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Impact of Instant Connectivity on Business Productivity: A Study Using the Community Embodiment Model (CEM)

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By

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I Abstract

The last decade has seen a significant growth in mobile technologies. Predominantly this technology has been relegated to the realm of personal use, but as this work will suggest, cost related effects of such technologies also need to be considered.

For most organizations maximizing operational efficiency is the main reason why new technologies are acquired. However, apart from basic costs, such as total cost of ownership of mobile technologies, other costs (business process reengineering, and employee morale) need to be measured in order to ascertain if an organization can withstand a change to a next-generation system.

This study attempts to evaluate ideas put forth by the Community Embodiment Model (CEM) as possible quantifiable variables which may assist an organization in coming to a conclusion about introducing a new product and process. The quantified variables are used in the development of a formula which alongside a simulation program and an Excel sheet gives a detailed picture of benefits gained, costs incurred, and the future picture of the initial investment. Through sensitive analysis the findings of the study will indicate the importance of factors such as employee morale on the success of a particular mobile device (Personal Digital Assistant) implementation at an organization level.

II Introduction

As communities have progressed throughout history, technology has also evolved, with people finding advanced ways to communicate with each other. Computer-mediated communication (CMC) and its overall impact is a topic in need of additional research, especially in the area of mobile devices and their effect at an organizational level.

Past published research has dealt with the impact of the Internet on everyday life, as well as on the emergence of fragmented communities due to a growing trend of separating physical communities from virtual ones[1]. According to published research, these virtual communities have grown not only in numbers but in preference as well, as now people prefer virtual meetings over in-person ones[1]. This study attempts to co-relate a by-product of CMC, that is, instant communication due to a personal digital assistant (PDA) and its effect on productivity in a telecommunication business environment through a series of formulas.

The Community Embodiment Model (CEM) will serve as the research framework. This model already has been used as a framework for research in virtual communities[1]. Presently, no research has been carried out that uses CEM to study instant connectivity through mobile devices, and whether instant connectivity has any quantifiable benefits in the working environment.

Instant connectivity and "anytime anywhere technology" are terms that first surfaced several years ago. However, research in these two areas has predominantly been focused on technical issues such as design and challenges due to small screen sizes of

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[1] Fox S., (2004). *The New Imagined Community: Identifying and Exploring a Bidirectional Continuum Integrating Virtual and Physical Communities through the Community Embodiment Model (CEM).* Journal of Communication Inquiry. 28(1). 47.

mobile devices. In contrast, implications for productivity due to instant connectivity have attracted significantly less attention from researchers.

Traditional, non-technical models of communication range from linear, which is one-way communication from sender to receiver, to transactional, which is dual communication between a sender and a receiver[2]. Other communication models which also can be applied to the field of information technology do exist. There is the flow model, which has been applied to environments involving individuals communicating with others using computers. The Community Embodiment Model (CEM) attempts to explain how individuals interact with each other using virtual communities. With the almost exponential growth of network technologies, there has been a change in how people interact with each other. There is the actor-network theory (ANT), which is specific to the idea of technological irreversibility and how it is established perennially in areas where technology is embedded in the physical and social landscape[3]. Thus, the requirement for further elaborating on existing communication models is necessitated by the fact that technology will only grow, and not recede in the future[4].

The process of research for this study was literature review. As research progressed it became evident that there are various models which try to explain the overall concept of the effects of mobile computing. Sections III, IV, and V of this report highlight these models.

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[2] Aberdeen Group (2000). *The Benefits of Mobilizing Enterprise Applications with Handheld Devices White Paper.* www.aberdeen.com . Accessed August 4 2004.
[3] McBride N., (2003). Actor-Network Theory and the Adoption of Mobile Communications. Geography. 88(4). 266.
[4] Castleman W., Harper R., Herbst S., Kies J., Lean S., Nagel J., (2001). The impact of mobile technologies on everyday life [Electronic Version]. *Conference on Human Factors in Computing Systems. CHI '01 extended abstracts on Human factors in computing systems.* 227-228.

CEM proposes a relationship between virtual and physical communities and how one can simply be an extension of the other. It also states how participants prefer the use of virtual communication over the traditional mode.

A problem which this author believes exists with generic models such as CEM is that, an idea such as "benefits of virtual communication" in an organization needs to be quantified in terms of dollar amounts. This is the fundamental purpose of this study. While CEM looked at the broad spectrum of benefits at an abstract level, this study further investigates the type of cost and benefits which may be incurred due to the use of mobile devices, and proposes distinct ways of measuring them.

Due to limited time and resources, rather than collect original data, published data from vendors such as Intel Corporation[5], Sprint[6], and BlackBerry[7] was used. Another report referenced was from the Journal of Management Information Systems[8], authored by M. Thatcher. An email which this author received by Mr. Erik Brynjolfsson highlights the traditional resource problems faced with collecting raw data. Mr. Brynjolfsson is a professor at the Sloan School of Management at the Massachusetts Institute of Technology and is the author of various works relating to the IT Paradox which have been repeatedly referenced in this study. He states that, "I think it would be very difficult to detect the effect of handhelds on productivity at the firm or industry level. You would need to get data on very specific applications, e.g. giving handhelds to

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[5] N. Author. (2002). White Paper-Wireless Technology for Enterprises. High-Payback Opportunities. Intel in Communications.
[6] N. Author (2005). *White Paper- Mobile Communication. Inside the Evolution.* www.sprint.com
[7] Ferneyhough C. (2004). Research Study-Analyzing the Return on Investment of a BlackBerry Deployment, 2004. Ipsos Reid.
[8] Thatcher M, Oliver J (2001). *The Impact of Technology Investments on a Firm's Production Efficiency, Product Quality, and Productivity.* Journal of Management Information Systems. 18,2.

all doctors in a hospital or all salespeople in a company's region, and look at specific before and after metrics... It's an important, though not easy, question to study."

It was after receiving this email that this study was directed towards the use of select white papers in order to extract any data which may be useful in determining a formula to calculate productivity in relation to the various costs incurred. Due to lack of time, it became infeasible to negotiate all possibilities regarding costs incurred and benefits gained. The best possible attempt was made to address the major causes for both.

After a formula was determined, a computer program in VB.Net was developed which would simulate the cash flow starting from the current year to whichever year the user specified. Various Excel sheets were also constructed which would allow for sensitive analysis to be performed during the first four years of the introduction of PDAs in an organization. A use of the Net Present Value (NPV)[9] takes into account the time value of money, and how it may be affected when amounts related to costs are changed as part of sensitive analysis. NPV provides the added benefit of looking at long term prospects of an initial investment paying itself off after a certain amount of time.

As a consequence of the formula being developed, changes to CEM are recommended. Since CEM combined the term "goals" with achieving success within a group, this study shows that some of these goals can be delicately linked with employee morale and business process reengineering.

It must be stressed that the research in the effects of mobile computing is in its infancy, and much more work is necessary in order to gain a complete understanding of the various models that have been presented as examples in this work. Time and resources permitting, this study can be enhanced quite easily to develop a more complete

[9] Dan Remenyi (1999). *IT Investment: Making a Business Case.* Butterworth-Heinemann

picture of organizational challenges that may arise when an enterprise project such as the introduction of PDAs on a wireless scale is undertaken.

III Mobile Technologies: Computer Industry's Next Billion Dollar Market

In 2001 [1], a *SIGCHI* panel discussion indicated how mobile technologies had infiltrated everyday life. Examples of this are personnel at movie theaters repeatedly requesting "patrons to turn off their cell phones and pagers" [1]. It is necessary to design some of these devices in terms of how they will affect the regular user. The *SIGCHI* panel also concluded that as computer professionals, certain responsibilities are inherited in terms of how future technologies will be designed in uncertain markets. In order to optimize a mobile device, a problem definition must be framed, according to which the developers can then design the device.

3.1 Problem Framing

Jonathan Allen introduced problem framing [2] in an *ACM* article published in 1998. He defines "problem framing as a set of basic assumptions about the problem technology is trying to solve" [2]. He further points out that research in technology innovation has shown that "shared assumptions about technologies play a key role in how technologies are designed and used over time, from the earliest conceptualization of a new technology to its creative use by the end consumer" [2]. These shared assumptions form the framework of what the goal of a particular technology is. In the case of a personal digital assistant (PDA), the goal is to underline the benefits of anytime anywhere technology. Granted that the technology itself poses challenges such as hardware and software limitations, one of the main problems lies with how hand-held technology is

approached. In other words, mobile technologies are not simply smaller desktops, but rather an entirely different medium of interaction.

3.2 A History of Problem Framing in Mobile Computing

A question that needs to be answered even before a design is made is that of timing. Is it too early to develop a product? Is it too late to introduce this technology? This is the beginning of a problem framework that is in its developing stages. It certainly is the case that new technology such as a personal digital assistant may be introduced too quickly without the people being ready for it. An ideal example is that of the Newton MessagePad launched by Apple in 1993. The MessagePad created tremendous momentum towards pen-based devices. The marketing [2] relied on an enticing argument of how people were always mobile, and therefore the MessagePad was an obvious answer to those who needed a computer while they commuted. This mass-market problem framework would have been appropriate had the technology been easy to use, but this was not the case. The MessagePad's screen display was hardly viewable, and it was unable to recognize natural handwriting. Furthermore, there was no seamless connection between the device and other computing devices. When users compared their expectations to what they had purchased, they were dissatisfied with the device, and stopped using it soon afterwards. Thus, the problem framework of mobile computers in a commuter environment failed to click.

By 1995 hand-held computers were routinely called PDAs. That is when PDAs became linked with wireless technology hence, redefining the problem framework the second time. In 1996 the Palm Pilot came out, and like its predecessors, seemed an initial marketing success. The difference here was that unlike other mobile platforms, the Palm

Pilot required "users to adapt their handwriting to a special alphabet rather than intelligently adapting to their handwriting" [2]. Another problem which the Palm solved was the ability to synchronize with a desktop computer. According to this problem framing, synchronization was nothing more than docking the device in a cradle connected to a desktop. With the press of a button users were able to solve what was the downfall of the first MessagePad.

The MessagePad and the Palm show how problem framing changes with time, a point agreed upon by Allen himself. He states that if problem framing did not change, then it would be unlikely that vendors will ever learn to develop what the user wants. As a result, today handwriting-recognition is not a prerequisite for a successful handheld device.

3.3 Responsibilities of Computer Professionals

With a variety of problem framings, a computer professional needs to consider his or her responsibilities towards creating and maintaining new technologies. Apart from just being able to identify their projects with the risk factors [2], computing professionals should also be able to:

- Recognize different directions their project may take.
- Recognize the pitfalls of locking their goals towards a particular vision.
- Identify a desire to further enhance initial development.
- Understand the technological agenda followed by customers.

None of these four points are easy to answer in an environment in which innovation holds the key, that too being an uncertain one. As highlighted by the MessagePad example, to

be successful a product needs to identify itself with what consumers would like, rather than what the product itself has to offer.

3.4 Context-Aware Applications as New Problem Framing

According to an article [3] published in *Personal and Ubiquitous Computing*, users now require PDA devices which are context-aware. This article states that "a system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task" [3]. The author of this article, Eija Kaasinen, carried out an experiment to measure the need for context-aware devices, and classified the results under five themes: contents, interaction, personalization, service entities, and privacy.

3.4.1 Contents

Kaasinen's interviews and user evaluations showed that contents were an essential feature for users. Contents include topical information, which is "information that may change while the user is on the move" [3]. According to Kaasinen an example of this is an airline's flight schedule. The schedule may change, and therefore, the user may need directions as to what should be done. Would it be simpler to assist the user in trying to acquire alternative ways of transport in case of delays? Or, should the user just wait for the next available flight? Kaasinen's survey shows that the users would prefer continuous information about alternative routes to be displayed on the PDA.

3.4.2 Interaction and Personalization

One of the differences between traditional mobile devices and their context-aware counterparts is that the latter can adapt it self as the user moves, whereas the former is

merely carried by the user. Kaasinen's study showed that "the usage situations are demanding because the user can often devote only partial attention to the device, concentrating on his/her primary task of moving. In addition [to this], the physical environment (e.g. background noise, illumination, weather) may disturb the usage situation" [3]. Another point that was brought up was the entry of a location aware device in personal space. This implied that the user wanted to know if the device actually "knew" where they were and, if so, would that be a breach of privacy? Lastly, the experiment showed that personalizing information for a particular user was necessary. Thus, it would be appropriate to provide the most commonly used information to be the easiest to use. In the case of a roaming user using multiple computers, "collaborative filtering can be used to identify similar users, and to adapt the system according to the group profiles…[therefore] the user should also be able to use the same profile with different devices" [3]. In this manner, the user will not have to worry about configuring a device as he or she changes locations.

3.4.3 Service Entities

According to Kaasinen, service entities mostly deal with consistency of the user interface. As devices continue to connect seamlessly to each other, it becomes vital for the structure and information contents to remain consistent with each interface. Kaasinen's study showed how users preferred going to previously viewed pages by clicking a back button which was located in the same place throughout.

Location based services, as used in this experiment, lead to questions about the impact they have on internationalization and localization of services. This is challenging because the users of the interface may be locals, or foreigners who may be visiting.

3.4.4 Privacy

Privacy is a concern in situations where a user is using a location aware device. According to Kaasinen, since the user's location is known by the device, a question that is posed is, if it is "right to locate a person, use the location, store the location and forward the location" [3]. Even though, presently, privacy protection is an umbrella offered by current legislation, certain social norms may affect the way location aware devices operate. During the experiment, "people were worried about their privacy and the 'big brother' phenomenon when considering services enabling people to be located" [3]. To prevent situations where the user may feel uncomfortable, it becomes necessary for the device to inform them of the type of data that is collected, how it is used, and who has access to it.

3.5 Gestures: An Extension of Context-Aware

Brereton et al [4] explored the use of gestures in "context of activities in the workplace and everyday life in order to understand the requirements, and devise concepts" [4] for future design of such devices. They defined gestures as, "an actual time-varying physical motion, or measurable intention to produce the same specific intent and meaning on the part of the user" [4]. This problem definition enabled them to explore the idea of all body movements as a type of communication.

In a scenario described by Brereton, a problem arose when the user raised his finger to activate the PDA, and display the time at which the next ferry departed. This

was described as the use of gestures as place holders, which in a densely populated area, as seen in the ferry example can lead to the device not being able to recognize a gesture.

Brereton's experiment shows that while design ideas may be extracted from themes such as the need for immediate information, there is no simple route "from analysis of activity to design of devices" [4]. However, the potential for gestures as place holders is tremendous, and one should take advantage of these human abilities in interface design.

With the case of new problem defining in mobile computing, Green [5] states that "the limits of time, and the incompleteness of data, are problems that are not only recognized and articulated, but have to be dealt with in what can best be described as practical ways" [5]. Marketing and business strategies need to evolve around user behavior, and thus move developers towards a common goal. That goal is to increase the likelihood that the user will choose a mobile device, over not having one.

IV Lowering the Barrier: The Problems with Mobile Resource Technology

It was reported [6] in 2002 that alongside significant growth of the World Wide Web, there have been "great advances in the area of wireless personal communications." It is not only the extensive use of cell phones that falls under the umbrella of wireless communications, but areas such as "application-aware adaptation" [7] systems are also a part of the juggernaut. An example which this author will cite later is called "Odyssey, a platform for mobile data access" [7]. Thus in regard to mobile resources the demand for high performance mobile devices which can connect to "corporate databases…and search on the World Wide Web" [8] will only increase as people get used to present day novel ideas such as anytime anywhere technology.

4.1 Networked Wireless Technology: Source of Information versus Network Problems

According to an ACM report, "Internet enabled personal digital assistants (PDAs), cellular phones and a wide range of mobile devices represent a promising facet to exploit digital library resources" [9]. The article alludes to the challenges which are posed to mobile computing. It is a generally accepted principle that "traditional techniques for information access are based on the assumptions that the location of hosts in distributed systems does not change and the connection among hosts also does not change during the computation. In a mobile environment, however, these assumptions are rarely valid or appropriate" [10]. Thus for a new paradigm such as mobile computing to prosper, the more archaic network architecture needs to be revamped, so that mobility based issues such as network delays and small screen sizes can be addressed.

In the case of the digital library example, stress has been paid on developing markup languages like WAP, which are tailor-made for mobile devices. The problem though is much more complex and requires a well rounded solution. For example even with WAP, if the network connection is too slow, then the mobile device will be unable to serve its purpose. Unlike desktops which make use of cache and virtual memory, mobile devices lag behind due to an architecture which simply cannot withstand that sort of work load.

4.2 Mobile Client-Server Relationship

ACM [10] reports that research is currently being done to fully understand the client-server model in a mobile environment. Presently [10] this relationship can be categorized in three different ways, namely:

- Mobile-aware adaptation
- Extended client-server model, and
- Mobile data access

4.2.1 Mobile-aware adaptation

Adaptation is a necessary tool considering the dynamics of a mobile environment. Mobile-aware adaptation covers various techniques as to how applications and systems respond to each other with a change in the environment as well as resources. In this scenario there is a need for the system to "dynamically [adjust] the functionality of computation between the mobile and stationary hosts" [10].

Satyanarayanan [11], a Carnegie Mellon University Research scientist indicated that two extremes exist in this adaptive structure. They are,

- *Laisse-faire adaptation*. Here the application that is currently being executed is solely responsible for adapting to the dynamic change.
- *Application-transparent adaptation*. In this right-most extreme the entire responsibility of adaptation lays with the system itself.

Satyanarayanan then reiterated what Noble [7] had already said, and that is, in between the two extreme adaptive techniques lays what this author had earlier referred to earlier as application-aware adaptation. The advantage is that this process enables collaboration between the system and the applications. Thus, when the dynamics of the environment change, a pure adaptation amongst the system and application can occur.

4.2.2 Extended Client-Server Model

Generically speaking in a client-server information setting the server is the retainer of a database, and the client requests information from the server. This means that the client can communicate with the server. As already mentioned by this author, in classical client-server models, the location and the connection of the client and server is static. According to Satyanarayanan [11] in a mobile scenario what needs to be done is for the client to forgo some of its traditional operations, and let the resource-rich server execute some of the client's data. This on one extreme would give rise to a thin-client architecture model which would require a static server to be mobile-aware. Satyanarayanan, who is well known for his papers dealing with extremes said that the "other extreme case is the full client architecture" [10]. In this system the client emulates the functions of a server in its entirety, thus the effects of a slow network connection are negated, since the client minimizes its communication with the static server.

4.2.3 Mobile Data Access

Stepping back to the classical model of data communication, there are two types of network protocols: TCP/IP and UDP. TCP/IP guarantees that information sent from the host reaches its destination, where as UDP is considered more "unreliable." For a UDP connection it is not a requirement that all data that has been sent should be received as well. Mobile data access in a sense falls under the same category as a transmission protocol because it deals with the consistency and maintenance of data as it travels between the mobile client and the static server. This is where the network problem lies. It is widely acknowledged that the volume of data that goes downstream from the server to the client is much greater than the upstream traveling data from the client to the server. This imbalance is called asymmetrical communication [10]. According to Jing "application examples of asymmetrical communications in wireless environments include Hughes's DirectPC (www.hns.com) and CAI's Wireless Internet Access (www.caiwireless.net), where clients at mobile hosts usually have a lower bandwidth cellular or PSTN link while servers at fixed hosts may have relatively high bandwidth broadcast capability" [10]. To tackle the problem of scalability in asymmetrical communication what has been proposed [12] is an architecture which exploits the broad-based dissemination ability of communications. In general, this architecture takes advantage of the volume of data which a server has to offer by allowing the server to broadcast it across multiple clients. This is called the push-server architecture which is different from the traditional client-pull architecture. In the client-pull case data was provided to locally running applications.

4.3 Cache Management Problems in Mobile Environments

Caching is a significant tool in network computing because it narrows the query time of almost all applications. For example, caching of web-pages enables the user to view a web page quickly, especially if the web page has not been updated since the last time it was cached. What happens is that the client sends a query to the server which checks if the date has changed between the cached page and the real-time one. If they are the same then the cached page is loaded instead of downloading the same page from the Internet.

In a mobile environment caching is not simply a matter of saving to disk. For one, the disk always lacks the resources for applications such as virtual memory and caching to run concurrently. To counter the problem of caching, a hoarding [10] approach has been proposed.

4.3.1 Automated Hoarding

In hoarding, files which are not local to the client are saved to the client cache before disconnection. The problem, however, is what to cache and what not to. All data cannot be cached due to resource issues such as hardware limitations.

Automated hoarding selects files by monitoring the user's behavior. By assigning semantic relationships to files and then feeding them to a co-relater component, a semantic distance is calculated. This semantic distance is a result of a complex algorithm which clusters the files and assigns a numeric value to them. This numeric value later becomes a priority indicator, with the highest priority file being saved first in cache and so forth.

4.4 Odyssey

Odyssey is a research project at CMU led by Satyanarayanan. It revolves around the application-aware adaptation approach, and deals with concurrency of mobile user environments. It is important to consider the fact that even in a successful adaptation between system and applications, the mobile device may be unable to cope with large swings in availability. For example if the bandwidth of incoming data is extremely high then the mobile device may be unable to cope with vast amounts of information due to its limited hardware capabilities. Thus, an optimum adaptation between the system and applications will not occur as proposed by the application-aware adaptation model.

Odyssey identifies [7] this problem by correlating quality with resource consumption. For example, in the case of a web browser, if there is a sharp drop in the bandwidth, then instead of waiting an inordinate time for images to load, Odyssey will load images which have been aggressively compressed. This notion of quantifying quality is called fidelity. According to fidelity, for any data item there "exists a most complete, current, detailed version of that item called the reference copy. When resources become scarce, the item will be degraded in some way...fidelity is defined as the degree to which a presented item matches the reference copy" [7]. Therefore fidelity solves the problem faced with the pure definition of application-aware adaptation systems.

There is no denying of the fact that mobile resources have a great demand, but there is a need to accept the notion that due to the diverse nature of a mobile device's hardware and software structure, solutions to some of the problems mentioned by this author will not come easily. However applications such as Odyssey do prove that the new paradigms proposed for mobile resources, that is mobile-aware adaptation, extended

client-server model, and mobile data access have the potential to finally lower the barrier faced by mobile technologies.

V User Interface, Design and Interoperability in Mobile Computing Environments

Mark Weiser's landmark paper introducing the idea of ubiquitous computing is fast approaching reality. The emergence of mobile technologies such as personal digital assistants (PDAs), IPod, and Tablet PC's have strengthened the notion of anytime anywhere access to information. However, there remain challenges that need to be overcome…the major one being interoperability.

User interface (UI) design and development certainly do pose unique challenges [13] for the field of mobile computing. UIs need to run on a plethora of platforms ranging from desktops to tiny cell phones. Each one of these platforms creates challenges native to their development. For example, "some devices are immobile (e.g. a home-based Internet Screen Phone) while others are mobile (e.g. a PDA); some support extensive graphical capabilities (e.g. a large monitor), while others only provide limited interaction capabilities (e.g. a cellular phone); some are equipped with enhanced input/output devices (e.g. a trackball)" [14]. Also, a case needs to be made for the influence of environmental change on mobile devices. In the case of a personal digital assistant, if a person is under an enclosed bridge, would it be beneficial if the screen automatically dims to a viewable level? Similarly it would be wonderful if there is noise disturbance around a device, and the audio level adjusts itself so that it could still be heard.

Traditionally, what has occurred is that individual UIs have been developed for each technology. This is a short term solution which gives rise to the devices not being able to "talk to each other". In other terms, they are not interoperable. Eisenstein [14] in his paper states that "current practices for UI design for mobile computers are in need of

significant improvement…user interface modeling will be an essential component of any effective long term approach to developing UIs for mobile computing" [14].

5.1 User Interface Modeling

Mobile devices can be classified as being "portal". What naturally follows is that if devices are portal then "the application should not be written with a specific device in mind" [15].

In this context, user interface modeling makes use of an extensive knowledge base which automatically generates a UI depending on the device in use. To highlight the need of such a technology the following scenario can be considered.

Adam uses his PDA as a personal information management system. One day, as he is walking towards his workplace, the PDA's batteries fail. Usually he is able to connect his PDA to a laptop and the PDA can then reroute the power source through the laptop. Today all he has is his cell phone and the PDA cannot be connected to the cell phone's power supply. Furthermore, the telephone numbers he has stored in his phone's directory are older than the ones on the PDA. It would be much simpler and easier if the PDA were able to transmit information to the cell phone automatically. If this were not enough, another problem he faces is that without his laptop connected to the PDA, Adam cannot print to any one of the print stations in his office. This is due to the different print applications that are installed on the laptop and the PDA. His frustration is a result of the mobile devices not communicating with each other, rather than not being able to operate the devices correctly.

To solve this problem, programming models must "allow for the description of abstract user interfaces and abstract services. The structure of the program should be

described in terms of tasks and subtasks. The granularity at which these tasks are presented to the user is a load-time issue, and therefore the relationship among the tasks must be rich enough for the user" [15]. This means that user interfaces are not dependent on the device in use, but in fact rely on the task which the user is going to perform. In Adam's case, the PDA would dynamically adjust its interface so that a printer could be accessed on a different network.

5.2 *Challenges of a Dynamic Model*

Banavar [15], in his work at the IBM T.J. Watson Research Center in Hawthorne, described the relationship between a human and a dynamic interface as "navigation." He indicated that there are four main challenges for developing a navigation model. They are described in the next four sections.

5.2.1 Inability to identify abstract interfaces

The interface has to be intelligent enough to recognize the user's intent, and abstract the mechanisms of the device itself. For example, an application running on a GUI system might be executed through a series of mouse clicks, but the same application running on a cell phone might be voice-activated. Hence there is a need for interfaces to be independent of hardware and more reliant on software in order to adapt itself to the changing environment.

5.2.2 Inability to identify a descriptive language for a dynamic setting

In the previous scenario, one of Adam's difficulties was the inability of the interface to link with a device other than the laptop, when the laptop was not present in the environment. The application model which the PDA was using is based on existing

technologies specific to each device. This is where the true problem of interoperability lies. Therefore, what is needed is an application logic which would allow not only the existing service to run, but in unexpected situations, allow for other services to provide the same function when the main service is not available.

This idea of having different levels of services is very similar in nature to what Ramanathan [16] describes as hierarchical. He highlights the need for a modularized system which can improve the quality of service in instances when the main service is not available. Even though this referred to mobile network structures, the fact remains that a similar configuration can be applied to interface settings, which would result in what Ramanathan calls a "multi-hop" [16] scenario. In Adam's case, the PDA's interface will be able to adjust to a change in the environment setting through a series of hops, and not lose any of its functionality.

5.2.3 Developing a task-model

If Adam's personal information system had a calendar application, and the PDA connected to larger monitors, a task-model should be developed. For example, in a calendar application, browsing appointments is one task, and entering new ones is another. If this information were displayed on a larger screen most of these tasks could be designed to fit just the one screen, whereas on a smaller screen, like that of a PDA, separate screens may be required. Therefore the application model should be able to designate tasks depending on the "presentation units; e.g. screens" [15].

5.2.4 Developing a navigation model

A navigation model complements the task model. It identifies what causes each task to start and end along with any intermediary stages. In the case of a presentation unit as described before, a navigation model automates the flow of data within the system when it is running.

5.3 Development Methodology

As already indicated, development based on individual user tasks and not interaction based on a specific device would be ideal for mobile computing. In order to accomplish this, the developer needs to employ user-centered design to generate the processes involved by recognizing the set of requirements. In other words, the developer needs to ask the following questions (among others):

- What sorts of tasks does the user want to accomplish, and does the task have any sub-tasks?
- During a task how is the program executed, and what happens between a task starting and a task ending?
- From the user's side, what requirements does he or she need to fulfill in order to complete the task?
- What is the logic behind each task? Can sub-tasks be independent of the environment the device is in or are they dependent on the main tasks?

Through the questions mentioned above, the developer will be able to identify the level of abstraction that is needed for an application to run across different platforms. Thus, Banavar concludes that the programming model will have an annotated task

structure with navigation flow, and "an abstract user interface for each task, [with a] scripting logic that details the task function" [15].

One of the restrictions posed by the methodology is the lack of programming tools which support a level of abstraction as proposed by a dynamic interface. Current tools may allow for the navigation flow of an interface to be developed, but areas such as "scripting logic" [15] may not be accessible via current programming paradigms.

5.4 Interval Scripts: A New Programming Paradigm

In an article [17] published in a 2003 issue of *Personal and Ubiquitous Computing* the concept of interval scripts was introduced. In interval scripts the "actions and states of the users and the system computational agents are associated with temporal intervals" [17]. A program is developed through the establishment of "temporal relationships as constraints between the intervals" [17]. What makes this constraint-based programming language different from others is its exhaustive use of Allen's interval algebra. The algebraic algorithm makes it possible to gauge mutually exclusive events and also to define complex temporal structures.

Currently [17], the interval scripts language is still at a research stage. More work needs to be done before it can be released to other researchers and programmers interested in developing a dynamic environment for their application's interface.

A case has been made here by regarding the challenges interoperability poses. Even though there may be some hardware limitations, such as the inability to connect to a remote network, the fundamental difficulty is posed by software design. With the general public wanting more robust and mobile computing platforms, there is an urgent need for

new concepts such as interval scripts to be deployed and tested. Without them Weiser's ideas may never be implemented in their truest sense.

VI The Community Embodiment Model

Long before the imagined landscape of cyberspace began to take shape, within each community there was a notion of solidarity which would result towards a collective goal [21] of overall success for the entire community. The "success" in this case is equivalent to business productivity. CEM as a model covers three areas: computer-mediated communication (CMC) and social relations being the first two. CMC in this [21] research structures social relations, and it is the medium in which communication amongst group members occurs. The third is a consequence of the first two that is overall "success for the community" [21].

Steve Fox argues [21] that, similar to physical communities, in virtual communities "if these collective goals stand too much in contrast with personal goals, then individual need for community can decay" [21], whereby having a direct impact on success. Therefore, the challenge to understanding this concept of community is to somehow balance the natural opposing force. In particular, there is a need to understand how an individual perceives him or her self as being a part of a community. That is, what role does he or she play to progress a community? In order for an individual to truly belong to a community he/she needs to perceive him or her self to be a part of the virtual as well as the physical. CEM has been proposed as an answer to the question as to where the physical and virtual communities begin to take shape.

With the advancement of technology, people have found new ways to communicate with each other. While physical communities have laid the foundations as

to how people interact in communities as part of a group, new technologies has extended these traditional processes of communication in to the realm of the virtual.

CEM attempts to offer a conceptual model of how an individual interacts within a virtual community and how these interactions might relate to the physical communities he or she may be a part of. CEM supports the "study [of] human communication across different conceptualizations of community, different technologies, and different cultures." However, present research only describes the "interaction within virtual communities as beginning with a conceptualization of community (imagined community) that embodies a continuum of physicality" [21]. The developers of CEM stressed that this research made use of CEM as a theoretical framework.

Based on Fox's pilot study with ten participants, CEM considers imagined community concept to embody both physical and virtual communities.

The current [21] experiment carried out using CEM defines the model as one that attempts to explain how a person might interact in a virtual community, compared with how he/she would react in a physical one. The experiment also indicates that virtual interaction could be a pragmatic extension of a person's offline life. For example it could involve a student using a mobile device (in this case a personal digital assistant) to check class schedules. This extension necessarily implies that any relationship between the physical and the virtual begins with physical reality, since there is someone who uses a mobile device to initiate connection. Only afterwards do things become more fluid and dynamic, depending on how the two parties interact.

The participants in this experiment highlighted a few interesting trends. For example, those using a mobile device to communicate with others placed special

emphasis on "virtual cues" (e.g. emoticons). On the other hand, 40% of the participants who communicated face-to-face afterwards stated that they would have preferred "virtual communication" as the prime mode for "talking" with fellow colleagues.

6.1 Approach

As this study progressed through the initial stages of literature review, it did become apparent to this author that gaining access to raw data for specific variables will prove to be difficult if not impossible. Also, as already stated, little research has been carried out in this area because of the enormity of the task itself. Hence, an approach was taken by which specific white papers and an academic journal were researched, and compared with each other for any baseline commonalities. After that, a series of dependent and independent variables were extracted from CEM and converted from their conceptual form to one which would make it easier to compare with what was found in the white papers and the academic journal. Once that was established, a formula was to be derived which would attach a dollar amount to the benefits of using a mobile device (PDA). For this study the white papers which will repeatedly be referenced are Blackberry [30], Intel [31], and Sprint [32]. The academic paper which would be referenced is written by Thatcher [33].

6.1.1 Derivation of Dependent and Independent Variables from CEM

Steve Fox mentions how people in virtual communities work towards collective goals, which as a consequence lead to success for the entire group. In this study success refers to an increase and/or decrease in business productivity. Therefore, it could be

stated that use of wireless devices could affect productivity at an organizational level, if all employees have similar goals.

Fox also reports a survey result which shows that participants "strongly preferred" using the virtual environment to communicate with colleagues. In an organization this could be translated to employee preference. Employee preference is important to gauge because it could be linked with morale in the long term. A high degree of employee preference could also lead to higher satisfaction levels, both of which could lead to success for a company.

The CEM study only measures the impact of a single product, which in this case is that of a PDA [28] on participants. This means that the study proposes a monopolistic model. In a monopolistic model only one product is used to measure its effects on participants. Also, during the process it is assumed that all outside influences will not be factors in gauging participant preferences. This is defined as a closed measurement.

Fox also alludes to the fact that people who regularly interact in the virtual environment tend to be much more inclined to using virtual cues to get their ideas across to colleagues. This could be translated to the impact a mobile device could have on people. Basically the users of the mobile device in this case are adapting to a new technology and extending their understanding from the virtual environment to a more physical one.

According to Fox the idea of understanding proliferation of the virtual environment is an "evolving process" [21] and that new means need to be developed to understand the connections between the two. For the purposes of this study this could be translated to the idea that the measurement of productivity is a long term issue.

Organizations that undergo an enterprise change might not be able to gauge the benefits at a short term level, and instead may have to first undergo a change in the business process.

Table 6.1 breaks down each of the previously mentioned variables into two categories: dependent variables, and independent variables, before listing each benefit in the appropriate category. Those variables are then compared with the white papers and the academic journal to see if each was mentioned or not. If a particular variable was addressed then a "Y" is used in the appropriate column and row, where as the letter "N" is used if it that is not the case. The dependent and independent variables are extracted from CEM itself, and serve as guidelines for the purposes of this study. Table 6.1 also shows three benefits which have not been mentioned in CEM: addressing production costs, treating personnel as assets [34], and close proximity benefits. These benefits were a significant part of the white papers and the academic journal which were researched, and were therefore added as a part of Table 6.1. It is the intention of this study to show that the three benefits not mentioned in CEM may be possible additions to the model itself.

Dependent variables in this study are variables which can be linked to one another. For example, if workers are impacted in a positive or a negative manner by personal digital assistants, then probability is high that as a consequence productivity will be affected in a proportional manner. Similarly a positive or negative impact on workers may lead to varying degree of satisfaction amongst them. On the other hand, the independent variables category lists variables which do not depend on one another. For example, using a monopolistic model does not necessarily mean that the same definition

of productivity should be used. Both independent and dependent variables will be clearly defined in the next section.

	Intel	Sprint	Blackberry	Thatcher
Dependent Variables				
Impact on workers	Y	Y	Y	N
Wireless effects production	Y	N	Y	Y/N
Satisfied workers	Y	N	N	N
Closed Measurements	N	Y	Y	Y
Address Production costs	N	Y	N	Y
Treat Personnel as assets	N	N	N	N
Closed Proximity Benefit	Y	N	Y	N
Independent Variables				
Same Definition of Productivity	Y	Y	Y	Y
Monopolist Model	Y	Y	Y	Y
Identify Employees prefer virtual	N	Y	Y	N
Productivity is a long term issue	N	N	N	N

Table 6.1[10]

6.2 Dependent Variables

This section further explains each dependent variable which was discussed in a particular white paper or the academic journal, alongside any data that may have been mentioned. Any data which may be mentioned has been annualized for normalization with a specified number of work weeks and work days.

6.2.1 Impact on workers

This means that employees of an organization feel part of a group and feel encouraged due to the use of new wireless technology. It also leads to a reduction in transcription errors, overall error- impact, and correction costs.

Intel

[10] Note: This table is not used for a comparative study, but quite simply only lists if a particular topic is discussed or not.

The Intel [31] white paper does have specific data about data entry savings when PDA's are used by maintenance personnel. Data entry savings are calculated by the formula:

(Hourly salary * 1.35) * (Hours saved because of PDA per week) * (Weeks per year)

The numeric "1.35" is a cost which is incurred by an organization for each employee. An example of this is employee benefits.

There is another set of data which looks at data processing savings. It is calculated through this formula:

(Hourly salary) * (Hours saved because of PDA per week) * (Weeks per year)

These two formulae show that in order to gauge productivity, one of the factors is the amount of hours saved. This variable becomes an integral part of the formula proposed by this study.

Sprint

This white paper [32] emphasizes that employees are motivated by remote access especially if they travel frequently. Of all the companies researched, 63.8 percent were in favor of achieving roaming access to wireless networks. Also, 62.8 percent were in favor of achieving access to the office network when the user was roaming. As mentioned previously, a high degree of motivation could be proportional to a business reaching optimum productivity.

BlackBerry

This paper [30] talks about the "feeling of improved quality of life" resulting in higher morale within the company. This leads to 77% of the employee saving an average of 27 minutes per day due to lack of errors.

6.2.2 Wireless Effects Production

This means that the use of a PDA leads to an increase or decrease in productivity.

Intel

The Intel [31] article states that at a minimum, six hours per week are saved due to the use of a PDA by maintenance personnel. It also adds that a further twelve hours per week in data processing time are saved due to the use of a PDA.

BlackBerry

Based on different salaries ($50,000, $100,000, $150,000), the productivity gains were $2450, $4900, and $7350 respectively. This shows that as the salary of an employee increases, the productivity gains also increase for the same amount of hours saved. The reason for the discrepancy in the productivity gains is that the hourly salary for each employee is different in this case. Also, the reported productivity gains have been halved. The reason is to accommodate the argument that suggests that mobile workers will not necessarily do more work with every extra minute that is converted from downtime into productive time.

Thatcher

This paper [33] states that an organization's productivity gains and losses are measured according to overhead costs. It states that if overhead costs are increased from $816.33 to $922.07, then productivity is decreased from 2.37 to 2.24. In this paper productivity is a ratio of the output value to its related input value, with outputs and inputs measured in dollars. In this model, the output of the production process is the revenue generated from the process, whereas, the inputs are the totals costs of production.

6.2.3 Satisfied Workers

This means that employees who use PDA's have few error complaints about the product itself, and are able to extract its benefits as predicted. Here error complaints could also refer to any technical problems an employee might face in operating the PDA.

Intel

It states that employees who used PDA's were satisfied by the overall quality of the product and its resulting benefits, but does not attach a dollar amount to it. It mentions the increased satisfaction levels due to improved responsiveness, and better communication, all leading to a consistent and predictable service.

6.2.4 Closed Measurement

Closed measurement means that an increase in productivity through the saved amount of hours does not affect product quality. Also, even though it is not realistic, all costs (savings or expenses) do not change over time.

Sprint

In calculating the percentage for future wireless data access (95.8% and 95.6%) all future costs are similar to the current year, with no reference to increased inflation.

BlackBerry

In calculating the productivity gains, it is assumed that percentages of users agreeing to the use of PDAs will not change over time [30]. This means that if 83% of the employees are influenced by a PDA in a positive manner, then that percentage will remain consistent for each subsequent year.

Thatcher

The increase and decrease of productivity constants is based on a theoretical assumption that any change will not affect the integrity of the formula for productivity. The changes could be in the shape of the following [33]:

- Benefits from technology investments are retained, since there is an absence of pressure in the shape of competition to reinvest. This means that an organization is never pushed into reinvesting into new technologies because another company might pose a business threat. A closed measurement assumption leads to the statement that there will be no competition.
- There are no delays in observing changes in productivity due to the learning curve for the employees. This means that as soon as a new product is introduced into an organization, the issue of the employees getting used to the product will not occur. It also means that benefits which are expected will be immediately incurred.
- Total cost of ownership will not affect productivity levels. This means that the cost of acquiring new technologies will not hinder a company's potential in recognizing productivity gains immediately.

6.2.5 Address Production Costs

Production costs deals with the investment in various technologies, with the hope of realizing gains in productivity in the subsequent years.

Sprint

On a scale of 1 (no concern) to 5 (major concern), this paper [32] states that funding (2.4) in new mobile technologies is the number one issue for all companies of all

sizes. Here the resulting measure is a result of a survey carried out for organization which had more than five hundred employees. Sprint also mentions how before implementation one of the main questions is about funding and its relationship with return on investment.

Thatcher

Production costs according to Thatcher [33] need to be addressed, and can be measured by the proposed formula:

F + fQ^2 + eQD, (Note[11])

F = Fixed cost

f = Fix cost of quality

e = Unit cost of quality

Q = Amount spent on Research and Development.

D = Variable costs associated with manufacturing products

where e and F are both greater than zero. F also includes costs that result form acquiring new technologies. According to Thatcher all organizations incur a fixed cost (F). It includes equipment depreciation and maintenance, and costs of acquiring, implementing, and maintaining technologies. Thatcher further states that firms must incur these costs to boost production. Alongside fixed cost, the second and third terms in the cost function are: a cost (fQ^2) to design and develop a product of a specified quality, and a per unit cost (eQD) to manufacture the product to meet demand. In this study, since there is no actual development of a product through the use of a PDA, and the issue of manufacturing is not addressed, this part of the productivity formula will not be addressed.

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[11] Q^2 means the variable Q is squared. During the course of this study [variable name][p] means that a variable, "variable name" has a footnote labeled "p." Therefore, it does not means it is raised to some power "p." For that the power will be preceded by a "^".

6.2.6 Treat Personnel as Assets

Due to the problems faced with quantifying certain intangibles, one of the solutions [34] is to attach dollar values to each employee, based on his/her capability and impact on the business, and then deriving to a possible dollar amount. Though this issue is not addressed directly by any of the papers, this author does believe that Blackberry's current results of the varying salary structures and effects on productivity gains could be further explored. It is not necessary that employees who earn more will see high productivity gains. The reason according to this author is that these could well be senior employees who have been with an organization for many years, and would therefore find it much more difficult to switch to a system they are not used to, sine they are accustomed to the old system.

6.2.7 Closed Proximity Benefit

This means that employees through the use of wireless personal digital assistants are able to execute business meetings and other traditional in-person communications with no impact to the qualitative edge of the required outcome.

Intel

Highlights [31] positives about workers being satisfied, but does not attach a dollar amount to it.

BlackBerry

According to BlackBerry 72% of the users agree that due to the use of a PDA, there was a 29% increase in efficiency [30]. This efficiency is mostly in the shape of instant connection with mobile workers. Based on different salaries ($50,000, $100,000, $150,000), the workflow (immediacy) gains were $10,875, $21,750, and $43,500

respectively. The reported workflow gains have been halved, since it may not always be the case that co-workers take full advantage of the workflow benefits received from their mobile counterpart.

6.3 Independent Variables

This section details each independent variable mentioned in Table 6.1.

6.3.1 Same Definition of Productivity

For all articles the definition of productivity is output of end results per each hour of work (input value).

6.3.2 Monopolist Model

For all articles the assumption is the existence of any single IT product, in this case, a personal digital assistant. This means that an organization is not allowed to gauge the benefits which may be gained due to the introduction of multiple products alongside a PDA.

6.3.3 Identify Employees Prefer Virtual

This means that the predominant preference of employees of an organization is the extensive use of wireless devices such as, personal digital assistants.

Sprint

According to this paper [32] 78.4 percent of the companies are not worried about not having fixed-line (wired) communication. This in essence implies that the friction factor with employees of switching to a new system will not exist.

BlackBerry

According to BlackBerry [30] 83% of the end users agree that the use of PDAs is beneficial. The reason the employees agree is that the typical end user recovered slightly "less than one hour per workday because of BlackBerry (54 minutes)" [30]. For the purposes of Return on Investment (ROI) calculation, the median value of 47 minutes per day was used. That is because using the median value is at times more "conservative than using a mean or average value as an average value can be skewed by a small number of respondents giving large values" [30].

6.3.4 Productivity is a Long Term Issue

This means that the measurement of increase or decrease in business productivity can only be correctly calculated over a period of many (>10) years instead of looking at just the short term. Factors which may influence a gradual increase in productivity and not an immediate occurrence could be due to employee friction, and the learning curve.

VII Quantifying CEM

The purpose of this section is not only to quantify the dependent and independent variables that have already been mentioned, but also to show the challenges that are faced in developing a formula for a theoretical model which has not been extensively researched. Table 6.1 highlighted the various dependent and independent variables both mentioned and not mentioned by CEM. The most challenging aspect of this study was the process of using those variables and developing a formula for each one, while also considering that all variables needed to be additive. The benefit of the variables being additive (having similar units) is that they could then be summed up to give one value. The following sections show the various changes the formula had to go through before reaching its final version.

7.1 *What is Cost Burden (a_i)?*

A reference was made in Section 6.2.1 to the numeric "1.35," as a burden of cost for a company. For an organization, considering only an employee's salary is not sufficient to determine how much that employee costs that company. Additional costs could be incurred due to benefits which are added to an employee's salary. For example, if an employee's hourly salary is $16.50, with 35% cost burden, the cost to the organization is $22.25

Hence, considering the cost burden gives a more accurate representation of costs incurred.

7.2 Cumulative Use of All Dependent and Independent Variables

The first version of the formula had all variables listed from Table 6.1 as possible benefits. The dependent variables were assigned to variables x_i in the following manner:

x_1 = Impact on workers

x_2 = Wireless effects productivity

x_3 = Satisfied workers

x_4 = Closed measurements

x_5 = Address production costs

x_6 = Treat personnel as assets

x_7 = Closed proximity benefit.

Similarly all independent variables were assigned to variables y_i in the following manner:

y_1 = Monopolistic model

y_2 = Identify people prefer virtual

y_3 = Productivity is a long term issue

This could be summarized (Table 7.1) as an update to Table 6.1

	x/y
Dependent Variables	
Impact on workers	x_1
Wireless effects production	x_2
Satisfied workers	x_3
Closed Measurements	x_4
Address Production costs	x_5
Treat Personnel as assets	x_6
Closed Proximity Benefit	x_7
Independent Variables	
Same Definition of Productivity	y_1
Identify Employees prefer virtual	y_2
Productivity is a long term issue	y_3

Table 7.1

Another variable a_i, where "*i*" is a value between 1 and 7 was used as a coefficient value which would either be negative or positive depending on the type of benefit it was. For example, certain benefits such as addressing production costs are costs incurred by an organization, and are therefore going to be negative as part of the formula. For simplicity purposes apart from a_1 all other coefficients were either "1" or "-1."

Hence,

a_1 = Coefficient for impact on workers

According to BlackBerry and Sprint the cost burden for "Impact on Workers" is 35% and 36.2%. Intel mentions two different values: 37.2%, and 23%, as cost burdens. The reason for the two values is due to the different company sizes. The former value refers to a company with more than 500 employees, and the latter represents a company with fewer than 500 employees. The average of which is approximately 32.9.

Therefore for all calculations involving a_1;

$a_1 = 1.329$

Since a_i is defined as a cost burden for an organization, values for a_2 to a_7 inclusive will either be "1" or "-1." The reason for that is that for all other dependent and independent variables there is a factor for the burden of cost does not exist. However, what does exist is that some variables may be costs incurred, hence a negative value, while others may be beneficial to a company, therefore they are positive. To reflect that part, values for a_2 to a_7 are as follows:

a_2 = Coefficient for wireless effects productivity

$a_2 = 1$

a_3 = Coefficient for satisfied workers

$a_3 = -1$

a_5 = Coefficient for address production costs

$a_5 = -1$

a_6 = Coefficient for treat personnel as assets

$a_6 = 1$

a_7 = Coefficient for closed proximity benefit.

$a_7 = 1$

Now Table 7.1 can be incorporated with the a_i values as shown in Table 7.2

	x_i/y_i	a_i
Dependent Variables		
Impact on workers	x_1	$a_1 = 1.329$
Wireless effects production	x_2	$a_2 = 1$
Satisfied workers	x_3	$a_3 = -1$
Closed Measurements	x_4	N/A
Address Production costs	x_5	$a_5 = -1$
Treat Personnel as assets	x_6	$a_6 = 1$
Closed Proximity Benefit	x_7	$a_7 = 1$
Independent Variables		
Same Definition of Productivity	y_1	N/A
Identify Employees prefer virtual	y_2	N/A
Productivity is a long term issue	y_3	N/A

Table 7.2

At this point it was also decided not to use variable x_4 as part of the formula, since the variable does not have an effect on the issue of production itself. Therefore, for all other variables x_i the formula for each was:

$x_1 = a_1$ * Hourly Salary * Hours Saved * Weeks Per Year (7.E1)[12]

a_1 = Cost Burden = 1.329

$x_2 = a_2$ * Hourly Salary * Hours Saved Due To Use of Device* Weeks Per Year (7.E2)

$a_2 = 1$

[12] This serves as identification for an equation in this study. Nomenclature used is (Chapter Number). E(equation number).

$x_3 = a_3$ * Hours Spent * Hourly Salary * Potential Revenue From That Worker (7.E3)

$a_3 = -1$

$x_5 = a_5 * (F + fQ + eQD)$ (7.E4)

F = Fixed cost

f, e = production capabilities of an organization.

Q = Amount spent on Research and Development.

D = Variable costs associated with manufacturing products

$a_5 = -1$

x_6 = Annual Salary / 10.20 * a_6 (7.E5)

The numeric 10.20 is based on the BlackBerry study results which showed that an employee with an annual salary of $50,000 recovered $4900 worth of downtime into productive time. Looking at the employees who earn $50,000 annually,

$$50000 / 4900 = 10.20$$

10.20 can therefore be used as a constant which would allow for an employee to have an asset value. An obvious question is how does the equation change for employees who earn amounts other than $50,000? This question was not answered until the next version of the formula was developed.

$a_6 = 1$

x_7 = Annual Salary / 117.0 * a_7 (7.E6)

The number 117.0 is based on the Blackberry report. Since a closed proximity benefit needs to be recognized, data needs to be used which shows that employees actually saved time when they used a PDA. According to BlackBerry an average of 27 minutes a day were saved due to the use of a PDA, which translates to 135 minutes being saved every

week. This means that 7020 minutes are saved every year, which is equivalent to 117 hours. We then divide the annual salary by this (117) number in order to recognize a closed proximity benefit based on an employee's salary.

$a_7 = 1$

At this point the author could not address a way by which the independent variables could be used as part of the formula in construction. Hence, it was not part of the first formula. The initial thinking was that if there is a dependency between variables then in order to prevent the addition of benefits multiple times, some type of subtraction should occur. In order to achieve that, two way relationships between variables were identified.

7.2.1 Two Way Relationships

x_1 (Impact on workers) and x_2 (Wireless effects production)

Both x_1 and x_2 are directly related to each other. If transcription errors are reduced as proposed by x_1, then employees are bound to save hours of work every week as mentioned in x_2. Therefore,

Total1 = ((Hours[13] for x_1 + Hours for x_2) * 1/4[14])*Weeks per Year*Hourly Salary (7.E7)

x_1 (Impact on workers) and x_7 (Closed Proximity Benefit)

Both x_1 and x_7 are related to each other. This is because according to x_1 employees are encouraged through the use of a wireless technology such as a PDA. Meanwhile x_7 proposes that even with the hours saved due to a PDA there is no effect on the qualitative edge of the required outcome. The fact that the employee morale is high, can possibly lead to the quality to be maintained.

[13] Hours for x_1 and x_2 are the hours saved every week due to a PDA being used.

[14] This is the weight of a particular cost. Taking the 25% of the real value as proposed by BlackBerry.

Total2 = Annual Salary * ((Hours for x_1[13]) * ¼ * Weeks per Year) / (117.0[15] * 4) (7.E8)

x_2 (Wireless effects production) and x_5 (Address Production costs)

Equation 7.E4 addresses the issue of investment in technologies in the future for an increase in productivity, as shown in equation 7.E2. It shows that there is a direct relationship between an increase in productivity, and an increase in future technology investment.

Total3 = (¼)[14] * (x_2 + x_5) (7.E9)

x_2 (Wireless effects production) and x_6 (Treat Personnel as assets)

In order to enhance the accuracy of the productivity calculation, it may be necessary to attach a dollar value to each employee. If an employee earns $50,000 a year and he saves approximately six hours every week due to a PDA, then his/her productivity levels will be different if compared with someone who earns $100,000 a year and saves an equal amount of hours each week. Therefore the value for each hour is different for the two employees.

Total4=Annual Salary * ((Hours for x_2[16]) *¼[17]*Weeks per Year) / (10.20) (7.E10)

After this it was decided that the formula would be a sum of all the x_i variables with the two way relationship variables providing the values necessary to be subtracted from sum of x_i.

Therefore, for the first version, the formula for gauging benefits is,

$$Benefits = \sum_{i=1}^{7}(a_i x_i) \; - \; (Total_1 + Total_2 + Total_3 + Total_4), \quad \forall x, a \quad \exists i, i \,|\, 0 \langle i \langle 8, i \in \mathrm{N} \qquad (7.E11)$$

[15] From equation 7.E6

[16] Hours for x_2 are the hours saved every week due to a PDA being used.

[17] This is the weight of a particular cost. Taking the 25% of the real value as proposed by BlackBerry.

In 7.E11 "N" denotes a series of all positive integers. The first summation is that of all values from equations 7.E1, 7.E2, 7.E3, 7.E4, 7.E5, and 7.E6. The reason we are subtracting (7.E7, 7.E8, 7.E9, and 7.E10) from the summation is because we need to prevent various dependent variables to be included multiple times. For example, if x_1 (Impact on workers) and x_2 (Wireless effects production) are linked, then it would be erroneous to just include their summation because some part of x_1 may already be calculated in x_2 or vice versa. Therefore a certain percentage needs to be taken away to accommodate for the dependence of the two variables.

7.3 Linking Dependent and Independent Variables with Quantifiable and Unquantifiable Variables

This version included a change in the way variables were defined. Dependent variables were now called quantifiable variables, and independent variables were called unquantifiable variables. Here the major change was the absence of most of the quantifiable variables, and also one of the unquantifiable ones. There was also a rethinking as to how the quantifiable variables were to be measured. One other important addition was an attempt to measure the unquantifiable variables.

7.3.1 Quantifiable Variables Excluded

Compared with equation 7.E11, this version did reduce the number of variables by a large amount. Equations 7.E2, 7.E5, 7.E6, 7.E7, 7.E8, and 7.E9 were excluded because the productivity benefits which they mentioned were already included as part of the calculations involving equation 7.E1. For example, if equation 7.E2 investigates the idea of wireless effecting production, then that would already be a part of the "Hours

saved" as proposed by equation 7.E1. Similarly equations 7.E5, 7.E6, 7.E7, 7.E8, and 7.E9, were addressed by equation 7.E1

7.3.2 Unquantifiable Variables Excluded

"Monopolistic Model" was excluded from the unquantifiable section. The reason for that was that the type of model used does not have an impact on productivity. Therefore, for this study it became an assumption that the formula derived will investigate the benefits of a single product. More specifically, it has already been decided in this study that the product in question is a personal digital assistant. This means that only the effects of a PDA are being gauged in terms of business productivity. There is no other product, wired or wireless which is being used for comparative purposes. Hence, it becomes unnecessary to incorporate "Monopolistic model" as part of the possible formula.

Hence for the second version the variables were as follows:

Quantifiable variables

x_1 = Impact on workers

x_2 = Satisfied Workers

x_3 = Address Production Costs

Variables which can not be quantified.

y_1 = Identify people prefer virtual

y_2 = Productivity is a long term issue

Then each x_i was assigned variables in the following manner:

x_1 (Impact on workers)

Hourly Salary = *hs*

Default value for hs = 20.00

Hours Saved per Week = hsw

Default Value for hsw = 10.00

Cost Burden = a_1

Default value for a_1 = 1.329

The impact on workers includes hours saved due to a variety of reasons. They could vary due to lack of input and transcription errors, and closed proximity benefits.

The dollar value for x_1 is calculated by multiplying the hourly salary to the hours saved per week; the result of which is converted to a dollar amount for the entire year.

Hence,

x_1 = Hourly Salary * Hours Saved Per Week * 52

Therefore,

$$x_1 = hs * hsw * 52 \quad (7.E12)$$

According to BlackBerry, Sprint, and Intel the cost burden for "Impact on Workers" is 35%, 36.2%, 37.2%, and 23%. The average of which is approximately 32.9[18] Therefore for all calculations involving a_1;

a_1 = Default Value for Cost Burden = 1.329

x_2 (Satisfied Workers)

Hours Spent Without a PDA per Week = hw

Default Value for hw = 2.00[19]

Hourly Salary = hs

Default value for hs = 20.00

---

[18] (35 + 36.2 + 37.2 + 23) / 4 = 32.9

[19] Factoring in time spent by an employee without a PDA when he normally does. This is to possibly calculate the impact on productivity when an employee is without a PDA.

Cost Burden = a_2

Default value for a_2 = -2.66

This deals with factors such as the successful operation of the PDA itself. If an employee is unable to perform his/her daily work due to the absence of a PDA, then he/she will spend more hours trying to achieve the same results which could well have been achieved sooner with a PDA. According to BlackBerry an average of 196 hours are saved per year due to the use of a PDA. This means that approximately 3.77 hours are saved per week due to the use of a PDA. Assuming that a person is without a PDA for the entire week it follow that he/she will lose the 3.77 hours which are normally gained via PDA usage. This means that the hours spent without a PDA should have an impact on the overall productivity.

Hence,

x_2 = (Hours Spent Without a PDA Per Week / 3.77) * Hourly Salary * 52

Therefore,

$$x_2 = (hw / 3.77) * hs * 52 \qquad (7.E13)$$

The cost burden for a_1 based on the fact that a PDA was used was 1.329. In the event that a PDA is absent then the value for the cost burden should increase by a certain percentage. By default if we assume that the value for *hw* is 1, then the user will lose approximately 26.5%[20] of the desired output in terms of average hours saved per week. Similarly in the event if the value for *hw* is 2, then the effect is almost 53.1%[21], which is an increase of almost 2.00 times the first value. Hence, we can assume that the effect on the cost burden will also be 2.00 that of a_1.

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[20] 100 * 1 / (3.77) where hsw = 1.
[21] 100 * 2 / (3.77) where hsw = 2.

Hence,

$a_2 = 2.00 * a_1$

$= 2.00 * 1.329$

$= 2.66$

***x_3* (Address Production Costs)**

Fixed cost = F

Research and Development Costs = fQ^2

Manufacturing cost = eQD

According to Thatcher all organizations incur a fixed cost (F). It includes equipment depreciation and maintenance, and costs of acquiring, implementing, and maintaining technologies. Thatcher further states that firms must incur these costs to boost production. Alongside fixed cost, the second and third terms in the cost function are: a cost (fQ^2) to design and develop a product of a specified quality, and a per unit cost (eQD) to manufacture the product to meet demand. In this study, since there is no actual development of a product through the use of a PDA, and the issue of manufacturing is not addressed. The formula for x_3

$$x_3 = F + fQ^2 + eQD \qquad (7.E14)$$

can be simplified to,

$$= F \qquad (7.E15)$$

Since Thatcher presents the formula as part of a monopolist model (one IT product), it does follow that in this study we can modify the formula according to our needs.

Each unquantifiable variable (y_i) was assigned weights in the following way so that intangible benefits can be quantified using a subjective, qualitative rating system [29]:

a) Provides Maximum Benefits (2 points)

b) Provides Some Benefits (1 point)

c) Provides No Benefits (0 points)

d) Provides Some Negative Benefits (-1 point)

e) Provides Maximum Negative Benefits (-2 points)

Hence,

y_1 (Identify people prefer virtual)

If more employees prefer communicating in the virtual environment using a PDA then the employee morale factor does become an important issue when it comes to increased productivity. For example, according to BlackBerry 83% of the employees have a favorable view of using a PDA. If PDA's were not given to those employees, then it is possible though not certain, that the productivity levels may go down.

y_2 (Productivity is a long term issue)

Brynjolfsson[22] states that computerization does not automatically increase productivity, but it is an essential component of a broader system of organizational changes, which does increase productivity. This is an expensive and time –consuming period of restructuring and organizations which accept this will make the biggest productivity gains.

Table 7.3 categorizes these two benefits, and uses the mentioned criteria to attempt to highlight the importance of y_1 and y_2 to an organization. An option that can be

[22] Erik Bryjolfsson. (1998). *Beyond the Productivity Paradox*. Communications of the ACM. 41(8).

used in a qualitative assessment is to "weight" each of the benefit criteria with regards to importance. The more important the benefit, the higher the weight will be. The advantage of weighting is that the more important benefits have a greater influence on the outcome of the benefit analysis. As Table 7.3 shows, "Option 1" applies to organizations that do not consider the y_1 and y_2 as important factors when it comes to productivity. "Option 2" applies to organizations that address the issues of morale and the long term effects. After they have been categorized, a weight is assigned. In the case of Table 7.3, a weight is assigned based on what was discussed in Brynjolfsson's and BlackBerry's study. After a weight is assigned, each column value is added and a total noted under the appropriate column. This would determine which alternative is the better one. In the case of Table 7.3 clearly "Option 2" is the more viable option. However, the main issue that remained in the case of y_1 and y_2 was that even in the case of the development of Table 7.3, the lack of a dollar figure meant that it could not be accumulated with the quantifiable variables to get one value for productivity.

Benefit	**Do not agree (Option 1)**	**Agree to the statement (Option 2)**
Favor technologies which increase employee morale (y_1)	-1	1
Recognize computerization is not the only answer for an increase in productivity (y_2)	-2	2
Total	-3	3

Table 7.3

Hence, Table 7.2 can now be changed to what is shown in Table 7.4,

	x_i/y_i	a_i
Quantifiable Variables		
Impact on workers	x_1	$a_1 = 1.329$
Satisfied workers	x_2	$a_2 = -2.66$
Address Production costs	x_3	N/A
Unquantifiable Variables		
Identify Employees prefer virtual	y_1	N/A
Productivity is a long term issue	y_2	N/A

Table 7.4

Once variables for x_i and y_i were ascertained, again the idea was that they could simply be summed together.

$$Benefits = a_1 x_1 + a_2 x_2 + x_3 + y_1 + y_2, \quad \forall x, y, a \, \exists i, i \mid i \in \mathrm{N} \qquad (7.E17)$$

$$= a_1(hs * hsw * 52) + a_2((hw / 3.77) * hs * 52) - F + y_1 + y_2 \qquad (7.E18)$$

Similar to equation 7.E11 "N" denotes all positive real numbers and incorporates the sum of all dependent and independent variables. At this juncture the method of attaching dollar amounts to the two unquantifiable variables was still not established. Of course, a problem here was that since variables for y_i were not expressed in dollars, they could not be added to variables x_i. This leads to the development of a third revision to the formula.

7.4 *Quantifying the Unquantifiable*

In this version there was a further reduction in the quantifiable variables as well as the unquantifiable ones. Another change was the absence of one of the values (23%) used to calculate the cost burden from equation 7.E1. The reason for that was that that particular value was too low compared with the other three cost burden values (35%, 36.2%, and 37.2%) which were available. Also, probability was used to calculate the effects of a working PDA, while one of the unquantifiable variables was translated into employee morale.

7.4.1 Quantifiable Variables Excluded

In this version 7.E13 and 7.E15 were excluded. The reason was that 7.E13 could be a part of 7.E12, where as 7.E15 was a part of the initial investment.

7.4.2 Unquantifiable Variables Excluded

The variable "Productivity is a long term issue" was omitted because it was more in line with a decision made by an organization's policy makers as part of strategic planning rather than a monetary value.

Therefore for the third version,

Quantifiable Variables

x_1 = Impact on workers

Variables Which Can not be Quantified

y_1 = Identify people prefer virtual

The formula for the quantifiable variable "Impact on workers" is,

x_1 (Impact on workers)

Number of employees = n

Default value for n = 500

Hourly Salary = hs

Default value for hs = 20.00

Hours Saved per Week = hsw

Default Value for hsw = 10.00

Cost Burden = a_1

Default value for a_1 = 1.361 (Explanation for this value later)

Probability of device working as intended (approximately 90% of the time) = p_w

Default value for $p_w = 0.906$ (Explanation for this value later)

Effect on productivity through change in cost = p_c

Default value for $p_c = 0.7143$ (Explanation for this value later)

The impact on workers includes hours saved due to lack of input and transcription errors, and closed proximity benefits. Also, what needs to be taken into account is the probability of the device working. In this study we will assume that the device will work as intended approximately 90% of the time. Another factor which needs to be considered is the impact of investing in particular PDA technologies, and its co-relation with productivity.

The dollar value for x_1 is calculated by multiplying the hourly salary to the hours saved per week; the result of which is converted to a dollar amount for the entire year.

Hence,

x_1 = Number of Employees * Hourly Salary * Hours Saved Per Week * 52 * Probability Device Works * Effect on productivity through change in cost

Therefore,

$$x_1 = n * hs * hsw * 52 * p_w * p_c \quad (7.E19)$$

According to BlackBerry, Sprint, and Intel the cost burden for "Impact on Workers" is 35%, 36.2%, and 37.2%. The average of which is approximately 36.1 Therefore for all calculations involving a_1;

a_1 = Default Value for Cost Burden = 1.361

The BlackBerry study states that an average 196 hours a year are saved by each employee through the use of a single PDA. In order to weigh in the probability that the

device works as intended, we use the total number of work hours[23] in a year (2080) and subtract from it the value of the average number of hours saved in a year (196) in order to get a default value for p_w.

Hence,

$p_w = (2080 - 196) / 2080 = 0.906$

Therefore Default value for $p_w = 0.906$ where $0 <= p_w <=1$

Thatcher states that if there is an increase (350K from 100K) in investment of PDA technology, productivity will also be raised.

Therefore,

Probability productivity will increase with increased investment = (350-100)/350 = 0.7143

Hence,

Default value for $p_c = 0.7143$

This version marked the first time an attempt was made to quantify variables which previously had not been quantified in dollars. Hence,

y_1 (Identify people prefer virtual)

Employee Training Cost = e_c

Human Resources Department Cost = h_c

Number of New Employees = n_e

If more employees prefer communicating in the virtual environment using a PDA then the employee morale factor does become an important issue when it comes to increased productivity. For example, according to BlackBerry 83% of the employees have a favorable view of using a PDA. If PDA's were not given to those employees, then

[23] Work Hours = Hours per week (40) * Weeks per year (52) = 2080

it is possible though not certain, that the morale of those employees would go down, in turn resulting in the possibility of a high turnover rate[24], and incurred new employee training costs.

Therefore

y_1 = Number of New Employees * (New Employee Training Cost + Human Resources Department Cost)

Hence,

$$y_1 = n_e * (e_c + h_c) \quad (7.E20)$$

Hence Table 7.4 is now updated as shown in Table 7.5,

	x_i/y_i	a_i
Quantifiable Variables		
Impact on workers	x_1	$a_1 = 1.361$
Unquantifiable Variables		
Identify Employees prefer virtual	y_1	N/A

Table 7.5

Therefore, for this version the formula is now,

$$Benefits = a_i n x_i + y_i, \quad \forall x, y, a \; \exists i, i \mid i \in \mathrm{N} \quad (7.E21)$$

$$= a_1 n x_1 + y_1 \quad (7.E22)$$

$$= a_1 * n(hs * hsw * 52 * p_w * p_c) - n_e * (e_c + h_c) \quad (7.E23)$$

7.5 *Introducing Business Process Reengineering*

This version was the first one to quantify and add business process reengineering as an integral part of the formula pertaining to costs incurred. The quantifiable variable was changed to not include p_c as proposed by equation 7.E19. Another minor change was the absence of variable names with multiple characters.

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24 From Journal of Property Management (ABI/INFORM) and Accounting Technology (Factiva – Down Jones and Reuters)

Quantifiable Variables

x_1 = Impact on workers

Variables Which Are Not Usually Quantified

y_1 = Identify people prefer virtual

y_2 = Business process reengineering

Therefore for the quantifiable variables,

***x₁* (Impact on workers)**

Number of employees = n

Default value for n = 500

Hourly Salary = s

Default value for s = 20.00

Hours Saved per Week = w

Default Value for w = 10.00

Cost Burden = a_1

Default value for a_1 = 1.361

Probability of device working as intended (approximately 90% of the time) = p_w

Default value for p_w = 0.906

Hence,

x_1 = Number of Employees * Hourly Salary * Hours Saved Per Week * 52 * Probability Device Works * Effect on productivity through change in cost

Therefore,

$$x_1 = n * s * w * 52 * p_w \quad (7.E24)$$

For the previously unquantifiable variables the changes were,

y_1 (Identify people prefer virtual)

Employee Training Cost = e_c

Human Resources Department Cost = h_c

Number of New Employees = n_e

Employee turnover percentage due to lack of use of PDA = b_1

If more employees prefer communicating in the virtual environment using a PDA then the employee morale factor does become an important issue when it comes to increased productivity. For example, according to BlackBerry 83% of the employees have a favorable view of using a PDA. If PDA's were not given to those employees, then it is possible though not certain, that the morale of those employees would go down, in turn resulting in the possibility of a high turnover rate[25], and incurred new employee training costs.

Therefore

y_1 = Number of New Employees * (New Employee Training Cost + Human Resources Department Cost) * (1 – 0.83) * b_1

Hence,

$$y_1 = n_e * (e_c + h_c) (0.17) * b_1 \qquad (7.E25)$$

y_2 (Business process reengineering)

Existing Employee Retraining Cost = r

Number of Employees = n

[25] From Journal of Property Management (ABI/INFORM) and Accounting Technology (Factiva – Down Jones and Reuters)

At this juncture business process reengineering is considered as costs incurred by an organization due to the retraining of its existing employees, which represents a process change for the organization.

Therefore,

y_2 = Existing Employee Training Cost * Number of Employees

Hence,

$$y_2 = r * n \tag{7.E27}$$

Hence Table 7.5 can now be updated as shown in Table 7.6

	x_i/y_i	a_i
Quantifiable Variables		
Impact on workers	x_1	$a_1 = 1.361$
Unquantifiable Variables		
Identify Employees prefer virtual	y_1	N/A
Business Process Reengineering	y_2	N/A

Table 7.6

Therefore for this version the possible formula was,

$$Benefits = a_i n x_i - y_i, \quad \forall x, y, a \, \exists i, i \mid i \in \mathrm{N}$$

$$= a_1 n x_1 - y_1 - y_2 \tag{7.E28}$$

$$= a_1 * n(s * w * 52 * p_w) - n_e * (0.17) * (e_c + h_c) * b_1 - r * n \tag{7.E29}$$

$$= 52 * a_1 \sum_{i=1}^{n} (s_i * w * p_w) - 0.17 * n_e * b_1 * (e_c + h_c) - r * n \tag{7.E30}$$

Equation 7.E30 converts the summation of all data from equation 7.E24 into annual data by multiplying sum to 52 (number of work weeks each year).

7.6 *Introducing Inflation Rates and Change in Salary*

This version is the last one to incorporate major changes, since subsequent changes involved only fine tuning this one. More variables were added in the business

process reengineering section, and inflation rates were used to increase a particular employee's salary by a certain percentage. Also, future costs incurred by a company are allowed to be reduced instead of remaining static. The reason for allowing inflation rates, changing the salary, and changing incurred costs is to make the scenario more realistic, since the ground realities of a business are bound to change after the year the new mobile technology was introduced. Finally, Net Present Value (NPV) is used to gauge the feasibility of a particular project.

Therefore, for this version the variables were defined as,

Quantifiable Variables

x_1 = Impact on workers

Variables Which Can not be Quantified

y_1 = Identify people prefer virtual

y_2 = Business process reengineering

For the quantifiable variable x_1 there were no changes so the equation remained the same as equation 7.E24. Similarly for the variable y_1 the formula remained the same as equation 7.E25

However y_2 did change from its original version in 7.E26.

Therefore,

<u>y_2 (Business process reengineering)</u>

Existing Employee Retraining Cost = r

Number of Employees = n

Parallel System Costs = l_c

Number of temporary employees = t

Number of hours lost per week by each temporary employee = o

Hourly salary of temporary employee = s_t

Any major technology related initiatives pose a number of business-level challenges, majority of which revolve around the need to adopt business processes to reflect the new system's capabilities. The most basic business-level challenge could be the need to train employees on how to use the new system. In addition to retraining issues, an organization may need to reengineer some of its core processes. The reason for this is that the old workflow procedures may need to change in order to reflect the increasing amount of automation afforded by the new system. An example which highlights this issue is the issue of work assignments using PDA's. In the old system employees may have been required to physically be present at a particular office space and meet regarding current assignments. With the advent of PDA's, employees could potentially have the capability to download assignments remotely. This represents a process change for a company in the shape of employee retraining.

Therefore,

y_2 = Existing Employee Training Cost * Number of Employees

Hence,

$$y_2 = r * n \qquad (7.E31)$$

Apart from retraining another cost which may be incurred by an organization is the parallel operation (l_c) of the old as well as the new system (with PDA's) during period of transition.

Therefore

$$y_2 = (r * n) + l_c \qquad (7.E32)$$

Finally, when existing employees are being retrained, temporary employees may need to be hired. This could result in productivity losses since these employees may not know the precise details of the business workflow.

Therefore,

$$y_2 = (r * n) + l_c + (t * o * s_t) \qquad (7.E33)$$

Although not a part of this study there may be other BPR costs. A few examples are development, quality assurance, testing, and implementation costs.

Hence the formula after 7.E33 is,

$$Benefits = a_i n x_i - y_i, \quad \forall x, y, a\ \exists i, i \mid i \in \mathrm{N} \qquad (7.E34)$$

$$= a_1 n x_1 - y_1 - y_2 \qquad (7.E35)$$

$$= a_1 * n(s * w * 52 * p_w) - n_e * (0.17) * (e_c + h_c) * b_1 - (r * n) - l_c - (t * o * s_t) \qquad (7.E36)$$

$$= 52 * a_1 \sum_{i=1}^{n} (s_i * w * p_w) - 0.17 * n_e * b_1 * (e_c + h_c) - (r * n) - l_c - (t * o * s_t) \qquad (7.E37)$$

This formula (7.E37) returns a dollar amount for the benefits which an organization has due to the use of a PDA. However, the amount can not be the same for each year after the first one. A factor which needs to be considered prior to calculating the Return on Investment (ROI) is:

- Effect due to employee salary increase after the first year. According to the Federal Reserve Bank, Inflation Rates for the years 2003, 2004, and 2005 have been 2.3%, 2.7%, and 3.0% respectively. As an assumption in this study, an employee's salary (f) is raised by 2.67% annually. This figure is calculated by averaging the inflation rates during 2003 and 2005 inclusive.

Hence the formula for the second year and beyond now becomes;

$$=52*a_1\sum_{i=1}^{n}(f*s_i*w*p_w)-0.17*n_e*b_1*(e_c+h_c)-(r*n)-l_c-(t*o*s_t) \quad (7.E38)$$

$$=52*a_1\sum_{i=1}^{n}(1.0267*s_i*w*p_w)-0.17*n_e*b_1*(e_c+h_c)-(r*n)-l_c-(t*o*s_t)$$

(7.E39)

The equations 7.E31 and 7.E32 have a training cost element to them. Predominantly these costs will be faced by an organization during the first year, hence, for each subsequent year they would either go down by a certain percentage of the previous year, or be eliminated altogether. Therefore,

$$y_1 = g_1 * (n_e * (e_c + h_c) (0.17) * b_1) \quad (7.E40)$$

where g_1 *= percentage decrease in cost*

And,

$$y_2 = g_2 * ((r * n) + l_c + (t * o * s_t)) \quad (7.E41)$$

where g_2 *= percentage decrease in cost*

Therefore, for each subsequent year, the equation now becomes,

$$=52*a_1\sum_{i=1}^{n}(1.0267*s_i*w*p_w)-g_1*(0.17*n_e*b_1*(e_c+h_c))-g_2*((r*n)-l_c-(t*o*s_t))$$

(7.E42a)

Where as, for the first year the equation is

$$=52*a_1\sum_{i=1}^{n}(s_i*w*p_w)-g_1*(0.17*n_e*b_1*(e_c+h_c))-g_2*((r*n)-l_c-(t*o*s_t))$$

(7.E42b)

The difference between 7.E42a and 7.E42b is that the former does not include the inflation rate, since the salary is assumed to increase after the first year has ended, and not during it.

7.7 *Introducing Miscellaneous Cost*

The final version included the equations 7.E24 and 7.E25 without any changes, but the cost related equation 7.E33 was changed. The reason for that was that those costs should have been realized in the initial investment. The equation for business process reengineering was therefore changed to now include only a miscellaneous value for costs which may not have been addressed initially, but may be a part of the business process reengineering cycle as the years passed. Therefore,

y_2 (Business process reengineering)

Miscellaneous costs = m

Default value of m = 0.00

Unforeseen costs may also be incurred by an organization during the lifetime of the PDA which may be part of the business process reengineering cycle. For this study, those costs will be labeled as miscellaneous.

Hence,

$$y_2 = m \qquad (7.E43)$$

Another change from equation 7.E42 was the absence of the cost reduction percentage variable. The reason for that was that costs incurred due to the implementation of a PDA in a company needed to be realized in the initial investment stages of the project.

Therefore for the first year

$$= 52 * a_1 \sum_{i=1}^{n} (s_i * w * p_w) - 0.17 * n_e * b_1 * (e_c + h_c) - m \quad (7.E44)$$

Hence for the second year onwards the formula now becomes;

$$= 52 * a_1 \sum_{i=1}^{n} (f * s_{i-1} * w * p_w) - n_e * (e_c + h_c) - m \quad (7.E45)$$

(Note: s_{i-1} indicates the salary of an employee for the year before).

$$= 52 * a_1 \sum_{i=1}^{n} (1.0267 * s_{i-1} * w * p_w) - n_e * (e_c + h_c) - m \quad (7.E46)$$

Equations 7.E44 and 7.E46 need to be used together for an organization to realize the benefits of using a PDA. The reason for that of course is that the employee salary variable which is concurrent to the inflation rate by default is allowed to be increased after the first year. The summation of the productivity part (equation 7.E24) of the formula is converted from weekly data to annual data by multiplying it by the total number of work weeks, which in this case are 52. For the first year, there is an employee preference factor, which considers the possibility that employees may leave the company due to the new technology being implemented. That is no longer a factor for the second year and onwards because it is expected that incoming employees realize the technological direction an organization has taken prior to joining.

7.8 Summary of Symbols Used

Appendix A2.1 has a summary of the symbols used in equations 7.E44 and 7.E46.

7.9 CEM Quantified

Equations 7.E44 and 7.E46 have been originally derived from Table 6.1, which listed dependent and independent variables extracted from CEM itself. Hence, it does

follow that based on the assumptions and proofs that lead to equations 7.E44 and 7.E46, a possible quantification of CEM has been achieved. Chances are that new additions could be made it to both the equations. The reason for that is if only the variables in Table 6.1 are considered, then yes, since all those variables have been addressed then for the purposes of this study CEM has been quantified completely. However parts of it like BPR and Employee morale could have a little more depth to them which is why it could be said that this is a possible quantification.

7.10 Validating the Formula

According to BlackBerry one method of measuring business productivity due to a PDA is to calculate the savings based on recovered downtime. Recovered downtime is the time which prior to the implementation of a PDA was not part of the regular work hours.

Hence, using the values given in the BlackBerry reports:

$a_1 = 1.35$

f = 0 (Inflation rate not considered in the study)

s = $ 25.00

Number of work weeks = 50[26]

$w = 3.92$

$p_w = 0.7682$

$n_e = 1$

$b_1 = 0$

[26] BlackBerry study indicated that the total number of work weeks for this calculation were 50, instead of the usual 52. Number of work hours per week remained 40.

$e_c =$ 0

$h_c =$ 0

$m =$ 0

After inserting these values in the Subsequent Years Excel Work Sheet (explained in Section 10.1) the first year benefit per employee was $5081.64 (Shown in Figure 7.1).

	A B C	D
1	Subsequent Years Worksheet	
2		
3	Year 1	
4		
5	Impact on Workers	
6	Cost Burden	1.350
7	Number of Employees	1
8	Work Weeks	50
9	Hourly Salary	$25.00
10	Inflation	0
11	Probability Device Works	0.7682
12	Hours Saved Each Week	3.92
13		
14	Training Cost Per Employee	0.00
15	HR Dept Training Cost	0.00
16	Percent leaving Due to PDA	0.00
17	Employee Preference	0.00
18	Current Number of Employees	0.00
19	Employee Morale Cost	$0.00
20		
21	BPR Misc Cost	$0.00
22		
23	Total Year One Benefits	$5,081.64

Figure 7.1

According to BlackBerry for an employee earning $25.00 per hour, the annual benefit for a company would be to the tune of $4900.

There is a difference of $181.64 (3.71%) in reference to the benefits incurred between the BlackBerry study, and this study. Considering that the difference is negligible a case could be made regarding the validity of the formula proposed by this study.

Investigating further, according to BlackBerry if an employee earns $20 per hour, the annual benefit is $3920. Using the same excel sheet shown in Figure 7.1, according to this study the benefit is $4065.31 (shown in Figure 7.2). This time the difference is $145.31 (also 3.71%) between the two studies.

	A	B	C	D
1	Subsequent Years Worksheet			
2				
3	Year 1			
4				
5	Impact on Workers			
6	Cost Burden			1.350
7	Number of Employees			1
8	Work Weeks			50
9	Hourly Salary			$20.00
10	Inflation			0
11	Probability Device Works			0.7682
12	Hours Saved Each Week			3.92
13				
14	Training Cost Per Employee			0.00
15	HR Dept Training Cost			0.00
16	Percent leaving Due to PDA			0.00
17	Employee Preference			0.00
18	Current Number of Employees			0.00
19	Employee Morale Cost			$0.00
20				
21	BPR Misc Cost			$0.00
22				
23	Total Year One Benefits			$4,065.31

Figure 7.2

In both tests the data used is the one supplied by BlackBerry. It is a point to note that BlackBerry did not incorporate some of the costs which are a part of the formula proposed by this study. For that reason, they were excluded from the validation process, thus having no impact on the final outcome.

VIII Initial Investment, Product Life Cycle, and Net Present Value

This section deals with parts of the recommended formula which were not addressed directly in the previous sections. It is difficult to argue the importance of initial investments and the product lifecycle. It would naturally follow according to Thatcher that continuous investments towards improved technologies as the product life cycle nears an end could lead to increased productivity levels. However, in order to calculate the value of a future investment, the concept of Net Present Value needs to be explored.

8.1 Initial Investment

Prior to the implementation of personal digital assistants in an organization, initial investment costs do need to be considered. These could include, cost of purchasing a PDA for each employee, server hardware, and support costs.

As already mentioned cost variables from equation 7.E33 were changed because they were thought to be a part of initial investment.

An excel sheet titled "Initial Investment" is being used for this study to highlight the initial investment costs incurred by a company. An example of which is on in figure 8.1.

	A	C
1	Intial Investment Work Sheet	
2		
3	Number of Employees	500
4	PDA Cost per Employee	$500.00
5	Total Cost for PDAs	$250,000.00
6		
7	Retraining Cost per Employee	$1,500.00
8	Total Cost for Employee Retraining	$750,000.00
9		
10	Number of Temp Employees	200
11	Hourly Salary of Temp Employees	$15.00
12	Work Weeks Per Year	$52.00
13	First Year Cost of Temp Employees	$156,000.00
14		
15	Parallel System Running Cost	$50,000.00
16		
17	Other Costs [server, support, etc] per Employee	$280.00
18	Total Costs for server, support, etc	$140,000.00
19		
20	Total Costs for First Year	$1,346,000.00

Figure 8.1

The initial investment worksheet includes some of the standard costs which may be incurred. For example if an organization has 500 employees, and a PDA valued at $500 is purchased for each employee then the immediate cost for the organization is going to be $250000. Similarly as shown in Figure 8.1, other costs such as, retraining, parallel system running, server, and support costs must also be considered as part of the initial investment process.

8.2 PDA Lifecycle

Even if an organization invests in new mobile technologies, there may be a lifetime for the devices, after which further investment may be necessary in order to keep gaining benefits. For this study, the lifetime of a PDA is 4 years, and due to time constraints only one lifecycle will be addressed.

8.3 *Net Present Value (NPV)*

The NPV is the difference between the Present Value of all cash inflows and the Present Values of all cash outflows. So the NPV determines whether an investment project is acceptable or not.

Therefore, according to Remenyi [35],

$$PV\,(i) = \left(A_0 / (1+i)^0\right) + \left(A_1 / (1+i)^1\right) + \left(A_2 / (1+i)^2\right) \ldots\ldots \left(A_n / (1+i)^n\right)$$

$$= \sum_{n=0}^{N} \left(A_n / (1+i)^n\right) \qquad (8.E1)$$

Where

PV(i) = NPV calculated at i.

A_n = Net cash flow at end of period n.

i = required rate of return.

n = Service life of project.

If PV(i) > 0, then the investment is acceptable. If PV(i) < 0, then the investment is unacceptable. If PV(i) = 0, then the investment is neither acceptable nor unacceptable.

Since this study assumes that the lifetime of a PDA is four years, the NPV will be calculated till n = 4

Therefore,

A_0 = Initial Investment

A_1 = Returns (benefits) due to the use of the PDA for the first year

$A_2 \ldots A_4$ = Returns (benefits) due to the use of the PDA for the second, third, and fourth years.

Hence,

$$A_1 = 52 * a_1 \sum_{i=1}^{n} (s_i * w * p_w) - 0.17 * n_e * b_1 * (e_c + h_c) - m \quad (8.E2)$$

$$A_2 \ldots A_4 = 52 * a_1 \sum_{i=1}^{n} (1.0267 * s_{i-1} * w * p_w) - n_e * (e_c + h_c) - m \quad (8.E3)$$

Where,

a_1 = Cost burden incurred by an organization for each employee.

f = 1.0267 = Rate of inflation, which is also the factor by which the employee salary increases.

s = Hourly salary of each employee.

w = Number of hours saved each week by an employee due to the use of a PDA.

p_w = Probability that the PDA works as intended.

n_e = Number of existing employees in a company.

b_1 = Percentage of employees who leave a company due to the use of a PDA.

e_c = Training cost incurred per new employee.

h_c = Cost incurred by the Human Resources Department of a company per new employee.

m = Miscellaneous business process reengineering or related costs incurred by a company not addressed in the initial stages.

An Excel worksheet titled "Net Present Value" has been created to calculate the net present value at the end of the year for each of the four lifecycles, alongside a graph

of the cumulative NPV against time. Figure 8.2 is an example of that.

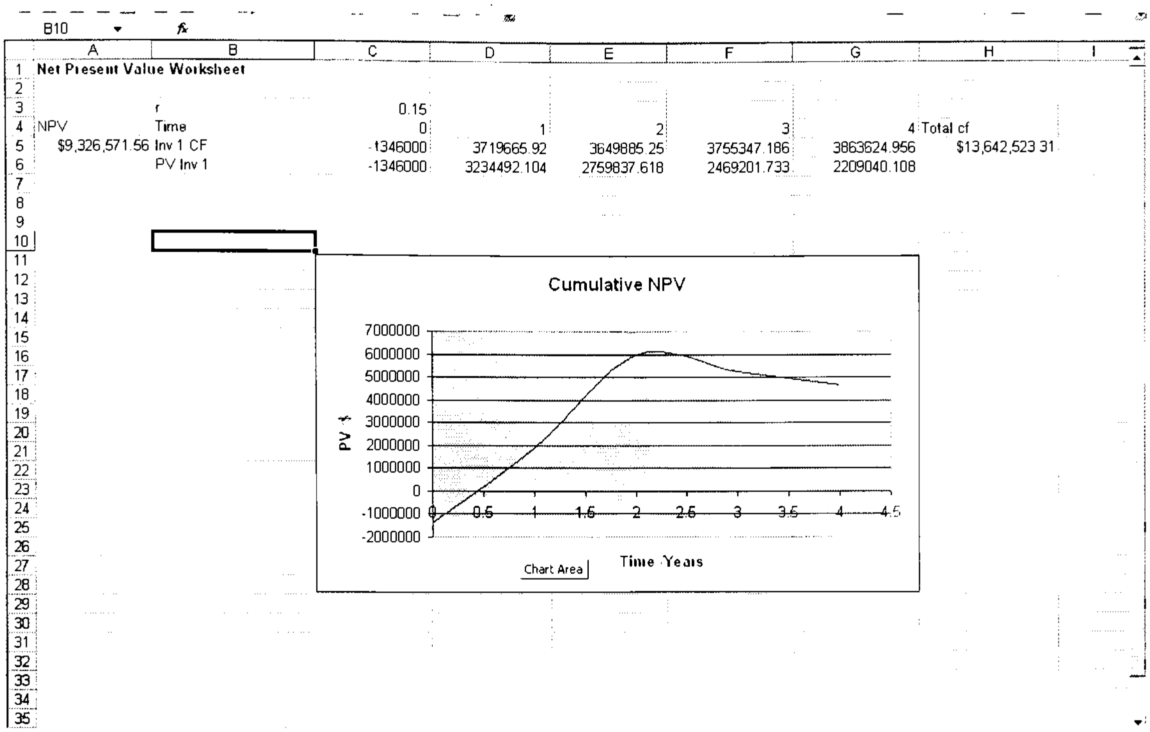

Figure 8.2

IX Simulation Program

The simulation program is a simple program developed in VB.Net which calculates the benefits in case the user decides to look ahead for more than four years.

The initial screen looks similar to what is shown in Figure 9.1, with the default values automatically loaded initially.

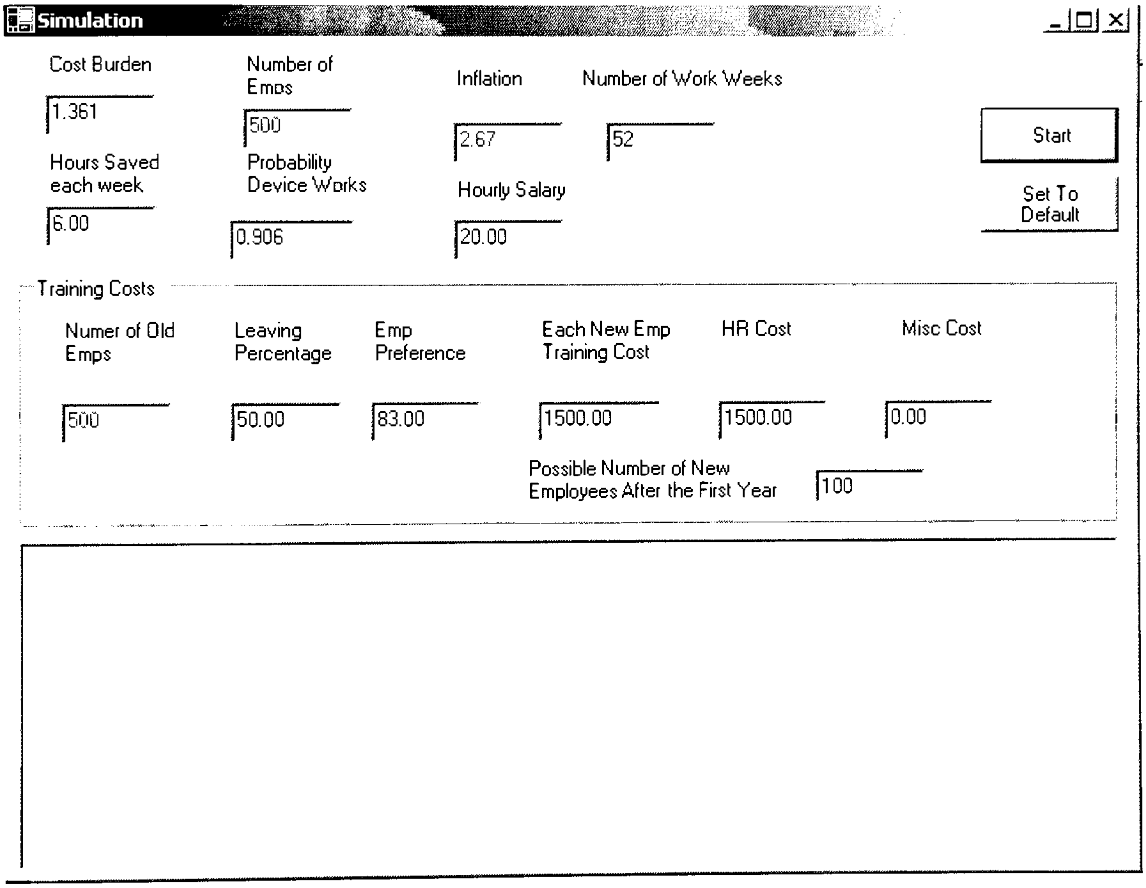

Figure 9.1

9.1 Description of Variables Used in the Program

Cost Burden: Actual cost incurred by an organization per employee. Usually this number is greater than 1.

Number of Employees: Number of employees currently working in the company.

Inflation: Rate of inflation which this program also uses as the annual salary increase after the first year

Number of Work Weeks: Annual number of work weeks.

Hours Saved Each Week: Weekly amount of hours saved each week due to the use of a PDA.

Probability Device Works: The probability (value between 0 and 1 inclusive) that the PDA will work and perform as intended.

Hourly Salary: Hourly salary of each employee. The salary entered is the same for all employees.

Number of Existing Employees: Number of employees working in a company.

Leaving percentage: Percentage of employees which may leave the company during the first year due to the use of personal digital assistants by a company. This value is not used for the second year of implementation and beyond, since by the second year the employees would already have known about the use of personal digital assistants.

Employee Preference: Percentage of employees who prefer the use of a personal digital assistant during the first year. This value is not used for the second year of implementation and beyond, since by the second year the employees would already have known about the use of personal digital assistants.

Each New Employee Training Cost: Cost incurred by an organization to train a new employee.

HR (Human Resources) Cost: Cost incurred by the HR department of an organization during the retraining of employees.

Miscellaneous Cost: Any additional costs which may be incurred by an organization that have not been considered.

Possible Number of New Employees After the First Year: Since "Leaving Percentage" and "Employee Preference" are not a part of the benefits calculation after the second year, an approximate value for possible new employees is needed so that the cost might be calculated for training them.

On clicking the "Start" button the user is asked to enter an ending year. For this example (shown in Figure 9.2) the ending year that will be inserted is 2010.

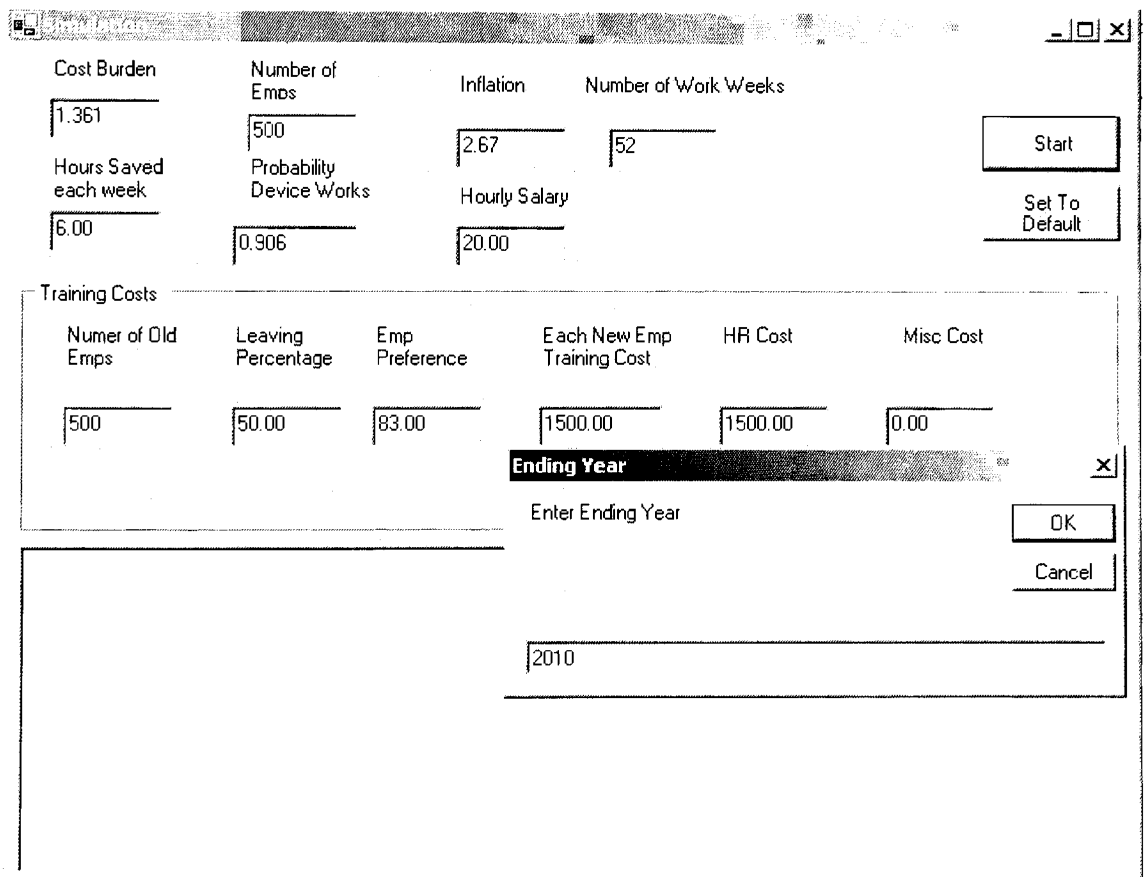

Figure 9.2

After the user clicks the "OK" button, benefits till the year 2010 are calculated as shown in Figure 9.3.

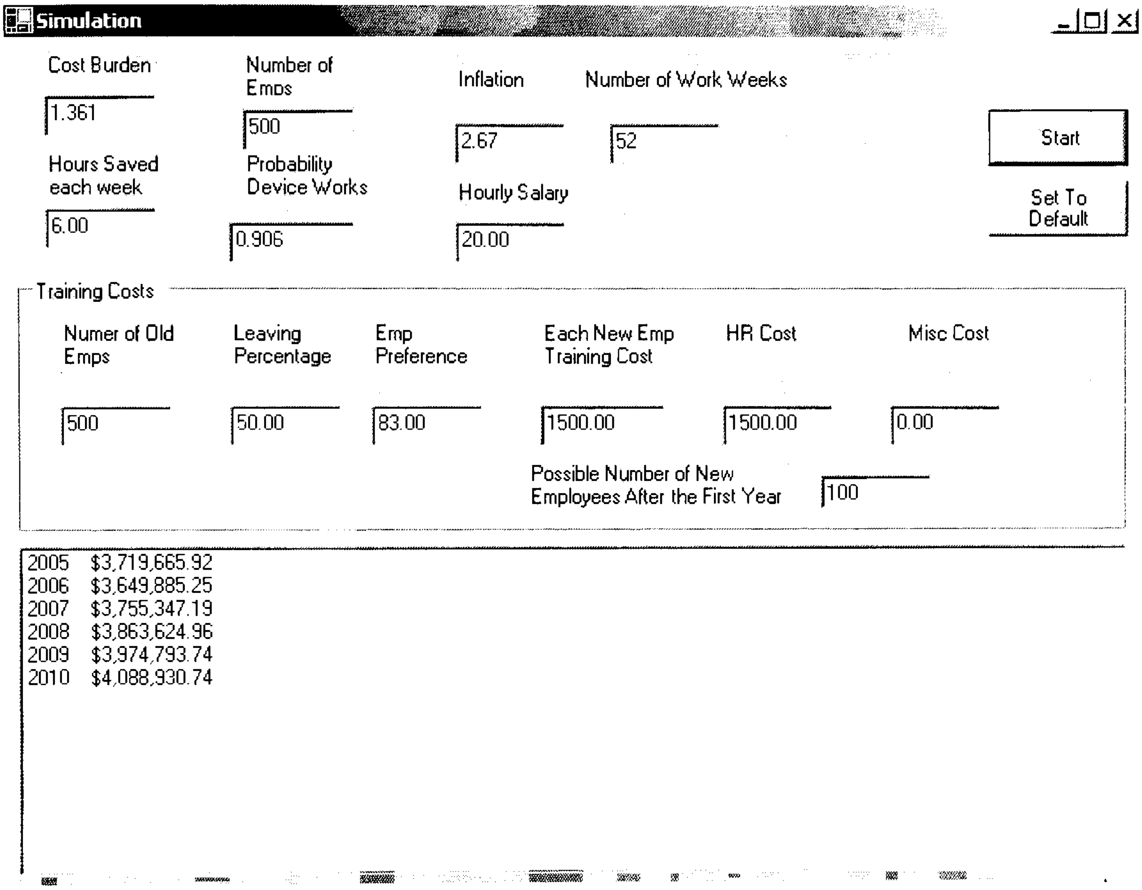

Figure 9.3

On pressing the "Set to Default" button the list box is cleared, and the program is reset. This is shown in Figure 9.4

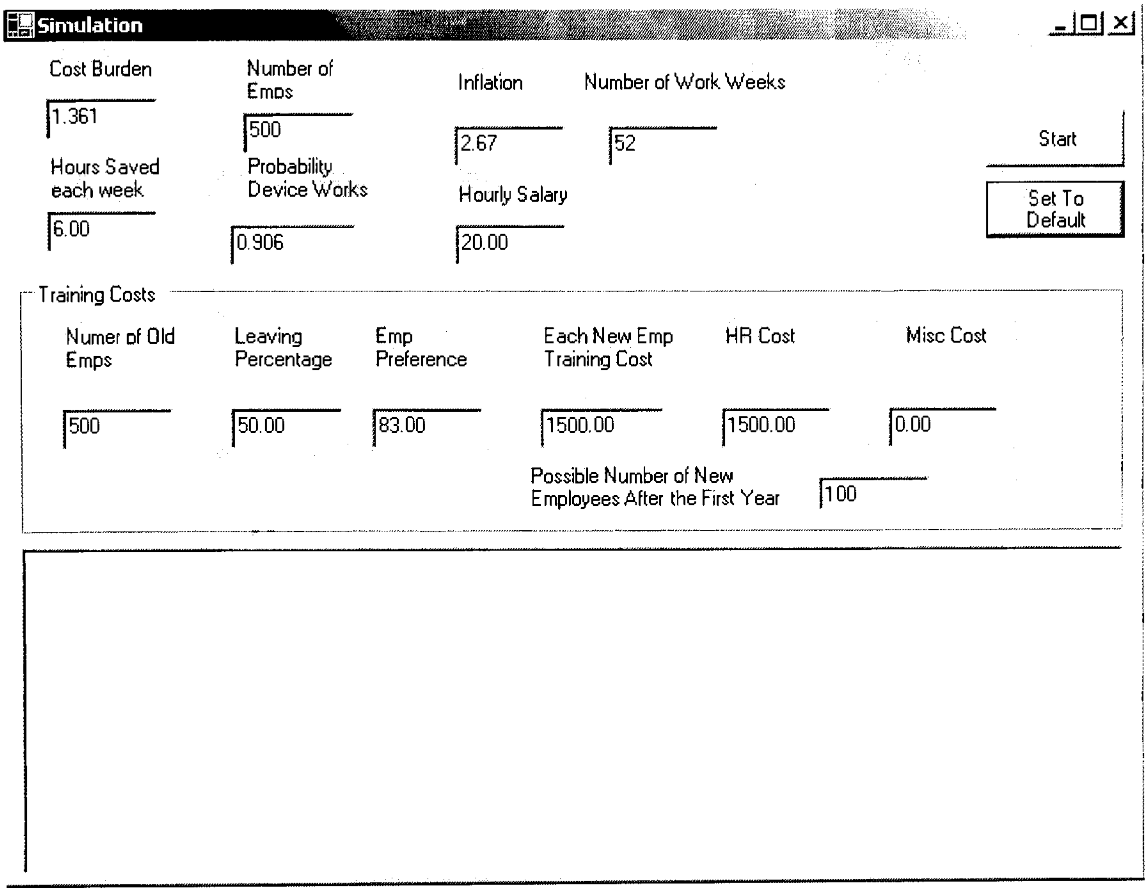

Figure 9.4

The program also allows the user to change the default values of all variables, and then view the results. An example of the program run with values other than the default ones is shown in Figure 9.5

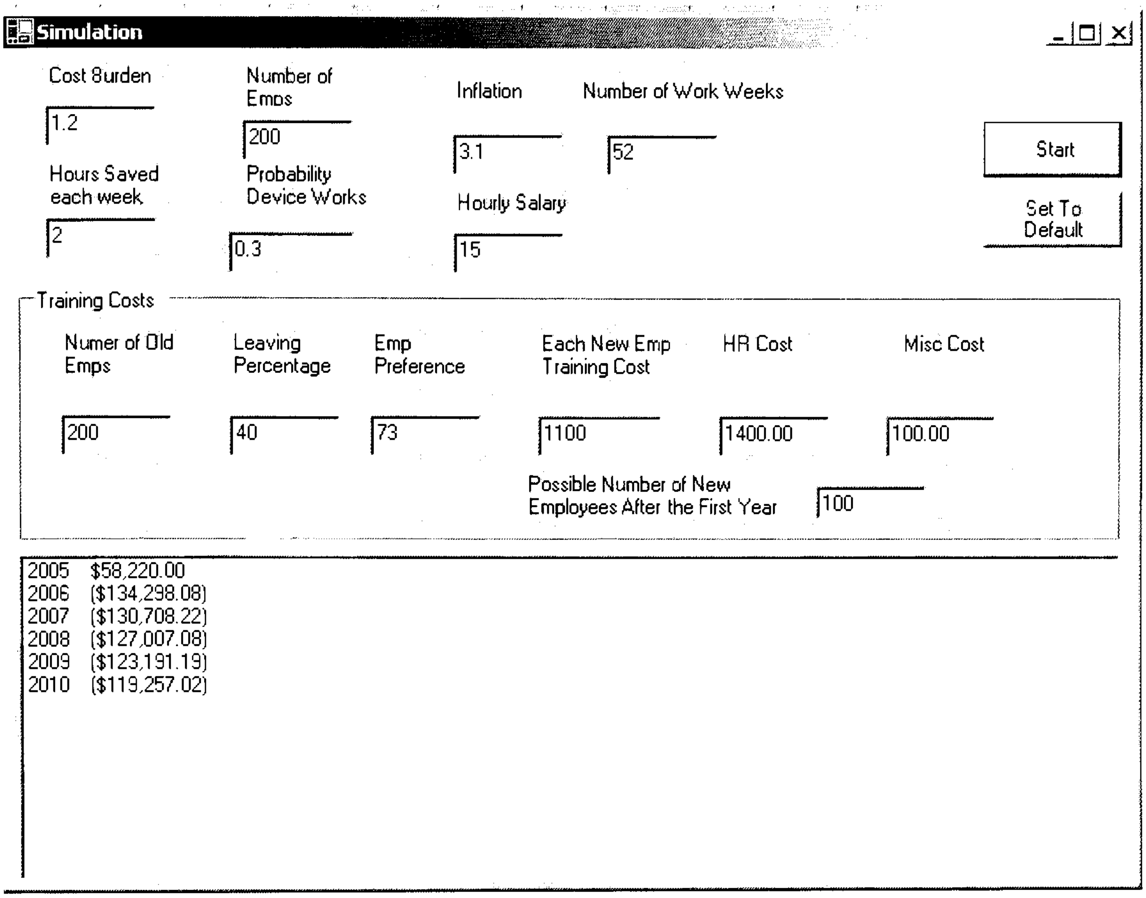

Figure 9.5

Unfortunately, due to time constraints this author was unable to attach a component to the program by which the user could perform sensitive analysis for each year, similar to what the three excel worksheets (Initial Investment, Subsequent Years, and NPV) allow for. However, in the future this program could be updated to include a saving to a database feature.

X Subsequent Years Excel Worksheet and Sensitive Analysis

This section deals with the part of the study which allows for various values to be changed, and their effect gauged.

10.1 The Subsequent Years Excel Work Sheet

Since the lifespan of a PDA for this study is four years, an excel sheet has been created which calculates the benefits for each year till the fourth year after the initial investment has been made. Any of these variables can be altered in case the user needs to gauge the effects in different scenarios on the NPV. An example of that sheet shown in Figure 10.1

Subsequent Years Worksheet	
Year 1	
Impact on Workers	
Cost Burden	1.361
Number of Employees	500
Work Weeks	52
Hourly Salary	$20.00
Inflation	2.67
Probability Device Works	0.9060
Hours Saved Each Week	6.00
Training Cost Per Employee	1500.00
HR Dept Training Cost	1500.00
Percent leaving Due to PDA	0.50
Employee Preference	0.83
Current Number of Employees	500.00
Employee Morale Cost	$127,500.00
BPR Misc Cost	$0.00
Total Year One Benefits	$3,719,665.92

Figure 10.1

For subsequent years there is a slight change (removed "Percent Leaving Due to PDA", and "Employee Preference") in the variables that are needed to calculate the annual benefit amount. Figure 10.2 displays the excel sheet with the updated amount of variables required.

Year 2

Impact on Workers	
Cost Burden	1.361
Number of Employees	500
Work Weeks	52
Hourly Salary	$20.53
Inflation	2.67
Probability Device Works	0.9060
Hours Saved Each Week	6.00
Training Cost Per Employee	1500.00
HR Dept Training Cost	1500.00
Number of New Employees	100.00
Employee Morale Cost	$300,000.00
BPR Misc Cost	$0.00
Total Year Two Benefits	$3,649,885.25

Figure 10.2

Hence it can be seen in Figure 10.2 that the Employee Morale Cost is no longer using the variables "Percent Leaving Due to PDA", and "Employee Preference." All other variables are similar to what was seen during the calculation of "Total Year One Benefits" in Figure 10.1.

10.2 Sensitive Analysis

The main purpose of the three developed excel sheets was to allow sensitive analysis to be performed. The user, in each of those sheets can alter the various variables.

Figure 10.3 shows the changes made by a user in the "Initial Investment" sheet and the overall effect on the initial cost.

1	**Intial Investment Work Sheet**	
2		
3	**Number of Employees**	200
4	**PDA Cost per Employee**	$500.00
5	**Total Cost for PDAs**	$100,000.00
6		
7	**Retraining Cost per Employee**	$1,800.00
8	**Total Cost for Employee Retraining**	$360,000.00
9		
10	**Number of Temp Employees**	200
11	**Hourly Salary of Temp Employees**	$20.00
12	**Work Weeks Per Year**	52.00
13	**First Year Cost of Temp Employees**	$208,000.00
14		
15	**Parallel System Running Cost**	$50,000.00
16		
17	**Other Costs (server, support, etc) per Employee**	$350.00
18	**Total Costs for server, support, etc**	$70,000.00
19		
20	**Total Costs for First Year**	$788,000.00

Figure 10.3

Similarly changes can be made to the "Subsequent year" worksheet too as shown in Figure 10.4.

	A–C	D	F–H	I
3	Year 1		Year 2	
4				
5	**Impact on Workers**		**Impact on Workers**	
6	Cost Burden	1.361	Cost Burden	1.361
7	Number of Employees	200	Number of Employees	200
8	Work Weeks	52	Work Weeks	52
9	Hourly Salary	$15.00	Hourly Salary	$15.40
10	Inflation	2.67	Inflation	2.67
11	Probability Device Works	0.8000	Probability Device Works	0.8000
12	Hours Saved Each Week	2.00	Hours Saved Each Week	3.00
13				
14	Training Cost Per Employee	1900.00	Training Cost Per Employee	2000.00
15	HR Dept Training Cost	2000.00	HR Dept Training Cost	2000.00
16	Percent leaving Due to PDA	0.50	Number of New Employees	250.00
17	Employee Preference	0.83	Employee Morale Cost	$1,000,000.00
18	Current Number of Employees	200.00		
19	Employee Morale Cost	$66,300.00	**BPR Misc Cost**	$5,000.00
20				
21	**BPR Misc Cost**	$100,000.00	**Total Year Two Benefits**	-$481,836.39
22				
23	**Total Year One Benefits**	$173,405.60		
24				
25	Year 3		Year 4	
26	**Impact on Workers**		**Impact on Workers**	
27	Cost Burden	1.350	Cost Burden	1.361
28	Number of Employees	200	Number of Employees	200
29	Work Weeks	52	Work Weeks	52
30	Hourly Salary	$15.81	Hourly Salary	$16.23
31	Inflation	2.67	Inflation	2.67
32	Probability Device Works	0.8900	Probability Device Works	0.9060
33	Hours Saved Each Week	2.00	Hours Saved Each Week	2.00
34				
35	Training Cost Per Employee	1900.00	Training Cost Per Employee	2000.00
36	HR Dept Training Cost	2000.00	HR Dept Training Cost	1500.00
37	Number of New Employees	100.00	Number of New Employees	100.00
38	Employee Morale Cost	$390,000.00	Employee Morale Cost	$350,000.00
39				
40	**BPR Misc Cost**	$0.00	**BPR Misc Cost**	$1,000.00
41				
42	**Total Year Three Benefits**	$5,153.19	**Total Year Three Benefits**	$65,362.50
43				

Figure 10.4

Once changes are made as shown in Figure 10.3 and Figure 10.4, then the "Net Present Value" worksheet will be automatically updated. The results will be similar to Figure 10.5

Net Present Value Worksheet

	r	0.15					
NPV	Time	0	1	2	3	4	Total cf
-$960,790.53	Inv 1 CF	-788000	173405.6	-481836.3907	5153.190849	65362.49561	-$1,025,915.10
	PV Inv 1	-788000	150787.4783	-364337.5355	3388.306632	37371.21901	

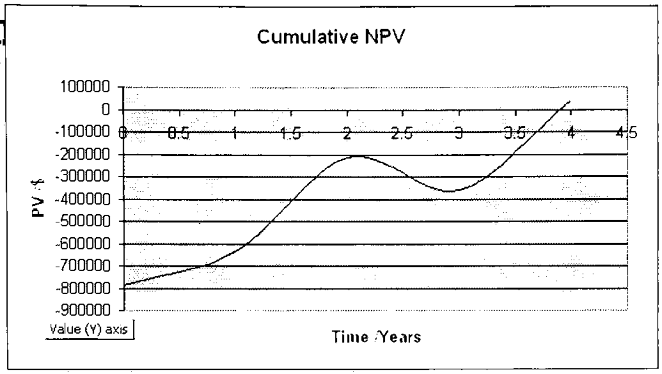

Figure 10.5

XI Potential Enhancement to CEM

As a theoretical model CEM did state that participants preferred mobile technologies. However, it did not address specific issues which may arise at an enterprise level due to their use. This study does attempt to quantify areas which were theoretically explained by CEM.

According to the findings of this study, possible additions to CEM include addressing costs, treating personnel as assets, and close proximity benefits. As shown already, costs related to a change in the business process of an organization (business process reengineering) can have an impact on the NPV for each subsequent year. Employees do need to be retrained, and the benefit can not be immediate, but is more gradual. Also, in order to more accurately gauge the effects of mobile technologies on people it may well be useful to attach a dollar value to each person. This for example would allow for an organization to understand how much of an impact each employee has based on how much he or she earns every year. Lastly, the implementation of a PDA changes the way workers would need to communicate with one another. Some may be able to fully exploit the benefits of a PDA, where as some workers might not be able to. In a group environment as CEM would suggest, collective goals in the same direction leads to success for the entire group, therefore, if some employees are not able to realize the true benefits of using a PDA then the company would need to gauge the effects that has on productivity.

XII Conclusion

11.1 Summary

The question posed by this study was if the use of mobile technologies, such as personal digital assistants, has any impact on the business productivity of organizations. Before an answer could have been reached, a clear concept of mobile technologies needed to be achieved. The study can be divided into three parts. The first part introduced the concept of various mobile technologies and the models that are used to address the issues that are faced with them today. CEM was also introduced which was the focal point of this study, with a listing of the benefits it alludes to in an abstract manner. White papers and an academic journal were also cross-referenced with what CEM had to say.

The second section was a transition from the qualitative (first part) to the quantitative. Various formulae were presented, which were later derived to a final equation representing the benefits incurred by an organization due to the use of a mobile device. Limited sensitive analyses were also carried out to see the impact of variables being changed on the overall dollar figure. Not unexpectedly it showed that the success of an organization varies when it comes to business productivity. Those variations could in some part have been a result of the variables mentioned in Table 6.1. If those issues are addressed then an organizations stands the best chance of succeeding.

The third part of the study recommended possible additions to the existing CEM model in the shape of addressing costs, treating personnel as assets, and close proximity benefits.

11.2 Future Extension of this Study

As already stated, one of the extensions to this study could be an addition of a database component to the simulation program. That could allow for the user to save multiple simulations, while also having the capability to match the results from different simulations for the same years.

Another extension could be the gathering of actual data. This would depend largely on the resources available.

11.3 Lessons Learned

The following were lessons learned:

- Literature review aside, a study should be done regarding the ease of gathering specific raw data from sources such as Gartner. Gartner did have data which would have been useful for the purpose of this study, but the average cost for each set of data was approximately $800.00. There was some data available at no cost, but it was almost always synthesized, without the numbers.
- Resources permitting there is no substitute for native data. If the experiment was carried out during the course of this study, then the issue of looking for data outside would not have arisen.
- Microsoft Project allows for a detailed calculation of slack time, besides providing useful tools for scheduling. The author of this study used Microsoft Project to keep track of deadlines and so forth, while also adjusting dates and times based on various completion dates of a task.

- Adding variables with the same units blindly is not the ideal solution. An investigation is needed to see what the underlying assumptions are.
- A derivation to a final formula can is a gradual process since many versions are needed before a satisfactory result is achieved.

A formula such as the one presented in this study is never finished, since it is based on a set of assumptions. Any of these assumptions can change based on the type of organization that is implementing it. Apart from the assumptions, the variables addressed in this study may not be all the variables that are present hence; it follows that the formula can always be improved.

Appendix I

A1.1 System Requirements for the Simulation Program

The following are the minimum system requirements for the simulation program to run:

- Microsoft Windows XP.
- 64 MB RAM.
- 100 MB of available hard drive space.
- 8 MB Video Memory.
- Microsoft Visual Studio.Net Professional 2003 Preinstalled.
- Windows compatible keyboard and mouse.
- 1024 * 768 true color display.

A1.2 How to Install and Run the Simulation Program

In order to install and run the Simulation program the following steps need to be followed:

- Insert program CD in CD Drive.
- Use Windows Explorer to browse to the CD Drive as shown in Figure A1.

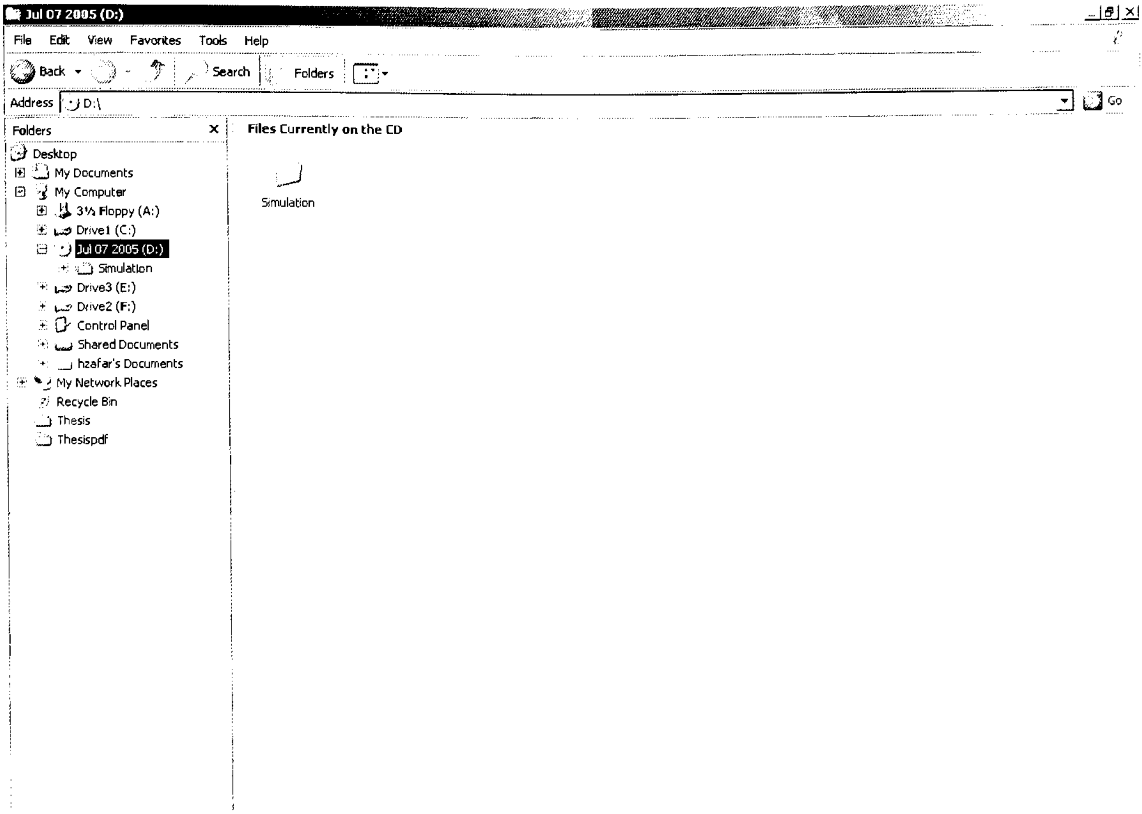

Figure A1.

- Double Click the "Simulation" folder. The contents of the folder will be displayed as shown in Figure A2

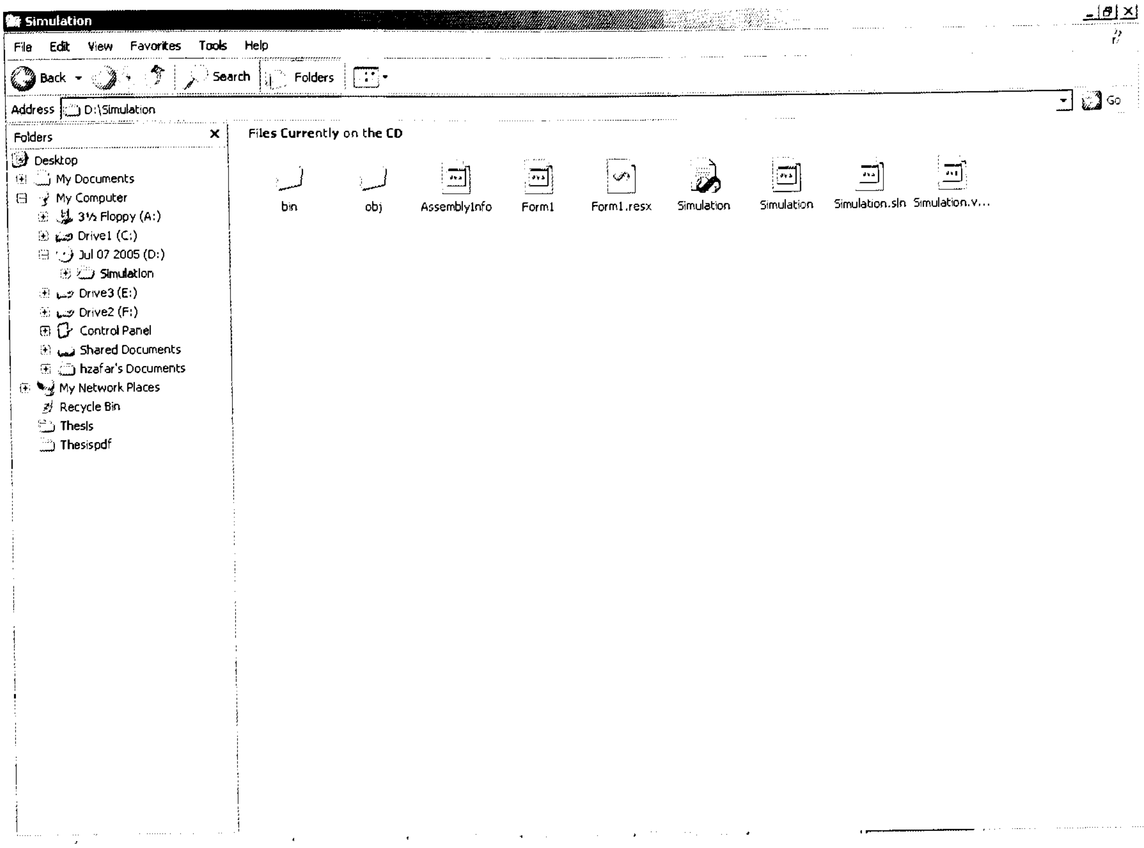

Figure A2

- Double click the "bin" folder. Only two files will be displayed as Figure A3 shows.

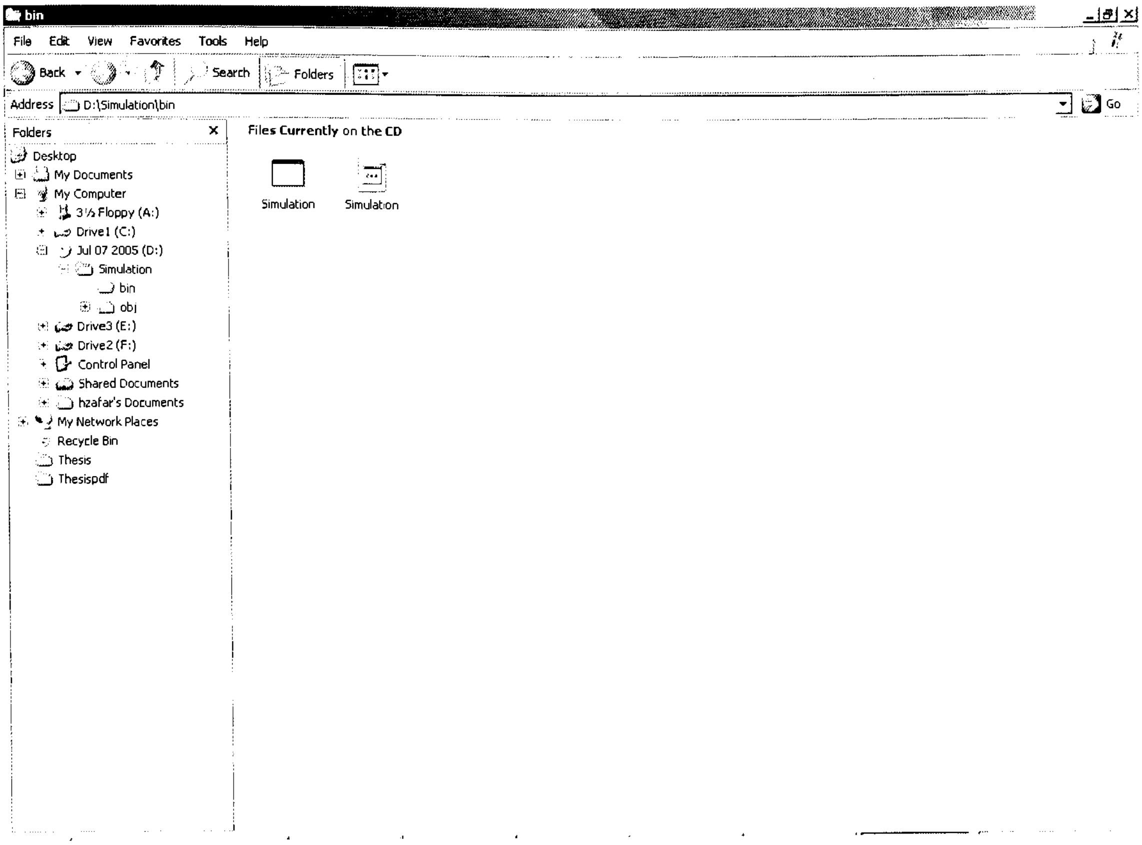

Figure A3

- Double click "Simulation.exe" to run the program (Figure A4).

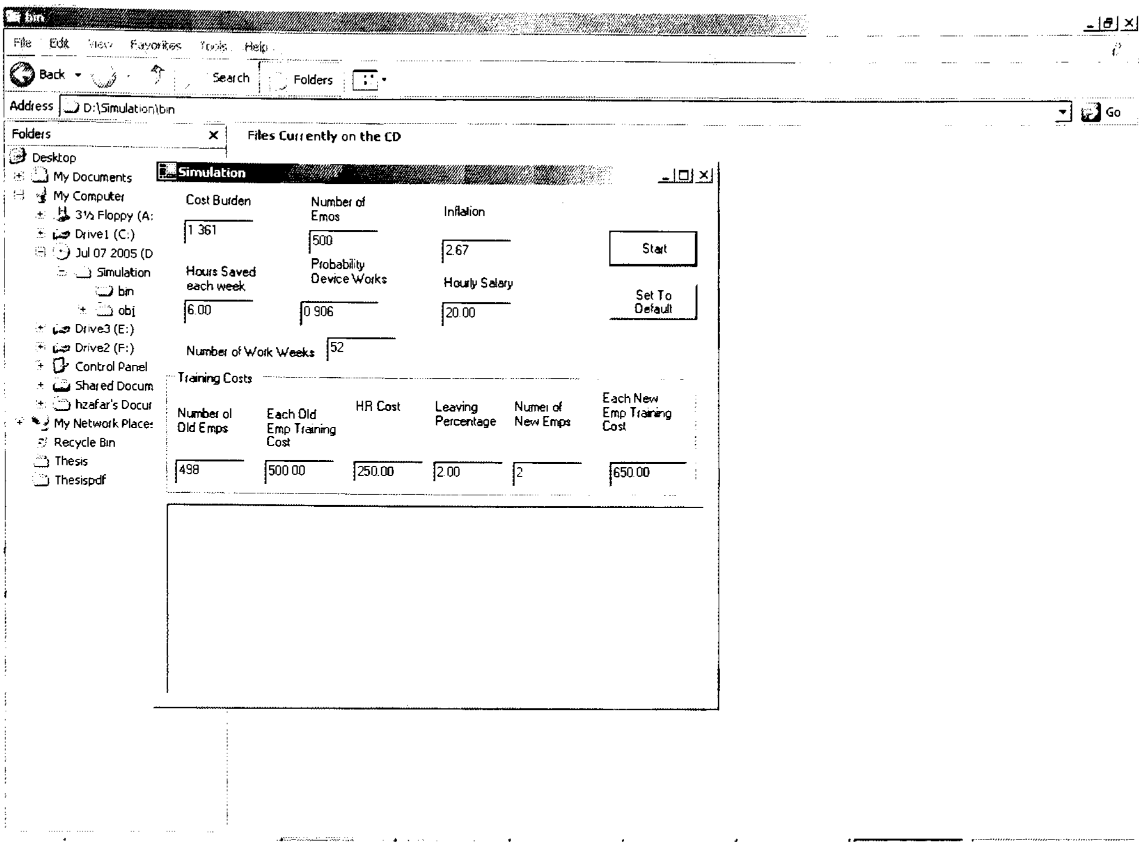

Figure A4.

Please note. Loading time for the program may vary based on the computer being used.

Appendix II

A2.1 Summary of Symbols Used

The symbols used in equations 7.E44 and 7.E46 are as follows:

a_1 = Cost burden incurred by an organization for each employee.

f = Rate of inflation, which is also the factor by which the employee salary increases.

s = Hourly salary of each employee.

w = Number of hours saved each week by an employee due to the use of a PDA.

p_w = Probability that the PDA works as intended.

n_e = Number of existing employees in a company.

b_1 = Percentage of employees who leave a company due to the use of a PDA.

e_c = Training cost incurred per new employee.

h_c = Cost incurred by the Human Resources Department of a company per new employee.

m = Miscellaneous business process reengineering or related costs incurred by a company not addressed in the initial stages.

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