Graphics Array (SVGA)
Macintosh IIfx with 40 MHz, Macintosh Classic (replaced Mac Plus) with 8 MHz 68000 processor, 9" B/W monitor & 1.4 MB floppy drive
Macintosh IIsi with 20 MHz 68030 processor
Macintosh LC with 16 MHz 68020 processor
Motorola 32-bit 25 MHz 68040 processor
IBM 10 MHz 80286 IBM PS/1 with VGA monitor
1991 – Apple and IBM ally to create PowerPC
Intel 20 MHz 486 SX processor
Sound Blaster Pro
AMD Am386DX - clone of Intel's 386DX
1992 – Sound Blaster 16 ASP
Intel 486DX2 25 MHz processor
1993 – Motorola 50 MHz and 66 MHz PowerPC 601s
IBM 50 MHz, 66 MHz, and 80 MHz PowerPC 601 and 80 MHz 604
First Intel Pentium Processor at 60 and 66 MHz
Apple Macintosh LC III with 25 MHz 68030 processor, 80 MB hard drive, 4 MB RAM, &14-inch monitor
Apple II is discontinued
1994 – Apple 66 MHz PowerPC Upgrade Card
First PowerMacs (6100/60, 7100/66, 8100/80) by Apple with PowerPC 601 processor, 8 MB RAM, & 160 MB hard drive
IBM and Motorola 66 MHz and 80 MHz 603 and 100MHz 604
Intel 75 MHz, 90 MHz, and 100 MHz Pentium processors
Intel DX4 processor
Iomega Zip drive and disks holding 25 MB or 100 MB of storage

Chronology of Major Computer Hardware Releases (continued)

1995 – IBM and Motorola 100 MHz 603e
IBM 120 MHz 601
First PCI Mac by Apple - the PowerMac 9500/120
Pentium 120 MHz and 133 MHz processors
Intel 150 MHz, 180 MHz, and 200 MHz Pentium Pro processors
1996 – IBM 166 MHz and 180 MHz 604e
Apple 200 MHz PowerPC 603e and 604e
Intel 150 MHz, 166 MHz, and 200 MHz Pentium processors
Compact Re-Writable Disk (CD-RW)
Cyrix 133 MHz Media GX processor
1997 – Motorola 300 MHz 603e & 350 MHz Mach 5 604e
Motorola PowerPC 750 (G3) Processor
Apple PowerMac 9600/350 and PowerMac G3
Intel 233 MHz, 266 MHz, and 300 MHz Pentium II processors
Intel 166 MHz, 200 MHz, and 233 MHz Pentium MMX processors for games and multimedia enhancement
AMD K6 166 MHz, 200 MHz, and 233 MHz MMX processors
1998 – Motorola 333 MHz, 366 MHz, and 400 MHz PowerPC processors for PowerMac G3 Pro
Apple iMac with 233 MHz G3 processor, 32 MB RAM, 4 GB hard drive, 24X CD-ROM, & 15 inch monitor
Pentium II 333 MHz, 350 MHz & 400 MHz processor
Intel Pentium II Xeon Processor
Intel 266 MHz Celeron Processor
Motorola G4 Processor
1999 – Intel Celeron, Pentium III, & Pentium III Xeon Processors
Apple PowerMac G4 with 400 MHz, 450 MHz, or 500 MHz versions with 64 MB RAM, CD-ROM drive, and 10 GB hard disk
Cyrix MII processor
AMD Athlon Processor
2000 – Intel Pentium 4
AMD 850 MHz Athlon Processor & 1.1 GHz Athlon Processor
Intel 1 GHz processor
Apple G4 Cube with 450 MHz G4 Processor, 64 MB RAM, 20 GB hard drive, & DVD drive
Apple iMac, DV, DV+, and DV+ Special Edition G3 computers

Note. Information obtained from Mesa (1999b), Polsson (2001), “Processor Hall,” (2001), & White (2000).

The rate at which new hardware is developed produces many questions. Can someone still use the older technologies? Yes. Can these older technologies still function without problems? Yes. Can these older technologies be used in today's world without fear of breaking down and not having support to fix or replace it at little cost? No. All of the hardware presented in the figure is still functional, but it is made obsolescent by our technological and economic climate. Operating systems and applications can still be run on older equipment, and our basic computer needs can still be satisfied. We can still play games, write documents, make a spreadsheet, use a database, and for those models within the past decade, we can still use the Internet on them.

So, what exactly is the problem? It is the marketing strategy of the manufacturers to give the consumer the ability to play more complex games, better tailor-write documents, use more complex spreadsheets, employ larger, multi-dimensional databases, and browse the Internet faster. "Faster and better" is thrust upon us, the computer consumer, when what we may do on our computers now, we can still do just as efficiently as we could on a newer, better, and faster computer down the road. However, this is all coupled with the fact that the manufacturers do not wish to support "out-of-date" products any longer since it is not cost effective and goes against their competitive marketing strategy. This aggressive psychological, technological, and economic climate is forcing the consumer to be on the cutting edge to survive and prosper in the technical world.

Since the idea of mass production is to make items cheaply, computers do not have to last very long, especially when disposal is free to the producers. Today, the average life span of a computer is three years or less. With the lightning fast pace of computer obsolescence, there is a serious backlog of equipment with no place to go. Hence, the major problem with computer obsolescence is the physical waste it creates because of unused, "obsolete" hardware. The main culprits are personal computers. The ratio of PCs currently used to those that have been discarded is decreasing, thus adding to the computer waste problem. In fact, approximately 20.6 million personal computers became obsolete in the U.S. in 1998 alone. Of those, only 11%, or 2.3 million units, were recycled ("How are computer," 1999).

Because PCs are worth close to nothing on the used market unless they are less than two or three years old, millions of PCs are headed toward landfills. Obviously, this creates a threat to the environment. According to the National Safety Council's Environmental Health Center, approximately 315 million PCs will be obsolete by 2004. This accounts for 1 billion pounds of plastic, 1.2 billion pounds of lead, 2 million pounds of cadmium, and 400,000 pounds of mercury (Pfaffenberger, 2001). Some estimates predict that 75% of the U.S.'s computers will be obsolete in three years (Heyboer, 2000). In 1999, the National Recycling Coalition conducted the very first large-scale survey of the U.S.'s electronic recycling efforts. It is estimated that between 2000 and 2007, 500 million computers will become obsolete (Schuessler, 2000). The situation is compounded by the fact that the rate of obsolescence is increasing and the amount of computers produced is growing exponentially. The same is going to happen to televisions with high-definition television becoming the affordable standard. Computer monitors and televisions are classified as hazardous waste because their screens contain lead and other toxic materials that are in their components and plastic casing. Monitors that end up in landfills and incinerators leak these contaminants into the ground water and pollute the air. Old peripherals such as printers, keyboards, and mice, as well as old floppy disks introduce another aspect to computer waste. Based on the Environmental Protection Agency (EPA), 86% of the 20 million computers that became obsolete last year were dumped in landfills, burned in incinerators, shipped as garbage overseas, or were stashed in someone's personal storage (Campbell, 2000).

Other estimates state that 10 million computers are trashed every year with about 2 million going to landfills and another 8 million collecting dust on shelves and in basements (Fearer, 1997). About one-third of all American company's computers are disposed of every year. Even though businesses cannot dispose computers in landfills, residential users can and are. It is predicted that by 2005, around 150 million computers will be in U.S. landfills. Even though they only represent 3% of all waste and take up less than 1% of a landfill's total volume, they are important because they are hazardous. Silicon Valley, California, home to the birthplace of the computer industry, has the highest concentration of hazardous waste sites in the United States ("Information Technology," 2000).

Lead, mercury, cadmium, and chromium are the dangerous parts of the computer. Lead constitutes about 25% of a computer monitor's 5-8 pound weight. Consumer electronics constitute 40% of the lead found in landfills. Lead itself is toxic to humans by effecting the central and peripheral nervous systems if ingested. It can seep into ground water and poison plants and animals. When monitors get placed in the landfill, they are crushed, materials laced with lead degrade, and rainwater sweeps this lead into the ground. This process can take several decades, but it does happen. Because lead is an element, it does not go away. It is interesting to note that most landfills will accept monitors with no problem, but if mattresses are disposed of, it will cost money since it is marked for diversion and processed a different way. Among other dangerous chemicals found in computers are cadmium, which is found in semiconductors, and some resistors and detectors. Mercury exists in switches and sensors, chromium is in steel housing, brominated flame-retardants are in circuit boards and connectors, and lithium, nickel, and cadmium are in batteries. Cabling and older casings have polyvinyl chloride (PVC), which release dioxins during their production and incineration that are extremely toxic (Fisher, 2000).

Even the manufacturing process of computers and peripherals harms the environment. According to the Silicon Valley Toxics Coalition, an organization that fights environmental problems caused by the high-tech industry, turning sand into computer chips requires tons of toxic chemicals, water, and volumes of toxic gases. In fact, workers in the semiconductor industry suffer industrial illnesses at a rate of three times higher than the average of all other industries. For example, the plastic (polystyrene) casing for a computer monitor, central processing unit (CPU), mouse, and keyboard require 1.5 gallons of crude oil and 300 cubic feet of natural gas (Campbell, 2000). In fact, approximately 25 million new computer systems are manufactured in the U.S. every year, which requires the consumption of 1 million barrels of crude oil and 7.5 billion cubic feet of natural gas, for just the plastics used to make the computer (Dvorak, 2001).

A typical computer is made up of 25 kg of plastics, metals, glass, and silicon. Computer chips are made up of 1/100th of a kg of silicon and metal formed into integrated circuits. Even though these chips are very small, they generate the most waste. To make a computer chip, a 400-step process occurs which involves silica, carbon, hydrochloric acid, hydrogen, ultra-violet rays, phosphorus, boron, gold, silver, and precision machinery. Circuit boards are made from copper, fiberglass, epoxy resin, heavy metals, water, tin solder, and other chemicals. To make a 25 kg computer, 63 kg of waste is generated, 27,700 liters of water is used, and 2300 to 2400 kilowatt hours of energy are used. (“Information Technology,” 2000).

Even though the EPA classifies computers as hazardous, it has not aggressively enforced disposal regulations. Because of regulations and pollution laws in the United States and Canada, it is often cheaper to export scrap to other countries. In 1997 alone, 1 million of the 1.7 million monitors recycled were shipped overseas to be disassembled and processed. In fact, the U.S. exports $40.6 billion in computer equipment to Europe each year. Europe, on the other hand, is making a tougher stand with their Waste from Electronics and Electrical Equipment (WEEE) directive. With this, Europe wishes to force computer manufacturers to take back obsolete equipment and have these companies phase out harmful materials used in the manufacturing process by 2004. The American Electronics Organization (AEA), comprised of over 3,000 companies including Microsoft, Intel, and IBM, indicates that the cost for computer manufacturers to take back their old products and make their manufacturing processes safer is too burdensome and a barrier to trade. In fact, the AEA claims that the WEEE Directive violates the international trade rules of the World Trade Organization (WTO) (Fisher, 2000; Nash, 2000).

The computer industry is aware of the environmental problem, but instead of promoting consumer take-back programs to successfully recycle obsolete computers, computer manufacturers and consumer electronics companies are lobbying to try to stop the WEEE directive. The U.S. federal government is not expected to do anything the WEEE proposes either. U.S. companies are fighting this global standard to reduce the effects of obsolescence and make computers safer, because they do not want to take full responsibility for what they produce. Hence, for now, the de facto global standard stands: the industry sells its products to consumers and the consumers are responsible for the products after that (Fisher, 2000).

There is so much waste being produced without the infrastructure to deal with it. IT managers need to devise computer retirement policies and figure disposal costs into their total cost of ownership estimates. Companies have to spend money on old machines either by paying recyclers to move them away or by warehousing them in storage facilities. According to a recent Computer World survey, only 39% of 102 IT managers have a consistent, company-wide policy for dealing with retired computers. Today, more than half of American households have at least one computer, and 75% of all computers ever bought in the U.S. are not used any longer and are stored away within a household. Home computer users are forced either to store their old computers, or seek out other disposal alternatives currently available. In another Computer World survey, 17% of users said they simply threw away their computers in the trash. (Fisher, 2000; Nash, 2000).

According to the National Safety Council's Environmental Health Center, in 1998, only 6% of computers were recycled compared to the number of computers marketed that year. Still, many computer recyclers are turning away business because they are so swamped. For recycling, specialized skills are required to get old machines to work with newer add-ins and software. Donating computer equipment to schools and non-profit organizations is an option, but if the equipment is "end-of life", it will not function properly, therefore it will not be wanted. Non-profit organizations have standards on what to accept and individual donations are usually rejected. This is not just because the equipment is older and slower, it is because they cannot afford the properly skilled help necessary to refurbish old equipment. Computer leasing is an option, but the problem with this is that you end up paying more, because once the lease is up and you trade the computer in for a new one, you do not get the full amount you paid for it toward the next computer. Computer dismantling is also an option, but since computers are made up of a mix of varied and toxic materials, it is a difficult and time-consuming process to separate all of the parts for the sale of raw materials from those parts. Incineration of computers is not an option, because of the release of toxic chemicals into the air, and dumping computers in landfills is obviously not viable either. The computer companies want local governments to set up facilities for the safe disposal of obsolete computer equipment, and the garbage collection companies want computer companies to use safer, nontoxic materials during manufacturing. It seems no one wants to take responsibility for hardware disposal (Fisher, 2000; Nash, 2000).

Software Aspects

Software obsolescence is extremely widespread, and it encompasses operating systems, applications, and computer languages. Since the software is what connects the user to the hardware, obsolescence in the software arena stimulates hardware obsolescence and user frustration and insecurity. Software obsolescence impacts the industry and people in areas of time, training, and money.

To begin with, software developers face their own obsolescence problem when developing applications because of all of the programming languages that are available. There are different kinds of languages and various flavors of different language types, which all basically do the same thing in different ways. Language types include imperative, declarative, procedural, applicative, functional, definitional, single assignment, dataflow, logic, constraint, object-oriented, concurrent, forth generation, query, specification, assembly, intermediate, and meta languages. Now, most of the current programming languages are based upon the World Wide Web. Examples are HTML, CSS, ASP, XML, Java, JavaScript, Flash and PERL. There are more variants of these languages obtainable now, and more will continue to become available.

The diversity of computer languages used translates into the varying amount of computer software available. The multitude of languages available also forms the basis of software compatibility issues, operating system interoperability problems, and speeds the rate of software obsolescence as the latest languages allow for new capabilities for software to utilize. To see the extent of the wide array of computer languages ever developed, a language list was compiled in January 1995 by Bill Kinnersley. It contains 2350 computer languages. From this list, Figure 4 provides a listing of the most influential computer languages.

Figure 4

Influential Computer Language Chronology (1957-1995)

1957 –	FORTRAN
1958 –	ALGOL
1960 –	LISP
	COBOL
1962 –	APL
	SIMULA
1964 –	BASIC
	PL/I
1966 –	ISWIM
1970 –	Prolog
1972 –	C
1975 –	Pascal
	Scheme
1977 –	OPS5
1978 –	CSP
	FP
1980 –	DBASE II
1983 –	Smalltalk-80
	Ada
	Parlog
1984 –	Standard ML
1986 –	C++
	CLP(R)
	Eiffel
1988 –	CLOS
	Mathematica
	Oberon
1990 –	Haskell
	HTML
1995 –	Java

Note. Information obtained from Kinnersley (1995).

There should not be such a variation and wide array of computer languages since they all fundamentally break down into the same thing: one computer machine language based upon 1's and 0's, which the computer's hardware understands. Of course languages have evolved to become more functional and easier for the user to program with, but fundamentally, they are all the same. Again, vast amounts of time and money are spent learning new computer languages because they themselves become obsolete. This is occurring with Internet languages right now, and at a much higher pace. A solution is needed to standardize an object-oriented type of language that is easy to program, can be used for any software application, and can be used on any hardware system. Currently, Java is closest to meeting these criteria, but much more work needs to be done with it to fulfill these requirements.

Operating systems are another important element of software obsolescence. Operating systems require specific hardware components to be able to function correctly. As a new operating system becomes available, it requires faster and better hardware causing any insufficient hardware to become obsolete. Along with this, software applications can only run on certain operating systems. Newer applications may not run efficiently or at all on older operating systems. Newer operating systems also may not support older applications. Therefore, an operating system-application coupling exists with the current von-Neumann computer architecture adding another dimension to software obsolescence. Figure 5 lists a history of major computer operating systems. The purpose of this figure is to illustrate just how immense the obsolescence problem is with all of the operating system types and versions.

Figure 5

Chronology of Major Computer Operating System Releases

1975 – UNIX first marketed
1980 – Microsoft XENIX operating system
1981 – MS-DOS 1.0 & PC-DOS 1.0 for IBM PC
1982 – MS-DOS 1.1, 1.25 & PC-DOS 1.1
1983 – Microsoft announces their new "Windows" program for the IBM PC
MS-DOS 2.0, 2.01, 2.11, & 2.25 & PC-DOS 2.0 & 2.1
1984 – Apple System 1.0 & 1.1 (System Software 0.1)
MS-DOS 3.0 and PC-DOS 3.0
Digital Research announces its GEM icon/desktop user interface for 8086- and DOS- based computers, and the Atari ST
"Window System X" announced at MIT to run on DEC VS100's displays connected to VAXen and VAXstations 1 and 2
1985 – MacOS System 0.3 & 0.5
GEOS for Commodore 64 and later the Apple II
Commodore introduces Amiga 1000 with Amiga Workbench 1.0
Wndows 1.01 – first Microsoft GUI OS
MS-DOS 3.1, 3.2 & PC-DOS 3.1, 3.2
1986 – MacOS System 0.7, 1.0, & 1.1
1987 – MacOS System 2.0, 2.01, 5.0 & 5.1
"Arthur" for the Acorn computer - basis for RISC OS
Windows 2.0
MS-DOS 3.3 & PC-DOS 3.3
OS/2 1.0 by Microsoft and IBM
1988 – Windows 2.03 & 2.1
GS/OS System 1 (16-bit GUI for Apple II GS)
IBM OS/2 1.10 Standard Edition (SE) - first IBM GUI
MS-DOS 4.0, 4.01 & PC-DOS 4.0
1990 – Windows 3.0
Commodore Amiga Workbench 2 for the A3000
PC-GEOS by GeoWorks
1991 – MS-DOS 5.0 & PC-DOS 5.0
Linux by Linus Torvalds
Macintosh System 7.0
1992 – Windows 3.1 & Windows 3.1 for Workgroups
IBM OS/2 Version 2.0 - first 32-bit OS
Amiga Workbench 3 for AGA Amigas
Linux 1.0 for PC
1993 – First version of Windows NT (3.1), their 32-bit OS for Intel, Power PC, Alpha, and MIPS systems
MS-DOS 6.0 & 6.2
IBM OS/2 2.1

Chronology of Major Computer Operating System Releases (continued)

1994 – Mac System 7.5 First embeddable microkernel windowing system, the Photon microGUI by QNX Software Systems Windows for Workgroups 3.11 & Windows NT 3.5 MS-DOS 6.21, 6.22 & PC-DOS 6.3 IBM OS/2 Warp 3 1995 – Microsoft Windows NT 3.51 & Windows 95 BeOS 1.0 MS-DOS 7.0, 7.1 & PC-DOS 7.0 1996 – Mac System 7.55 New Deal Office 2.5 - formerly PC-GEOS IBM OS/2 Warp 4 Microsoft Windows NT 4.0 Windows CE 1.0 for handheld-PCs BeOS 2.0 Windows 95 System Release 2 1997 – Mac OS 7.6 - (System renamed to OS) Mac OS 8 Windows CE 2.0 & Windows NT 4.0 Option Pack BeOS 3.5 1998 – Microsoft Windows 98 & Windows CE 2.1 BeOS 4.5 1999 – Mac OS 9 Apple Mac OS X Server - Unix based OS with Macintosh GUI RISC OS 4 for RiscPC, A7000 or A7000+ machines Windows 98 Second Edition Linux Kernel 2.2.0 2000 – Apple Aqua - for MacOS X client Microsoft Windows 2000 (Windows NT 5) Windows Millennium Edition BeOS 5.0

Note. Information obtained from Condron (2000), “Graphical User,” (2000), Mesa (1999a), Mesa (1999b), Polsson (2001), & White (2000).

In Figure 6, a history of some of the most important computer software releases are listed. Obviously, a listing of all of the major software application initial and version releases would be a mammoth undertaking. Therefore, only some of the most significant computer software releases are listed here.

Figure 6

Chronology of Major Computer Software Releases

1973 – Pong - first computer video game
1976 – Electric Pencil - first word processing program
1979 – VisiCalc - first “killer app”
1981 – DBase II database program
1982 – Lotus 1-2-3 spreadsheet program
1983 – Visi On - first integrated graphical software environment for IBM PCs
Lotus 1-2-3 1.0 for MS-DOS
Novel Netware
Microsoft Word 1.0
1984 – Microsoft Word, Multiplan, File, Chart, and BASIC for the Mac
1985 – Microsoft Excel for the Macintosh
1987 – Microsoft Excel for Windows – its first application
1988 – Microsoft Office for the Macintosh
1992 – Wolfenstein 3D – first 3-D computer action game
1993 – Doom - secures the PC as a serious game playing machine
Microsoft Office 4.0
1994 – Doom II - PC gaming booms
1995 – Microsoft Office 95
1997 – Microsoft Office 97
1999 – Microsoft Office 2000

Note. Information obtained from Mesa (1999b), “PC-Software,” (1996), Polsson (2001), “Software History,” (2000), & White (2000).

This application timeline only shows significant application landmarks. There are just too many applications out there that basically do the same thing. Versions are nearly impossible to keep track of. Basically, there are word processing, number processing, spreadsheet, database, image/drawing processing, networking (telnet, ftp, email, web browsing, virus protection), and gaming applications available for personal computers, as well as other specialty applications. The software obsolescence problem is also manifested in the software compatibility problem. For example, versions of the same application may be different from one platform to another. This creates great confusion and wasted development time and money by trying to support everything on the market. Why not have just one standard hardware platform running one standard operating system written using one standard language to access a variety of applications remotely on the Internet? The reason is basic economics. Market competition by computer hardware and software manufacturers results in so many different hardware platforms, operating systems, and applications, that the manufacturers must compete against each other to make profit and consequently, expand computer obsolescence.

For the purposes of this study, the web-browser version is set aside from software applications because of its link to the average computer application and the Internet. It is the most widely used piece of software now, since most computer users browse the Internet. The web browser is the gateway between the popular personal computing paradigm and the new Internet computing paradigm. Figure 9 will present the obsolescence issues of web browser versions as an Internet technology solution to the obsolescence paradigm. It is also important to consider Figures 3, 4, 5, and 6 to understand their inter-reliance and depth of the obsolescence issue. Only with this information, and the accounts of the following examples of the human aspects of obsolescence, can one truly begin to understand just how far reaching the obsolescence paradigm has become.

Human Aspects

There are many human aspects of computer obsolescence, which are often overlooked in the obsolescence paradigm. Human skills and experience relating to computer hardware and software can become obsolete as the corresponding hardware and software also becomes obsolete. Education, training, and certifications for particular software and hardware components need to be constantly updated. Great time and money are unnecessarily wasted because of the rapid pace of technological change. This obsolescence affects us as a society as well by speeding up our lives and causing great frustration, insecurity, and fear of what will happen next in the technological world.

In 1984, only 8 of 100 households had a personal computer. By 1994, 1 out of 3 had one. Computers propelled culture itself to be faster, more complex, and have more variety and multiplicity. The rate of change in PC technology is having an effect on the rate of change in culture altogether. It is a unique psychological and social phenomenon. Computer technology not only affects the ways businesses operate, but also speeds up our lives. This is the only time in history that so many people have been “simultaneously immersed in the swirling waters of transience and impermanence” (Bertman, 2001).

Stephen Bertman also notes that an excess of persistent and urgent change can induce stress. Alvin Toffler coined the phrase “future shock” which describes that condition caused by too much change in too short a time. Toffler notes that, "Unless man quickly learns to control the rate of change, we are doomed to a massive adaptational breakdown." Permanence and constancy are replaced by transience and flux. Bertman believes we live in the pressured influence of high-speed living, and this transience created by technology is reinforced by America's economic success as our level of wealth and comfort is raised. This causes us to then think of anything old as useless and obsolete. We are becoming more materialistic by being consumers of companies that increase their profits by "making and selling goods that are frequently replaced because they no longer work or are no longer desired" (Bertman, 2001).

Purchasing a new computer can be a daunting task. Consumers often ask themselves what kind of PC should they buy that will not be obsolete in a couple of years. Charles Montgomery's answer is to buy any PC you can afford because it is already obsolete. In fact, when budgeting for a new PC, he suggests doubling the amount you plan to spend to factor in the costs of buying software such as a good anti-virus package, a word processing package, and maybe some games. These are the three most commonly purchased pieces of software. There are extra hardware peripherals that may be needed such as a scanner, a CD-ROM writer, or speakers. In 1982, when IBM first released its personal computer, there was a great difference in what you were able to purchase for $1200 compared to what you could purchase for $1200 in 1998 (see Table 1). Keep in mind that because of inflation, $1200 in 1982 equaled approximately $3700 in 1998 (Montgomery, 1998).

Table 1

Comparison of Personal Computers (1982 vs. 1998)

PC Part	1982	1998
CPU	8086	Pentium II
Processor Speed	8 MHz	400 MHz
RAM	512 KB	32 MB
Hard Disk Space	5 MB	13 GB
Peripherals	Case and keyboard	Case, keyboard, mouse, and modem or network card
Backup Option	Audio cassette tape recorder	External Zip or Jaz disk and drive with 10 MB-1 GB of space
Disk Drives	5 ¼” floppy disk holding 360 KB	3 ½” floppy disk holding 1.44 MB
Monitor	14” amber text-only screen	15” full color monitor
Operating System	DOS 1.0	Windows 98 or Windows 2000
Software	Optional spreadsheet program, VisiCalc	Many pre-loaded software packages

Note. Information obtained from Montgomery (1998).

People are developing a new economical psychology when purchasing new computers. Tom Halfhill explains that in 1997, only 5% of PCs cost less than $1000. In 1998, 40% cost less than $1000. Hence, people have been buying more and more PCs in recent years, but they have been paying less and less for them. In the past, consumers resisted buying lower priced PCs because they feared the machines would become obsolete too quickly. Now, consumers are resisting high-priced PCs for the same reason. The public has accepted the obsolescence paradigm and has adapted by purchasing cheaper PCs more frequently. Each new software “upgrade” turns big and fast computers into small and slow computers, because of how processor intensive new software is. Once the performance becomes intolerable, it is time to buy a new, bigger and faster computer. That is why the phrase “disposable computer” has become so universally accepted (Halfhill, 1998).

Stephanie Miles reports that 65% of readers on a CNET NEWS.COM poll believed that new low-cost computers can meet users’ needs as efficiently as powerful PCs, while 35% preferred to invest in more pricey and powerful PCs. In 1997, the sub-$1000 sector made up 32% of the retail PC market compared to just 9% in 1996. This is because most people use computers for word processing, email, and Web browsing applications, and these applications run just as well on an inexpensive computer as they do on an expensive one. It was noted that it was better to buy a $1000 PC today and another $1000 PC in two to three years than to buy a $2000 machine today that will be outperformed in two to three years by a sub-$1000 machine (Miles, 1998).

Dan Strassberg believes that the previous attributes that made PCs so successful are now unsuitable in the age of ubiquitous computing. Because of a PC's general-purpose nature, they are really too complex for the average user. He also points out an important compatibility issue. Many industries use their own instruments to connect to personal computers. This introduces the issue of PC and instrument interaction. Instruments can be bench-top or handheld test and measurement devices, which are widespread in the industry. Instruments may connect to PC's internally with a card inserted onto the motherboard. If hardware technology advances too much for the card to work in the PC or the software controlling the instrument through the PC fails to work with a new operating system, a significant obsolescence issue is created (Strassberg, 2000).

The cost involved with setting up and maintaining a computer is of great importance. A study by the Gartner Group estimated that the total business cost of owning a PC with Windows 95 is $38,900 over five years assuming a new PC is purchased every three years. This takes into account administrative expenses for technical support, requisitions, purchasing, legal reviews of contracts, security, policy enforcement, and asset management. Tom Halfhill explains that the way to deal with the costs is to "minimize your investment in transitory technology and administrative costs while carefully matching the computer to the user." Still, users get new features that they do not necessarily want or need merely by purchasing a new system (Halfhill, 1998).

The look and feel of the average computer has changed as well. It is no longer a giant beige box that sounds like a vacuum cleaner and takes three minutes to turn on. Now, the computers are becoming an aesthetic appliance by coming in different colors, smaller sizes, and with built-in speakers in an effort to make the user more comfortable with the computer. Different kinds of computers are being developed such as Web PCs, TV-PCs, and home-theater PCs. The segmentation can be beneficial by matching a computer device to the task with greater granularity. Such is especially true for business with options of network computers (NCs), NetPCs, Windows CE Palmtops, PalmPilots, and various types of notebook computers. However, this simply broadens the obsolescence aspect as hardware and software upgrades are required in each segment (Halfhill, 1998).

Interestingly, even the software industry acknowledges the problem and provides advice as to how to deal with obsolescence. Graham Clark, the group manager of retail and distribution industries for Microsoft, gave advice to a group of restaurant operators in an address entitled “The Shortening of Technology Life Cycles – Planning and Budgeting to Outpace Obsolescence” to warn them against installing outdated technology that may not handle future problems. Clark stated that Microsoft’s core products and services need to be updated every three to six months to remain problem free. Originally, Microsoft planned on recycling its technology on an 18-month cycle. He believes that it costs more to maintain an old, unreliable system than it is to buy a new expensive one and acknowledges that other hidden costs of obsolescence are frustrated customers, inefficient marketing, and increased training times (Milford, 1996).

Karl Whelan looked at the effect computers had on U.S. productivity growth while accounting for technological obsolescence. In recent years, there has been an explosion in the application of computing technologies by U.S. businesses. Expenditures on computing equipment grew 44% from 1992-1998 as computer prices decreased to gain powerful hardware, which could use sophisticated software. These computer developments helped improve core business functions and facilitated new business models. This has also caused improved economical productivity performance. However, technological obsolescence needs to be taken into account when determining just how profitable computing technologies are in U.S. businesses. Whelan also states that as new computers become available, old ones are passed from high-human-capital workers to low-human-capital workers, and then they are used as backups. Computers decline in price as they age not only because of physical decay, but because the introduction of new and improved computing technologies implies falling rates of utilization. Computer systems must be coupled with technical support and maintenance as well, hence the recent explosion in demand for IT positions. In fact, as of 1998, for every dollar businesses spent on computer hardware, there was another 2.3 dollars spent on wages for IT employees and consultants. Once the productivity of a machine falls below the support cost, it will usually be retired (Whelan, 2000).

Computer obsolescence also causes IT professional obsolescence. Because of the rapid pace of technological innovation, the diverging application of information technology, and the changing roles of IT professionals, it is extremely difficult to maintain up-to-date professional competency. Because of this, some companies forgo implementation of new technologies. Companies and workers have experienced rapid changes, and because of advances in technology, skill sets of workers need to change. Global economic markets and altered work roles facilitate these changes. It is important to maintain the intellectual capacity of professional workers. With new technologies becoming available that present a new way to do things, the role of the IT worker is constantly changing. There is new software to learn, new tools to use, new hardware to install, and new considerations to be made regarding effective integration (Trimmer, Blanton, & Schambach, 1998).

IT professionals must always upgrade their professional knowledge and skills because their existing intellect, like existing computers, will become obsolete in a few years. This professional obsolescence spawned from computer obsolescence and new technologies not only refers to knowledge itself, but to problem solving and adapting to the new technology and changes. Keeping professionally up-to-date is a complex task faced by IT professionals who interact with rapidly changing computer technologies, especially when obsolescence is an invisible threat that becomes secondary to more immediate concerns. IT professionals need to accept that their roles will be constantly changing as new technology changes, and they must be adaptable and willing to constantly learn new skills (Trimmer, Blanton, & Schambach, 1998).

Technology-driven companies are under a lot of pressure to make wise computer technology investment decisions balanced with their business rationale while facing the obsolescence threat, explains Lisa Cross. The fast pace of technology introduction and obsolescence coupled with limited capital leaves companies with little room for error. Many companies are forced to go with their “gut feeling” when deciding to acquire a new technology, because spending too long researching a new technology renders that technology obsolete as something new and better comes along. Yet, investing in technology for technology’s sake is not the prudent choice either. Basically, new computer technology should be acquired to improve efficiency, cut costs, and/or increase revenue for a company. Computer hardware should not be purchased when something new comes out because of its novelty, but rather the production or business benefits of the new product should be understood before a purchasing decision is made. Companies are even creating research departments to do this by constantly assessing and evaluating new technologies (Cross, 2000).

Jane Bird examined further effects obsolescence has upon companies. A major problem that IT managers face is that computer technology is becoming increasingly complex and is getting entangled with telecommunications. More variables need to be taken into consideration when determining whether to upgrade computer systems. Off-the-shelf and open systems may appear to be easy and more efficient to use, but they can be extremely difficult with getting them to interact with other systems. IT purchasers cannot just think of the needs of a single machine, but must consider the software and hardware and compatibility of the whole organization. The lack of computer industry standards causes buyers to resort to big market share products, and they often get locked into that product for their future (Bird, 1995).

With the decreasing costs of hardware and software, some companies do not rely on centralized purchasing, Bird explains. This can cause discrepancies between departments within an organization as purchasing occurs department by department, and compatibility problems may occur between these departments. Too many different systems generate extra overheads for technical support as well. Picking suppliers for computer equipment is difficult since there is no way of knowing whether the supplier is good or bad or will even be around next year. There are also no standard industry contracts for IT. There are questions of how much support should be purchased, if there should be fixed price contracts, or if support should be based on the amount of materials or a basis of time needed. Customers are buying an intangible entity, and no one knows where technology will be years down the road or how needs will change (Bird, 1995).

Bird states that, “users should determine the management function rather than worrying about their computer literacy or allowing themselves to be bamboozled by technology." For example, when upgrading an operating system from Windows 95, to Windows NT, for example, a single license may not seem expensive, but the cost is tremendous when applied to a whole organization along with the fact that the hardware of each machine may need to be upgraded as well. If the old operating system was adequate and the new one will save workers just a few minutes during the day, then the money spent on the upgrade may have been wasted. The IT industry worldwide is driven towards moving customers to the next generation (Bird, 1995).

One of the biggest examples of the computer obsolescence problem is demonstrated in the United States government, particularly, in the Internal Revenue Service (IRS). The $7 billion IRS agency uses computer systems "designed in the 1950's, built in the 1960's, and jury-rigged every since," states Jeffrey Birnbaum. Most of the 62 million lines of IRS computer code are so antiquated and archaic that young technicians cannot even read it. Their system is composed of 80 mainframes, 1,335 minicomputers, and 130,000 desktop computers that are largely unable to communicate with each other. Frustration and job vacancies abound in the IRS computer arena as the agency fights to keep programmers who can read their code. The IRS has tried to modernize its computer systems for the past 25 years and has failed. In the 1990's alone, $4 billion was wasted on this attempt (Birnbaum, 1998).

The obsolescence problem has affected the IRS so much that in 1989, the IRS scheduled over 30 modernization projects to process 80 million tax returns electronically by 2001. They purchased a machine called the Service Center Recognition/Image Processing System (SCRIPS) that could theoretically scan the returns directly into the computer. However, the volume and variety of tax returns overwhelmed the technology. One of the main problems was that the scanners could not decipher taxpayers' handwriting. This $200 million machine was a failure. Another scanner project, the Document Processing System (DPS) cost $1.3 billion, but became too complicated to operate. Some computers were upgraded in the IRS, but they were never integrated. The IRS developed 9 disparate databases that could not communicate with each other. Though serious restructuring plans are in place and new capable personnel have been hired to upgrade the systems properly, it will be at least 15 years before the transition is complete; the worst-case scenario: "a system-wide collapse due to sheer obsolescence" (Birnbaum, 1998).

The User's Opinion

There is clear evidence that there is a worldwide computer obsolescence problem, but how does the computer user really feel about this issue? Do computer users generally try to keep up with the latest technology or do they hold off upgrading as long as possible? How do they feel about upgrading their hardware, operating systems, application versions, and web browser versions? How do they feel about the progress, training issues, costs, pressure, and effort relating to implementing new computer technology? How do users feel about the new emerging computer technology of Internet application and data warehousing and using smaller computer devices such as personal data assistants (PDAs) and cellular phones? Would they rather see computers disappear and be replaced by smaller Internet devices that do not need upgrading? These questions were addressed in a survey given to a variety of computer users to find out just how they feel about the computer obsolescence paradigm (see Appendix). This study provides empirical evidence of user opinions and proposes how to address the current problems using emerging computer technology. The focus of the survey is to measure user opinions based on their interaction with computers currently and in the past, as well as their impressions on how future technology will affect them and how they feel about the path the computer age is following.

Since this study's populations are composed of students and Information Systems (IS) employees, their differences in opinion were analyzed. Also of interest were the differences in opinions between males and females, since males historically tend to be more technology oriented, as evidenced by the ratio of males to females of employment in technological fields. Because most of the computer users surveyed are students, they were separated into two groups: a group encompassing Computer Science (CS) and Computer Information Systems (CIS) majors, and another group containing all other non-computer related majors. Finally, differences between participants with varying years of computer experience were investigated since the obsolescence phenomenon has the most affect on those who have used computers the longest.

It is hypothesized that participants will generally not keep up with the absolute latest technology because of the high costs and frustrations, however; they should not be more than five years behind the current technology. This should be particularly true of students (especially those who are not computer majors), because many are young enough to not be out-of-date with the latest technology, yet may not have enough money, time, or interest to keep up with the latest computer components. Information System employees will most likely keep current with the technology available, mainly due to work-related necessities. All participants should generally be either indifferent or frustrated in their opinions of having to upgrade their hardware, operating system, applications, and web browser versions. The IS employees and those with the most computer experience will tend to be more frustrated by having to perform constant computer upgrades. The student group will likely not have gone through many computer upgrades, so they should not have strong opinions about such questions, particularly students representing the non-computer oriented majors.

All of the participants will most likely believe that the progress of computer technology is too rapid, since this is a main cause of the obsolescence problem. Also, they will most likely be frustrated by having to be “re-trained” to learn about new software, with the exception of the students with computer majors, who will likely enjoy learning about the newest technology since this is their field of interest. Universally, everyone participating should feel that keeping up with computer technology is too expensive, since the cost of upgrading to keep up with technology requires excessive time and money. IS employees will probably feel increased marketing pressure to upgrade their computers, because their jobs require it in today's competitive technological economy. The remaining participants will likely be indifferent to the marketing pressure to keep up to date with the latest hardware and software. The participants should also view upgrading to a newer computer system as requiring a large amount of effort.

Generating the most varying opinions will be on the topic of proposed obsolescence solutions. The participants should believe that having their applications stored on the Internet is a good idea, particularly the students. As for personal files being stored on the Internet, most participants will likely feel this should not be done because of privacy and security concerns. Most participants will have either negative or indifferent feelings about having non-PC devices and cellular phones take care of their computer needs, because there are still questions of whether these are viable solutions since the technology is still so young. However, the female participants will likely be more supportive of this idea as they can carry a hand-held device in their purses and easily carry their "computer" wherever they go. Finally, most participants should be resistant to having personal computers being replaced by Internet devices, particularly those who have used computers the longest, because they are familiar with the computer systems they use, they question the overall usefulness of the new technology as a solution to the obsolescence problem, and they are reluctant toward making drastic changes. However, the students should be more open-minded about obsolescence solutions, which involve the Internet and small computer devices, and probably welcome such technological advances, particularly the students in computer majors.

METHOD

Participants

Surveys were collected from a total of 245 participants, which included 47 Information Systems (IS) employees and 198 Towson University students. Of the participants, 156 were male and 89 were female. Participants were asked to identify their ages by category. 37 participants were 20 years old or younger, 141 were 21 to 30 years old, 50 were 31 to 40 years old, and 17 were over 40 years old. Participants were also characterized by their years of computer experience. 9 participants had less than one year of computer experience, 60 had 1 to 3 years, 56 had 3 to 5 years, 68 had 5 to 10 years, and 52 had over 10 years of computer experience. The IS employees who participated in this study were from four local health care companies which the author was in contact with. The student population came from nine computer science and computer information systems courses: two 100-level, one 300-level, four 400-level undergraduate classes and two 600-level graduate classes. Of the students who participated, there were 6 freshman, 9 sophomores, 42 juniors, 87 seniors, and 54 graduate students. The students surveyed were comprised of 153 computer science (CS) and computer information systems (CIS) students and 45 students from all other majors. A third group consisting of administrative assistants from Towson University was chosen to participate in this study as well. However, due to a lack of adequate response, this group was not used in this study.

Apparatus

The Appendix contains the four-page questionnaire used in this study. A cover page accompanied the survey describing the nature and purpose of the study, as well as its voluntary and anonymous nature in accordance with Institutional Review Board (IRB) exempt status requirements. The survey instructed participants to assume the phrase “your computer” meant their home computer. If they did not have one, they should consider their work or school computer. They were asked to consider their own computer experience and computer issues they faced such as costs, marketing, time, training, resources, ease of use, ease of maintainability, etc. Many of the questions involved answering on a scale of 1 to 5, where 1 and 5 represented the extreme responses, 2 and 4 were the moderate responses, and 3 being an indifferent response.

The questionnaire was divided into five sections. At the end of the last four sections, space for comments about the questions and their answers was provided to allow participants to elaborate on their responses. The first section contained demographic questions. Participants were asked whether they were a student or employee, their gender, their age as defined by the categories of 20 years old or under, 21 to 30 years old, 31 to 40 years old, and over 40 years old, and their years of computing experience being either less than 1 year, 1 to 3 years, 3 to 5 years, 5 to 10 years, or over 10 years. If participants were in the employee group, they were asked their job title. If participants were in the student group, they were asked their major and class status from the choices of freshman, sophomore, junior, senior, and graduate student.

The second section asked computer use questions. Participants were asked "Yes/No" questions about whether they currently used an application, operating system, and computer more than five years old. They were also asked if they currently used a computer more than 10 years old. The next section asked four computer obsolescence questions. Participants were asked how they felt about upgrading their computer's hardware, operating system, applications, and web browser version. Answers were chosen on a scale of 1 to 5, with one extreme representing a feeling of enjoyment of keeping up with the latest technology and the other extreme representing immense frustration about upgrading to avoid obsolescence. The middle choice represented indifference in their attitude toward the question. The extreme response choices switched from one question to the next to avoid answer patterns and to force the user to read the choices carefully.

The following section asked five computer issue questions. Participants were asked what they thought about the progress of computer technology, particularly, whether they thought it was either too rapid or not fast enough. They were asked how frustrated they felt about being "re-trained" to learn new software. Answers could range from feeling this was frustrating and a waste of time to enjoying learning about new application technology. Next, a question about the costs associated with upgrading computer hardware and software was asked. Participants could choose from not minding the extra costs associated with this to thinking that it is a waste of money to keep up with technology. A question about how much marketing pressure to upgrade was asked. Participants could choose from feeling no pressure to feeling huge pressure. Finally, participants were asked how much effort was required to transition from an old computer system to a new one, with answers ranging from tremendous effort to none at all.

The final section asked five computer obsolescence solution questions. The first question asked how the participant felt about having software applications stored on the Internet instead of on his or her hard drive. The next question was similar, asking about storing the participant's data files on the Internet instead of their hard drive. The following question asked for the opinion of using a non-PC device, such as a PDA, to connect to the Internet for their computing needs instead of the traditional personal computer. Next was a similar question asking about using an Internet-connected cellular phone to service the participant's computer needs. For these four questions, responses ranged from thinking this was a great idea to thinking that this should not be done, again, with alternating response orders. The final question asked how much the participant thought that personal computers should be replaced by smaller Internet devices which do not require hardware or software upgrades. The response could range from not wanting this at all to this being an absolute alternative.

<u>Procedure</u>

To recruit participants for this study, three different methods were utilized. First, for the student group, five Computer Science and Computer Information Systems professors volunteered to distribute the survey to their students in one or more classes of their choosing. Students were allowed ten minutes in the beginning of class to complete the survey. For the IS employees, surveys were distributed to each individual in each department. They could complete the surveys on their own time and were given a week to do so if they chose to participate. A representative from each IS department associated with the author distributed and collected the completed surveys. For the administrative assistants, each department chairperson was contacted for permission to use their administrative assistants in this study. For those who responded, the surveys were sent to those department offices through inter-departmental mail with instructions of where to send the completed surveys. Unfortunately, too few surveys were returned to include this group as a part of this study.

For the computer use section of the questionnaire, the overall percentages of each response were reported for informational purposes. However, for the remaining three sections, the percentages and frequency distribution of each response chosen for each question were presented for all participants. Each question’s mean response and standard deviation was shown as well for the whole population and for the groups of males, females, employees, students, computer-oriented majors, non-computer-oriented majors, and for each category of computer experience. Group comparisons of each question included employees versus students, males versus females, computer-oriented majors versus non-computer-oriented majors, and a comparison between each category of years of computer experience. To compare the responses of corresponding groups, t-tests were used, except for the computer experience groups, which were analyzed using ANOVAs with Newman-Keuls post-hoc comparisons.

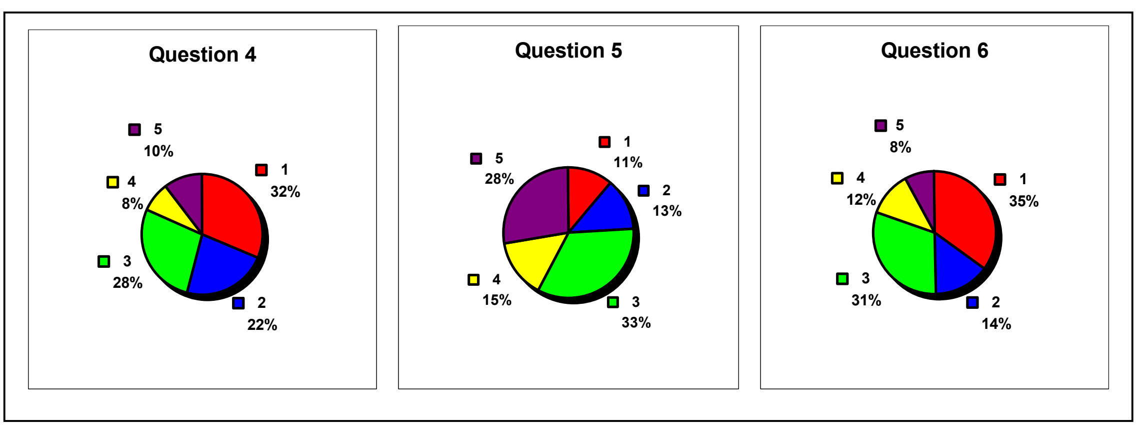
RESULTS

The survey responses were analyzed for all of the participants (N = 245). In the second section of the questionnaire, 22% (n = 54) of the participants responded that they currently used an application on their computer more than five years old for Question 1. In Question 2, only 6% (n = 14) of the participants reported to be currently using an operating system more than five years old. Question 3 showed that 20% (n = 50) of the participants reported that they use a computer more than five years old, while only 3% (n = 8) use one more than 10 years old.

Figure 7 shows the percentage distribution of each answer to the questions presented to all participants. Table 2 lists the corresponding frequency distribution of all responses for all of the participants.

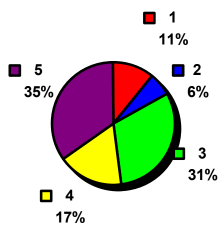
Figure 7

Percentages Of Survey Responses

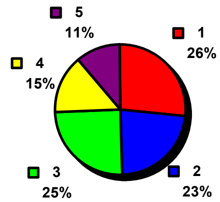


Percentages Of Survey Responses (continued)

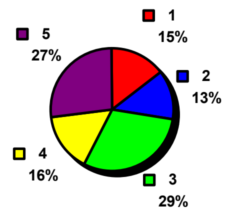
Question 7



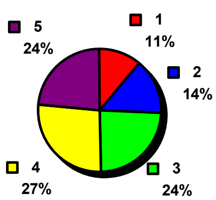
Question 8



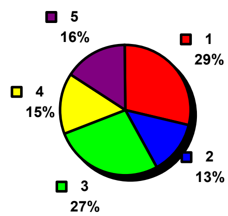
Question 9



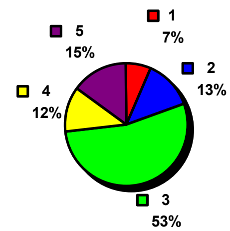
Question 10



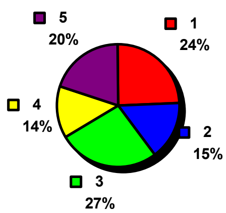
Question 11



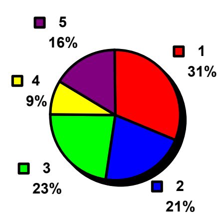
Question 12



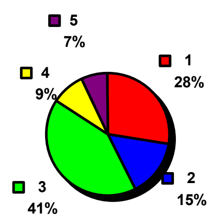
Question 13



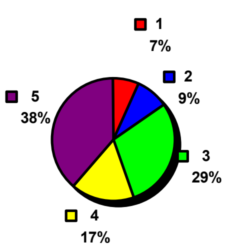
Question 14



Question 15



Question 16



Question 17

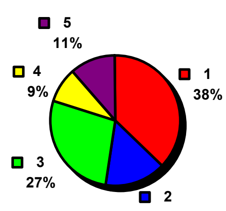


Table 2

Frequency Distribution of Survey Responses

	Responses By Answer Number (n, (%))				
Question	1	2	3	4	5
4	77 (31.43)	55 (22.45)	68 (27.76)	20 (8.16)	25 (10.20)
5	28 (11.43)	31 (12.65)	82 (33.47)	36 (14.69)	68 (27.76)
6	86 (35.10)	35 (14.29)	76 (31.02)	29 (11.84)	19 (7.76)
7	27 (11.02)	15 (6.12)	75 (30.61)	42 (17.14)	86 (35.10)
8	65 (26.53)	56 (22.86)	61 (24.90)	36 (14.69)	27 (11.02)
9	36 (14.69)	32 (13.06)	72 (29.39)	38 (15.51)	67 (27.35)
10	28 (11.43)	35 (14.29)	58 (23.67)	66 (26.94)	58 (23.67)
11	71 (28.98)	32 (13.06)	66 (26.94)	37 (15.10)	39 (15.92)
12	16 (6.53)	32 (13.06)	131 (53.47)	29 (11.84)	37 (15.10)
13	60 (24.49)	37 (15.10)	65 (26.53)	34 (13.88)	49 (20.00)
14	77 (31.43)	51 (20.82)	56 (22.86)	21 (8.57)	40 (16.33)
15	68 (27.76)	36 (14.69)	102 (41.63)	22 (8.98)	17 (6.94)
16	17 (6.94)	21 (8.57)	71 (28.98)	41 (16.73)	95 (38.78)
17	91 (37.14)	37 (15.10)	67 (27.35)	22 (8.98)	28 (11.43)

A majority of the responses tended to enjoy keeping up with the latest hardware, operating system, software application, and web browser technology. In Question 4, which asked opinions about upgrading the computer's hardware, 54% responded that they either somewhat or fully enjoyed keeping up with the latest hardware technology compared to only 18% who were frustrated by hardware obsolescence and 28% who were indifferent toward the issue. While 33% of the participants were indifferent toward upgrading their operating system (Question 5), 43% felt some enjoyment in keeping up with the latest operating system technology, while 24% were frustrated by operating system obsolescence. For Question 6, 49% of the participants felt positive about upgrading their software application versions to keep up with the latest technology, 31% were indifferent, and 20% were on the negative side of this issue. Finally, in Question 7, 52% of the respondents enjoyed keeping up with the latest web browser technology, while only 17% were frustrated about upgrading their web browser version so often, and 31% were indifferent about this issue.

Responses to the computer issue questions were also analyzed. For Question 8, which asked about the progress of computer technology, 49% felt that the progress was on the rapid side, 26% stated it was not fast enough, and 25% were indifferent. Responses to Question 9 indicated that 43% of participants did not mind being “re-trained” to learn about the latest software, 28% felt frustrated by having to do this, and 29% were indifferent. 51% of the participants felt it was on the expensive side to update their computer hardware and software in Question 10, while 25% did not mind the extra costs and 24% were indifferent to this issue. In Question 11, 42% responded by indicating they did not feel any marketing pressure to upgrade their computer, 31% did feel pressure to do so, and 27% were indifferent. For

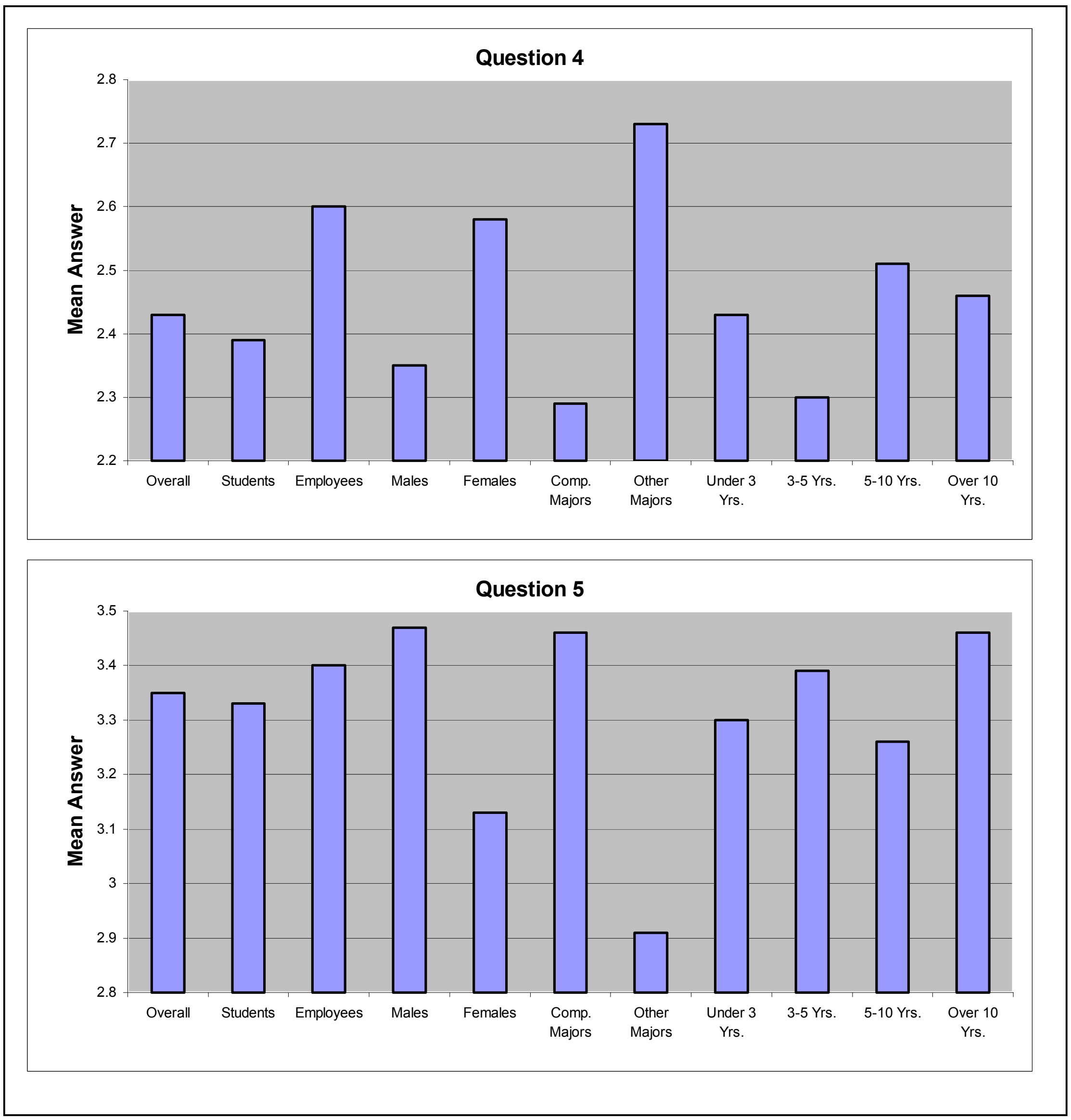
Question 12, 53% of the participants indicated that average effort was required to transition from an older computer system to a newer one, only 27% believed no effort was required at all, and 20% thought this required tremendous effort.

Question 13 began the final section of the survey about computer obsolescence solutions. There was a fairly even distribution of responses to having applications stored on the Internet instead of on participants' hard drives. 39% thought this was a good idea, 27% were indifferent, and 34% did not think this should be done. However, for Question 14, 52% of participants believed their personal files should not be stored on the Internet instead of on their hard drives. Of the remaining responses, 23% were indifferent towards this issue, and 25% thought it was a good idea. There was strong support in Questions 15 and 16 about using a non-PC device like a PDA or a cellular phone to serve the needs of the computer user instead of a traditional PC. For Question 15, 43% thought the non-PC device such as a PDA was great idea, 41% were indifferent, and only 16% did not think this was a good solution to the obsolescence problem. There was even stronger support in Question 16 with 55% believing the cellular phone was a great idea, 29% were indifferent, and only 16% thought this was a bad idea. Finally, in Question 17, 53% of responses did not want PCs to disappear and be replaced by smaller devices, 20% did want PCs to be replaced, and the remaining 27% were indifferent.

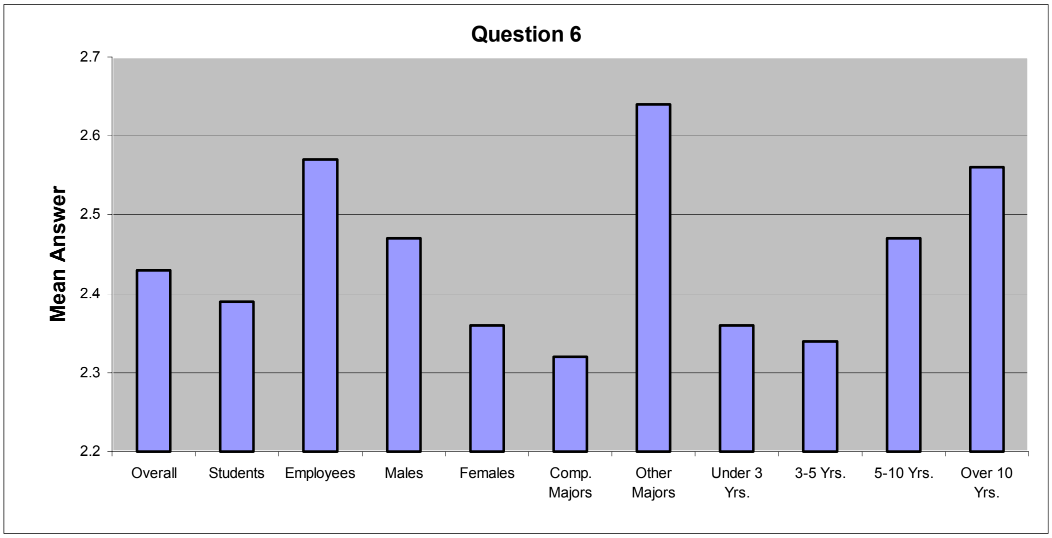
Graphs showing the mean response for each group on each question are shown in Figure 8. In Tables 7, 8, and 9, the means and standard deviations of the responses are presented for the whole participant population and for each group. Because there were only 9 participants who had less than one year of computer experience, they were combined into the group of those with 1 to 3 years of computer experience.

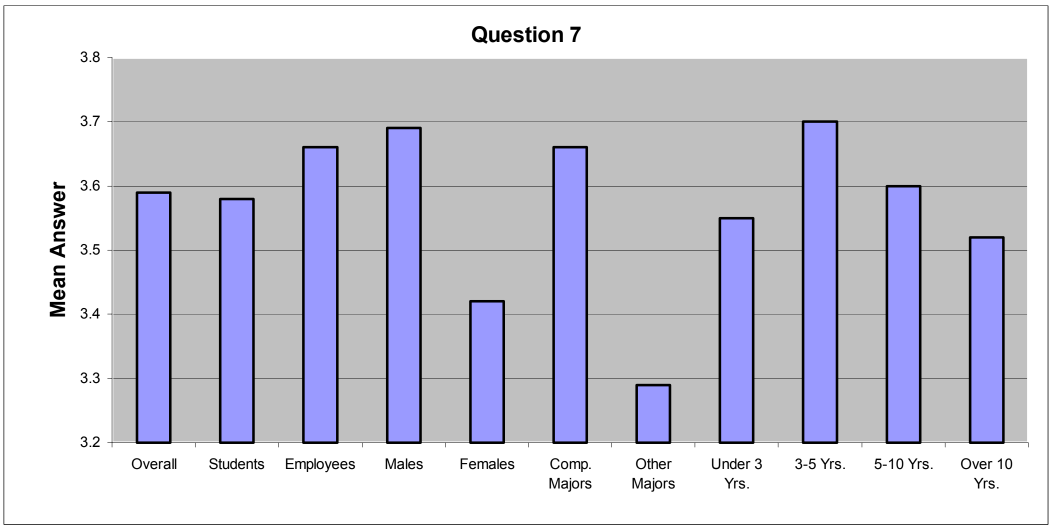
Figure 8

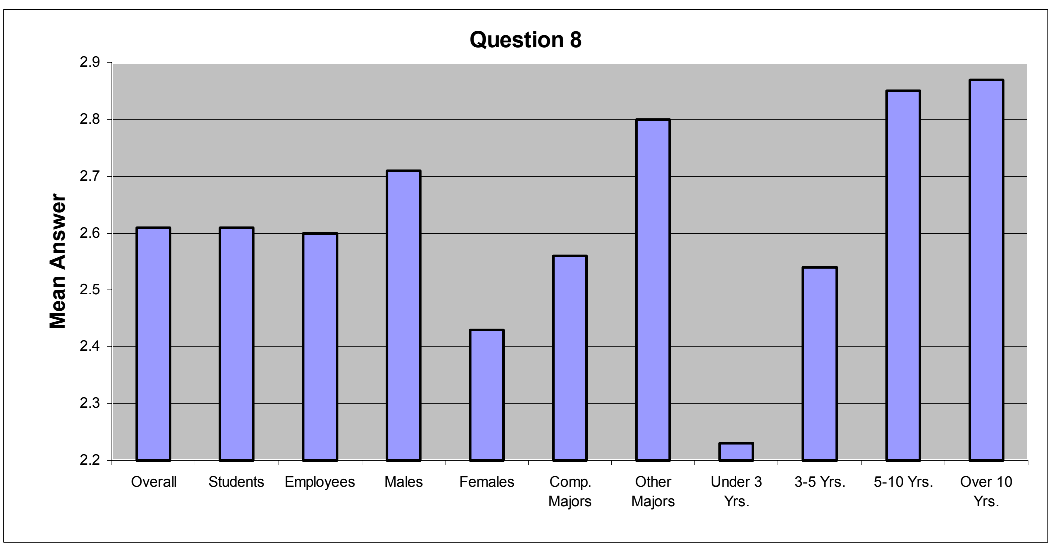
<u>Group Mean Comparison Graphs</u>



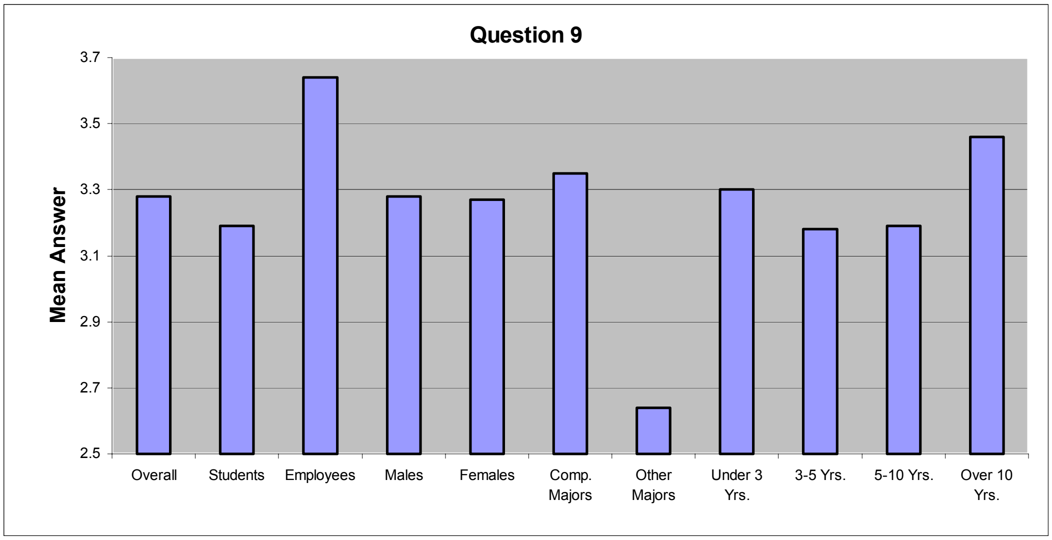
Group Mean Comparison Graphs (continued)

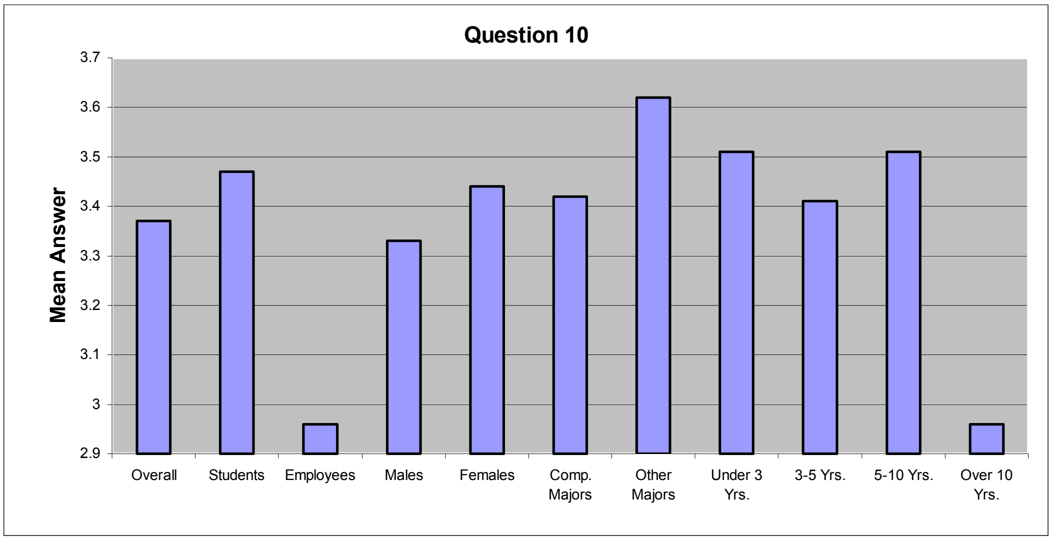


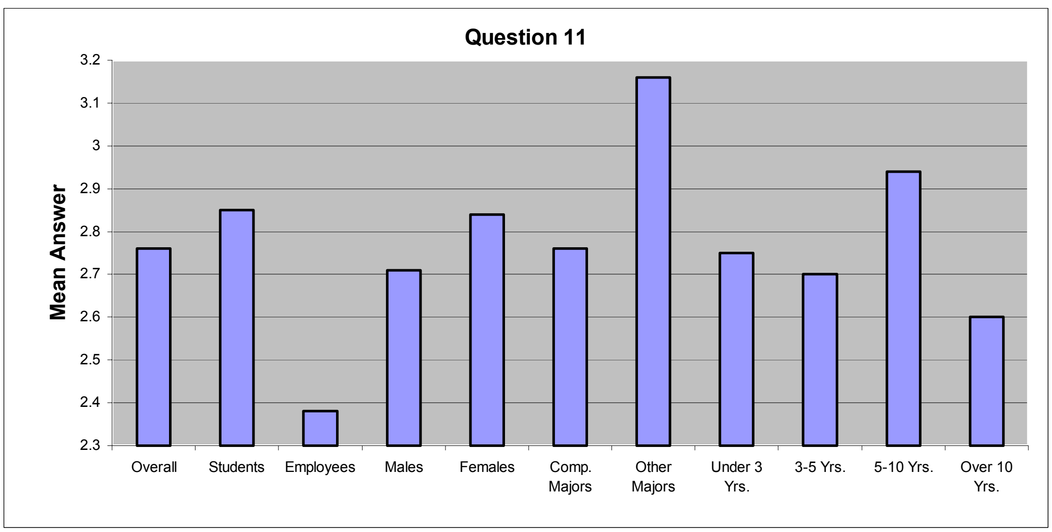




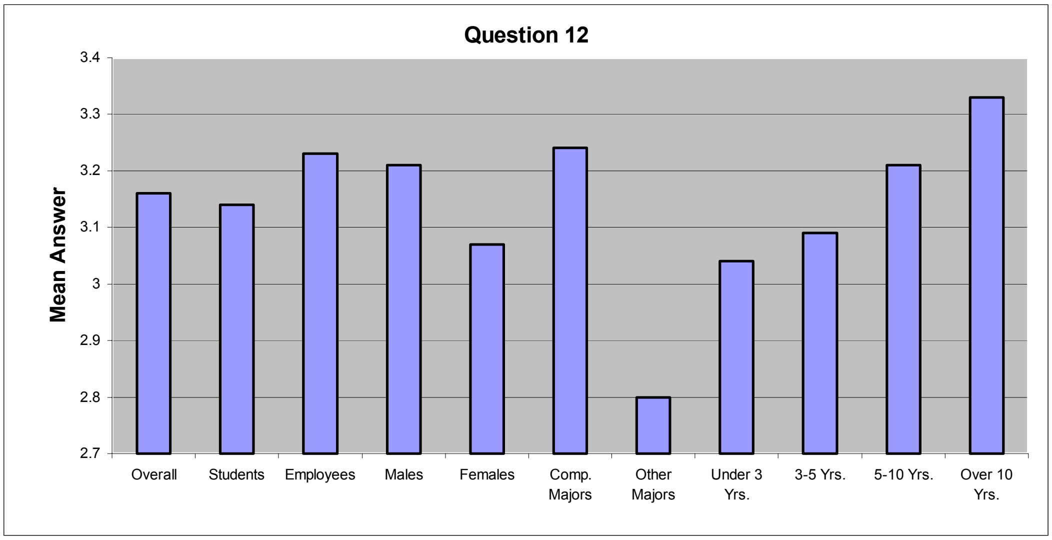
Group Mean Comparison Graphs (continued)

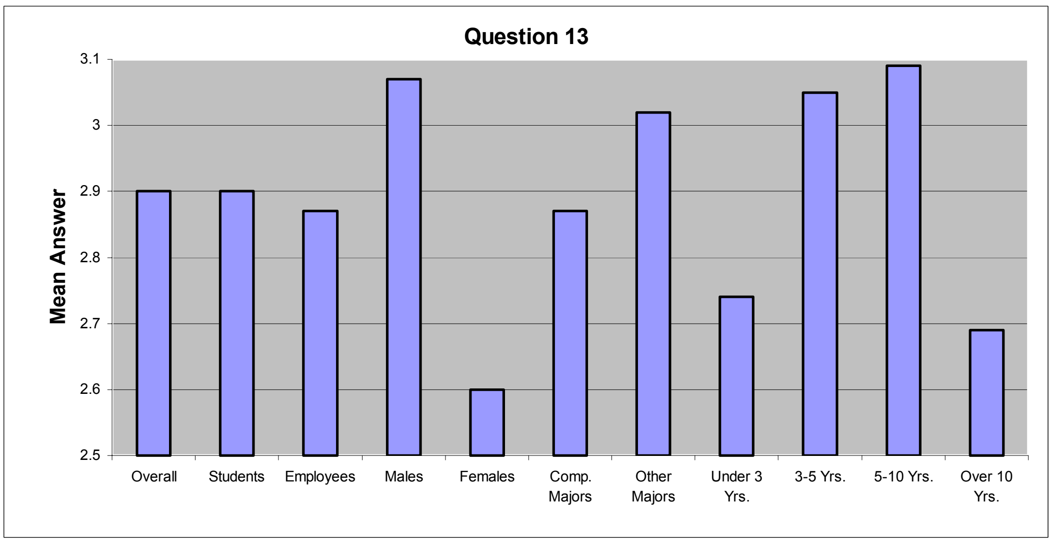


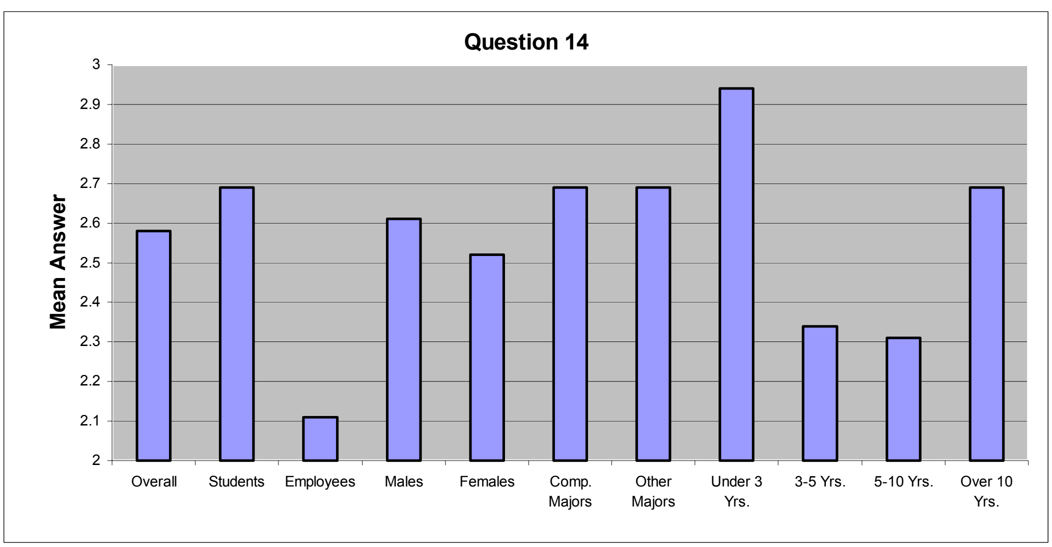




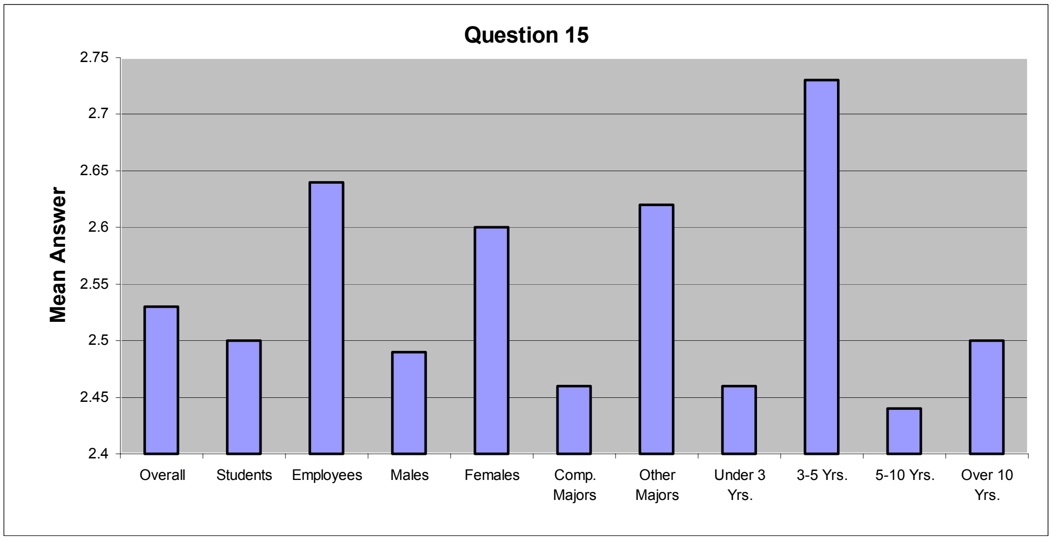
Group Mean Comparison Graphs (continued)

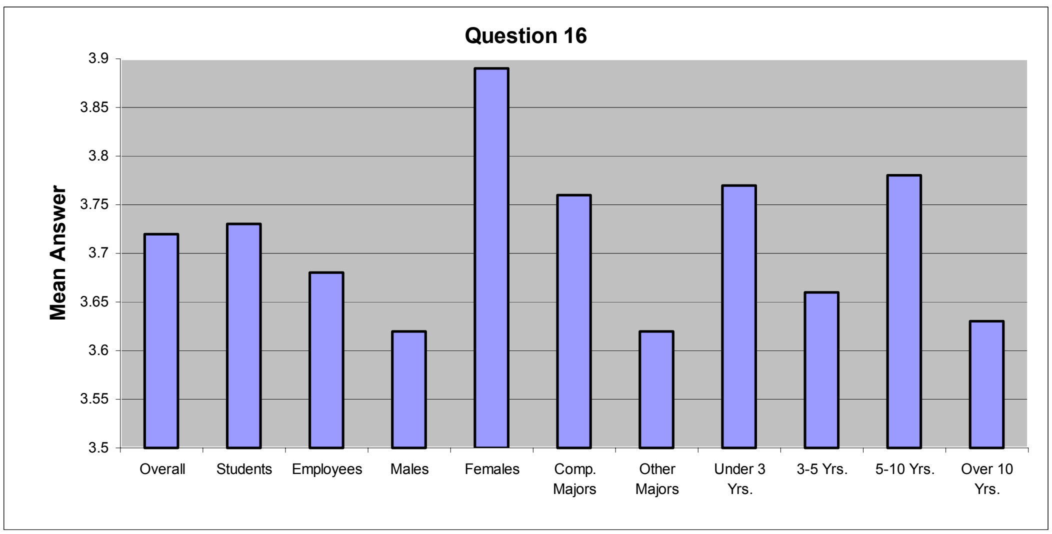






Group Mean Comparison Graphs (continued)





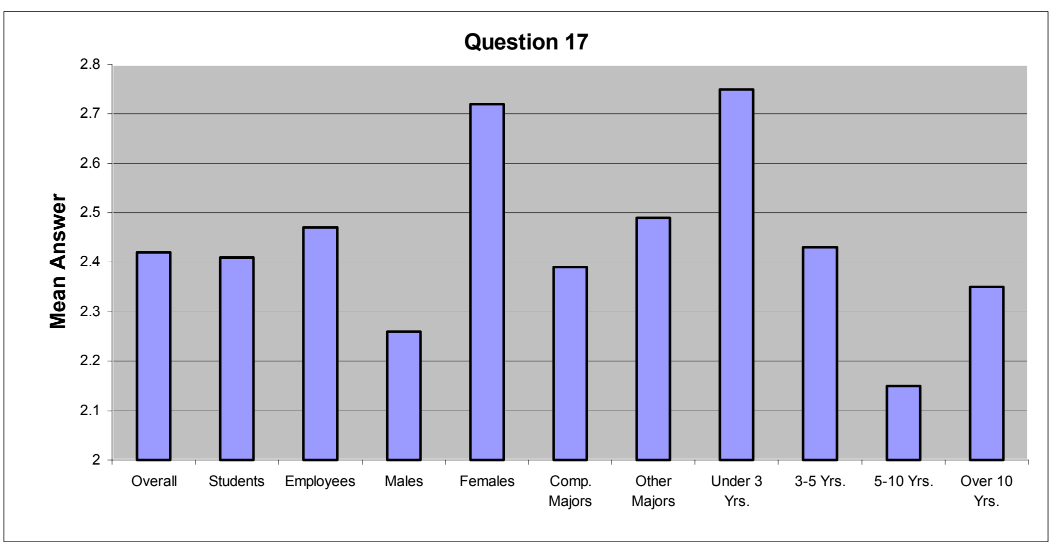


Table 7

Mean Survey Responses for Computer Obsolescence Questions

		Question 4		Question 5		Question 6		Question 7	
Group	n	M	SD	M	SD	M	SD	M	SD
Overall	245	2.43	1.29	3.35	1.31	2.43	1.29	3.59	1.32
Students	198	2.39	1.28	3.33	1.32	2.39	1.28	3.58	1.34
Employees	47	2.60	1.33	3.40	1.30	2.57	1.30	3.66	1.22
Males	156	2.35	1.32	3.47	1.31	2.47	1.29	3.69	1.37
Females	89	2.58	1.22	3.13	1.31	2.36	1.28	3.42	1.21
Comp. Majors	153	2.29	1.27	3.46	1.38	2.32	1.32	3.66	1.39
Other Majors	45	2.73	1.27	2.91	1.02	2.64	1.13	3.29	1.12
Under 3 Yrs.	69	2.43	1.31	3.30	1.28	2.36	1.22	3.55	1.24
3-5 Yrs.	56	2.30	0.99	3.39	1.19	2.34	1.25	3.70	1.28
5-10 Yrs.	68	2.51	1.39	3.26	1.37	2.47	1.31	3.60	1.34
Over 10 Yrs.	52	2.46	1.42	3.46	1.45	2.56	1.39	3.52	1.45

Table 8

Mean Survey Responses for Computer Issue Questions

	Q 8		Q 9		Q 10		Q 11		Q 12	
Group	M	SD	M	SD	M	SD	M	SD	M	SD
Overall	2.61	1.32	3.28	1.38	3.37	1.30	2.76	1.42	3.16	1.05
Students	2.61	1.37	3.19	1.39	3.47	1.30	2.85	1.44	3.14	1.03
Employees	2.60	1.08	3.64	1.28	2.96	1.20	2.38	1.31	3.23	1.13
Males	2.71	1.35	3.28	1.36	3.33	1.30	2.71	1.44	3.21	1.11
Females	2.43	1.23	3.27	1.42	3.44	1.31	2.84	1.40	3.07	0.91
Comp. Majors	2.56	1.40	3.35	1.41	3.42	1.35	2.76	1.47	3.24	1.07
Other Majors	2.80	1.24	2.64	1.19	3.62	1.15	3.16	1.30	2.80	0.79
Under 3 Yrs.	2.23	1.25	3.30	1.48	3.51	1.22	2.75	1.39	3.04	1.02
3-5 Yrs.	2.54	1.36	3.18	1.38	3.41	1.40	2.70	1.51	3.09	0.77
5-10 Yrs.	2.85	1.26	3.19	1.32	3.51	1.31	2.94	1.44	3.21	1.20
Over 10 Yrs.	2.87	1.33	3.46	1.34	2.96	1.22	2.60	1.36	3.33	1.12

Table 9

Mean Survey Responses for Computer Obsolescence Solution Questions

	Q 13		Q 14		Q 15		Q 16		Q 17	
Group	M	SD	M	SD	M	SD	M	SD	M	SD
Overall	2.90	1.44	2.58	1.43	2.53	1.19	3.72	1.25	2.42	1.36
Students	2.90	1.45	2.69	1.46	2.50	1.20	3.73	1.28	2.41	1.39
Employees	2.87	1.39	2.11	1.17	2.64	1.13	3.68	1.12	2.47	1.25
Males	3.07	1.46	2.61	1.47	2.49	1.21	3.62	1.28	2.26	1.32
Females	2.60	1.35	2.52	1.36	2.60	1.15	3.89	1.19	2.72	1.39
Comp. Majors	2.87	1.48	2.69	1.49	2.46	1.24	3.76	1.28	2.39	1.41
Other Majors	3.02	1.36	2.69	1.36	2.62	1.05	3.62	1.30	2.49	1.36
Under 3 Yrs.	2.74	1.36	2.94	1.47	2.46	1.24	3.77	1.29	2.75	1.40
3-5 Yrs.	3.05	1.51	2.34	1.37	2.73	1.20	3.66	1.46	2.43	1.41
5-10 Yrs.	3.09	1.45	2.31	1.28	2.44	1.14	3.78	1.18	2.15	1.31
Over 10 Yrs.	2.69	1.44	2.69	1.52	2.50	1.16	3.63	1.09	2.35	1.28

Upon visual inspection of the means tables and graphs, the side of the issue most participants of each group supported can be generalized. A response greater than 3, the median, denotes one opinion, and a response less than 3 indicates the opposing opinion. A difference in views between groups in each question can be found by comparing the mean to the median. Of note, one difference between groups occurs between computer majors and non-computer majors in Question 5. This indicates that those in computer majors tend to enjoy keeping up with the latest operating system technology while those in all other majors tend to be on the frustrated side of this issue. Question 10 shows a general difference in opinion between students and employees. Students appear to side with the opinion that it is too expensive to keep up with computer technology, whereas employees side with not minding the extra costs associated with this. There are three notable differences in opinion between computer majors and non-computer majors. In Question 9, computer majors tend to enjoy learning about the latest application technology whereas those in other majors feel the “re-training” aspect is a waste of time. Results from Question 11 indicate that computer majors do not feel much marketing pressure to upgrade their computer software and hardware and those in other majors do feel this pressure. Question 12 results illustrate that computer majors do not believe there is much effort associated with transitioning from an old computer system to a new one, whereas non-computer majors do believe a high level of effort is required. Another difference was found in Question 10, where those with over 10 years of computer experience tended to not mind the extra costs of upgrading their software and hardware, and those of all other levels of computer experience did mind the associated costs.

A noticeable difference in opinion between males and females was found in Question 13. Females supported the notion of applications being stored on the Internet whereas males believed applications should be stored on their local hard drives. A similar difference was found between computer and non-computer majors, with computer majors supporting the female's view and non-computer majors supporting the male's opinion. Of final note, the same question elicited support for Internet applications from those with both less than 3 years and more than 10 years of computer experience. Those with between 3 and 10 years of experience generally did not support this idea.

To find statistically significant group comparisons, two-tailed t-tests and ANOVAs were used as shown in Tables 10 and 11.

Table 10

Survey Response Differences Between Groups

Question	Employees vs. Students (df = 243) t	Females vs. Males (df = 243) t	Computer Majors vs. Non-Computer Majors (df = 196) t
4	.97	1.4	-2.04*
5	.33	-1.92	2.9**
6	.86	-.63	-1.49
7	.39	-1.59	1.64
8	-.07	-1.63	-1.05
9	2.01*	-.07	3.07**
10	-2.46*	.61	-.89
11	-2.03*	.69	-1.64
12	.55	-1.09	3.03**
13	-.14	-2.51*	-.62
14	-2.54*	-.49	-.01
15	.72	.69	-.78
16	-.23	1.6	.62
17	.24	2.58**	-.41

*$p < .05$. **$p < .01$.

Table 11

Analysis of Variance for Computer Experience

Question	Source	SS	df	MS	F
	Total	404.14	244		
4	Treatment	1.43	3	.48	.29
	Error	402.7	241	1.67	
	Total	421.51	244		
5	Treatment	1.39	3	.46	.27
	Error	420.12	241	1.74	
	Total	404	244		
6	Treatment	1.74	3	.58	.35
	Error	402.26	241	1.67	
	Total	423.18	244		
7	Treatment	1.01	3	.34	.19
	Error	422.17	241	1.75	
	Total	422.38	244		
8	Treatment	17.58	3	5.86	3.49*
	Error	404.81	241	1.68	
	Total	463.13	244		
9	Treatment	2.87	3	.96	.5
	Error	460.26	241	1.91	

Analysis of Variance for Computer Experience (continued)

	Total	411.2	244		
10	Treatment	11.49	3	3.83	2.31
	Error	399.71	241	1.66	
	Total	494.79	244		
11	Treatment	3.86	3	1.29	.63
	Error	490.93	241	2.04	
	Total	266.79	244		
12	Treatment	2.81	3	.94	.85
	Error	263.98	241	1.1	
	Total	504.45	244		
13	Treatment	7.76	3	2.59	1.25
	Error	496.69	241	2.06	
	Total	495.85	244		
14	Treatment	17.94	3	5.98	3.02*
	Error	477.91	241	1.98	
	Total	343.08	244		
15	Treatment	3.17	3	1.06	.75
	Error	339.91	241	1.41	
	Total	383.57	244		
16	Treatment	.98	3	.33	.2
	Error	382.59	241	1.59	

Analysis of Variance for Computer Experience (continued)

	Total	453.85	244		
17	Treatment	13.03	3	4.34	2.37
	Error	440.82	241	1.83	

*$p < .05$.

As noted in Table 10, significant differences between groups were found in many of the questions. Table 11 shows significant differences in only two questions. Beginning with the computer obsolescence questions, there was a significant difference in opinion between computer majors and non-computer majors in Question 4, $t(196) = -2.04$, $p < .05$. This shows that computer majors enjoyed upgrading their computer's hardware significantly more than non-computer majors. A similar effect was found in Question 5 with computer majors enjoying keeping up with the latest operating system technology significantly more than non-computer majors, who were frustrated by this issue, $t(196) = 2.9$, $p < .01$.

For the computer issue questions, a few significant group differences were found. For Question 8, a one-way ANOVA indicated that there were significant differences of opinion about the progress of computer technology between the computer experience groups, $F(3, 241) = 3.49$, $p < .05$. Post-hoc Newman-Keuls multiple comparisons were performed to see which groups significantly differed. Those with less than 3 years of computer experience felt that the progress of computer technology was much more rapid than those with 5 to 10 years and over 10 years of computer experience, $\underline{CR}_{N\text{-}K}$ (3, 241) = 3.966 and 3.764, $p < .05$, respectively. The results of Question 9 showed that employees enjoyed being "re-trained" to learn about the latest software technology significantly more than students, $t(243) = 2.01$, $p < .05$. This question also demonstrated that computer majors enjoyed learning about the latest application technology significantly more than non-computer majors, who felt that this was frustrating and a waste of time, $t(196) = 3.07$, $p < .01$. In Question 10, students believed that it is too expensive to keep up with the latest computer technology significantly more than employees, who tended not to mind the costs associated with this, $t(243) = -2.46$, $p < .05$. There was also a significant difference between these groups in Question 11. Employees felt significantly less marketing pressure than students to upgrade their computer's hardware and software, $t(243) = -2.03$, $p < .05$. Finally for this section, in Question 12, computer majors felt the effort required to transition from an older computer system to a newer one was significantly less than the effort felt by non-computer majors, who believed a great amount of effort was required, $t(196) = 3.03$, $p < .01$.

The final survey section, which asked opinions of possible computer obsolescence solutions, elicited more significant group differences. For Question 13, females felt it was a significantly better idea to store software applications on the Internet instead of on local hard drives than males, who tended to believe this should not be done, $t(243) = -2.51$, $p < .05$. There was a difference in opinion for Question 14 between students and employees. Employees felt significantly stronger than students that storing their files on the Internet instead of on their hard drives was a bad idea, $t(243) = -2.54$, $p < .05$. In fact, there was a significant difference in opinion in this question between the participants with varying years of computer experience, $F(3, 241) = 3.02$, $p < .05$. Post-hoc Newman-Keuls multiple comparisons showed that those with 3 to 5 years and 5 to 10 years of computer experience felt that file storage over the Internet instead of on local hard drives was a significantly worse idea than those with less than 3 years of computer experience, CR_{N-K} $(3, 241) = 3.721$ and 3.365, $p < .05$, respectively. Finally, in Question 17, males felt significantly stronger than females that personal computers should not be replaced by smaller computing devices which use the Internet, $t(243) = 2.58$, $p < .01$.

DISCUSSION

The results of the survey exhibited many interesting and unexpected results. Before examining the results question by question, some fundamental observations need to be made about the population surveyed. First of all, the results may have been more significant if the groups had had an equal number of representatives. The disproportion of compared groups may have skewed the results, which may have been different if the number of group participants were equal. Also, there may have been some crossover between the student and employee groups since some students, particularly graduate students, may have also been employees, particularly in IS positions. If the participant answered the survey in the classroom setting, however, they were considered a student in this study.

Group comparisons were based upon the number of years of computer experience rather than differences in age, because years of computer experience was a more reliable indicator of computer obsolescence effects on the user than the participant's age when analyzing the differences between the participants over time. Finally, the reason for choosing this particular population was because of their increased awareness of the extent of the obsolescence problem, and because this population most likely uses computers on a daily basis and are familiar with the technological changes in recent years. However, the decision to choose this population seemed to weigh against eliciting responses that indicate a negative attitude toward obsolescence since computers and technology are generally this population's primary interest. Therefore, the participants are generally excited by and interested in new technologies. Also affecting the results may be the opinion of many of the younger participants being that obsolescence is natural and is not a negative aspect of technological growth at all. Additional varying populations should be chosen in the future, which should provide different attitudes toward the computer obsolescence issue.

When interpreting the results of this study the aforementioned reasoning needs to be taken into consideration. First of all, it is interesting to note that few of the participants use computer technology more than five years old. Of the older technology that was still used, most of it was in the form of software applications. Since there are so many applications available, there are bound to be some that suffer no performance problems over a long period of time. Also, some users may be so comfortable with their current application versions, they do not feel the need to upgrade and undergo such a drastic and unwelcome change. A small portion of the participants still use an older computer most likely because of the cost associated with upgrading a computer system. Some may feel that if their computer still works efficiently enough, then replacement is not required. Most participants used newer, more affordable operating systems as well.

The results of the computer obsolescence questions contradicted the stated hypothesis. Instead of feeling frustrated about upgrading their computer’s hardware, operating systems, applications, and web browsers, most participants did not feel this was burdensome and actually enjoyed the endless process of keeping up with the latest, available technologies. This may have been because, as previously mentioned, a majority of the population is interested in computer technology since it is their field of study or occupation, and this interest outweighs the stress involved with upgrading their hardware and software. Another interpretation of this could be that people are so accustomed to the rapid pace of technological change, they have adapted to it; hence, new hardware and software upgrades are expected and not seen in a negative manner.

Many participants commented that they would continuously upgrade their hardware and software if the costs were lower and they had more time. Some even said they upgraded their software just to experience the new features and increase their productivity and capabilities. However, a few participants stated that they do not wish to upgrade because newer versions of applications have unwanted features that demand more resources, which in turn require hardware upgrades. Some participants even noted they were weary of software upgrades because of the fear of the inability to access their old data and of potential software bugs in newly released applications. One participant noted that they only upgrade when something does not run any longer. A couple of participants stated that they would not upgrade their software if it would affect their hardware performance. Once a new computer system was purchased, then they would upgrade the software.

Results from Question 4 showed that there was a difference in opinion between the computer and non-computer major groups on the topic of hardware upgrades. Since computer hardware may not be fully understood by non-computer majors, upgrades in this area could be more daunting for these users. As predicted, the reason for the differences may be because non-computer majors may not have gone through many upgrades and therefore do not have strong opinions about this issue. The difference between group means for Question 5 likely has to do with the computer majors' interest in learning about new operating systems. The non-computer majors view the operating system as that aspect which has the least permanency of the other forms of technology and are therefore more frustrated when it comes to upgrading the OS. Also, since the operating system is the gateway between software and hardware functionality, upgrading the operating system may create more frustration for users because of this interactivity and potential for problems. Not predicted were the results that all of the other groups seem to be in agreement in their attitudes towards keeping up to date with computer technology.

Results from the computer-issue section were more predictable. The hypothesis was supported by the responses to Question 8, which indicated the participants generally feel the progress of computer technology is too rapid. This is the fundamental problem driving the obsolescence issue, and was successfully identified by participants. An unpredictable difference was found between the computer experience groups. This may be due to the fact that those with the most computer experience are familiar with the rate of technological change. Therefore, it does not seem rapid to them. However, for the inexperienced computer user, they are just becoming aware of the obsolescence problem by realizing their new computer is now obsolete, and because in recent years the most rapid pace of technological advancement has taken place. Therefore, they are more likely to interpret technological progress as being too rapid.

For Question 9, it was surprising to note that most of the participants tended to enjoy being “re-trained” to use the latest software technology. However, this may be because most of the population sampled was made up of students with computer majors who would, of course, enjoy learning about the latest technology. This can be seen in Tables 8 and 10, which shows the difference in attitudes between computer-majors and non-computer majors. Of particular interest was the difference in opinion between students and employees. Employees mostly enjoyed being “re-trained” because of the potential of new software to solve problems encountered in real-world circumstances. Another reason may be because IS employees are accustomed to and enjoy being “re-trained” since is it a fundamental aspect of their careers. However, some participants did comment that even though they enjoyed learning about new software, they wished their applications were more backwards compatible.

Results from Question 10 supported the initial hypothesis; however, the difference between students and employees was not expected. IS employees may feel the costs associated with upgrades are tolerable because they are more familiar with the price of computer software and hardware than students and may not perceive the cost of upgrading a home computer as great compared to costs incurred for upgrades in a business setting. Also, IS employees may not pay as much for upgrades because they may be able to get better deals through computer distributors, or because they “borrow” hardware or software from work to use at home. Also in Table 8, it was indicated that those with more than 10 years of computer experience, as compared to the other groups of computer experience, did not mind upgrade costs most likely because they were either accustomed to the costs, or because they had more experience to know how to purchase properly enough to minimize the obsolescence issue.

This mixed response in Question 11 does not necessarily contradict the stated hypothesis. Since responses were so evenly distributed with this question, it is more important to look at group differences. It is interesting to note that non-computer majors feel more marketing pressure than computer majors to upgrade their hardware and software. This may be because computer majors are more interested in keeping up with the latest technology. Non-computer majors may want to stay with the systems and software that they have, but are influenced by marketing of new products and lack of support for old ones. Therefore, they are truly being caught in the obsolescence paradigm. However, the results from Table 10, which indicate that employees feel significantly less marketing pressure than students, are completely unexpected. Perhaps this is because of the knowledge IS employees have of computer marketing strategies that they are not pressured by manufacturers to upgrade. More efficient planning to combat obsolescence is becoming more commonplace in IS departments as well. This incorporates proper research into not only what to upgrade, but what not to upgrade in an attempt to circumvent hardware and software manufacturers' marketing pressures.

The response to Question 12 did not support the original hypothesis. This may be because it is much easier, with today's technology, to transition between older and newer computer systems. Some possible reasons include the availability of inexpensive backup solutions and the fact that many computers purchased today already come with an operating system and a variety of software packages. However, as expected, non-computer majors believed a greater than average amount of effort is required to make the transition. This is likely due to their lack of knowledge and poor computer troubleshooting skills, thus making the transition a more stressful event. One participant commented that different amounts of effort are required if transitioning from an older Macintosh to a newer PC, as opposed to transitioning from an older Macintosh to a newer Macintosh.

The final survey section yielded a mix of results for computer obsolescence solutions. The fairly even blending of responses to Question

13 was unexpected. When examining group differences, females accepted the new Internet technology of hosted applications significantly more readily than males. Perhaps females are more accepting of Internet technology than males. Males could also be more ambivalent than females toward moving their applications from their local hard drives to the Internet. Computer majors also seemed to support applications over the Internet more than non-computer majors. This may be due to the computer majors' interest in Internet technology, or they may be more accepting of change than non-computer majors. Of interest in Table 9 were the differences found between the computer experience groups. Those with less than 3 years of computer experience are so new to computer technology, that they are more open minded to change and are more likely to have a more fresh and exciting view of the Internet and its possibilities than those with 3 to 10 years of computer experience. Participants with more than 10 years of computer experience seem to be awaiting a change in the current computing paradigm to battle computer obsolescence. Therefore, the Internet solution of remotely stored and maintained applications is appealing to this group. However, many participants commented that at present, ISPs are not fast or reliable enough for file and/or application storage on the Internet. One participant even commented that this idea goes back the dummy terminal concept, with users interfacing with CRTs that are hooked up to a mainframe.

The original hypothesis was supported for Question 14, especially since there are still many issues associated with storing personal files remotely on the Internet. Many participants commented on the security and privacy concerns that encompass this issue. In fact, employees felt significantly stronger than students about this issue. This may be because IS employees use their company's proprietary data and rely on security and ownership of this data too much to trust it being stored remotely. Also, since they deal with computer technology on a daily basis, they probably know that the time is not yet right for moving file storage from the hard drive to a server on the Internet because of security concerns. This can also explain the computer experience group differences. Those with less than 3 years of computer experience may be more naive to the security concerns of this issue, may be more receptive of such a change, or they may trust the Internet more than those with more computer familiarity.

Results from questions 15 and 16 did not support the original hypothesis. In fact, most participants were very supportive of having a device such as a PDA or even a cellular phone instead of a PC to take care of their computing needs. This result could be a reflection of the current and growing popularity of hand-held computer devices and immense spread of cell phone use, especially since these devices are paving the way to be the replacements of traditional computers. All of the participants seemed to agree on these possible solutions since there were no group differences in either of these questions. A few participants did comment that they believed cell phones were a great idea in this area, but only if there was no cancer risk.

Finally, the original hypothesis was supported in Question 17. This indicates the participants are not totally ready to surrender currently used PC technology for smaller devices. This is because most people are uncomfortable with the drastic change this would entail. Participants also question how capable these devices are at performing what a personal computer can do. The only group difference for this question was between males and females. Again, females may be more receptive to the technology found in portable Internet devices. Many participants commented on the favorable ubiquitous aspect that Internet devices have over PCs. One participant commented that laptops are a more viable solution to PCs right now, since PDAs and cell phones are only appropriate for e-mail and web-access purposes at this time. Smaller devices have a long way to go before they can successfully replace PCs.

CONCLUSION

Managing Obsolescence

Even though the results of this survey indicated that participants generally did not mind keeping up with the latest hardware and software technology, the fact remains that computer obsolescence creates problems for the environment, industry, and many computer users. There was agreement that the progress of computer technology was very rapid and costly, and participants were receptive to using smaller computer devices and the Internet for their computer needs. However, there was still concern about security and privacy, which elicited hesitant responses to having PCs disappear. During this time of transition into the Internet age, current obsolescence problems must be dealt with and future obsolescence issues need to be averted to lessen the impacts of computer obsolescence.

There are numerous ways to deal with the current state of computer obsolescence, but most of the methods proposed are only partial solutions. What truly needs to be done is to implement a radical change slowly over time to allow users to adapt easily and allow computer hardware and software manufacturers to plan properly to avoid the obsolescence problem in the future. A combination of computer recycling and new environmentally friendly design and manufacture needs to be implemented to deal with the current obsolescence problem, particularly for currently used and stored personal computers. Along with this, a new computer architecture needs to be developed to eliminate the need for costly hardware upgrades, make the technology smaller and easier to use, and interact with the Internet, which is becoming the center of the universe for computer technology. New Internet technology needs to be studied and implemented to take the data out of the client computer and place it onto the Internet for use. Applications and user files need to be remotely and securely stored on servers, which are regularly maintained and upgraded by support personnel. This would virtually eliminate the software obsolescence problem for the user. Additionally, future applications need to be more object-oriented for better interaction with smaller computer devices, which need to be easier to maintain. The user's perception of this new technology needs to be taken into consideration to allow for a comfortable and trusting transition. Computer obsolescence will never go away completely, but the problems it causes because of its rapid rate can be managed. With all of these techniques implemented simultaneously and using proper forethought as technology evolves, the problems obsolescence causes can be significantly reduced.

Many other predictions have been made of what the future of the computer obsolescence problem will hold. Stephen Manes reports on several proposed solutions by computer professionals to replace personal computers, the primary obsolescence culprit. Some say the Linux box system is the key since it claims to do everything a PC or Mac can do without crashing or needing replacement, however, it is not flexible enough for the variety of software applications available. Other professionals say that once fiber optics are more widespread on networks, then all data residing on secure mainframe servers elsewhere will be able to be retrieved instantly. Others say wireless-phones are the key, but not until wireless communication is as fast as fiber optic networks, and that may be many years from now. Finally, it may be that inexpensive new Internet appliances and PDAs are the future (Manes, 2000).

Yet, Manes notes, PC sales are still going strong primarily because of their flexibility. A PC has the ability to connect to so many different pieces of hardware including a printer, scanner, PDA, cell phone, digital camera, etc. Nothing is better than a PC's storage and speed capabilities at this time either. For smaller devices to compete, they need to have their own Internet address and maintain fast network connections. There is also the fact that PCs are getting cheaper and faster as time goes by. People are comfortable with local data storage and running programs without connecting to the Internet. Users need to be satisfied by the fact that Internet appliances eliminate the need for a hard disk. PCs are everywhere already, ubiquitous in today's society, and smaller computing devices are becoming this way as well. Web sites are mainly designed for PCs, so there is also a need for programmers to code for Internet appliances to use the web to its fullest extent (Manes, 2000).

PCs also have a dedicated base of users, programmers, and peripherals. To move away from the PC would be a tremendous effort and a truly evolutionary step in computing history. Right now, Internet devices are over-priced, over-hyped, and under-developed. The problem with these devices is the slow and unreliable network communication, limited graphics, and browsing constraints. However, this sounds like the birth of the personal computer in the early 1980's. With time, wireless Internet devices that incorporate a phone, organizer, detachable wireless keyboard, and new applications will take over the computing market and reduce the obsolescence problem (Manes, 2000).

Terry Brock offers tips for coping with computer obsolescence for small businesses. People have to be willing to accept the fast technological changes today and not fight them. Users need to obtain and learn about tools that will be purposeful for a long time. Technological obsolescence needs to be understood and worked with rather than fought to avoid frustration and stay competitive. The younger generation is more immune to the obsolescence problem since they may not be fully aware or affected by how much computers have changed. Younger workers are not as resistant to computer changes either. Finally, a major obsolescence problem has to do with retaining and accessing data. Data stored on computers from the early 1980's is already unreadable by machines in today's market. The web is the best place to store data since it can be retained for long periods of time and can be accessed by more people (Brock, 1998).

Bucknell University published their “Desktop Computing Replacement Plan” to overcome the challenge of replacing computer equipment before it becomes obsolete. The recent dilemma is replacing computer equipment on a large scale in a short time frame. Previously at colleges and universities, mainframes were replaced every seven to ten years after many upgrades. Now, with distributed personal computers and the rapid obsolescence problem, the task of replacement is daunting. Usually, additional computers were purchased to replace older ones, but that added to the inventory and pushed the older computers to other users. Therefore, in 1995, the Desktop Team of Computer and Communication Services looked into the technology replacement issue. There were four major reasons for coming up with a plan. They were an increasing support burden, too many levels of technology within departments, an unpredictable annual budget, and too many machines shifted around the university. Many replacement factors were taken into consideration such as necessary funding, the allocated budget, computing power requirements, how to acquire the equipment, how to allocate the equipment, the distribution and installation procedures, the plan’s effect on the campus’ reputation, and how to dispose of the unnecessary equipment. As an illustration of the massive extent of the obsolescence problem, the plan took two years to develop and three years to completely implement (Ritschard, 1998).

Basically, the plan is a five-year, cyclical, planned replacement scheme for the campus’ computing equipment. Each department will receive all new computing equipment every five years and requests for upgrades or replacements will be considered every other year. This scheme is handled departmentally to facilitate interdepartmental communication. Their plan for disposing computers that are no longer needed is to offer a warehouse sale to the campus. Computers not sold will be offered to vendors and resellers. This is used as a model to other colleges and universities as a way to deal with the obsolescence problem (Ritschard, 1998).

Recycling

It is estimated that 95% of computer parts can be reused through recycling, states Kelly Heyboer. In April 2000, Massachusetts became the first state in the U.S. to ban computer monitors, televisions, or anything else with a glass picture tube from the state’s landfills. Landfill operators can even face up to $25,000 in fines if they allow computer monitors to be deposited in the landfill. Hopefully, this will encourage other states to follow suit and inspire more research into recycling computer parts. Federal environmental laws already state that it is illegal for businesses to dispose of computers as trash anywhere in the United States. One way to recycle computer monitors is use their components for x-ray shielding and soundproofing. Since the cathode ray tubes in monitors contain over four pounds of lead to shield users from harmful radiation, experimentation is under way into melting down the computer glass and turning it into tiles and blocks to line x-ray labs in hospitals and doctor’s offices. Research is also under way to soundproof airplane cabins by lining them with recycled computer materials. A computer's plastic casing can even be melted down and used as pothole filler (Heyboer, 2000).

Computer manufacturers are now offering programs to help users deal with the costs of obsolescence. To ease the financial burden of the obsolescence problem, some companies offer "obsolescence protection" in the form of computer trade-ins, leasing, and financing programs. Even though upgrading will still be required, it is made more affordable and hassle-free with this method. An example of this "protection" is Micron Electronics' MPower program, which allows customers to trade-in, finance, lease and even dispose of their computers. Any manufacturer's computer can be traded in for a rebate on a new Micron computer. "Cradle to grave" PC lifecycle management leasing options are available for businesses as well ("Trade-in," 1998).

Mark Fearer explains that the best way to recycle computers is to sell or consign them. More and more companies have emerged over the years that do this. However, if the machine needs critical repairs or is too old to be of use, it can be given to companies that "demanufacture" computers by breaking it into metal, plastic, and glass. Action Recycling is a company that takes CPUs, monitors, keyboards, and other computer components. Atlas Metals does the same and has recycled 125 tons of computers in 1996 alone. Microchips and circuit boards can be reused since they rarely go bad, and it is also becoming more and more common to use refurbished components. IBM and Compaq are already starting to take back their obsolete computers.

Another trend is "Design for Environment" or DFE, which means that computers should be designed with components that are easily upgradeable and more easily recycled. IBM, Dell, Compaq, Hewlett-Packard, and ITT are leading manufacturers of DFE components. Electronics-reuse operations can create thousands of new jobs. In 1997, the National Safety Council's Environmental Center organized the first Electronic Product Recovery and Recycling Conference, which had about 200 people from industry, government, and non-profits in attendance (Fearer, 1997).

Hopefully, more computer manufacturers employ new design considerations to make computers more environmentally friendly and easier to reuse, such as using cradle-to-cradle design. To do this, all screws and weldings can be replaced with snap-together design. Then, manufacturers can use fewer materials that have greater purity, as well as label components. Parts that wear out quickly can be bought separately and be replaced easily. Manufacturers should make parts more durable and allow computers to be forward compatible by allowing computers to access extra ports, additional memory, and newer microprocessors. Finally, manufacturers need to eliminate hazardous materials by using mercury-free connectors, and cadmium or mercury-free batteries. Computer remanufacture is also a new emerging business area. By 2005, about 80 million computers will be available for take-back, and for every computer land-filled, three will be remanufactured. More Extend Producer Responsibility (EPR) product support systems need to be put in place by the manufacturers. This means that leasing and repair/upgrade agreements, quality assurance and warranties for upgraded and reused items, reuse and repair licenses, and take-back, deposits and trade-ins for old equipment need to be established ("Information Technology," 2000).

More and more computer recycling organizations are appearing. Bryan Pfaffenberger reports that people can now donate their old working PCs to different organizations found through the PEP National Directory of Computer Recycling Programs. One such organization is the National Cristina Foundation, which provides computer technology to people with disabilities, students at risk, and economically disadvantaged people throughout the world. Another organization is the East West Education Development Foundation, Inc., which accepts computer donations from donors and remanufactures them for students around the world. For PCs that may be refused by charitable organizations because they are too old, there are computer-recycling organizations such as Carnegie-Mellon University's Computer Recycling Program, a part of their University's Green Design Initiative (Pfaffenberger, 2001).

Some large computer manufacturers have internal recycling programs already in place, reports Heidi Schuessler. For example, Hewlett-Packard recycles 3.5 million pounds of electronic equipment every month and it has its own recycling center. IBM recently introduced a service to allow individuals and small businesses to ship their old computers to a designated recycling center. Sony is also currently working out a cooperative take-back program with the state of Minnesota that will allow that state's residents to bring their old Sony products to designated drop-off sites for free. Since it began in 1992, the local electronics recycling program in Minneapolis and surrounding areas has grown 30% each year and has already collected 1,000 tons of electronic waste in 2000. Also, the Internet Nonprofit Center, which is run by the Evergreen State Society, has an online list of organizations that will accept donated computers to be used by schools and community organizations. Beginning in 2001, the Electronic Industries Alliance is offering a nationwide database on its web site that lists places where people can donate working computers or recycle older computers in their areas. Elsewhere, a similar law like the WEEE will become enforceable in Japan in 2001 (Schuessler, 2000).

<u>The Internet</u>

In today's computing world, the exponential growth of the Internet influences so many things that computing is very much viewed as a global computing paradigm. New capabilities have been introduced such as housing applications on the Internet instead of on users' machines. Any files that users create with these Internet applications can either be stored on the users' machines or on remote servers with an allotted and secured portion of disk space. The current problems associated with this are security, reliability, and speed of access. For this new paradigm to take effect and earn the trust of computer users, stable security measures need to be employed, uninterrupted access to the Internet needs to be virtually guaranteed by service providers, and fiber optic networks, along with faster wireless access standards, need to be implemented.

IT outsourcing is a means by which a company can hide from the full affects of obsolescence. This outsourcing can take the costs, management and equipment out of an enterprise's responsibility. Unfortunately, in reality, only certain applications can be safely and economically outsourced. Years ago, the trend was to replace mainframe-based systems with client/server systems. The plan was to minimize obsolescence, simplify upgrades, and keep costs manageable. However, this did not happen. Instead, computer hardware and software got more complex, more difficult to manage, and costs were spread not just to the hardware and software, but also to communications, management, development, integration, and training. The IT trend moved from mainframe systems to timesharing operations to client/server systems to distributed computing to a mix of these systems found on the Internet with application service providers (ASPs) and application outsourcing (Gould, 2000).

This final step basically works by paying a monthly fee to use your own software applications on a "black box" somewhere in cyberspace. Lawrence Gould states that a user no longer has to worry about buying computer software or software upgrades since they are taken care of. All that is required is data communications to the "black box" and a security firewall for protection. This is a great way to minimize the total cost of ownership (TCO). Enterprise resource planning (ERP) outsourcing applications have not become popular yet though, because companies really want these to be in-house and protected. Still, other more common applications like basic word processing and spreadsheet applications would be perfect for something like this. Now, it seems communication technology is almost ready to handle access to remote applications through the Internet at the same speed as client/server systems via fiber-optic LANs, secure firewall technology, and 128-bit encryption algorithms (Gould, 2000).

Mike Hogan reports that Halfbrain.com and Bitlocker offer a couple of free online applications. They offer free spreadsheets and databases to users with a web browser. They are limited in what they can support, but they are a preview of what is to come. Halfbrain currently supports Excel 2000 only, but it is customizable and there is unlimited on-site storage available as well. Bitlocker offers pre-configured databases for business contact management, inventory and pricing data, employee evaluations, and meeting or product schedules. Templates can be customized, and a customer can build his or her own databases as well. 25 MB of free space is available and for $100/year, the customer gets 100 MB of storage space and priority customer support. Dynamic HTML is used for speed and security (Hogan, 2000).

Figure 9 provides a brief history of the Internet, including when its protocols were developed, as well as versions of web browsers, thus illustrating how software obsolescence is already permeating the Internet.

Figure 9

A Brief Internet History

1969 – Advanced Research Project Agency Network (ARPANET)
(the Internet is born)
1970 – ALOHAnet
1971 – First e-mail program
1972 – First computer to computer chat
1973 – Ethernet
Network Voice Protocol (NVP)
File Transfer Protocol (FTP) specification
1974 – Telenet - first public packet data service (later Telnet)
1975 – MSG e-mail program
Transmission Control Protocol (TCP)
1979 – USENET
1981 – Because It's Time Network (BITNET)
1982 – Transmission Control Protocol/Internet Protocol (TCP/IP)
1983 – FidoNet
1984 – Domain Name System (DNS)
1985 – Symbolics.com becomes first registered domain
1986 – National Science Foundation Network (NSFNET)
Internet Engineering Task Force (IETF)
Network News Transfer Protocol (NNTP)
1987 – Unix to Unix Network (UUNET) - first commercial Internet access
1988 – Internet Relay Chat (IRC)
1989 – World Wide Web (WWW), by Tim Berners-Lee
1990 – ARPANET decommissioned
The World - first commercial Internet dial-up access
1991 – Wide Area Information Server (WAIS)
Gopher
1993 – Mosaic 1.0 - first WWW GUI
Internet Radio
Businesses and Media begin using Internet
1994 – Netscape 1.0
First communities and shopping malls on the Internet
First banner ads
1995 – Internet Explorer 1.0 and 2.0
Mosaic 2.0
Netscape 1.1
Real-time audio on Internet
Major ISPs begin (Prodigy, America Online, Compuserve)

A Brief Internet History (continued)

1996 – Internet Explorer 3.0
    Mosaic 2.1
    Netscape 2.0 and 3.0
    Opera 2.1
    First Internet phones
1997 – Internet Explorer 4.0
    Mosaic 3.0 – Mosaic Ends
    Netscape 4.0
    Opera 3.0
1998 – Netscape 4.5
    Opera 3.5
1999 – Internet Explorer 5.0
2000 – Internet Explorer 5.5
    Netscape 6.0
    Opera 4.0

Note. Information obtained from White (2000), Wilson (2000), & Zakon (2000).

The Internet is at an interesting stage right now. It holds the key to abating the computer obsolescence problem, yet it is susceptible to obsolescence itself as it grows and develops. Web browser versions are constantly upgraded, and new web-based computer languages keep emerging as developers stretch the boundaries of the Internet. The Internet is like an operating system, which houses applications that users can access with different types of hardware. There are so many avenues available for the Internet to progress into, and it is a means by which developers and manufacturers can learn from and not repeat the mistakes of the past relating to the obsolescence phenomenon.

A New Computer Architecture

The dominant computer standard for years has been the x86-based PC. Now, a market fragmentation is occurring. Tom Halfhill predicts that four main fragmented market layers will occur at the beginning of this century. 1) The IA-64-bit processor will become available to users for high-end Windows workstations and servers. 2) The x86-based PCs will still thrive for desktop PCs, notebook computers, and smaller servers. 3) Super-integrated CPUs based upon the x86 processor will address the low-end PC home and business market and will be relatively cheap. 4) For those who do not need full-blown PCs, TV Internet terminals will be available, thanks to WebTV. These network computers (NCs) will become very popular for technology-resistant users (Halfhill, 1998).

There is also a tremendous software fragmentation. Take Microsoft for example; in 1999, there were seven not-so-compatible versions of Windows in use: Windows CE, Windows 3.1, Windows 95, Windows 98, Windows NT 3.51, Windows NT 4.0, and Windows NT 5.0. With each upgrade, there is a group of users who do not have the hardware or desire to keep up. Microsoft says it had planned on converging the PC operating systems into a Windows NT version and smaller device OS to Windows CE, but the first would be too big and the latter would be too small for the average user. Of course, there will always be other operating systems like Java, Linux, Unix, Mac OS, OS/2, BeOS, and Rhapsody to compete. There is also a diversity of competing processor types, motherboards, and chip sets that can cause compatibility problems. New hardware technologies are also widely prevalent in today's PCs all of which create confusion for the user and broaden the compatibility and obsolescence problems. Therefore, there is a great need for industry standardization as this fragmentation gets out of hand (Halfhill, 1998).

A fundamental observation is that current applications are environmentally sensitive, i.e. there are differently coded programs based upon whether they run on Windows 98, NT, or Linux. The environment changes too rapidly for software developers and manufacturers to keep up. There is a myriad of hardware and software releases from vendors and great effort is required to port code between environments, which creates a tremendous waste of unproductive software development. Optimally, it would be best if all applications were object-oriented and the objects of applications existed publicly on the Internet. Also, new applications such as new versions and patches would inherit directly from the existing application. Devices, whether hand-held or PC type, would access these applications and be able to use them independent of the environment they are run under by using a virtual machine-type interface that could run on any environment and interact error-free with the application on the Internet. Operating systems would then be greatly minimized and their only purpose would be to monitor battery life, control the connections to the Internet, control access to peripheral devices, as well as run the virtual application object to interface the user to the remotely stored application (Bradley & Karne, 1997).

In the technology market today, industry and government both desire the same thing: low cost, high quality, reduced development time, fast turnaround time, plug-and-play systems, and open architecture. The features of object-oriented programming for software application development address these needs perfectly. This technique will also greatly reduce computer obsolescence. Right now, it is getting to the point that as soon as a new application is released to the public, it becomes obsolete. New applications should follow an object-oriented paradigm to offer abstraction, encapsulation, inheritance, reduced code, reusability, polymorphism, modularity, virtual functions, extensibility, fast development time, portability, open architecture, and hierarchy. Fundamentals of applications have remained the same and will continue to remain the same for some time. For example, a typical word processor requires the following capabilities: editing, storage, spell checking, grammar checking, and formatting. Using the object-oriented application paradigm, there is no reason why any of these applications should become obsolete (Karne, 1995).

For software to work on any device that does not require a vendor-specific operating system, but a virtual OS to run the application upon, applications must adhere to the object-oriented programming paradigm. With this, objects are the basis for all programs and data and control of the data are coupled together. The object’s interface is clearly specified, and access to the object is easily controlled. The characteristics of object-oriented applications are as follows: Abstraction refers to suppressing irrelevant details of an object such as how it is implemented while focusing on higher level concepts of object properties and purpose. Encapsulation refers to hiding the details of the implementation from the user. This includes physical independence of the behavior of an object with anything external to it. Here, data access can be controlled in the object's definition. Inheritance is deriving new objects from other objects. The new objects then inherit the properties of parent objects to reduce the amount of code and the creation of new, redundant objects. Reducing the code makes the applications smaller by applying the previous concepts. Reusability allows objects or parts of objects to be used in different applications so different versions of them do not have to be re-written.

Polymorphism allows common objects to be used in different applications that have many forms, so they basically implement objects in a varying manner. Modularity means that objects are constructed with standardized units or dimensions to allow flexibility and variety for object use to communicate with other objects. Virtual functions simulate other objects in a way to allow them to interoperate efficiently. For example, a virtual application could run on any operating system since it only requires a bare minimum of code to be able to function. Extensibility means that the application can grow and more functionality can be placed upon it as it is updated without having to change the base version that exists. Applications are extended by adding inherited objects or deriving new objects that have no impact on the existing application. Fast development time includes time for ironing out the application requirements, coding them, testing the application, and deploying it to the public for use. Portability goes along with virtual functions in that the application can be “ported” or moved to other operating system environments and still function error-free and correctly.

Open architecture means that a varying array of developers can work independently on different parts of the application at the same time so that once it is complete and the parts are all put together, the application serves its desired purpose. Finally, hierarchy refers to the structure of the application in how it is built. For example, a word processing application would, at the base of its hierarchical structure, be able to save and load text that is typed into it. Above that, there would be a certain function such as changing the font or size of the text. Even higher in the hierarchy would be a method to spell-check the text document, for example. This hierarchy climbs higher and becomes more derived as the function of the application becomes narrower and less necessary for the application to function. Derived objects basically are specialized where parent objects are generalized.

The key to fighting computer obsolescence is to break the interoperability dependence chain of hardware, operating system, and software using a new computer architecture. In this novel approach, the traditional roles of hardware and software are redefined. Ramesh Karne and James Bradley propose and have been researching a new architectural computer base established upon the philosophy similar to that of the construction of buildings and other engineering structures. The proposal will save billions of dollars in reengineering efforts, the waste of computers, and user training of wasted systems and applications. These computer systems should be based upon applications instead of environments, with the applications being object-oriented and user-driven. From a hardware standpoint, objects used by applications on the users' machines should be mapped to the computer's memory and be executed there to control processing and communication. (Bradley & Karne, 1997; Karne & Bradley, 1996).

A global network of computers would be used in this scheme, which would contain servers with various applications and the users accessing those applications. The users could pick which application(s) to access either on a temporary basis or on a permanent basis using a license. Licensing, fees, and security issues would be encapsulated in the application objects on each user's machine accessed through the virtual machine interface. Now the user does not need a full operating system, just a virtual machine type of interface to access the Internet and communicate with the applications. The user does not need to worry about whether hardware on their machines is "up-to-date" since a bare minimum is required to interface with applications now. This scheme basically takes the processing power and disk drives out of the end-machine and places it on the application and storage servers of the Internet. Therefore, utilizing a combination of object-oriented and Internet-hosted applications, software version upgrades and patches can be updated seamlessly and be made available to the user without the user having to do anything or worry about the application not functioning properly. An application-based, object-oriented, memory-centric approach is a method, which virtually solves the PC obsolescence problem from hardware and software standpoints.

Further Research and Development

This study presented an overall model of the computer obsolescence paradigm from hardware, software, and human positions. Since the problem is so immense in scope, an overview of the current computer obsolescence situation and how it developed was illustrated based upon current literature. The impacts of computer obsolescence were also explored from environmental, industrial, and humanistic perspectives. Many proposed solutions were presented to minimize the negative aspects of the computer obsolescence problem. Future research could probe deeper into the specific obsolescence aspects presented here. Research and development should be applied to the Internet, smaller computer devices, new computer architectures, and application engineering methods such as object-oriented programming and open-source application development. Standards for hardware and software development need to be set to minimize obsolescence and increase compatibility since hardware and software have become so fragmented in today's market. The Internet's power lies in unifying the world's information for people to access and share. It can also make computer users' lives easier by expanding its ever-boundless capabilities. However, it should be able to do this in a more standardized and efficient manner that will not become obsolete in such a short period of time.

This study also quantified opinions of how the various aspects of computer obsolescence affected users, their view of the current computer technology environment, and their attitudes of future technologies in their attempt to alleviate the problem of computer obsolescence. Of important consideration is the population presented in this study. Most of the participants were college-aged students, and most of those were either studying computer science or computer information systems. As previously mentioned, because of the students' ages and lack of computer experience compared to the older employee population, the obsolescence problem did not affect them as much.

The employee group represented an interesting contrast in opinion since they have been involved in the technology industry and have dealt with computers much longer. Future studies similar to this one could find the opinions of computer users in other employment types that use computers on a regular basis, such as administrative assistants, which were unsuccessfully surveyed in this study. Also, more IS employees could be polled as well for a stronger sample. Those who use computers primarily at home could also be a sample population, and could elicit strong opinions of the obsolescence situation. Also, different results would most likely be found when analyzing data from participants grouped by income levels. Of particular interest would be a sample of computer users who have been in the industry and used computers for over 20 years, since obsolescence primarily affects them the most. Another population obsolescence primarily affects that would illicit strong results would be software and hardware engineers and developers.

A separate parallel study could focus upon the aspects of computer compatibility issues dealing with hardware and software since this is a by-product of computer obsolescence. Also, a study from a developer perspective could be investigated focusing on the obsolescence of different computer languages, the pressure to develop better and more functional applications for competition sake, and the complexities of software development on different platforms and issues associated with porting applications to different systems. There are many problems that are the result of how computers and applications evolved that can be studied. Now, using Internet technology, ways to eliminate the obsolescence and compatibility problems should be researched and considered during future development and manufacture.

In summary, a long-term, economical solution is needed to address this obsolescence problem. Hardware and software need to have a greater longevity to realize their full potential. Presently, there is a tremendous waste of resources and skills in the computer hardware and software arena. Ironically, to alleviate the PC obsolescence problem, the current computing paradigm may itself have to be made obsolete as a new Internet-based computer architecture takes its place.

APPENDIX

Computer Obsolescence Survey

Directions: Answer as many questions as possible to the best of your knowledge. For all questions using a scale of 1-5, place a check mark in the box above the number that best represents your opinion using the upper, middle, and lower boundary suggestions as guides. Answering ‘2’ indicates you feel in between answers 1 and 3, and answering ‘4’ indicates you feel in between answers 3 and 5. In all questions, assume “your computer” refers to your home computer (IBM or Mac based personal computer). If you do not have a computer at home, consider the one you use at work or school. For all questions, consider computer issues such as costs, marketing, time, training, resources, ease of use, ease of maintainability, etc.

Demographic Questions: (place a check mark next to the appropriate answer)

Student or Employee: __Student __Employee

If Student, Class Status: __Freshman __Sophomore __Junior __Senior __Graduate

If Student, Indicate Major: ____

If Employee, Indicate Job Title: ____

Gender: __Male __Female

Age: __20 or Under __21-30 __31-40 __Over 40

Years of Computing Experience: __Less than 1 __1-3 __3-5 __5-10 __10+

Computer Use Questions: (circle the appropriate answer)

1) Do you use a version of an application on your computer that is more than 5 years old? Yes/No

2) Do you use an operating system on your computer that is more than 5 years old (before Windows 95 or Mac OS 7.5)? Yes/No

3) Do you use a computer that is more than 5 years old? Yes/No
   More than 10 years old? Yes/No

Any additional comments about your answers for this section:

____

____

____

Computer Obsolescence Questions:

4) How do you feel about upgrading your computer's hardware (ex. computer itself, processor, memory, disk drives, sound card, video card, modem or network card)? Consider how often you do so.

   1 – I enjoy upgrading to keep up with the latest hardware technology
   3 – I am indifferent
   5 – I am very frustrated and wish my computer's hardware would not become obsolete so quickly

1	2	3	4	5

5) How do you feel about upgrading your computer's operating system (ex. DOS, Mac OS, Windows 95, Windows 98, Windows NT)? Consider how often you do so.

   1 – I am very frustrated and wish my computer's operating system would not become obsolete so quickly
   3 – I am indifferent
   5 – I enjoy upgrading to keep up with the latest operating system technology

1	2	3	4	5

6) How do you feel about upgrading your computer's software application versions (ex. Word, Excel, Access, WordPerfect, Outlook)? Consider how often you do so.

   1 – I enjoy upgrading to keep up with the latest software application technology
   3 – I am indifferent
   5 – I am very frustrated and wish my computer's software application versions would not become obsolete so quickly

1	2	3	4	5

7) How do you feel about upgrading your computer's web browser version (ex. Internet Explorer, Netscape)? Consider how often you do so.

   1 – I am very frustrated and wish my computer's web browser version would not become obsolete so quickly
   3 – I am indifferent
   5 – I enjoy upgrading to keep up with the latest web browser technology

1	2	3	4	5

Any additional comments about your answers for this section:

____
____
____

Computer Issue Questions:

8) What do you think about the progress of computer technology?

1 – It is too rapid
3 – I am indifferent
5 – I don't think it's fast enough

1	2	3	4	5

9) How do you feel about having to be "re-trained" to learn a new operating system or application that is fundamentally the same as the old one (ex. learning Word 2000 after knowing Word 97 or learning Windows 98 after knowing Windows 95)?

1 – I feel that it is frustrating and a waste of time
3 – I am indifferent
5 – I like learning about the latest application technology

1	2	3	4	5

10) How do you feel about the costs associated with upgrading your computer's hardware, operating system, and applications?

1 – I don't mind the extra costs to keep up with computer technology
3 – I am indifferent
5 – I think it is too expensive and a waste of money to keep up with computer technology

1	2	3	4	5

11) How do you feel about the marketing pressure to upgrade your computer's hardware, operating system, and applications?

1 – I don't feel any pressure to do so
3 – I am indifferent
5 – I feel great pressure to do so

1	2	3	4	5

12) How much effort do you believe is required for you to make a transition from an old computer system to a new one?

1 – Tremendous effort
3 – Average effort
5 – No effort at all

1	2	3	4	5

Any additional comments about your answers for this section:

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<u>Computer Obsolescence Solution Questions</u>:

13) How do you feel about using software applications stored on the Internet instead of on your computer's hard drive?

1 – I think it's a great idea
3 – I am indifferent
5 – I don't think it should be done

1	2	3	4	5

14) How do you feel about storing your files (ex. e-mails, application files) on the Internet instead of on your computer's hard drive?

1 – I don't think it should be done
3 – I am indifferent
5 – I think it's a great idea

1	2	3	4	5

15) What is your opinion of using a non-PC device, such as a PDA, which connects to the Internet (that you could hook up to a monitor, mouse, keyboard, printer, speakers, etc.) for your computer needs instead of a traditional personal computer?

1 – I think it's a great idea
3 – I am indifferent
5 – I don't think it should be done

1	2	3	4	5

16) What is your opinion of using a hand-held wireless device such as a cellular phone that can connect to the Internet for your computer needs?

1 – I don't think it should be done
3 – I am indifferent
5 – I think it's a great idea

1	2	3	4	5

17) Would you rather have personal computers go away and instead use smaller devices that access the Internet and do not require hardware, software, or application upgrades to serve your computer needs?

1 – Not at all
3 – I am indifferent
5 – Absolutely

1	2	3	4	5

Any additional comments about your answers for this section:

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