AN ABSTRACT OF THE THESIS OF

Anand Moulik for the degree of Master of Science in Industrial Engineering presented on February 22, 2006.

Title: Investigating Usability of Search Engines in Small Screen Devices: A Systems Engineering Approach

Redacted for privacy

Abstract approved: ______________________________

Kenneth H. Funk, II

In today's world, desktop computers have become such an integral part of our lives that it is practically impossible to imagine anything being done without the aid of computers. As the world becomes more and more fast paced and users feel a need to have computers on the go, desktop computers have reduced in size without compromising on performance. The late 90s saw the desktop segment make room for the laptop and the small screen devices (SSD) segment, which demonstrated faster growth rates than the desktop segment. The SSD segment, however, had a growth rate that was nowhere near the combined growth rate of desktop and laptop computers. Portability of SSD was one factor that stood out among many others to account for the unprecedented growth rate of the SSD segment that the computer industry had witnessed. One of the most important, albeit under-represented and neglected, factors of a product is its usability. Usability, or the ease with which a product can be used, can be considered to be one of the most important factors in the success or failure of product. Determining the usability of small screen devices presents a bigger challenge, primarily because of the screen size of the SSD. The process of usability engineering aims to solve some/most of the problems that the SSD has. To make up for the drawbacks of usability engineering, systems engineering was used in this thesis, since both disciplines have considerable overlap in their processes. A growing number of SSD users use the Internet in one form or the other. The Internet has grown rapidly in the last decade, and nearly everyone using the Internet has come across a search engine sometime or other. Although research has been limited to the area of desktop search engines, there has not been enough research done in the area of search engines for small screen devices. This thesis compares two different search engines on small screen devices to find the better between the two. To do so, it takes a close look at the usability engineering approach from a system engineering perspective revealing several deficiencies, which may have hitherto gone unnoticed. It also shows a method to integrate several key Systems Engineering components into the usability engineering approach.

Investigating Usability of Search Engines in Small Screen Devices: A Systems Engineering Approach

by

Anand Moulik

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented February 22, 2006
Commencement June 2006

Master of Science thesis of Anand Moulik presented on February 22, 2006

APPROVED:

Redacted for privacy

Major Professor, representing Industrial Engineering

Redacted for privacy

Head of the Department of Industrial and Manufacturing Engineering

Redacted for privacy

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Redacted for privacy

Anand Moulik, Author

ACKNOWLEDGMENTS

Throughout the course of this research project, there have been a number of mentors, friends, and professors who contributed a great deal of support and encouragement, adding to the overall enjoyment of this learning experience. It is with great pleasure that I thank these people.

I would like to give special thanks to my Major Professor, Dr. Ken Funk, for his guidance, enthusiasm, and knowledge that helped me in staying focused and on my toes throughout the entire duration of this thesis. His willingness to invest time, his attention to detail and his positive feedback were some of the key things in making a success out of this thesis. Thanks to my Minor Professor, Dr. David Porter and my committee member, Dr. Shiwoo Lee for willing to serve on my committee on such a short notice. I'd also like to thank Phyllis Helvie, Denise Emery, Jean Robinson and Bill Layton for their continuous help during my years at OSU.

Certainly the success of this thesis exists in part, due to the round-the-clock help and support from friends during my stay at Oregon State University. In this regard, I'd like to thank my second family – The Watson's, who have been good friends since my early days in Corvallis. Thanks to Mrs. Gloria Smith, for allowing me to stay at her place forever, and being a good friend at the same time. The quality time I spent with both and the lessons learnt in life from them will be treasured for ever...

Thanks to a few graduate and undergraduate students who I met during the course of my study, all those wonderful moments that we shared together and their willingness to help will always be remembered. Eric Roe deserves special thanks for painstakingly proof reading my entire thesis and doing an excellent job.

Finally, I would like to thank my parents (Ma and Bapi) for their love, faith and support throughout my stay in the U.S. I consider myself very lucky and privileged to have such aspiring role models, who have always taught me that perseverance and hard work always pays off in the long run. I am also thankful to them for instilling in me the drive not just to finish what I start, but also to finish what I start well. I will everlastingly remember their encouragement, timely advice and above all, faith in me throughout life's journey.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

Figure Page

LIST OF TABLES

LIST OF TABLES (Continued)

Investigating Usability of Search Engines in Small Screen Devices: A Systems Engineering Approach

1 Introduction

1.1 Introduction

In today's world, desktop computers have become such an integral part of our lives that it is practically impossible to imagine anything being done without the aid of computers. As the world becomes more and more fast paced and users feel a need to have computers on the go, desktop computers have reduced in size without compromising on performance. The late 90s saw the desktop segment make room for the laptop and the small screen devices (SSDs) segment, which demonstrated faster growth rates than the desktop segment. The SSD segment, however, had a growth rate that was nowhere near the combined growth rate of desktop and laptop computers. Portability of SSDs was one factor that stood out among many others to account for the unprecedented growth rate of the SSD segment that the computer industry had witnessed.

One of the most important, albeit under-represented and neglected, factors of a product is its usability. Usability, or the ease with which a product can be used, can be considered to be one of the most important factors in the success or failure of product. Determining the usability of small screen devices presents a bigger challenge, primarily because of the screen size of the SSDs. The process of usability engineering aims to solve some/most of the problems that the SSDs has. To make up for the drawbacks of usability engineering, systems engineering was used in this thesis, since both disciplines have considerable overlap in their processes.

A growing number of SSD users use the Internet in one form or the other. The Internet has grown rapidly in the last decade, and nearly everyone using the Internet has come across a search engine sometime or other. Although research has been limited to the area of desktop search engines, there has not been enough research done in the area of search engines for small screen devices.

The overall objective of this thesis was two-fold: (1) Investigate usability of search engines in small screen devices, where two different types of search engines were compared to find the better between the two, and to compare and contrast their strengths and weaknesses; (2) Use a systems engineering approach to develop an integrated usability-system engineering process, by combining the major advantages or strengths of systems engineering and usability engineering.

1.2. Organization of this Thesis

Chapter 2 introduces the chronology of desktop computers and small screen devices, discusses Usability and Systems Engineering, and concludes with the Objectives for this thesis.

Chapter 3 describes the research methodology and procedures for this study.

Chapter 4 presents the results and statistical analysis of the data gathered in this study.

Chapter 5 discusses the main findings and significance of this research. It also discusses the limitation of this study, and presents recommendations for future research.

2 Background, Literature Review, and Objectives

2.1 Overview of Chapter

This literature review consists of four sections. Section 2.2 (Desktops and Small Screen Devices) starts off with a brief description of the chronology of desktop computers, and then proceeds to describe how desktops are slowly but surely being replaced by small screen devices for some or more applications. A comparison chart highlighting the advantages and disadvantages of both desktop computers and small screen devices concludes this section.

Section 2.3 (Search Engines) talks about the importance of search engines, how they work, and the types of search engines available today. The display of results on both big and small screen devices is discussed briefly.

Section 2.4 (Usability Engineering) discusses the concept of usability and its importance to a product's success. Various methods to test usability are then discussed. The section then talks about usability of small screen device interfaces, and ends with a possible alternative method to complement usability engineering.

Section 2.5 (Systems Engineering) discusses what a system is, and how systems engineering and some of the systems engineering tools can help in improving core usability engineering processes.

Finally, an overall summary of Chapter 2 summarizes Sections 2.2 through 2.5.

2.2 Desktops and Small Screen Devices (SSDs)

Section 2.2 gives an overview of the history of desktop computers and takes a look at what the future holds for the desktop computer market. Small screen devices (SSDs), said to be the next desktop replacement after the laptop/notebook computer, are discussed briefly, and a comparison between desktop computers and the SSDs are highlighted.

2.2.1 Desktops

"Who invented the desktop computer?" is not a question with a simple answer. The real answer is that many inventors contributed to the history of computers and that a computer is a complex piece of machinery made up of many parts, each of which can be considered a separate invention (Spencer, 1999).

Desktop computers have gained substantial amounts of computing power over the years in order to keep up with the rapid pace of software development. As the need for sophisticated software increases day by day, desktop computer manufacturers are being forced to come up with faster computers that can meet the needs of software programs. Today's desktop computers are not meant to be carried around, and that was one of the reasons computer manufacturers came up with an alternative to the desktop computer: one that could be carried around, but also possessed the equivalent computing power of desktop computers. The late 90s saw the introduction of laptops, and that affected desktop sales in a big way. In the quest for portability, smaller and smaller computers have become essential, without compromising on computing power and functionality.

The late 1990s also saw the market dominance for small screen devices, which have been growing at a faster rate than desktop computers. Particularly notable was the entry of SSD computers, which were as fast as the desktop/laptop computers, but at the same time could be carried around. This SSD was called a hand-held computer, also known as the Personal Digital Assistant (PDA). The PDA has been the fastest growing segment among any other computer category to date. In 2001, Gartner Research (Bloomberg News 2001) predicted a 260% increase in unit sales, from 9.39 million units in 2000 to 33.7 million units in less than a decade. Strategy Analytics (2000), among other market research groups, predicts that by 2004 there will be over one billion mobile device users, some 600 million wireless Intemet subscribers, and a $200 billion mobile e-commerce market.

For the sake of convenience, cell phones, smart phones, communicators, and any other device having a small screen will be referred to hereafter as Small Screen Devices (SSDs).

2.2.2 Small Screen Devices (SSDs)

More and more people feel the need to access information on the go. To meet this demand, manufacturers of electronic devices are making smaller and smaller gadgets that allow us to get Web content and other networked information. (Fulk, 2001). Whether it is a cell phone with a built-in Internet browser or a PDA, SSDs have come a long way. For instance, the PDA market has been anything but stagnant since PDAs were introduced. Growing at an astounding rate of 200% every year (Bloomberg News 2001), the PDA market seems to get stronger as the years go by. PDAs today offer astounding performance, comparable to their desktop counterparts, but fall behind when it comes to their storage capabilities.

The most frequent users of SSDs are people always on the move. These people constitute the greatest share of SSD users and are indirectly forcing SSD manufacturers to seek new levels of complexity, without compromising on functionality.

2.2.3 Chronology of SSDs

The SSD category can be broadly classified into cell-phones, PDAs/hand-helds, smart phones, and communicators. Several other devices fall into sub-categories of the above-mentioned devices. Cell phones/mobile phones have a history that can be traced to as early as 1921 (inventors.about.com, 2001), while PDAs/hand-held computers were introduced in 1972 (Polsson, 2004). Other devices, such as smart phones and communicators, were introduced much later, mostly towards the late 1990s.

Although SSDs have portability as their biggest advantage, they have a few disadvantages too. Table 1 compares desktop computers and SSDs from the author's viewpoint to illustrate some of the advantages and disadvantages of both large screen and small screen devices.

2.2.4 Advantages and Disadvantages of Desktop Computers and SSDs

Desktop computers typically offer more speed, memory, and storage for a lower price, and have a lower failure rate as compared to SSDs. It is easier to upgrade key components in a desktop such as large hard drives, additional memory, and special purpose cards, since they are much cheaper than those for SSDs. However, the biggest advantage that desktop computers have is bigger screens, which allow for better Graphical User Interface (GUI) navigation. An average desktop screen displays about 200 words at a time, while most small screen devices only display about 50 to 75 words (MacKay, 2003). Also, keyboards found on most desktops offer better typing speeds, allowing for faster data input.

Desktop computers are severely disadvantaged when it comes to portability. Apart from taking up valuable space, desktops are difficult to ship if repair/replacement is needed.

So, while desktop computers are better equipped for storing massive amounts of data and have a variety of software applications, SSDs offer portability and are soon expected to offer more data storage, on par with storage capacities of desktop computers.

2.2.5 Summary of Section

While the computing power of desktop computers has increased over the years, the market for computers has demonstrated the need for portable computers that will not compromise on computing power. David Daoud (2000), a senior analyst with IDC, said: "Demand for mobile computing is really increasing, while the market for desktops is shrinking." For SSDs, the current trend is convergence. Manufacturers are offering cell phones that can send messages, browse the Web, take pictures, and play music (Alpert, 2004). Using a SSD to browse the Web and perform other Web-related activities might not be a good idea, however, due to the fact that cell phone screens are smaller than PDA screens and long sessions of staring at a smaller-than-normal screen may cause vision-problems.

		Desktop Computers	Small Screen Devices (SSD)	Verdict	Comparison Result
1	Price	Cheap options available	Relatively expensive, but prices falling rapidly	Desktop computers hold a slight edge here. For the kind of money you pay for getting a hand-held computer, you get more value for money buying a desktop.	Desktop computers
2	Weight	Heavy	Very light	Hand-held beats the competition hands down	SSD
3	Size	Bigger and occupies lots of space	Small	Hand-held beats the competition hands down	SSD
4	Portability	Not easy to carry around	Can be easily carried on one's person	Hand-held beats the competition hands down	SSD
5	Latest Technological Advances	Rapid technological advances	Rapid technological advances	Rapid advances in both sectors would make this neutral	No result
6	Data Storage	Massive storage space possible	Relatively expensive storage options	Hand-helds have a severe disadvantage in this area. While the minimum requirements for desktop computers start from 20 GB, hand-helds have yet to move beyond the 1GB of space provided in the form of memory cards.	Desktop computers
7	Reliability	Quite reliable	Quite reliable	Equally reliable. While you can get a desktop computer fixed at your neighborhood dealer, the same can't be said for the hand-held. However, should a major problem arise, it's easier to ship the hand-held than to ship the desktop.	No result
8	Software Applications Available	More variety	Less variety	Although it's possible to get almost all kinds of software for the hand-held, it still lags behind the desktop when it comes to software.	Desktop computers

Table 1. Chart comparing desktop computers and small screen devices. Several physical and technical factors of desktops and SSDs are compared in this chart. SSDs fare better when it comes to portability, but lag behind when it comes to data storage.

Smart phones, which are essentially a combination of PDAs and cell phones, are expected to have record sales in the forthcoming years, since they capture the best features of both PDAs as well as cell phones. Data collected from a study comparing the use of laptops, PDAs, and mobile phones suggests that some people prefer PDAs and/or laptop and a small mobile phone (Perry, 2004). Todd Kort, principal analyst in Gartner's Computing Platforms Worldwide group, had this to say: *"Smart phones will generally have a negative impact on the low end of the PDA market, as many individual users will find the personal information management (PIM) and email capabilities of smart phones acceptable. These users will tend to become less interested in low-end PDAs that have provided these capabilities."*

Although there is not sufficient data to support the fact that users prefer one SSD over another or prefer to have a multitude of SSDs, it would be safe to assume, from available data and the record number of SSD sales, that SSDs are certainly going to replace a sizeable number of desktops in the forthcoming years.

2.2.6 How Do You Find Information?

Advances in computer and Internet technologies have made it easier for people to access enormous amounts of data at the click of a button. One of the most common modes of accessing information in the World Wide Web (WWW) is browsing through a myriad of Web pages using hyperlinks (Huberman, 1999). This process is laborious and time consuming. To make things easier, there are numerous search engines available today, which cater to a variety of needs.

The overwhelming success of SSDs may make major search engine companies create an exclusive market for mobile search engines, which are presently focused on the desktop environment.

2.3 Search Engines

Section 2.3 provides an overview of search engines. The section discusses the concept of a search engine, the importance of search engines, how search engines work, the desktop and the SSD search engines, the importance of how results are displayed, and the future of search engines. How search engines display results, especially in small screen devices, is also discussed, since this is one of the most challenging aspects of user interface design for SSDs.

2.3.1 Overview of Search Engines

2.3.1.1 What Is a Web Search Engine?

A search engine is a collection of software programs that collect information from the Web, index it, and put it in a database so that it can be searched (Ackermann, 2000). Reding (2001) defines a search engine as: "A search tool that indexes keywords within some or all documents in Web sites. Keywords are found within a document and have contextual meaning to that topic. A search engine matches your keywords with its index."

A search engine can thus be described as a software program that searches a database and gathers and reports information that contains or is related to terms specified by the user.

2.3.1.2 History of Web Search Engines

Web search engines did not come into existence until 1994. Literature covering search engines has an even shorter span. The World Wide Web Worm (WWWW) (McBryan, 1994), one of the first Web search engines, had an index of 110,000 Web pages and Web accessible documents. The WWWW consisted of two parts: one that located resources, and the other, which provided the search interface (McBryan, 1994). The search interface was quite confusing, and keeping track of both parts took time to get used to. In contrast, today's search engines usually have a search input box as the main source of interaction between the user and the search engine.

Search engine technology has had to scale up dramatically to keep up with the growth of the Web (Brin, 1998). As of today, a comprehensive index of the Web contains over a billion documents, and top search engines handle hundreds of millions of queries per day. Today's search engines are capable of searching billions of pages and summarizing the results in a matter of seconds. From a user's perspective, several reasons—like the reliability of the search engine, the way the search results are displayed, the number of results that are displayed, and, most importantly, the ease of use in using the results—may play an important part in deciding which search engine to use, and which not to use.

2.3.1.3 The Importance of Web Search Engines

Over the years, search engines have gained in popularity as more and more people try to access information without having to browse multiple Web pages in order to find what they are looking for. Search engines offer users the convenience of browsing a list of 10-15 results summarized in a single page. The results can save users the frustration of traversing across multiple Web pages for information.

Following is a collection of the best quotes on search engines, provided by some of the leading experts in Web analysis and statistics, which stress the importance of search engines.

"Search engines are the top way consumers find new web sites online, used by 73.4% of those surveyed." (Forrester Research, March 2001)

"Nine out of ten web users visit a search engine, portal or community site each month. They also revisit frequently, nearly five times per month." (Nielsen-Net Ratings, May 2001)

"Search engine positioning was the top method cited by web site marketers to drive traffic to their sites (66%), followed by email marketing (54%)." (Direct Marketing Association, August 2000)

"57% of Intemet users search the web each day, making search the second most popular Internet activity." (How people use the Internet, February 2000)

"Over 75 percent of web users use search engines to traverse the web." (Real Names Survey, April 2000)

The above quotes illustrate the fact that finding information by way of search engines is the most preferred method of users today, evidenced by the high volume of users using search engines, and that searching can be said to be one of the most popular Internet activities.

2.3.1.4 Major Search Engines Today

Although many search engine companies are trying to build a faster and better search engine than what is currently available, Google, MSN, and Yahoo have the top three search engines today (www.searchenginewatch.com, 2001).

Figure 1 shows the market percentage of the top three search engine companies. As the search engine competition intensifies, search engine companies are diversifying their search engines in such a way that they cater to every possible user need.

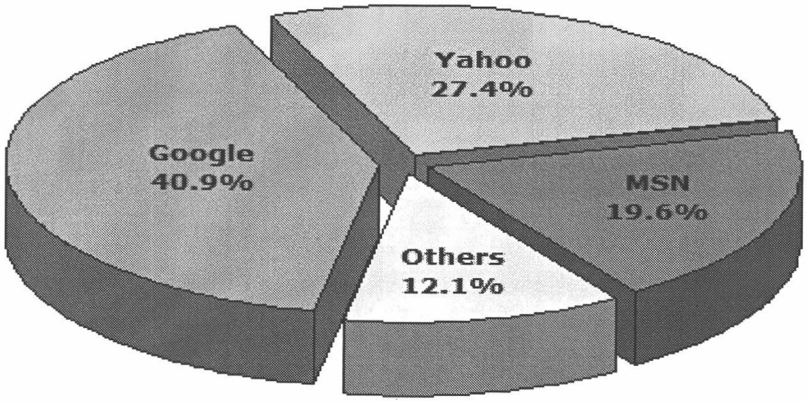


Figure 1: Market share of search engines (source: searchenginewatch.com)

2.3.1.5 How Do Search Engines Work?

In search engines, a computer program, which is usually called a spider or a robot, gathers new documents from the World Wide Web. The program retrieves hyperlinks that are associated with these documents, loads them into the database, and indexes them using a formula that differs across databases. The search engine later searches the database according to the request entered by a user. Although robots have many different ways of collecting information from Web pages, the major search engines all claim to index the entire text of each Web document in their databases. Figure 2 provides a graphical representation of how a search engine works.

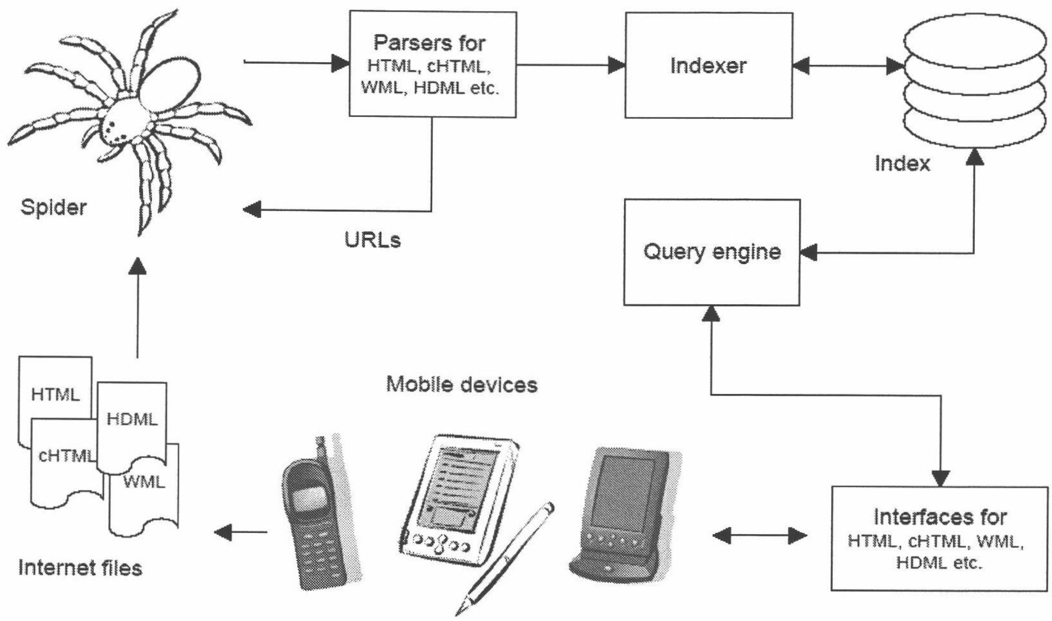


Figure 2: Search engine architecture for small screen devices. The figure shows the graphical representation of how a search engine works for SSDs. The only difference is that the SSD search engine parses files which are exclusively meant for SSDs as opposed to the standard HTML/XHTML files for the desktop environment (source: sonera.com, 2001).

2.3.2 Desktop Search Engines

Although Google, MSN, and Yahoo continue to be the most preferred search engines today, there are different variants of search engines available in the market. Currently, Google indexes 8 billion pages; Microsoft indexes 5 billion; and Yahoo is estimated to index about 4 billion (nytimes.com, 2001). Almost all the search engines have similar search technologies, with the sole exception of Google. The four major types of search engines available today follow:

Automated search engines rely on software-based "ranking algorithms" to determine which key words a Web site can be found under, and also to determine the ranking of the Web site. Automated search engines are rapidly decreasing in popularity and are converting to a more human-edited and/or pay-per-click format. The best example of automated search engines is iWon (www.iwon.com).

Human-Edited search engines require acceptance by a human editor, who can approve or reject the Web site submission. The editor can influence certain ranking elements if the ranking and submission process is not executed perfectly. Most traffic today is generated from human-edited search engines. Examples of human-edited search engines include Look smart (www.looksmart.com) and Open Directory Project (www.dmoz.org).

Pay-Per-Click search engines are essentially performance-based search engines, where listing is not possible unless the customer pays for the traffic received by the Web site. Pay-per-click search engines are the fastest growing type of search engines. Examples of pay-per-click search engines include GOTO (now www.overture.com) and Find what (www.findWhat.com).

Hybrid search engines are a combination of the three different styles of engines described above. For instance, AltaVista (www.altavista.com) borrows its Web site database from Look smart, but applies a unique ranking algorithm. In addition, it incorporates search results from GOTO (now www.overture.com) at the top of the page.

Apart from the services of the four types of search engines available today, search engines also cater to a variety of needs and requirements. Search engine companies have been known to offer customized search solutions to various industries and institutions. The search technology is the same but offers higher levels of customization. Search engines usually charge the industry or institution a premium for making the searches customizable to fit their needs. All the major search companies, like Google, MSN, and Yahoo, have customized paid search systems available for a variety of clients.

Do Search engines function the same way for SSDs? The next section discusses how they are similar to and different from traditional desktop search engines.

2.3.3 PDA Search Engines

Given the plethora of search engines available, why would one want a search engine for the PDA? Secondly, are they any different from the regular search engines? Traditional search engines are not suited for small screen devices because the search engine results are formatted for the desktop environment. To actually see the results that are displayed, some sort of horizontal or vertical scrolling has to be done every time on the PDA, which can be annoying.

2.3.4 Display of Search Results

Do users really care about how advanced the search engines they use are, or do they care more about the quality of results and how well the results are displayed? Often, users return back to an ineffectual search engine because it was "easy on the eyes" and they liked the way the results were displayed (Berry, Browne, 1999).

Other factors notwithstanding, the most important factor from the SSD user's perspective is the user interface. A user interface generally consists of the following components: metaphors, mental models, navigation, interaction, and appearance (Marcus, 2001). Metaphors are fundamental concepts that are communicated through words, images, sounds, and perhaps even experiences. A mental/internal model is created through the sight of some display of data, and navigation is the creation and interpretation of an internal model (Spence, 2001). Finally, interaction deals with the input and output techniques, and the appearance of the user interface involves the visual, auditory, and tactile characteristics (Marcus, 2001).

The user interface design for mobile devices presents special challenges for designing an efficient and effective user interface. Much of the work on user interface design that has been done for the desktop computer cannot be generalized for mobile devices (Munusamy, 2002). This is primarily due to the fact that most of the desktop interface designers did not take into consideration the fact that desktop interface characteristics might not be transferable to other environments, like the SSDs environment.

A normal search query using a search engine in a desktop environment can yield hundreds of results, which are often displayed on 10-15 pages. Navigating to and fro, browsing the list of results to see which results are the most relevant is usually done much faster on a desktop environment. The screen size of a Pocket PC PDA is 320x240 pixels, while a cellular phone may have screen space for seven rows of 16 character-wide texts with graphics resolution around 100x45 pixels. These are the main reasons why traditional search engines available on the Web today are not directly suited for mobile devices.

Font sizes are usually smaller for SSDs than those found on conventional desktops. Reading small font sizes on a small screen device for extended periods of time may cause eyestrain, and reading for extended periods on a daily basis may cause eye damage. Navigating using a stylus also forces the eyes to focus on certain navigational elements on the interface. Navigational elements may also vary from SSD interface to interface, thus increasing eyestrain. A common way to accommodate both navigation and reading issues would be to increase the font size on certain SSDs. This, however, raises the problem of vertical and/or horizontal scrolling, and may cause inconvenience to the user.

A search engine which takes into consideration the various challenges that the small screen devices present in terms of screen space, as well as the way results are displayed on the user interface, and which comes up with a new markup language that the various SSDs could use for better display of results would be something to look forward to, given the ever growing popularity of both search engines and small screen devices.

2.3.5 The Future of PDA Search Engines

How the PDA market matures and how many people would want a personalized search engine that works exclusively with just their PDA would be one of the deciding factors in shaping the outcome for PDA search engines. Judging by the number of sales in the PDA market, more and more people will be using PDAs and the Internet for a variety of needs. Searching for information would definitely be one of the top priorities, as was evident by the facts discussed in section 2.3.1.3. The quality of SSD search engines is directly proportional to the interest generated by the SSDs consumer market. The future of PDA search engines ultimately depends on desktop search engines, as the majority of people accessing the Internet are predominantly desktop computer users and more research is being done in the field of desktop computers. This, however, translates into good news for PDA users, since both these classes of search engines have similar search technologies.

As scientists come up with even more complex algorithms to improve current search engine technology, more work to improve the way search results are displayed—allowing users to retrieve accurate results from usable interfaces—would certainly be beneficial and helpful.

Most search engines present query results as long, often overwhelming, ranked lists, making users scroll and examine documents in detail as they proceed to make relevance judgments (Jones, 2002). Such approaches mean that even on conventional large displays search interfaces are not highly usable. As Schneiderman (1986) put it, "...the result is confusion and frustration."

Do users really need 20 pages of results on entering a search query? Are there results of any relevance after the first few pages? Can search engines predict the way users use the search engine and display results based on their preferences? These are some of the questions that may decide where search engines are truly headed.

2.3.6 Are Products We Use Easy to Use?

In today's information age, usability is critical to almost every new product or service. Usability, or the ease of using a product, is fast becoming one of the key factors in a product's dominance in the market. Usability is an increasingly important competitive issue in the software industry. Companies that have had the foresight to embrace usability as part of their product development lifecycle have experienced tremendous return on investment. Usable products support users' workflows and help users avoid errors. Usable products can also provide users with feedback, give users control, and minimize users' cognitive loads. Products that are not usable are both frustrating and inefficient for users.

Although emphasis on usability is not as widespread as it should be, several leading usability experts are taking the initiative to make it so by conducting seminars, workshops, conferences, and even road shows to promote usability.

2.4 Usability Engineering

This section discusses the concept of usability, how to measure usability, and why measuring usability is important, then shifts focus to SSD usability and talks about future advances in this area. Usability testing and the various types of usability testing are then discussed briefly. Limitations of usability testing are highlighted and other options that might be better than conventional usability testing and more worthwhile to use are discussed at the end of the section.

2.4.1 Introduction

The term usability has been defined as "The *effectiveness, efficiency*, and *satisfaction* with which specified users achieve specified goals in particular environments" (ISO 9001).

2.4.2 Usability Attributes

The International Standard Organization defines usability as consisting of five distinct components, or attributes (ISO 9001):

Effectiveness

"The accuracy and completeness with which users achieve certain goals. Indicators of effectiveness include quality of solution and error rates."

Efficiency

"The relation between (1) the accuracy and completeness with which users achieve certain goals and (2) the resources expended in achieving them. Indicators of efficiency include task completion time and learning time."

Satisfaction

"The users' comfort with and positive attitudes towards the use of the system. Users' satisfaction can be measured by attitude rating scales such as Software Usability Measurement Inventory (SUMI)."

Memorability

Barnum (2000) defines the requirement for Memorability as: *"The system should be easy to remember, so that the casual user is able to return to the system after a time and not have to learn it all over again."*

For example, the "Home" icon on most browsers is a little house. The reason for this is that people assume this house represents their home. Thus the home concept is communicated to them via a visual cue.

Learnability

Barnum (2000) defines the requirement for Learnability as: *"The system should be easy to learn so that the user can rapidly start doing some work."*

For example, users familiar with the user interface on a Windows environment would find it easy to learn and adapt to a slightly different interface having the same elements as the Windows environment.

The last two attributes are not used as frequently.

2.4.3 Usability Principles/Heuristics

"Usability heuristics" are key principles, or measures of usability, which may contribute towards making a product easy to use. They can help to indicate the "utility" of a product - that is, the extent to which the product is useful, is usable, and will be used. These heuristics can be used as a checklist for usability specialists in helping them to assess the usability of a product.

Following are Nielsen's ten general principles for user interface design. They are called "heuristics" because they are more in the nature of rules of thumb than specific usability guidelines (Nielsen, 1994).

1. Visibility of system status

   The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
2. Match between the system and the real world

   The system should speak the user's language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
3. User control and freedom

   Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Supports undo and redo.
4. Consistency and standards

   Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
5. Error prevention

   Even better than good error messages is a careful design, which prevents a problem from occurring in the first place.
6. Recognition rather than recall

   Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
7. Flexibility and efficiency of use

   Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
8. Aesthetic and minimalist design

Dialogues should not contain information that is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

9. Help users recognize, diagnose, and recover from errors

   Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

10. Help and documentation

    Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Although there are several different versions of a few basic usability principles, Nielsen's list of "Ten Usability Heuristics" is the most widely recognized and referenced list today (Nielsen, 1994). Tognazzini also has a list of basic principles for interface design (Tognazzini, 2003). Xerox Corporation has combined both Nielsen and Tognazzini's lists of usability principles to come up with their own heuristic checklist, which can be found at the Society of Technical Communication's special interest group Web site (http://www.stcsig.org/usability/resources/toolkit/toolkit.html). Several other major corporations like Microsoft (http://www.microsoft.com/usability/default.mspx), IBM (http://www-306.ibm.com/ibm/easy/eou_ext.nsf/publish/1996), and last but not the least, Oracle (www.ui.us.oracle.com) have their own customized set of usability principles and/or guidelines, which can be found on the companies' respective Web sites.

2.4.4 Usability Testing

The process of learning from users about a product's usability by observing them using the product is called usability testing (Barnum, 2002). Since the primary goal is to improve the usability of a product, specific goals and concerns must be articulated for each test. The participants must represent real users, and they should do real tasks. The usability team records the participants' input and analyzes the data, diagnoses the problems, and recommends changes to fix problems, based on the participants' feedback (Redish and Dumas, 1999).

Although there are different types of usability testing methods, utilizing a combination of two different usability testing methods usually provides the best result. A quick overview of the major types of usability tests follows (Nielsen, 1994).

Heuristic evaluation is the most informal method and involves having a small set of evaluators examine the interface and judge its compliance with established usability principles.

Cognitive walkthroughs use a more explicitly detailed procedure to simulate a user's problem-solving process at each step in the human-computer dialogue, checking to see if the simulated user's goals and memory for actions can be assumed to lead to the next correct action.

Pluralistic walkthroughs are meetings where users, developers, and human factors specialists step through a scenario, discussing usability issues associated with dialogue elements involved in scenario steps.

Feature inspections focus on the function delivered in a software system. For example, they evaluate whether the function as designed meets the needs of intended end users.

Consistency inspections have designers representing multiple projects inspect an interface to see whether it does things in a way that is consistent with their own designs.

Standards inspections have an expert on some interface standard inspect the interface for compliance.

Formal usability inspection is a combination of individual and group inspections in a six-step process with strictly defined roles, drawing on elements of both heuristic evaluation and a simplified form of cognitive walkthroughs.

When should usability-testing methods be used?

With a few exceptions, such as feature inspections, inspection methods are not suited for use in the very early phases of the usability engineering lifecycle where no user interface has been designed or implemented (Nielsen, 1994). As mentioned earlier, a combination of two different usability-testing methods provides the best results, in terms of usability problems being detected. Heuristic evaluations, along with situation-specific usability testing methods, have proven to be the best combination for evaluating the usability of a product. Although lots of research has been done in usability testing for the desktop environment, not much research has been done in the area of small screen devices.

2.4.5 SSD Usability

Over the past two decades, human-computer interaction standards have been developed and tested, and there has been a lot of ongoing research done by both industry and independent experts in the field of human-computer interaction, allowing a marked improvement in usability of desktop computers. However, such standards cannot always be applied to design applications for mobile devices (Masoodian, 1999).
It is beyond the scope of this thesis to describe the usability of all existing SSDs in detail. However, several relevant and significant research papers have used the PDA as the primary model, as opposed to other SSDs. PDAs were used in the experiment for this thesis, so PDAs are considered to be a good representation of SSDs.

2.4.5.1 PDA Usability

The current state of PDA usability

Designers of interfaces for hand-held devices have come to realize that novel user interface design for small screens is far from a straightforward adaptation of techniques developed for traditional large screens to their smaller counterparts (Holmquist, 1999).

User interface design for mobile communication devices has not been a central research topic in the past. Future communication devices will incorporate much of the functionality of today's information processing devices, preserving important characteristics like the fact that the devices must be personal and highly individualized and increase the quality of life for their users (Ruuska, 2001).

The limitations of the SSDs small screen size require special attention, because they affect the user's experience (Buyukkokten, 2000). A recent study found that users with small screens follow links less frequently than their counterparts who were furnished with larger displays, and that their success rate was lower (Kawachiya, 1999). The study calls for improvements in navigation facilities for small screens.

What happens when small screen users access a site designed for a conventional large screen display? It seems obvious that there would be some sort of degradation in interaction time and user effort. However, an extensive literature survey by Jones (2002) revealed no published studies that have looked directly at such issues.

2.4.5.2 Future of PDA Usability

Mobile hand-held Web browsing has been described as the next big thing for the Web (Nielsen, 1999). Many believe that in several years' time, there will be more people accessing the Internet via mobile devices (PDAs, cell phones etc) than via conventional PCs (Jones, 2002).

As the capacity of wireless communication and the capabilities of mobile devices grow, the challenge of finding ways around the severely limited display area associated with these devices becomes increasingly urgent (Bruijn, 2001).

2.4.6 Summary of Section

Hypothetically speaking, if we take into consideration the SSD market comprised of only the PDA and cell phone, these two collectively are expected to post a record number of sales in forthcoming years. For instance, the personal digital assistant (PDA) market has grown dramatically in recent years. In 2002 alone, over 12 million handheld devices were sold (Kawamoto, 2003), and a 17.6% annual growth in sales is expected between 2003 and 2006 (Europe media, 2002). One factor that could have played an important role in the record number of sales is usability. There is a strong probability that the usability of the SSDs would play a major role in attracting potential users and retaining current users.

More and more people are using SSDs – mobile phones, PDAs, etc. — to search online. Clearly, these services will be useful; especially to meet specific, focused, and urgent information needs (Jones, 2003). But users of online search services on small screens find it difficult to cope with the large number of potentially useful results returned to their handheld devices (Buchanan, 2002).

More research needs to be done to find better ways to navigate through the pages of results that a search query produces. As screen sizes shrink, navigation gets more and more challenging. As search engines get more and more powerful, the quality and quantity of results is bound to improve. Whether or not the results are displayed in a usable manner and can be easily interpreted by users remains the next big challenge for search engine companies.

Usability testing does not guarantee that the product will be usable, because usability testing is performed in artificial laboratory settings and the test participants are rarely fully representative of the end user population.

The next section discusses how usability engineering can be improved by using a discipline that develops and exploits structured, efficient approaches to analysis and design to solve complex engineering problems.

2.5 Systems Engineering

Section 2.5 provides an overview of systems engineering, a long established process for the development of complex systems. The section discusses what a system is and what systems engineering is all about, then proceeds to discuss the systems engineering tool used for this thesis. The section closes by discussing how systems engineering can be integrated into the usability engineering lifecycle to help the latter.

2.5.1 What Is a System?

Systems engineers define a system as a set of interrelated components working toward a common objective. Systems are made up of components, relationships, and attributes (Carlsson, 2002). Components are usually the operating parts of the system. They can be physical artifacts, such as turbo generators, transformers, and transmission lines in electrical Power systems. They can also be institutions in the form of legislative artifacts, such as regulatory laws, traditions, and social norms (Carlsson, 2002). Relationships are the links between the components, and attributes are the properties of the components and the relationships between them; they characterize the system.

2.5.2 What Is Systems Engineering?

Systems engineering has several definitions. Martin (1997) defined Systems Engineering as “the process that controls the technical system development effort with the goal of achieving an optimum balance of all system elements.”

The Systems engineering method

The Systems engineering method can be thought of as the systematic application of the scientific method to the engineering of a complex system (Kossiakoff, 2003). The method can be considered to consist of four basic activities, as shown in Figure 1. A brief description of the systems engineering method follows:

- **Requirements Analysis** (Problem Definition) is the process of studying user needs to arrive at a valid definition of a system, functional hardware, or software requirements (Kossiakoff, 2003).
- **Functional Definition** (Functional Analysis and Allocation) is a process that specifies the tasks, actions, or activities that a system or a system element must be able to perform, and, where appropriate, the precision required in the performance of a specified action (Kossiakoff, 2003).
- **Physical Definition** (Synthesis, Physical Analysis, and Allocation) is a direct representation of specifications of some or most of the physical characteristic of the actual system or element under study (Kossiakoff, 2003).
- **Design Validation** (Verification, Evaluation, Testing) involves evaluation of the capability of the delivered system to meet the customer's requirements in the most realistic environment achievable (Kossiakoff, 2003).

Although the systems engineering method is quite similar to the usability method, the biggest difference is that systems engineering offers a more structured approach to the whole process. Section 2.5.3 explains how usability engineering can benefit from systems engineering.

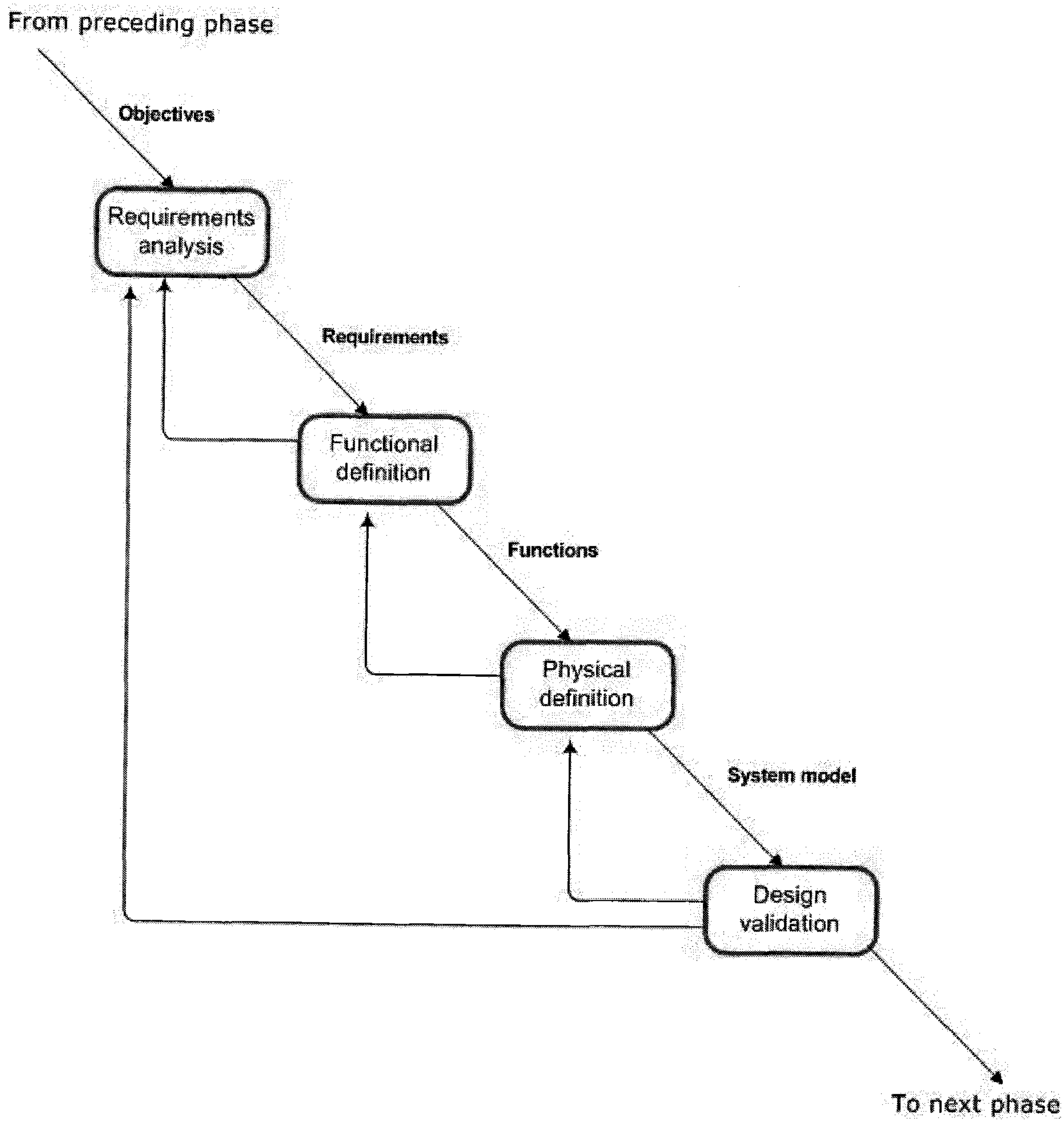


Figure 3: The four basic activities of the systems engineering method (Kossiakoff, 2003).

Systems engineering tools are those tools that support systems engineering processes and systems engineering management. Systems engineering tools include capability maturity models, standards, data flow diagrams, work breakdown structures, and so on. There exists a plethora of systems engineering tools that can be used in the systems engineering process, and these are listed on the International Council on Systems Engineering (INCOSE) Web site (www.incose.com).

2.5.3 Integrating Usability Engineering and Systems Engineering

Usability engineering is a combination of management principals and techniques, formal and semiformal evaluation techniques, and computerized tools. Systems engineering is a systematic process that may fill in the deficiencies that usability engineering has. Producing a usable interactive system may therefore require complementary and parallel application of systems engineering and usability engineering.

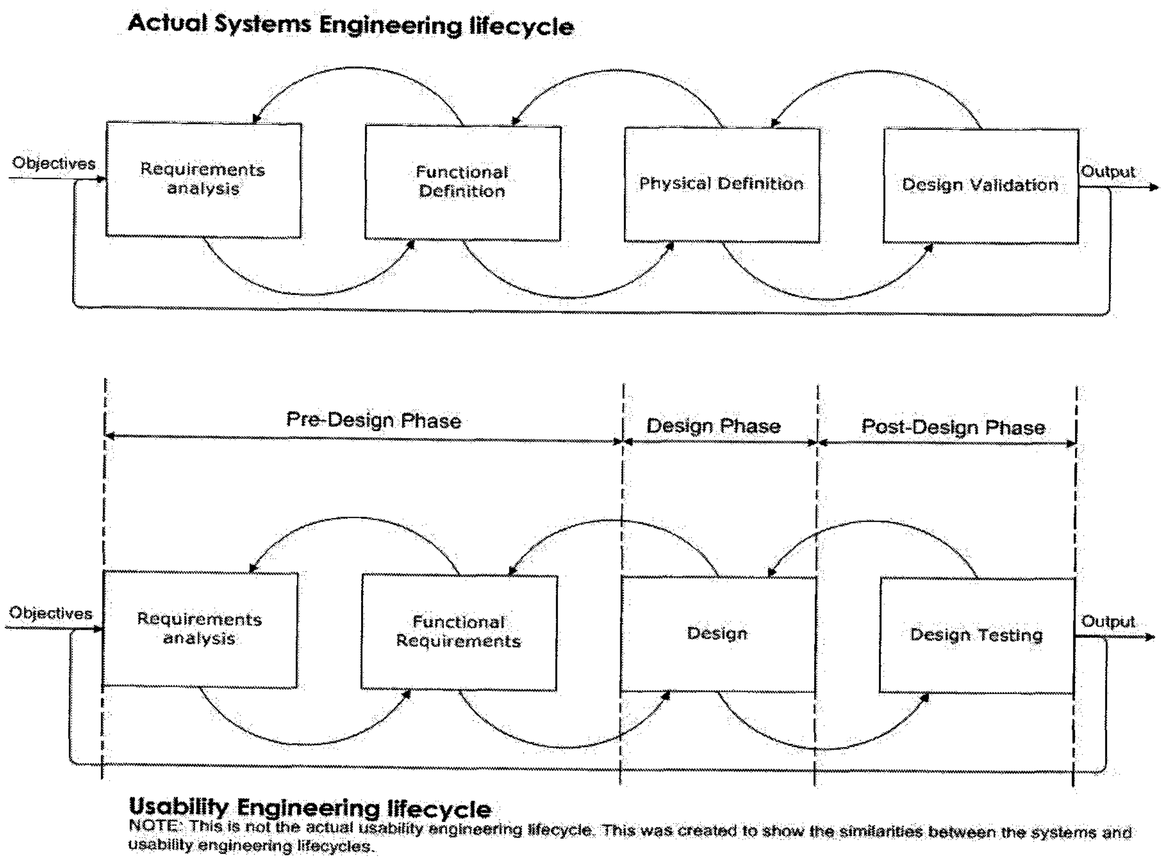


Figure 4: Figure showing the systems and usability-engineering life cycle. Although the actual engineering lifecycle is shown, the usability engineering lifecycle has been scaled down from the original version to show similarities and differences between the two lifecycles (Mayhew, 1992).

The similarities of the usability and systems engineering lifecycles are evident from both diagrams in Figure 4. A closer look at the functional requirements stage in the usability lifecycle shows where systems engineering can prove to be an invaluable resource. Functional requirements capture the behavior of the system, which can be expressed as tasks or functions the system is expected to perform. A good approach to capturing functional requirements is to utilize use cases. A use case defines a goal-oriented set of interactions between external actors and the system under consideration. Actors may be a class of users outside the system that interact with the system.

The functional definition step of systems engineering translates requirements into functions (actions, tasks) that the system must accomplish (Kossiakoff, 2003). On the other hand, use cases capture who (actor) does what (interaction) with the system, for what purpose (goal), without dealing with the system (UML, 1999).

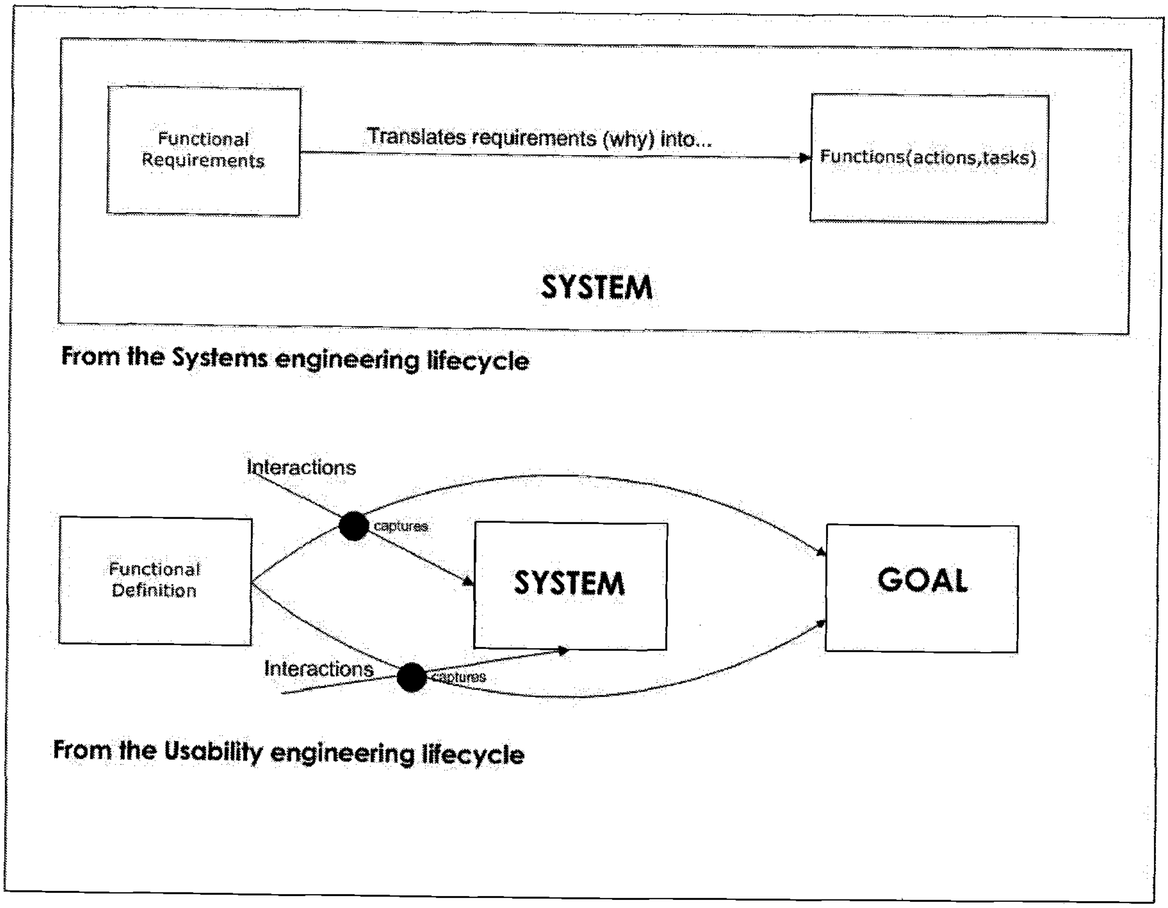


Figure 5: Figure shows how the functional definition stage of the usability engineering lifecycle bypasses the system and how the functional requirements stage of the systems engineering lifecycle is involved within the system.

Since use cases do not deal with the system, this can be problematic in situations where several decisions are to be made based on functional requirements, which happens to be a fundamental and important step in the usability engineering lifecycle. As several design decisions depend on producing effective functional requirements in the usability engineering lifecycle, systems engineering can thus really help by integrating several systems engineering concepts (as the case may be), like functional modeling—for example, IDEF0 modeling (described below)—into the lifecycle. This would enable the usability engineering lifecycle to benefit from the many advantages of following a systematic systems engineering method.

A revised usability engineering lifecycle, which includes integrating the systems engineering method, is shown in Figure 6.

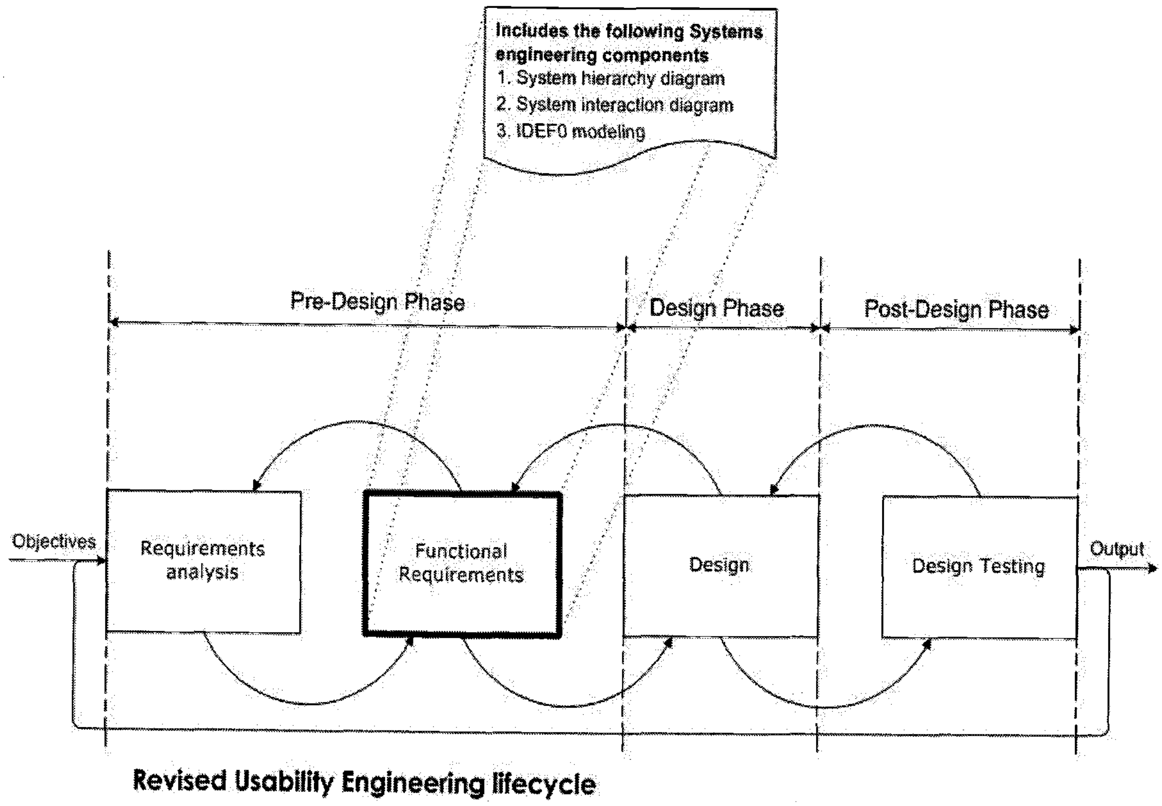


Figure 6: Figure shows the revised usability engineering lifecycle with key components of the systems engineering included in the functional requirements stage of the usability engineering lifecycle.

2.5.4 Summary of Section

As of today, systems engineering is practiced to solve complex engineering processes. Although elements of systems engineering are embedded in all engineering endeavors, many engineering projects do not seem to benefit from the numerous advantages that systems engineering has to offer. Usability engineering is one of those disciplines.

Although the usability engineering lifecycle looks pretty straightforward and easy to follow and implement, in order to claim product success the end user needs to confirm that the product is indeed "usable." Considering the fact that a user using software with a graphical user interface or GUI interacts almost all the time with the interface, software usability is one of the main criteria to ensure product success. The usability engineering lifecycle has several steps that can make a product usable, but with a stricter and better defined approach to the whole process, usability of products can be taken a notch higher.

Systems engineering is a discipline that develops and exploits structured efficient approaches to analysis and design to solve engineering problems of varying complexity levels. Although one of the disadvantages of the process is the amount of time involved, once implemented it can improve efficiency and effectiveness and improve satisfaction, attributes necessary to term a product usable.

Although there are several areas in the usability engineering lifecycle where systems engineering methods can be applied, the functional requirements or definition stage is one of the most important aspects in the usability engineering lifecycle. The systems engineering method of applying a modeling approach to the functional requirements stage of usability engineering is thus a small but significant step in integrating systems engineering with usability engineering.

2.6 Research Objectives

The overall objective of this thesis was two-fold: (1) Investigate usability of search engines in small screen devices, where two different types of search engines were compared to find the better between the two, and to compare and contrast their strengths and weaknesses; (2) Use a systems engineering approach to develop an integrated usability-system engineering process, by combining the major advantages or strengths of systems engineering and usability engineering

To achieve the first objective, the author did a study of usability methods for small screen devices. Based on the study, an experiment was conducted, the data collected was analyzed, and the better of the two search engines was determined. For the second objective, the author combined systems engineering methods with usability methods to develop an integrated process. The process developed to meet the second objective was actually applied to meet the first objective.

3 Research Methodology

3.1 Overview of Chapter

The overall purpose of this chapter is to show how systems engineering and usability engineering were integrated, and to compare the usability of two search engines for PDAs. Figure 1 provides an overall plan for the study. Analysis of the search engine user system (1) was carried out in parallel with determining (2) a list of usability metrics for search engine functions. An experiment (3) was conducted based on the information collected from (1) and (2) and the analysis (4) was done based on data collected from the experiment.

3.1.1 Overall Plan for the Study

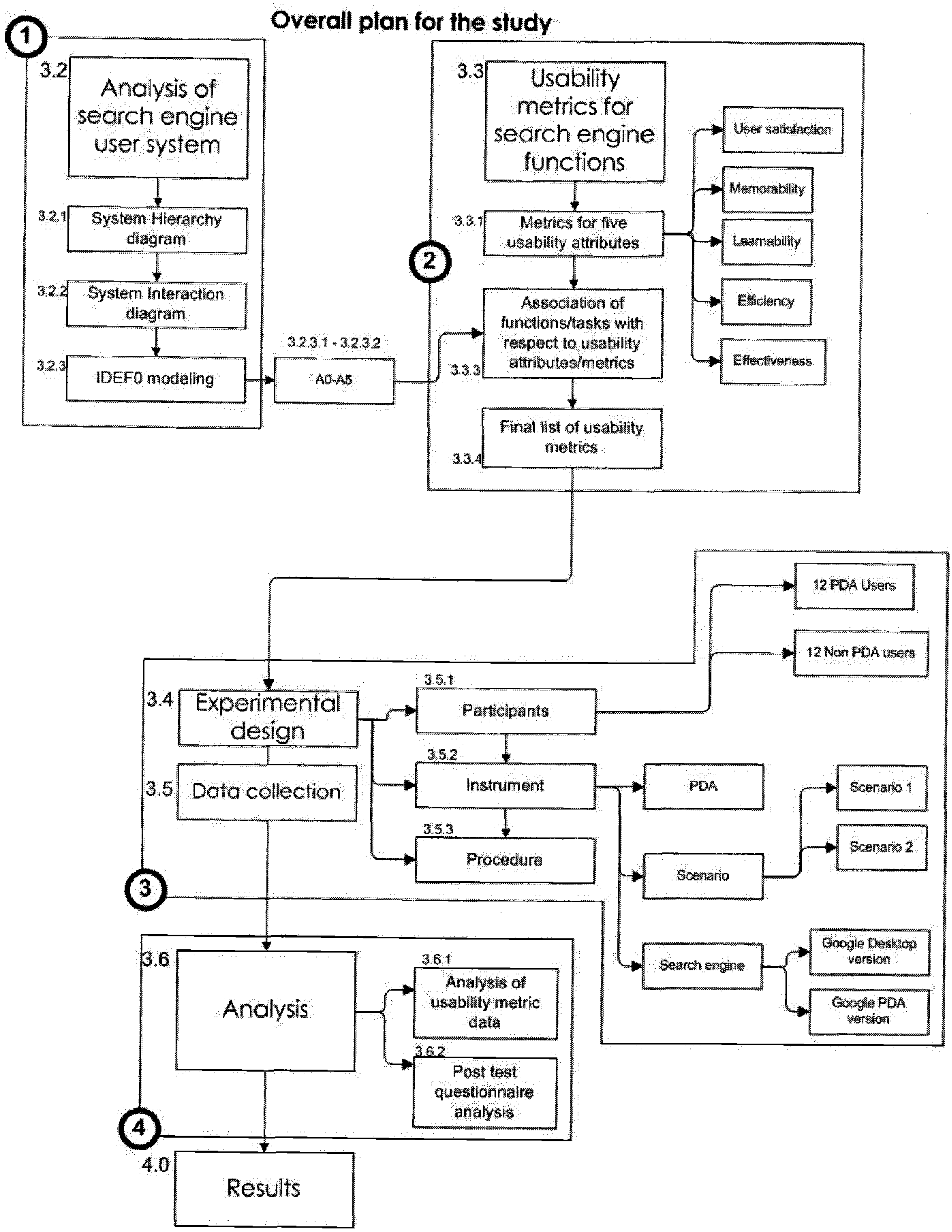


Figure 7: Overall plan for the experiment mapped to sections of this chapter.

3.2 Analysis of Search Engine User System

The analysis of the search engine system started with creation of the system hierarchy diagram, which was followed by the system interaction diagram. The diagrams aided in providing a foundation for modeling, explained in detail in Section 3.2.3 below.

3.2.1 System Hierarchy Diagram

A system hierarchy diagram is used to represent the overall architecture of a system to be evaluated. This diagram illustrates how the product is broken down into chunks. The system's main objective was to search the Web using the PDA. The system was broken down to smaller and smaller subsystems. Based on the system hierarchy diagram, a system interaction diagram was created to better understand the interactions within the system. Figure 8 shows the system hierarchy diagram.

Search engines were broken down based on software and hardware. Software could be further broken down into spiders/robots, which indexed the databases, and the graphical interface, which displayed the results. Hardware was broken down into a server, which hosted the database.

The **PDA** is made up of the hardware components and software powering the PDA. Hardware was broken down into display, controls, battery, and wireless card. The software for the PDA was broken down into the operating system and the browser.

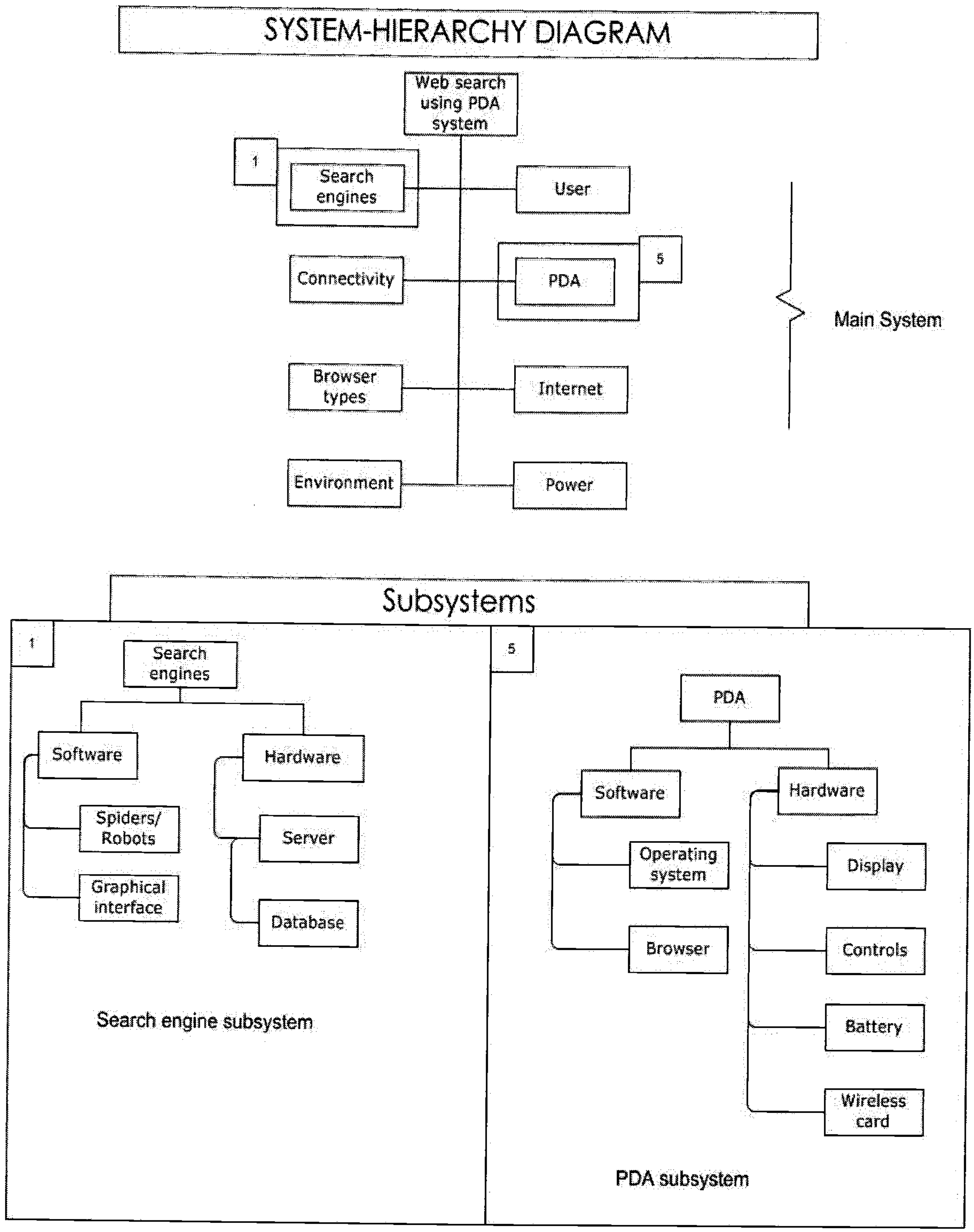


Figure 8: System Hierarchy Diagram. The figure shows the overall architecture of Web search using a PDA. The main system is then broken down into smaller chunks.

3.2.2 System Interaction Diagram

The system interaction diagram is useful for system structuring purposes and represents system functionality. In Figure 9, a continuous line arrow represents information, and the flow of energy is represented by dashes.

The two important aspects of the system, the search engine and the PDA, were broken down based on software and hardware components. The search engine consists of software in the form of spiders or robots, responsible for indexing the pages, and the graphical user interface, responsible for displaying the search results. On the hardware front, the search engine was broken down into an indexing and retrieval program responsible for indexing and retrieving search results, a search engine server used for storing search-related components, and also the search engine's database index storing search queries.

The PDA was broken down to the hardware and software level too. The hardware front of the PDA consisted of the display, which essentially displayed the search results the search engine produced, and also provided possible interactions between the PDA and the user. Buttons and a stylus for more precise control of the PDA actions essentially operated the controls of the PDA. The PDA was battery-powered when mobility was desired, and at other times electricity-powered. The operating system was the main part on the software front, and browsers were the only way the user could interact with the World Wide Web.

Interactions between these two main system components and other parts of the system, like the wireless network, the Internet, and others, were then shown. Although both the system hierarchy diagram and system interaction diagrams are not mandatory procedures prior to the IDEF0 modeling process (see 3.2.3 and 3.2.4, below), they do provide a foundation for the IDEF0 methodology and can be used as guiding tools.

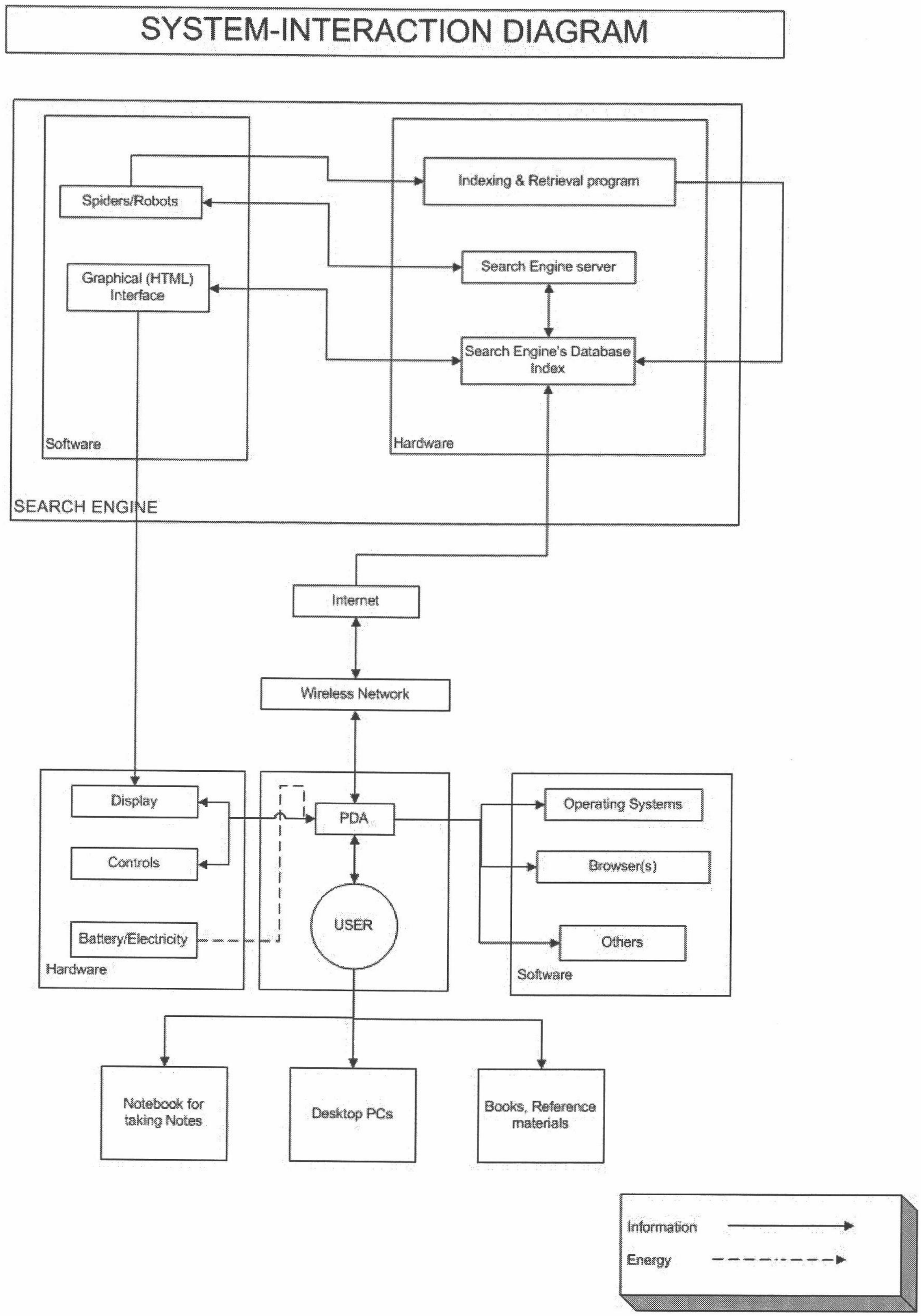


Figure 9: System Interaction Diagram. The figure illustrates the various system functionalities.

3.2.3 IDEF0 Modeling

System Architect, a product of Popkin™ software, was used for modeling in this thesis. Microsoft Visio can also be used for such modeling; however, it does not offer the same level of functionality that System Architect provides. Microsoft Visio can be used as a fast alternative to quickly transfer ideas from a paper to an electronic version. The IDEF0 models used in the thesis were developed using a combination of System Architect and MS Visio, although other tools can also be used for IDEF0 modeling.

3.2.4 IDEF0 as a Systems Engineering Method

Although systems engineering has several well-known methods, the author makes an assumption that IDEF0 is twice more likely to be used than any other method. A list of advantages, detailed later in this section, explains why IDEF0 may be the most used systems engineering method to date.

IDEF0 (Integration DEFinition language 0) is based on SADT™ (Structured Analysis and Design Technique™), developed by Douglas T. Ross and SofTech, Inc. IDEF0 is neither data flow nor workflow diagramming. Data flow diagramming is about automating a process in the most efficient way, whereas workflow diagramming deals with how an operation is conducted (Hill, 1995). In its original form, IDEF0 included both a definition of a graphical modeling language (syntax and semantics) and a description of a comprehensive methodology for developing models. (Hill, 1995)

3.2.5 Description of the Top-Level IDEF0 Model

IDEF0 may be used to model a wide variety of automated and non-automated systems. An IDEF0 model is a graphic description of the functions or activities of a system or subject that is developed for a specific purpose and from a selected viewpoint. A generic top-level A-0 IDEF0 model is as shown in Figure 10.

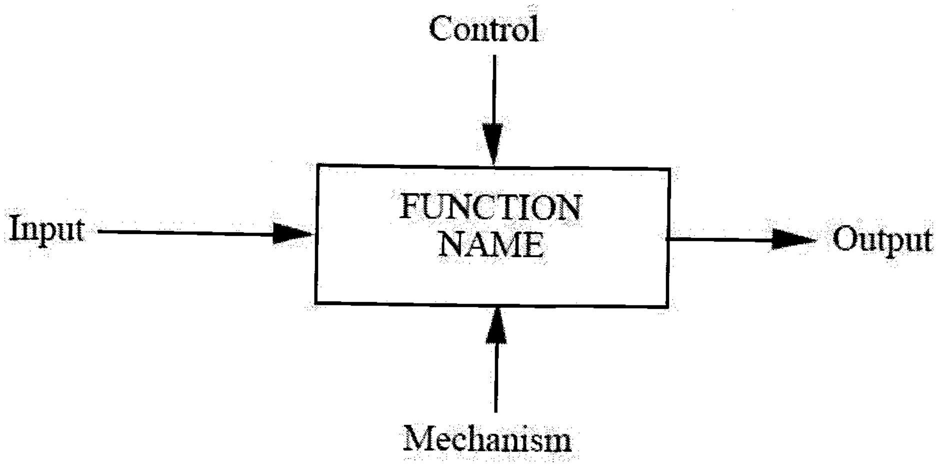


Figure 10: Diagram showing the top level of an IDEF0 model.

An IDEF0 model contains three types of inputs and one type of output to and from a function box, represented by arrows. Arrows do not represent data flow or sequence as they do in traditional flow diagrams; they represent data or objects that interact with the function (Hill, 1995). IDEF0 arrows are defined as follows:

- **Input Arrow**: The class of arrows that express IDEF0 Input, i.e., the data or objects that are transformed by the function into output. Input arrows enter the left side of an IDEF0 box.
- **Control Arrow**: The class of arrows that express IDEF0 Control, i.e., conditions required to produce correct output. Data or objects modeled as controls may be transformed by the function, creating output. Control arrows enter the topside of an IDEF0 box.
- **Mechanism Arrow**: The class of arrows that express IDEF0 Mechanism, i.e., the means used to perform a function; Mechanism arrows connect to the bottom side of an IDEF0 box.
- **Output Arrow**: The class of arrows that express IDEF0 Output, i.e., the data or objects produced by a function. Output arrows are associated with the right side of an IDEF0 box.

Figure 11 depicts the top-level function of the IDEFO model developed in this study. This top-level function transforms a PDA in an off state (represented as an IDEF0 input) into a PDA, which has the displayed results (the corresponding IDEF0 output).

The user who is in a state ready for search is transformed into a user who views results displayed on the PDA. The function is performed by the PDA and the user (represented by IDEFO mechanisms). Numerous factors constrain, facilitate, and guide the function (represented as IDEF0 controls). These include factors affecting search on the PDA (e.g. mobile or fixed environment), search engine factors (e.g. technology of search engine), user preferences (e.g. large font size), user factors (e.g. experience using a PDA), and search goal (e.g. find information about PDA usability).

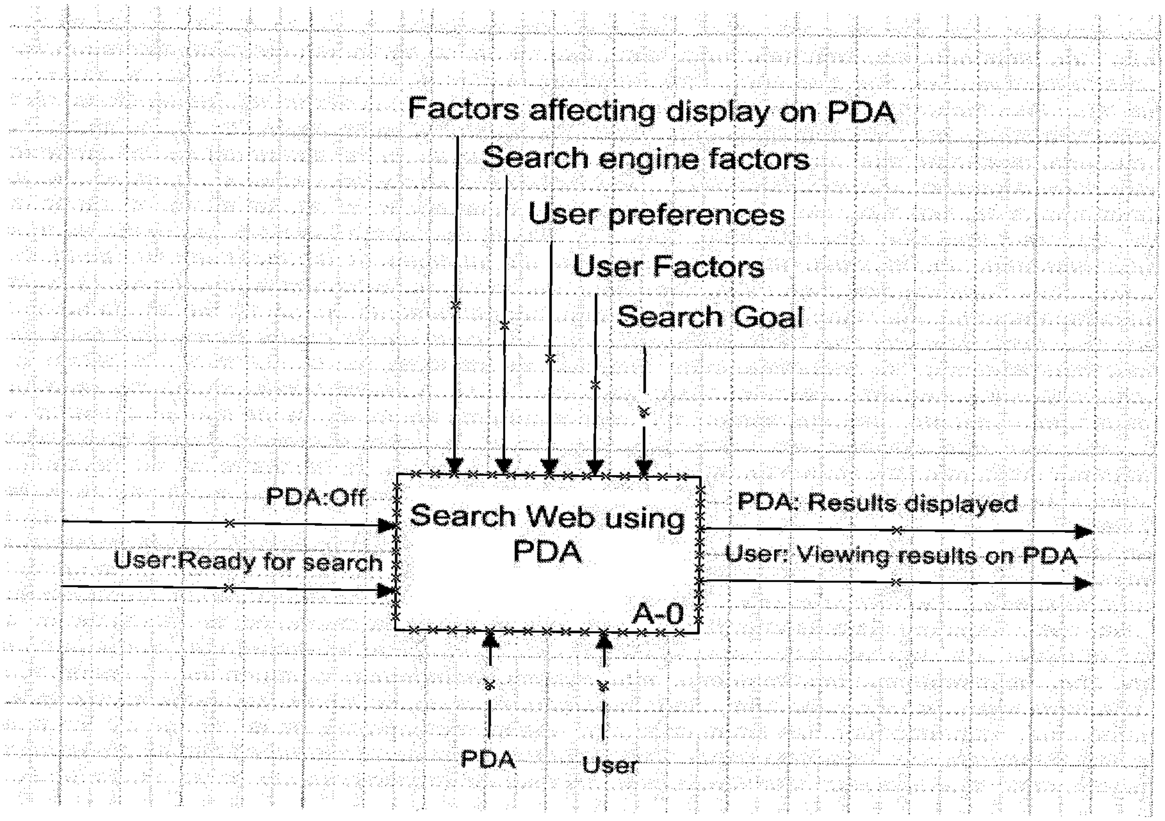


Figure 11: Figure showing top level (A-0) of the IDEF0 model used in the thesis.

3.2.6 Why Was IDEF0 Chosen for This Thesis?

IDEF0 was chosen for this thesis because of the author's familiarity with IDEF0 and also for the fact that the IDEF0 method was appropriate for the study.

The primary strength of IDEF0 is that the method has proven effective in detailing the system activities for function modeling, the original structured analysis communication goal for IDEF0. The description of the activities of a system can be easily refined into greater and greater detail until the model is as descriptive as necessary for the decisionmaking task at hand. The hierarchical nature of IDEF0 facilitates the construction of models that have a top-down representation and interpretation.

IDEF0 models can provide a solid baseline for applying metrics, which can be used for improving process and output. From a business perspective, it provides an abundance of documentation and also provides a sufficient understanding for attaching cost. Finally, it provides an architecture that can be studied, refined, and improved.

One of the major weaknesses with IDEF0 models is that they often are so concise that they are understandable only if the reader is a domain expert or has participated in the model development. Also, IDEF0 models tend to be interpreted as representing a sequence of activities, which they cannot. IDEF0 models can expose (1) processes that do not deliver outputs, (2) overly complex processes that need improvement, (3) "high cost" processes, (4) exorbitant process flow types and cycle times, and (5) redundant processes for elimination (Hill, 1999). The problems that IDEF0 presents are actually disguised as positive results, since the problems can be viewed as opportunities to make improvements.

3.2.6.1 A0 Level

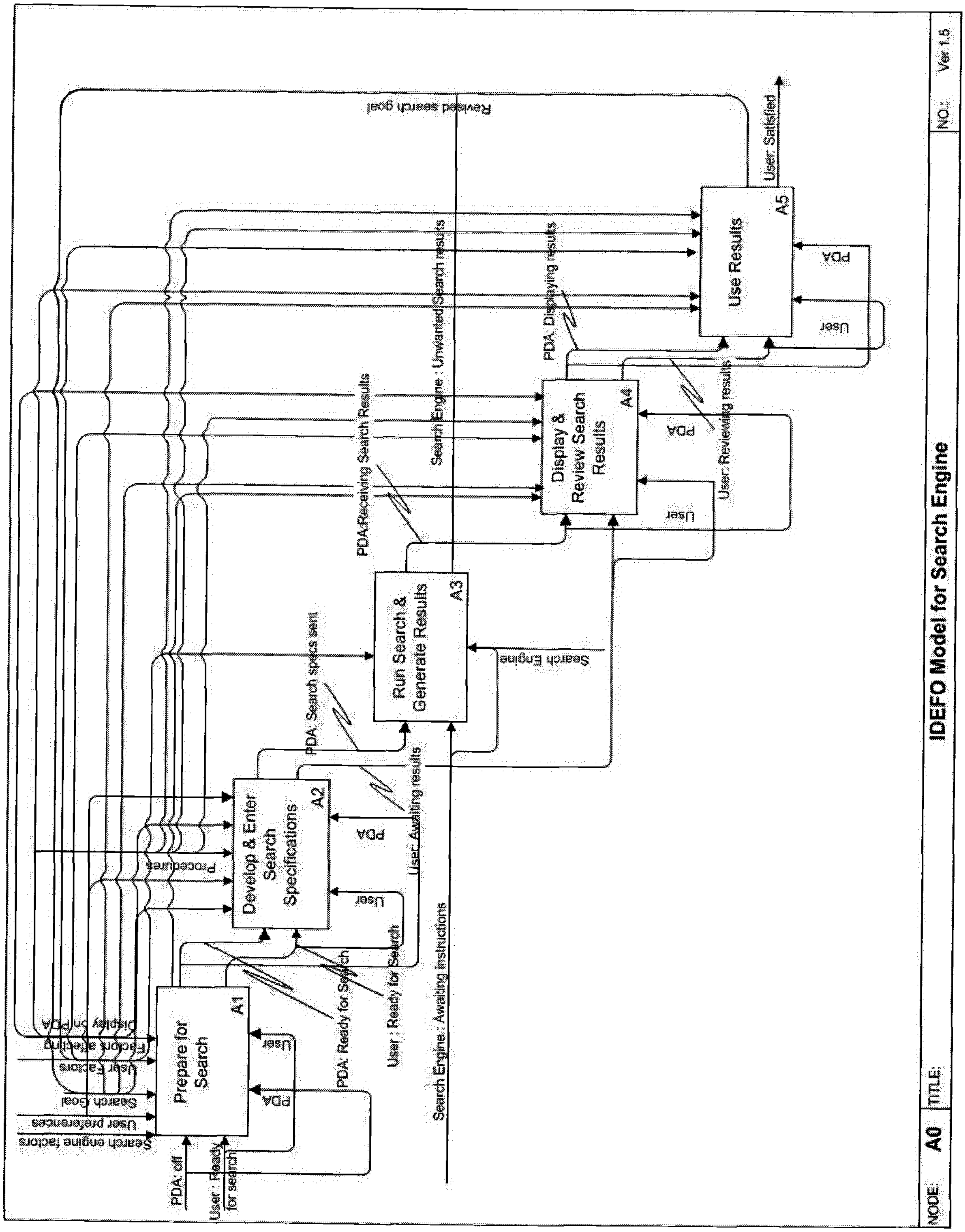


Figure12: A0 level. See Appendix III for the detailed breakdown of each level (levels A0 through A5).

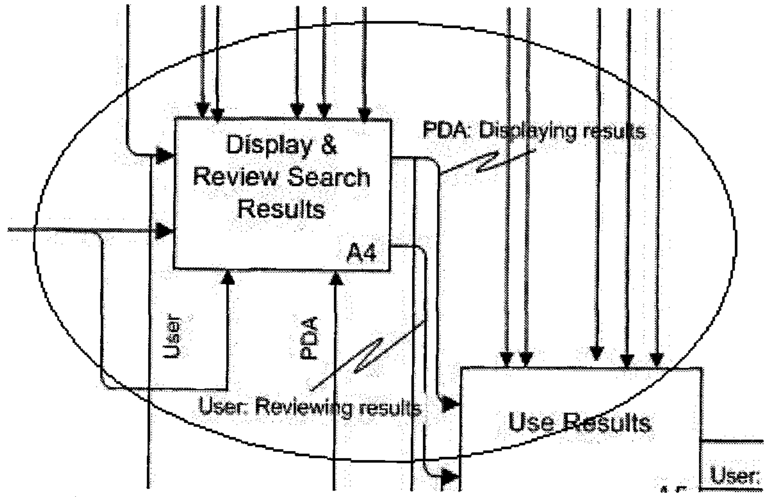


Figure 13: Sample taken from Figure 4 as an example.

As an example, Figure 12 depicts one of the many functions of the IDEFO model developed in the thesis. The A4 function, "display and review search results," transforms a PDA retrieving search results into a PDA displaying results. The user who is awaiting search results is transformed into a user viewing results displayed on the PDA. The PDA and the user perform the function. Factors like user preferences (e.g. large font size), user factors (e.g. experience using a PDA), factors affecting search on PDA (e.g. mobile, fixed environment), search engine factors (e.g. technology of search engine), and search goal factors (e.g. find information about PDA) constrain, facilitate, and/or guide the function.

In the same way, each level was broken down for the model. Appendix III shows the detailed breakdown of each level (levels A0 through A5).

Figure 13 (see above) shows level A0 of the model. Appendix III shows the detailed breakdown of each level (levels A0 through A5).

In the first part of Section 3.2, the overall plan for the experiment indicated that IDEF0 models were used for comparing with usability attributes/metrics. How IDEF0 models were applied to usability attributes/metrics is discussed later in Section 3.3.2.

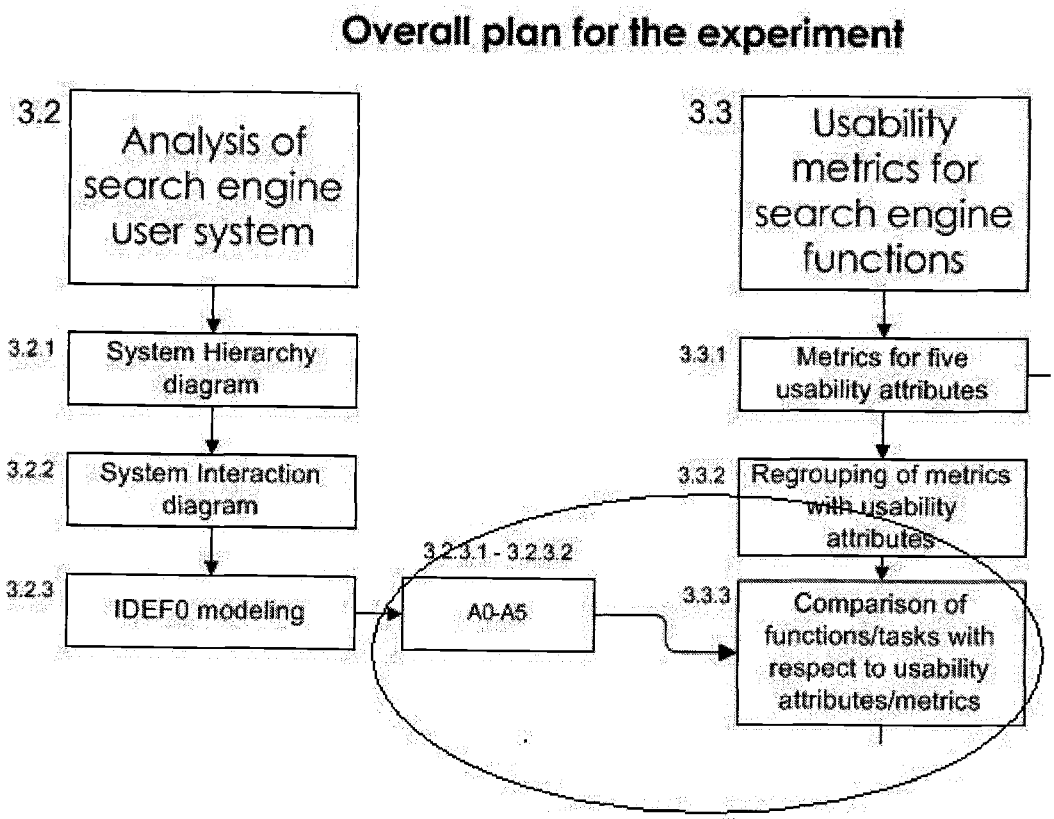


Figure 14: Figure showing how IDEF0 modeling was integrated with the usability metrics part

3.3 Usability Metrics

While doing the IDEF0 modeling, a parallel process of identifying appropriate usability metrics was done. Usability metrics provide a way to measure usability attributes, as explained in Section 4.1.3, 4.1.4. Possible usability metrics which could be used to measure the five attributes of usability (efficiency, effectiveness, user satisfaction, memorability, and learnability) were chosen.

3.3.1 Metrics with Regard to Five Usability Attributes.

Nielsen's full list of usability metrics (Nielsen, 1991) were arranged arbitrarily with respect to the usability attributes (Section 4.1.2) in a matrix form. The matrix approach was followed to group the metrics in a better manner with the attributes. This process also helped to eliminate recurring metrics for the attributes. The metrics were then classified according to being either qualitative or quantitative with regard to the five main usability attributes.

The main usability attributes considered were:

1. Effectiveness
2. Efficiency
3. User Satisfaction
4. Learnability
5. Memorability

The metrics were then classified according to being either quantitative, designated with a #, or qualitative, designated with a ❖.

The list of generic usability metrics arranged with respect to the attributes follows:

1. Effectiveness: The accuracy and completeness with which users achieve certain goals. Indicators of effectiveness include quality of solution and error rates.

Number of errors
Percent of tasks completed
Ratio of successes to failures
Number of features or commands used
Number of times interface misleads user
Number of times user loses control of the system

❖ Ease of entry and exit
❖ Ability to accommodate user's personal preferences

- ❖ Location of controls affecting the interface accessibility and usability
- ❖ Availability of shortcuts
- ❖ Means of providing feedback
- ❖ Knowledge and understanding required by user to use interface
- ❖ Skill level required to use the interface
- ❖ Standardization of interfaces with respect to others
- ❖ Consistency within the interface
- ❖ Ability to allow user to change settings or to initiate or perform a function
- ❖ Control attributes location affecting users accessibility and operability
- ❖ The speed with which the user must accomplish procedures or the time allowed for those procedures to be executed

2. Efficiency: the relation between (1) the accuracy and completeness with which users achieve certain goals and (2) the resources expended in achieving them. Indicators of efficiency include task completion time and learning time.

Time to complete a task
Time spent on errors
Time spent recovering from errors
Number of errors
Time spent using Help
Number of repetitions or failed commands
Number of times user needs to work around problem
Number of times user is disrupted by a work task

- ❖ Frequency of help or documentation use

3. User Satisfaction: the user's comfort with and positive attitudes towards the use of the system. User's satisfaction can be measured by attitude rating scales, such as Software Usability Measurement Inventory (SUMI).

Rating scale for usefulness of the product or service
Rating scale for satisfaction with functions and features
Number of times user expresses frustration or anger
Rating scale for user's perceived control

- ❖ Attributes of the design making user interface worthy of the user's trust
- ❖ Ability of the interface to accommodate the user's personal preferences
- ❖ Location of controls affecting the interface accessibility and usability
- ❖ Availability of shortcuts
- ❖ Means of providing feedback

4. Learnability: The system should be easy to learn so that the user can rapidly start doing some work

Time to learn

- ❖ Knowledge and understanding required by user to use interface
- ❖ Standardization of interfaces with respect to others
- ❖ Consistency within the interface
- ❖ User movement accuracy affecting ability of the user to achieve accuracy

5. Memorability: The system should be easy to remember, so that the casual user is able to return to the system after a time and not have to learn it all over again.

Number of features recalled by user

- ❖ Standardization of interfaces with respect to others
- ❖ Consistency within the interface
- ❖ Consistency of the interface with various principles

3.3.2 Association of Functions/Tasks with Usability Attributes/Metrics

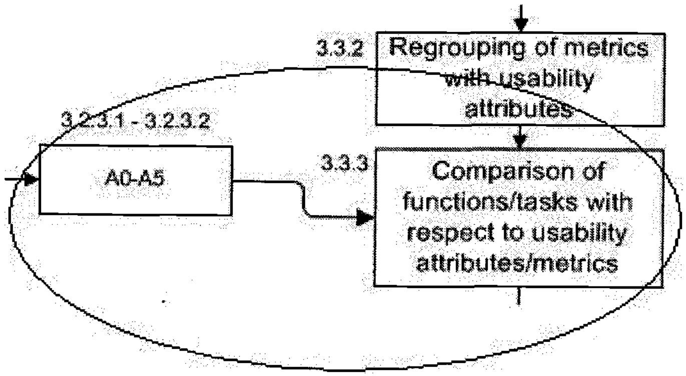


Figure 15: Figure showing how IDEF0 modeling was integrated with the usability metrics part for association

Functions/Tasks from the IDEF0 model were then put into an Excel worksheet and compared with the generic usability metrics of the five usability attributes in order to provide metrics, which were more applicable and specific to the functions/tasks at hand. Including all known usability metrics was well beyond the scope of this thesis, so a simple five-step exercise was done to reduce the number of metrics for the association.

1. All the metrics were grouped under their respective attribute.
2. Metrics which appeared under more than one attribute, were highlighted.
3. The highlighted metrics were retained only for the attribute that seemed like the best fit. The other highlighted metrics were eliminated.
4. The remaining metrics, apart from the highlighted ones, were then compared with the functions/tasks, and if there appeared no possible fit, they were eliminated. Due to a possibility of error on the author's part, the entire exercise was repeated three times. Repetition helped in eliminating metrics that did not quite logically associate with the attribute.
5. In the end, each attribute had a unique metric. This exercise produced a much cleaner, more manageable, and reduced list of metrics, which was used in the experiment.

Table 2 presents the reduced list of usability attributes/metrics. The author used the list extensively for the experiment, as described in the next section.

HF Considerations Matrix																			
Click here to view Help Page		Effectiveness																	
		Quantitative						Qualitative											
		Number of errors	Percent of tasks completed	Ratio of successes to failures	Number of features or commands used	Number of times interface misleads user	Number of times user loses control of the system	Ease of entry and exit	Ability to accommodate user's personal preferences	Control location affecting the interface accessibility	Availability of shortcuts	Means of providing feedback	Knowledge and understanding required by users to use interface	Skill level required to use the interface	Standardization of interfaces with respect to others	Consistency within the interface	Ability to allow user to change settings or to initiate or perform a function	Control attributes location affecting users accessibility and operability	Time allowed for procedures to be executed
Lvl	Function/Tasks																		
A0	Search Web Using PDA																		
A1	Prepare for Search																		
A11	Get Info for Search																		
A12	Start & configure PDA																		
A13	Start & configure Browser																		
A14	Default webpage opened																		
A2	Develop & enter search specs																		
A21	Get Knowledge for specs																		
A22	Configure Browser																		
A23	Develop Search Specs																		
A24	Enter Search Specs																		

Table 2: A sample of the final list of Usability Metrics which were grouped under their respective attribute. For the entire list refer section 3.3.1

E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	
	HF Considerations Matrix																													
		Effectiveness																		Efficiency										
	Click here to view Help Page	Quantitative						Qualitative												Quantitative								Qualitative		
		Number of errors	Percent of tasks completed	Ratio of successes to failures	Number of features or commands used	Number of times interface misleads user	Number of times user loses control of the system	Ease of entry and exit	Ability to accommodate user's personal preferences	Control location affecting the interface accessibility	Availability of shortcuts	Means of providing feedback	Knowledge and understanding required by users to use interface	Skill level required to use the interface	Standardization of interfaces with respect to others	Consistency within the interface	Ability to allow user to change settings or to initiate or perform a function	Control attributes location affecting users accessibility and operability	Time allowed for procedures to be executed	Time to complete a task	Time spent in errors	Time spent recovering from errors	Number of errors	Time spent using Help	Number of repetitions or failed commands	Number of times users need to work around problem	Number of times user is disrupted by a work task	Frequency of help or documentation use	Rating scale for usefulness of the product or service	Rating scale for satisfaction with functions
Lvl	Function/Tasks																													
A0	Search Web Using PDA																													
A1	Prepare for Search																													
A11	Get Info for Search																													
A12	Start & configure PDA																													
A13	Start & configure Browser																													
A14	Default webpage opened																													
A2	Develop & enter search specs																													
A21	Get Knowledge for specs																													
A22	Configure Browser																													
A23	Develop Search Specs																													
A24	Enter Search Specs																													
A3	Run Search & generate results																													
A4	Display & review search results																													
A41	Get Knowledge & review																													
A42	Display results																													
A43	Review results																													
A44	Configure browser for review																													
A45	Revise query																													
A5	Use Results																													
A51	Get knowledge for Search																													
A52	Review & Display Results																													
A53	Advanced Search																													
A54	Revise query																													

Table 3: Metrics, which appeared under more than one attribute, were highlighted. The highlighted metrics were retained only for the attribute that seemed like the best fit. The other highlighted metrics were eliminated.

HF Considerations Matrix	Click here to view Help Page	Effectiveness								Efficiency					User Satisfaction					Learnability				Memorability				Others	
		Quantitative				Qualitative				Quantitative				Qualitative	Quantitative		Qualitative			Quantitative	Qualitative			Quantitative	Qualitative			Quantitative	Quantitative
		Number of errors	Percent of tasks completed	Number of features or commands used	Number of times interface misleads user	Ability to accommodate user's personal preferences	Ability to allow user to change settings or to initiate or perform a function	Control attributes location affecting users accessibility and operability	Time allowed for procedures to be executed	Time to complete a task	Time spent in errors	Time spent using Help	Number of times users need to work around problem	Frequency of help or documentation use	Rating scale for usefulness of the product or service	Number of times user expresses frustration or anger	Ability of the interface to accommodate the user's personal preferences	Location of controls affecting the interface accessibility and usability.	Means of providing feedback	Time to learn	Knowledge and understanding required by users to use interface	Standardization of interfaces with respect to others	User movement accuracy affecting ability of the user to achieve accuracy	Number of features recalled by user	Standardization of interfaces with respect to others	Consistency within the interface	Consistency of the interface with various principles		
Lvl	**Function/Tasks**																												
A0	Search Web Using PDA																												
A1	Prepare for Search																												
A11	Get Info for Search																												
A12	Start & configure PDA																												
A13	Start & configure Browser																												
A14	Default webpage opened																												
A2	Develop & enter search specs																												
A21	Get Knowledge for specs																												
A22	Configure Browser																												
A23	Develop Search Specs																												
A24	Enter Search Specs																												
A3	Run Search & generate results																												
A4	Display & review search results																												
A41	Get Knowledge & review																												
A42	Display results																												
A43	Review results																												
A44	Configure browser for review																												
A45	Revise query																												
A5	Use Results																												
A51	Get knowledge for Search																												
A52	Review & Display Results																												
A53	Advanced Search																												
A54	Revise query																												

Table 4: The final set of usability metrics were then compared with functions/tasks.

3.4 Experimental Design

As discussed in Section 2.4.5 of the literature review, several relevant and significant research papers have used the PDA as the primary model in their research, as opposed to other small screen devices. PDAs were also easier to obtain for the experiment, due to their easy availability within the College of Engineering, and there was a greater chance of finding participants who had used a PDA for the Internet than any other SSD. For all the above reasons, PDAs were used in the experiment for this thesis.

Getting participants who had prior experience using a PDA for the experiment from within the Oregon State University campus was a huge challenge. Since this thesis was not funded, compensating participants from outside the campus was not a feasible solution either. It was therefore decided to forego the Pilot study and start the actual experiment. The limitations of not doing a pilot study are discussed in the conclusions section.

3.4.1 Participants

Participants were recruited by bulletin board announcements and by word of mouth at Oregon State University. The participant population was not restricted to any gender or ethnic group. A total of 24 participants were recruited, which were later divided into two groups of 12 each. Out of the 24 participants, 12 participants had used a PDA before; the remaining 12 had never used a PDA before.

3.4.2 Experimental Setup

The experiment was conducted in one of the office spaces in the industrial engineering department at Oregon State University. Figure 16 shows the setup for the experiment. A fixed video camera recording both video and audio was used for capturing the facial expressions of participants. The videos were later analyzed on a case-by-case basis to provide data for the experiment. A PDA (HP Compaq iPAQ 720) was used as the SSD for the experiments. The PDA was connected to the College of Engineering's wireless network by means of a wireless card.

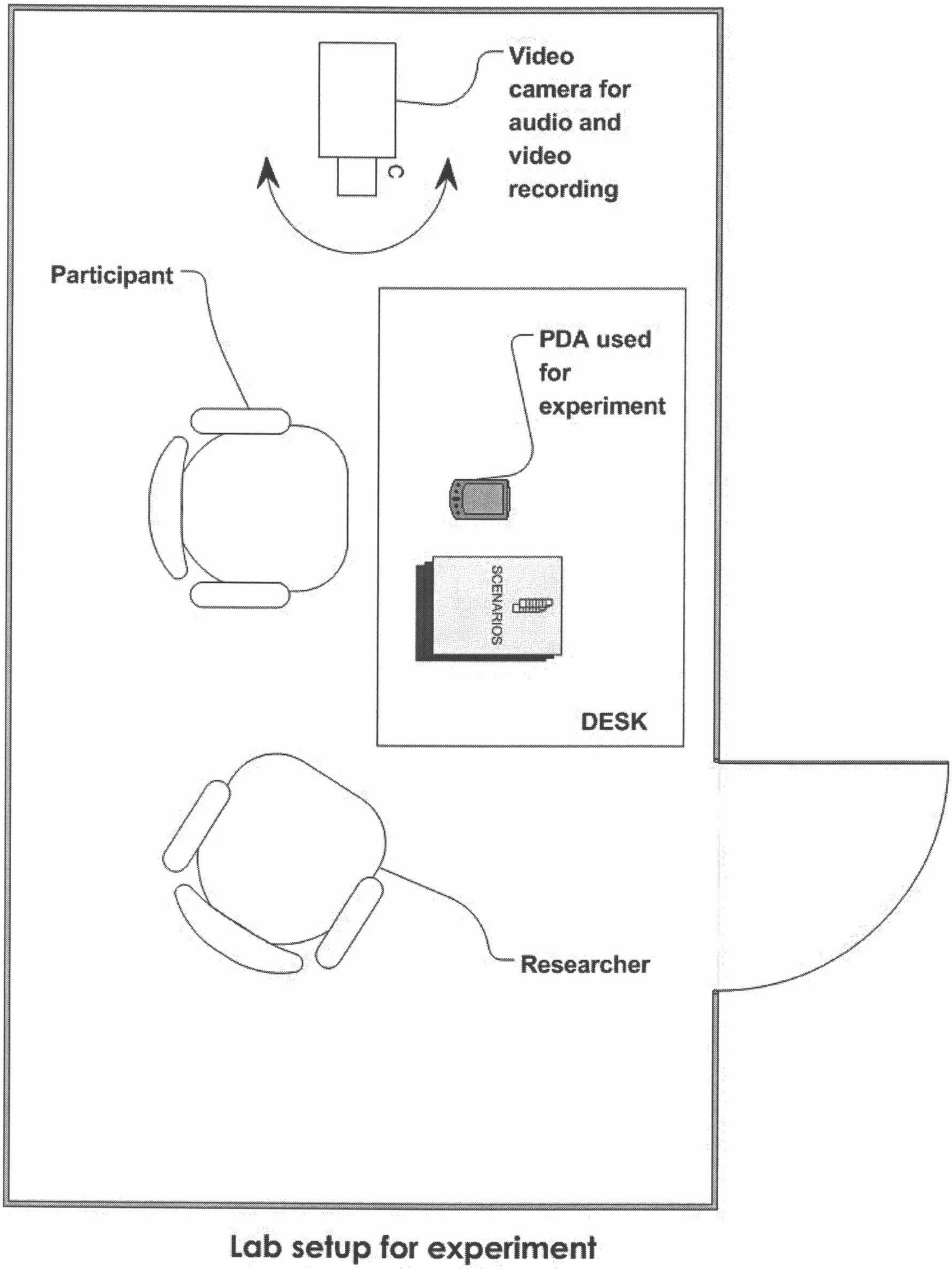


Figure 16: Figure shows the lab setup for the experiment. It consisted of a video camera recording the expressions of the participant. The participant was asked to perform a series of search tasks using the PDA

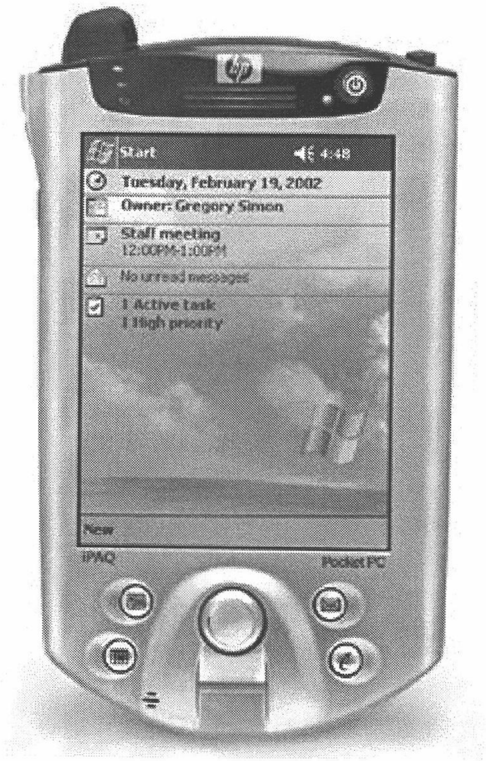


Figure 17: Figure of the PDA (HP Compaq iPAQ 720) used for the experiment.

3.4.3 Procedure

Two search engines, Google-desktop version and Google-PDA version, were chosen for this experiment, based on the search engines' popularity (Section 2.3.14) and also because of the fact that Google was the only search engine offering both desktop and PDA versions at the time this experiment was conducted.

Since the main goal of the study was to compare the usability of search engines in PDAs, gathering every bit of information from the experiment was a necessity. Video- and audio-taping and having the participants fill out questionnaires were thus of great help. Reviewing and analyzing video tapes was essential because this provided the investigator with a way to review facial expressions (reflecting satisfaction, frustration, anger, etc.) that would normally be very difficult to capture while the investigator was attending to other tasks, such as data collection and management of the experiment.

Questionnaires were designed to give an overall idea about the participant in terms of education, computer skills, etc. Analysis of the questionnaires allowed the investigator to gather data that would otherwise be difficult to gather while doing the experiment.

Before the data collection, an Informed Consent form was given to the participant. After reading it, the participant was invited to ask any question related to the experiment, and was asked to sign the form if he/she agreed to be part of the study.

The step-by-step procedure was as follows:

1. After the participant read and signed the Informed Consent form, the investigator gave him/her a brief demonstration of the PDA, which was as follows:
   - The investigator clicked the power button on the upper right hand corner of the PDA and started the PDA.
   - The investigator clicked on the PDAs Start button (similar to the desktop start function).
   - The investigator selected the Intemet Explorer icon, which appeared on the menu list after clicking Start, and the default home page was displayed on the browser.
   - A bright green light on top of the PDA indicated that the wireless network was working and the investigator was connected to the World Wide Web.
   - The investigator then explained to the participant the different icons/images onscreen and what they did (View, Tools, Back, Refresh, Home, Favorites, and Stop).
   - The investigator then demonstrated the entry of Web page addresses using the keyboard available on the PDA.

2. The PDA was then handed over to the participant, and the participant was given up to 15 minutes to make himself or herself familiar with the device. After familiarization with the device, the participant indicated to the investigator that he/she was ready to begin the experiment.

3. Video recording was then started and the participant was asked to open the default PDA browser (Internet Explorer in this case).

4. The investigator asked the participant to start the search engine (either the Google PDA or Desktop version) and perform a set of tasks for a Web search.

5. As mentioned earlier, each participant had 2 runs to complete. The order of the scenario and the search engine was switched randomly for all the participants. Table 3 gives a complete listing of all combinations for all the participants. To describe an experimental run in detail, the following section tracks participant 10 (P10) through one scenario. Sample screenshots are shown in Figures 18 and 19.

			Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
			Run	Run	Run	Run	Run	Run
PDA	SC1	G1	P1	P5	P9	P13	P17	P21
	SC2	G2						
	SC1	G2	P2	P6	P10	P14	P18	P22
	SC2	G1						
	SC2	G1	P3	P7	P11	P15	P19	P23
	SC1	G2						
	SC2	G2	P4	P8	P12	P16	P20	P24
	SC1	G1						

	PDA user
	Non-PDA user

SC1	Scenario 1
SC2	Scenario 2
G1	Google Desktop version
G2	Google PDA version

Example

	Run 1	Run 2
P10	SC1	SC2
	G2	G1

Table 5: This table shows how participants were allocated search engines and scenarios during the experiment. For example, Participant 10 had Scenario 1 and the Google PDA version during the first half of the experiment. For the second half, the participant had Scenario 2 and the Google desktop version for performing the tasks.

P10 had Scenario 1 and the Google PDA version in Run 1. For Run 2, P10 had Scenario 2 and the Google Desktop version. After the briefing about using a PDA/hand-held was done, P10 was handed over a copy of the scenario, where h/she was asked to assume the role of the character present in the scenario and follow the instructions mentioned in the copy of the scenario to achieve the end result. The author kept track of time taken to complete each task throughout the entire experiment.

Scenario 1: Main Page

John Smith works for a big computer firm in Austin, Texas, and is presently in Corvallis to fix some major flaws in the computers at his firm's Corvallis unit. After his work is done, he decides to visit his friend in Eugene. Help him find his way to Eugene and to the Portland Airport, from where he will catch a flight to take him to Austin, Texas.

For the tasks coming up, imagine yourself to be in John's shoes and carry out ALL the tasks John thinks would help him get to his destination.

The main page gave an overview of the scenario, and asked P10 to complete tasks as s/he proceeded.

Task 1 of 4

John is unsure of the best & cheapest way to get to Eugene. He opens his favorite search engine on the computer to find out. Flying and taking the train are out of the question since they are either expensive or do not fit his schedule. Left with no other option, he decides to drive.

What does John do next?

Looks for one or more than one popular **rental car companies** in **Corvallis** (Find a List)	
What P10 did	What the experimenter did
Typed "rental car companies Corvallis" in the search box. From the list of search results, clicked on the first search result, which took the participant to a Web page, which was quite different from what P10 expected. P10 traversed several times till s/he found what s/he was looking for. P10 informed the experimenter when s/he was ready to move on to the next task.	Recorded 9 minutes as the time taken to complete the task.

Makes a **comparison** of **prices** and settles for the cheapest rental car	
What P10 did	What the experimenter did
Typed in "price comparison rental cars Corvallis." Not finding anything relevant to the search in hand, revised the search criteria a couple of times till s/he found out exactly what the task demanded. P10 informed the experimenter when s/he was ready to move on to the next task.	Recorded 6 minutes as the time taken to complete the task. Recorded "satisfaction" expression.

Task 2 of 4

He meets his friend in Eugene and they catch up on old times. Their pleasant conversation is interrupted by a phone call from John's boss asking him to come to Austin ASAP. His tickets have already been purchased and he has to collect them from the Portland Airport. But since the earliest flight leaves Portland Airport in the next hour, he has no option but to fly from the Eugene Airport.

What does John do next?

Looks for information about **Eugene Airport**	
What P10 did	What the experimenter did
Typed in "Eugen airport" instead of "Eugene airport," but corrected the error before clicking the search button, and was able to find information on clicking the first search result. P10 informed the author when s/he was ready to move on to the next task.	Recorded 4 minutes as the time taken to complete the task. Recorded "satisfaction" expression. Recorded "spelling" error.

Looks for **flight options and pricing** for a **one-way trip** from Eugene to Portland (Find a List)	
What P10 did	What the experimenter did
Typed in" expedia" as the search criteria and clicked on the first search result, which was from expedia.com. P10 informed the experimenter when s/he was ready to move on to the next task.	Recorded 2 minutes as the time taken to complete the task.

Looks for **maps** showing Eugene Airport	
What P10 did	What the experimenter did
Typed in "Eugene airport map" as the search criteria. The first search result was a link about Eugene Airport. P10 clicked the link, found what s/he was looking for, and informed the experimenter that s/he was ready to move on to the next task.	Recorded 3 minutes as the time taken to complete the task. Recorded "satisfaction" expression.

Task 3 of 4

Leaving the car at Eugene Airport, John finally arrives at Portland Airport and gets his flight tickets. Checking the flight schedule, he sees that this flight has been cancelled and the next flight is in 3 hours. Cursing his luck, he decides to check the art galleries in the city. He rents a car from the airport and heads to the city. Before heading out, he decides to find out about the galleries in downtown and how he would get there.

What does John do next?

Looks for 3-4 **art galleries** in the **Portland city area** (List them)	
What P10 did	What the experimenter did
Typed in "art galleries in Portland" as the search criteria. P10 had to traverse a couple of times till s/he found what they were looking for. P10 informed the experimenter when s/he was ready to move on to the next task.	Recorded 4 minutes as the time taken to complete the task.

Looks for **Portland city** area maps	
What P10 did	What the experimenter did
Typed in "Portland city area maps" as the search criteria, and from the search results clicked on one of the map links, among an array of map-related links, just below the search box. P10 informed the experimenter when s/he was ready to move on to the next task.	Recorded 1 minute as the time taken to complete the task. Recorded "satisfaction" expression.

Task 4 of 4

The art galleries turn out to be impressive. Getting to and from one gallery to another is no problem, since they are in close proximity to each other—until he realizes that he is lost. He retraces his steps and heads back to the last gallery, where the manager generously offers to let John use the gallery computer. He also decides to check the flight schedules while he is online.

What does John do next?

Re-confirms his flight schedules from the **Portland Airport** (Just find a list of schedules of any airplane)	
What P10 did	What the experimenter did
Typed in "Portland airport" as the search criteria. Clicking the first search result took P10 straight to the Portland Airport Web page, where s/he was able to find what s/he was looking for by clicking on the flight schedules link. P10 informed the experimenter when s/he was ready to move on to the next task.	Recorded 3 minutes as the time taken to complete the task. Recorded "satisfaction" expression.

For both runs, the experimenter noted any instance of frustration, anger, or satisfaction. Later on, this was double-checked with the video tape recordings to makes sure data was captured correctly. Errors, along with instances of asking the author for help, were also noted and counted at the end. The author also made note of comments, if any, provided by the participant during the experiment.

During the first run, P10 expressed **5** instances of satisfaction, since s/he could finish the task easily. P10 misspelled the search criteria **once**, and had **3** comments during the experiment, which were duly noted by the experimenter.

For run 2, P10 had Scenario 2 and the Google Desktop version. Similar to Run 1, the author collected data based on his observations. P10 showed **1** instance of anger, and had **2** more comments, which the author duly noted during Run 2.

The same procedure for collecting data was used by the experimenter for the other tasks in the study. Appendix I provides both scenarios used and lists all tasks performed in the experiment.

5. The video recording was stopped upon completion of the session.
6. The experiment was repeated with the second search engine (Google PDA/Desktop version) and the second scenario, having a different set of tasks respectively.
7. All participants were asked to go through the same set of tasks, but the order of search engines and scenarios was switched for each participant. Table 5 shows the order of search engines and scenarios.

Enlarged view - Top half of the search results page as it appeared on the iPAQ 720

Screenshot of the search results page(Google Desktop version)on the iPaq 720

Enlarged view - Bottom half of the search results page as it appeared on the iPAQ 720

Figure 18: Screenshot of the search results page (Google Desktop version) on the iPAQ 720, and enlarged views of the top and bottom half of the search results.

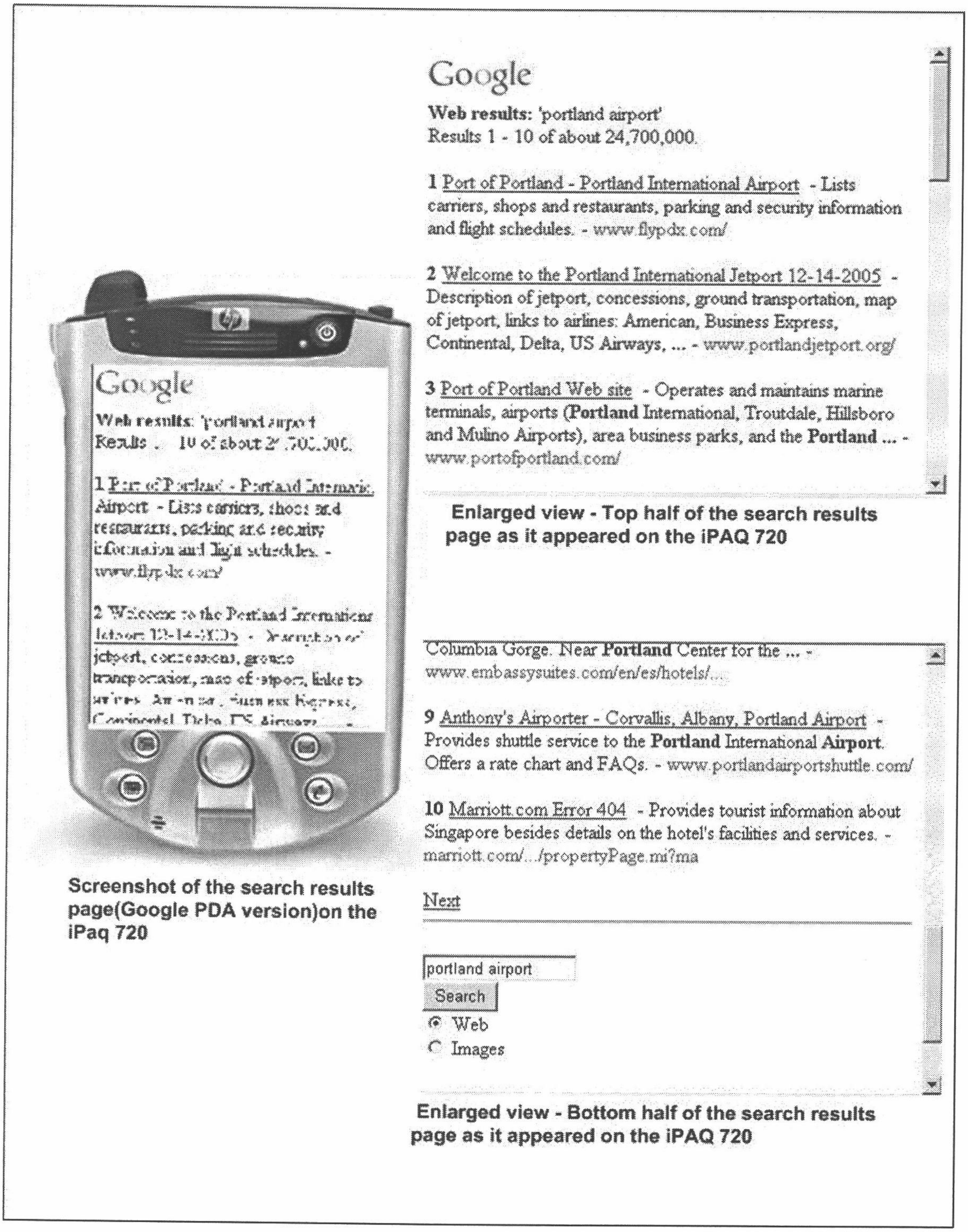


Figure 19: Screenshot of the search results page (Google PDA version) on the iPAQ 720, and enlarged views of the top and bottom half of the search results.

8. The participants were asked to fill out a post-experiment questionnaire at the end of the experiment. The questions related to experience using the Internet, search engines, and PDAs. Appendix II provides the entire questionnaire used in the experiment.

Data (e.g., time to complete task, number of errors, and types of emotions) was collected by means of video and audio recording, observation and questions related to the tasks, and a post-experiment questionnaire, which follows:

1. *How long have you been using the Internet?*
2. *In an average week, how often do you use the Internet?*
3. *In an average week, how often do you use a search engine?*
4. *Please circle each search engine you have used in the past year?*
5. *When did you first start using your primary search engine?*
6. *How often are you able to find the information you are looking for on your primary search engine?*
7. *Have you ever used a PDA before? (Please circle one)*
8. *Which PDA (manufacturer) have you used before?*
9. *Please indicate your PDA usage.*
10. *Have you used a PDA to perform a search before?*
11. *Did you use the PDA/hand-held version of the search engine?*

3.5 Analysis

StatGraphics 5.1 was used for analysis of the data collected during the experiment. All data was analyzed for normality and the residual plots were found to be normal. Since more than two sets of data were always involved while doing the analysis, Analysis of Variance (ANOVA) was chosen as the most appropriate method to do the statistical analysis and was performed to compare the results from Google desktop use with those from Google PDA use.

The following **independent** variables were considered.

Google desktop search engine

Google PDA search engine.

The **dependent** variables were:

(1) Time taken to complete task

(2) Total Number of errors, which were broken down further:

- Page not loading
- Unable to complete task
- PDA freezes
- Spelling mistake(s)
- Asks evaluator for help

(3) Emotions (Positive), which were broken down further:

- Satisfaction

(4) Emotions (Negative), which were broken down further:

- Frustration
- Anger

4 Experiment Results

Data collected was analyzed using StatGraphics, and a Post-test questionnaire was administered to participants after the experiment was completed. The data that was collected was transferred to MS Excel sheets, and all the questions were analyzed on a case-by-case basis. Categorized summaries and histograms were prepared for the following post-test questionnaire questions (3.4.3).

4.1 Experimental results

Using StatGraphics, normality of the data was verified and the residual plots were found to be normal. ANOVA was decided upon as the most appropriate method to do the statistical analysis.

4.1.1 ANOVA comparing the Google desktop version against the Google PDA version

An ANOVA was done comparing the Google desktop version against the Google PDA version with respect to task completion time, total number of errors and emotions (positive and negative).

	Desktop mean(SD)	PDA mean(SD)	p-value
Time taken to complete task	30.52(8.42)	29.41(8.21)	0.76
Total Number of errors	6.45(2.76)	7.16(2.98)	0.51
Emotions	5.95(1.13)	6.5(1.01)	0.44

Table 6: Google Desktop version Vs Google PDA version

Nothing was statistically significant in this case, failing to establish if either search engine was better with respect to the metrics.

4.1.2 ANOVA comparing the Google PDA users against Non PDA users

An ANOVA was done for comparing PDA users against Non PDA ones with respect to task completion time, total number of errors and emotions (positive and negative).

	Desktop mean(SD)	PDA mean(SD)	p-value
Time taken to complete task	27.08(7.85)	26.52(7.60)	0.02
Total Number of errors	5.58(2.52)	6.87(2.82)	0.13
Emotions	1.04(0.66)	0.66(0.65)	0.86

Table 7: PDA Vs Non PDA users

As was expected, Non PDA users took more time to complete the tasks than PDA users, as is evident from the p-value.

For the PDA and Non-PDA users, the means and standard deviations were calculated to give a better analysis of the data.

1. With regards to the **Time taken to complete task**, for PDA and Non PDA users, the mean and standard deviation were calculated:

	Std. Dev	Mean
Non-PDA	7.853295	27.08333
PDA	7.600837	26.5

Table 8: Standard deviation and mean for PDA and Non-PDA users

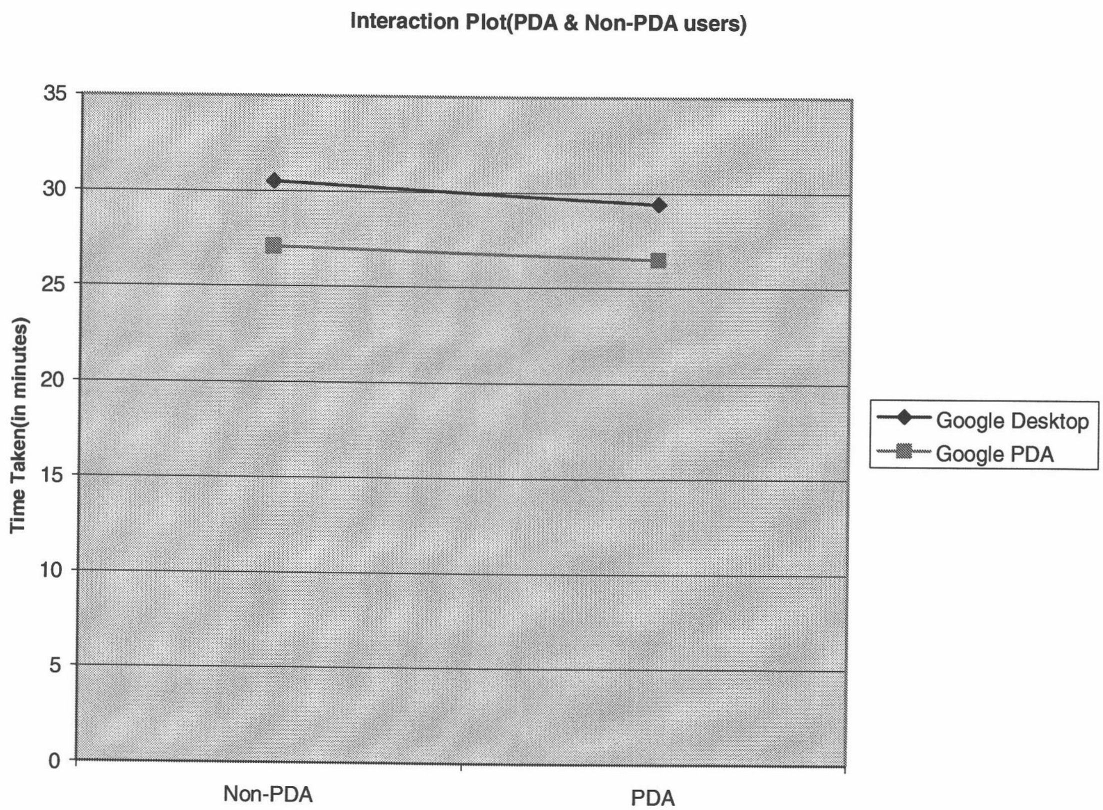


Figure 20. Graph showing the time taken (mean) by PDA and Non-PDA users to complete the tasks assigned to them.

2. With regards to the **Total Number of errors**, for PDA and Non PDA users, the mean and standard deviation were calculated:

	Std. Dev	Mean
Non-PDA	2.521123	5.583333
PDA	2.829431	6.875

Table 9: Standard deviation and mean for PDA and Non-PDA users

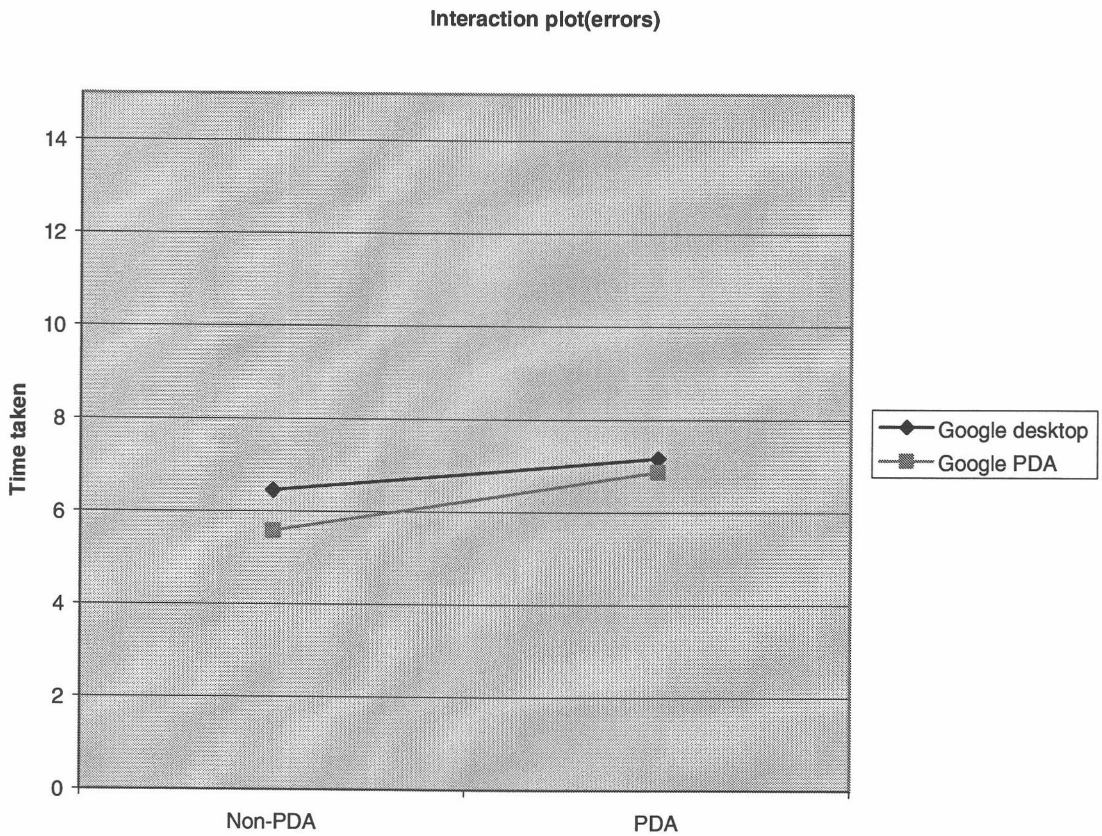


Figure 21. Graph showing the Total Errors (mean) by PDA and Non-PDA while completing the tasks assigned to them.

3. With regards to the **Emotions** displayed by PDA and Non PDA users, the mean and standard deviation were calculated:

	Std. Dev	Mean
Non-PDA	0.655686	1.041667
PDA	0.651339	0.666667

Table 10: Standard deviation and mean for PDA and Non-PDA users

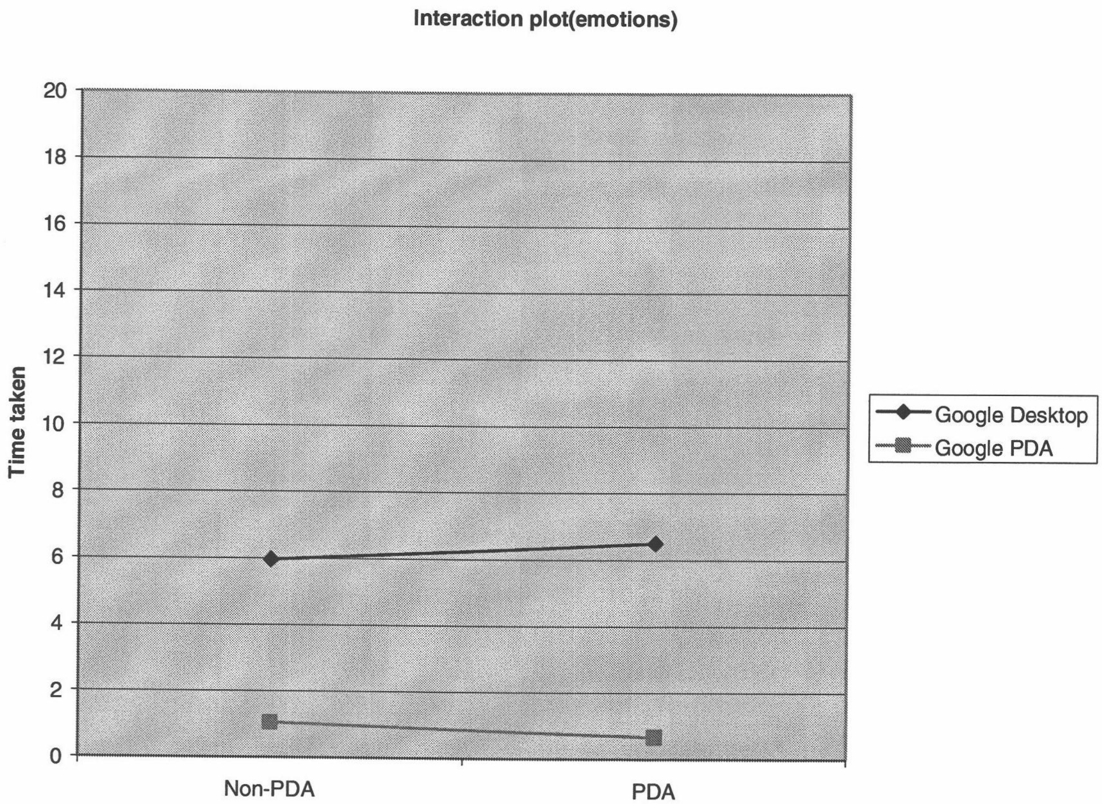


Figure 22. Graph showing emotions (mean) by PDA and Non-PDA while completing the tasks assigned to them.

4.1.3 Errors for Google versions and PDA, Non-PDA users

The total numbers of errors were then broken down to find if there was anything of statistical significance.

	Desktop mean(SD)	PDA mean(SD)	p-value
Page not loading	3.47(0.87)	4.15(1.02)	0.87
Unable to complete task	1.12(0.54)	0.74(0.44)	0.07
PDA freezes	2.17(0.64)	3.27(0.89)	0.91
Spelling mistake(s)	1.04(0.53)	0.76(0.74)	0.06
Asks evaluator for help	1.17(0.65)	0.96(0.32)	0.04

Table 11: Errors broken down and compared for the PDA, Non PDA and Google search engines.

Except Non-PDA users asking for more help, there was marginal significance among Non PDA users not being able to complete the task and having more spelling mistakes than PDA users.

4.2 Post-test questionnaire analysis

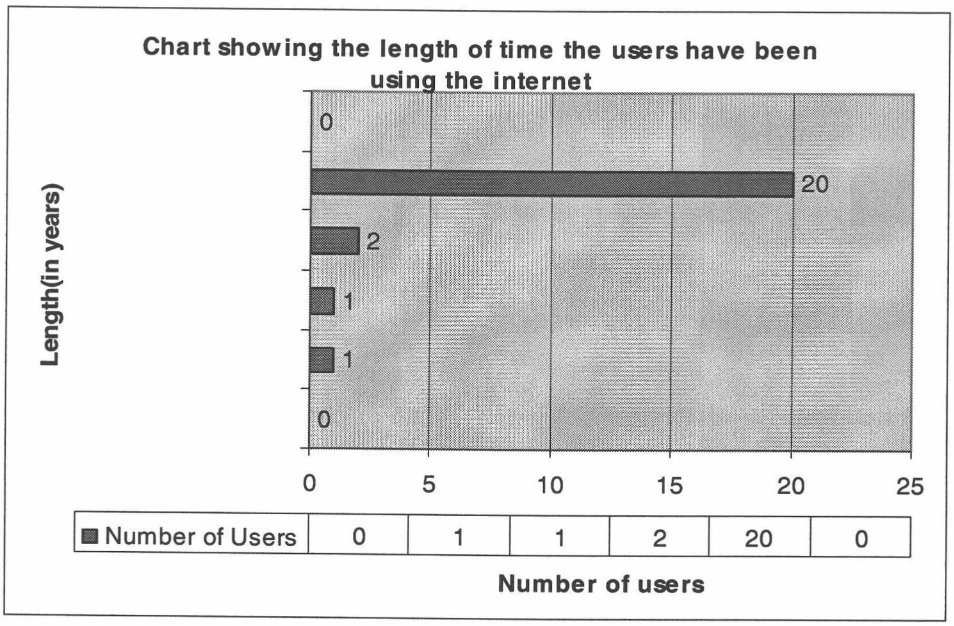
For the post-test questionnaire, participants were asked to fill in a questionnaire, which gave an idea about their familiarity with the internet, their computer background and experience and experience using a PDA. Appendix II shows the final questionnaire.

Question 1 addressed the length of time participants had experience using the internet. On average, PDA and Non-PDA users had more than 4 years of experience using the internet.

1. How long have you been using the Internet? (Please Circle one)

	PDA	Non PDA	Combined
> 6 months	0	0	0
1-2 years	1	0	1
2-3 years	0	1	1
3-4 years	0	2	2
4+years	10	10	20
Other	0	0	0

Table and graph showing Length of time participants used the internet.

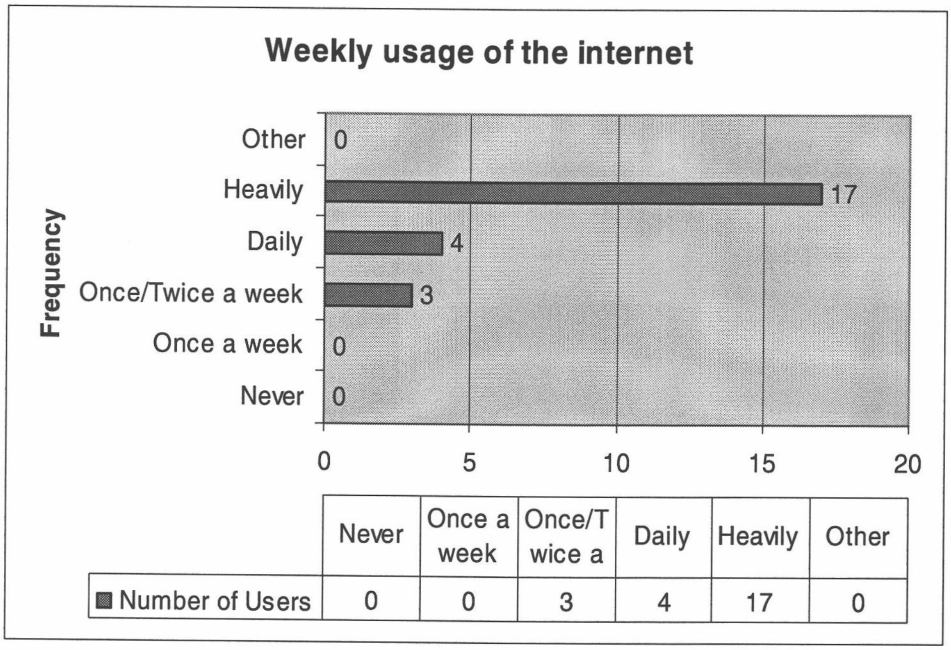


Question 2 addressed weekly internet usage of participants. On an average, PDA and Non-PDA users were found to be heavy users of the internet.

2. In an average week, how often do you use the Internet? (Please Circle one)

Never	0	0	0
Once a week	0	0	0
Once/Twice a week	1	2	3
Daily	0	4	4
Heavily	10	7	17
Other	0	0	0
	PDA	Non PDA	Combined

Table and graph showing Weekly internet usage of participants.

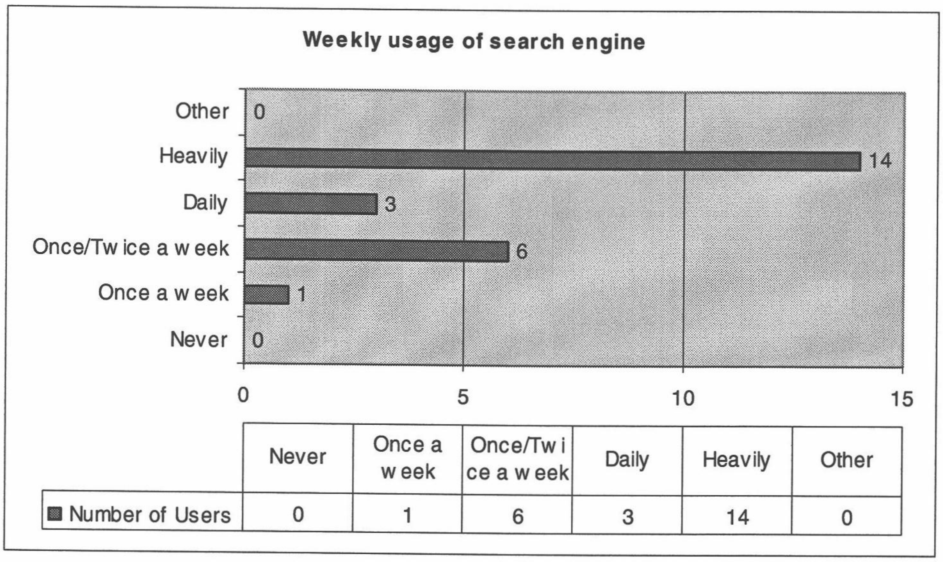


Question 3 addressed weekly search engine usage of participants. Most of the PDA/Non-PDA users used search engines heavily. Overall, most users used a search engine more than once or twice a week.

3. In an average week, how often do you use a search engine?(Please Circle one)

	PDA	Non PDA	Combined
Never	0	0	0
Once a week	0	1	1
Once/Twice a week	3	3	6
Daily	1	2	3
Heavily	8	6	14
Other	0	0	0

Table and graph showing Weekly search engine usage of participants.

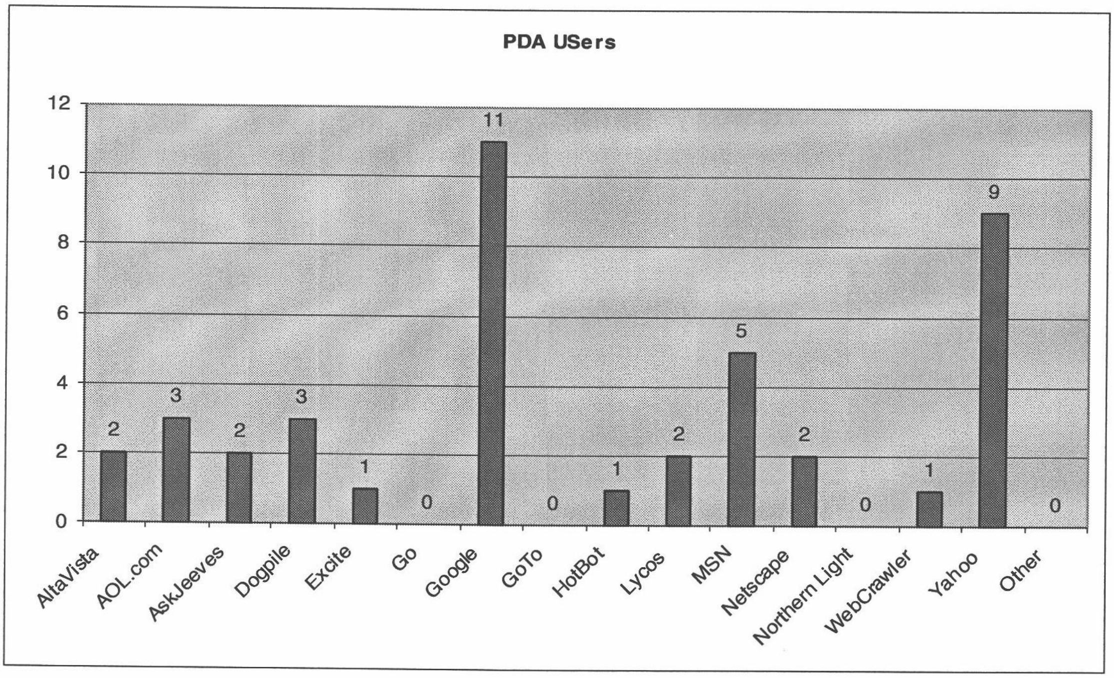


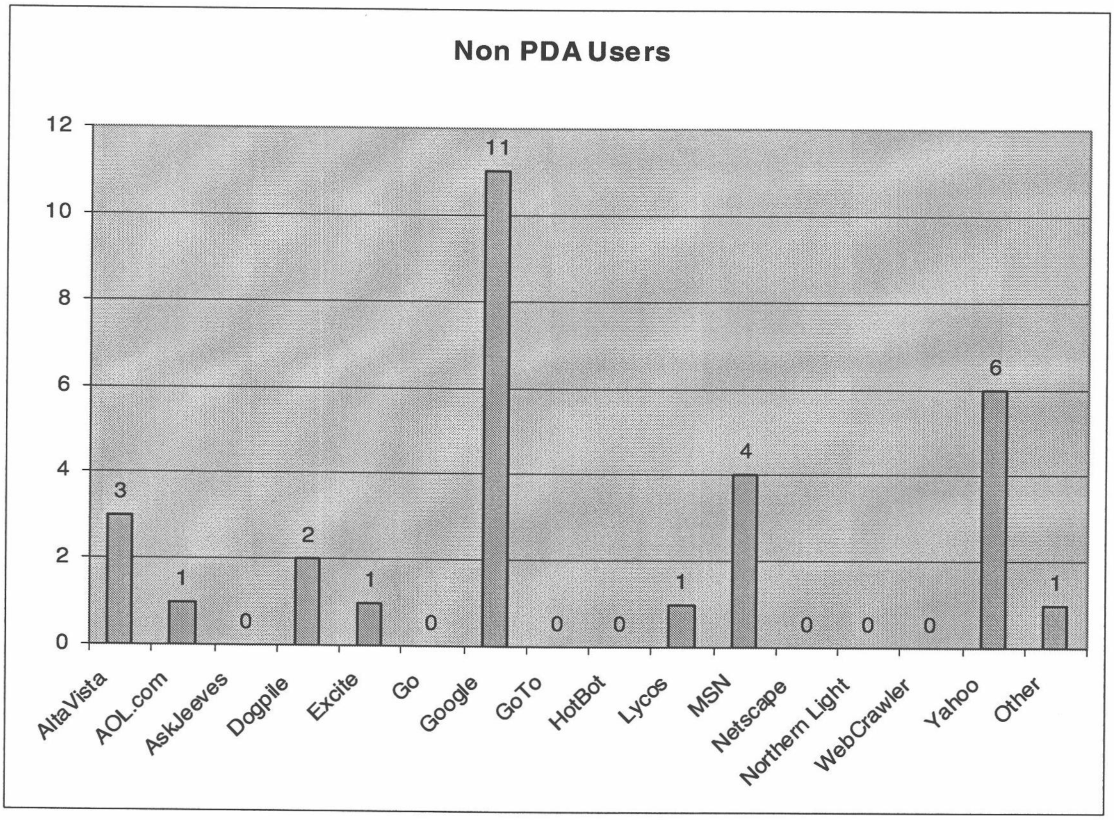
Question 4 addressed search engine used by participants in the year prior to this study (2003).Google was found out to be the most popular and most frequently used search engine among PDA and Non-PDA users.

4.Which of the following search engines have you used in the past year?

AltaVista	2	3	5
AOL.com	3	1	4
AskJeeves	2	0	2
Dogpile	3	2	5
Excite	1	1	2
Go	0	0	0
Google	11	11	22
GoTo	0	0	0
HotBot	1	0	1
Lycos	2	1	3
MSN	5	4	9
Netscape	2	0	2
Northern Light	0	0	0
WebCrawler	1	0	1
Yahoo	9	6	15
Other	0	1	1
	PDA	Non PDA	Combined

Graph showing Search engine used by participants before.



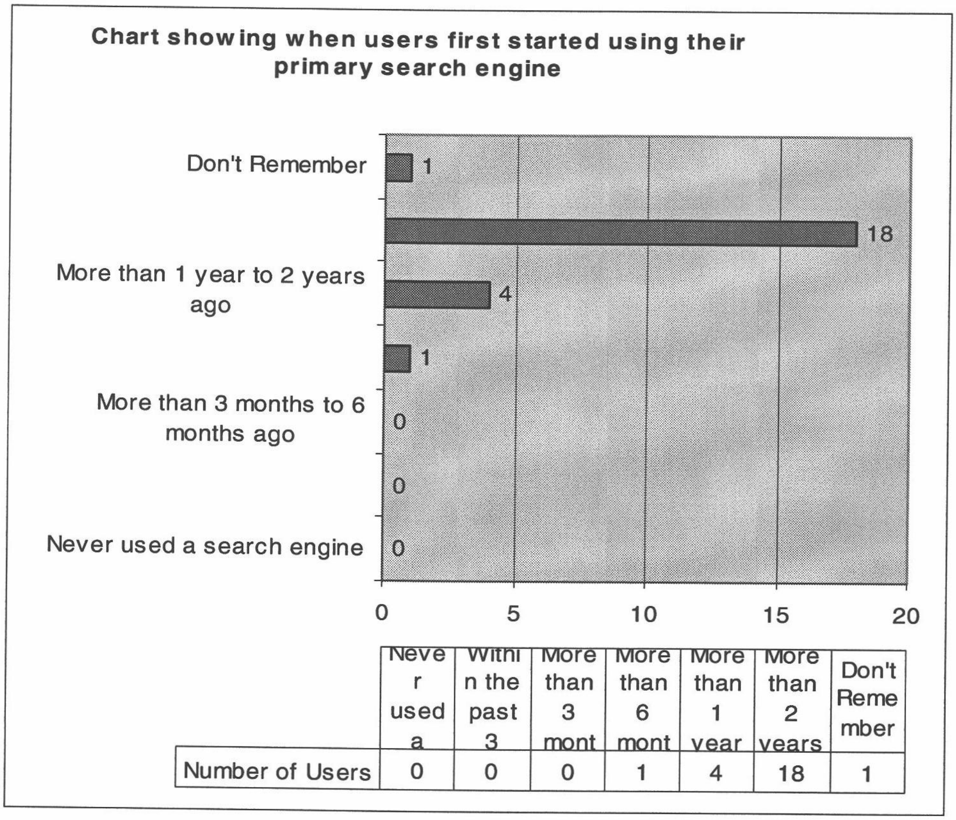


Question 5 addressed the first time participants used a search engine. Almost all the participants had started using a primary search engine almost two years before the experiment.

5.When did you first start using your primary search engine? (Select one)

Never used a search engine	0	0	0
Within the past 3 months	0	0	0
More than 3 months to 6 months ago	0	0	0
More than 6 months to 1 year ago	1	0	1
More than 1 year to 2 years ago	3	1	4
More than 2 years ago	7	11	18
Don't Remember	0	1	1
	PDA	Non PDA	Combined

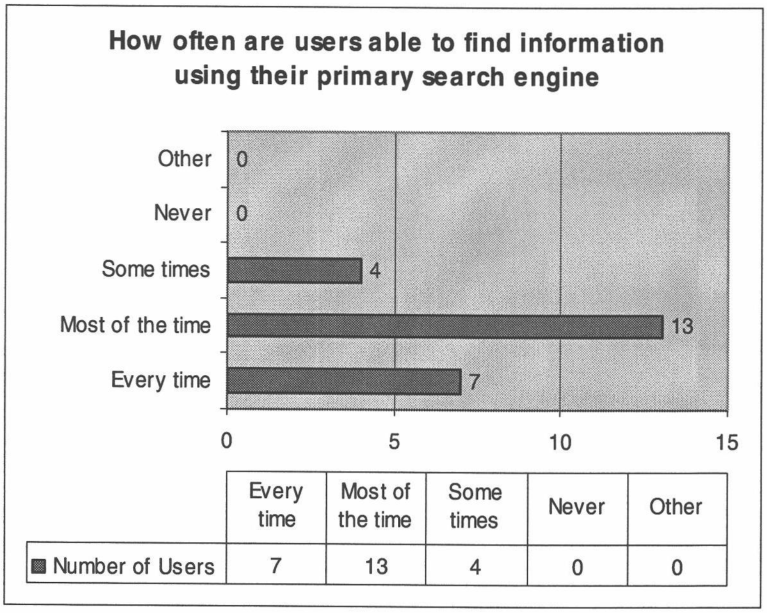
Table and graph showing First time usage of search engine by participants.



Question 6 addressed the issue of finding information using a search engine. Both PDA/Non PDA users were able to find information they were looking for most of the time and in a few cases every time.

How often are you able to find the information you are looking for on your primary search engine?	PDA	Non PDA	Combined
Every time	4	3	7
Most of the time	7	6	13
Some times	1	3	4
Never	0	0	0
Other	0	0	0

Table and graph showing Ability to find information using a search engine.

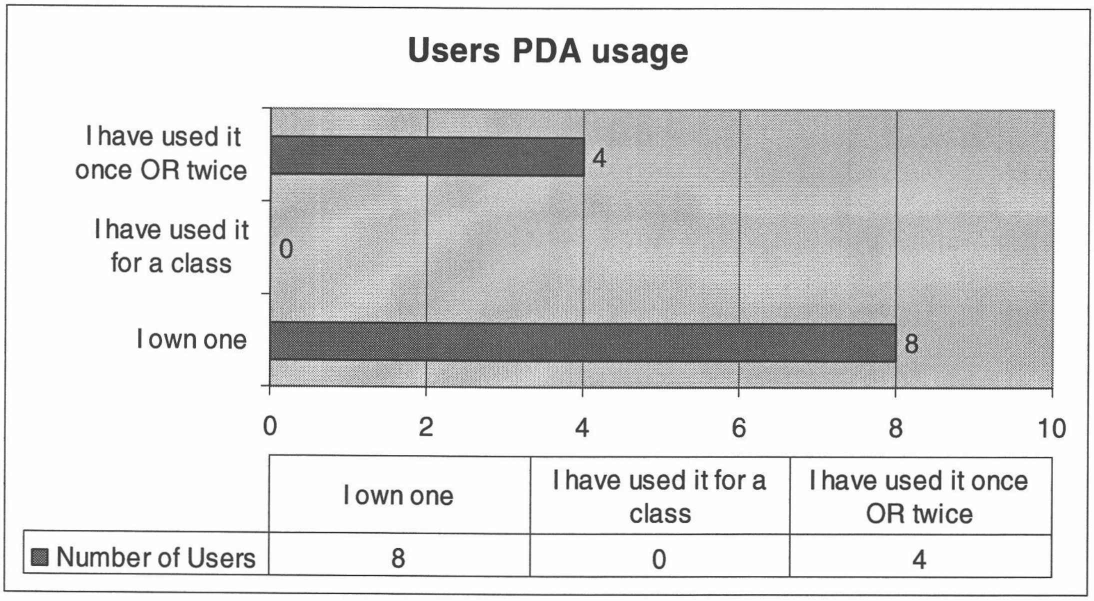


Question 7 addressed the issue of participants using a PDA. Out of the twelve participants who had used a PDA before, eight participants owned a PDA, whereas four participants had used a PDA once or twice.

7.Have you ever used a PDA before? If No, skip to question 12
If yes, please circle one OR more of the following

I own one	8
I have used it for a class	0
I have used it once OR twice	4
	PDA only

Table and graph showing Previous PDA usage.

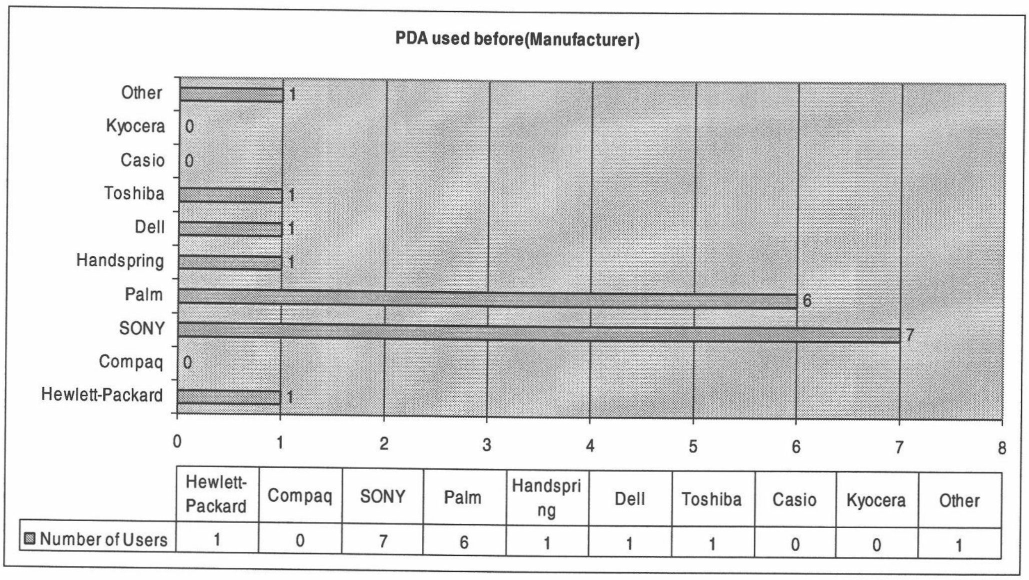


Question 8 addressed PDAs used by participants' before. Out of twelve participants, SONY and Palm seemed to be the favored PDA for users.

8.Which PDA (manufacturer) have you used before? (Please Circle one)

Hewlett-Packard	1
Compaq	0
SONY	7
Palm	6
Handspring	1
Dell	1
Toshiba	1
Casio	0
Kyocera	0
Other	1

Table and graph showing Brand of PDA used before.

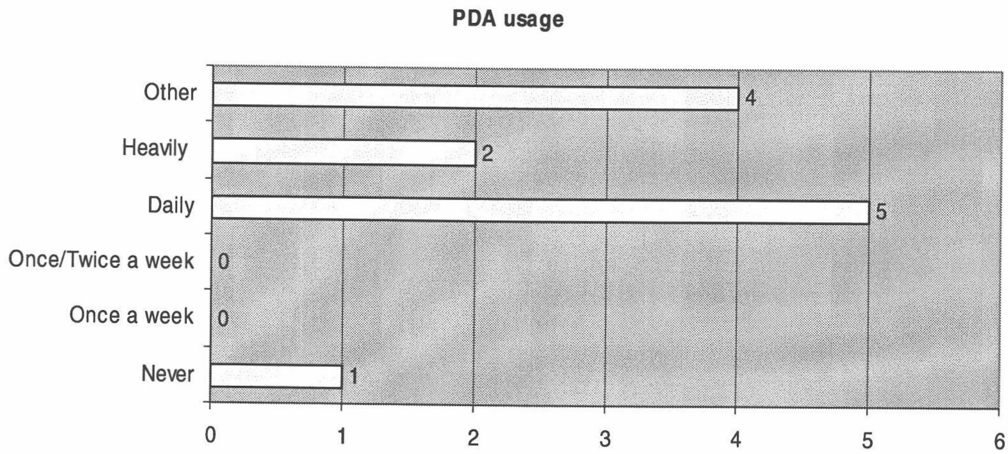


Question 9 addressed PDA usage. Out of twelve participants, five used a PDA daily.

9.Please indicate your PDA usage (Please Circle one)

Never	1
Once a week	0
Once/Twice a week	0
Daily	5
Heavily	2
Other	4

Table and graph showing PDA usage.



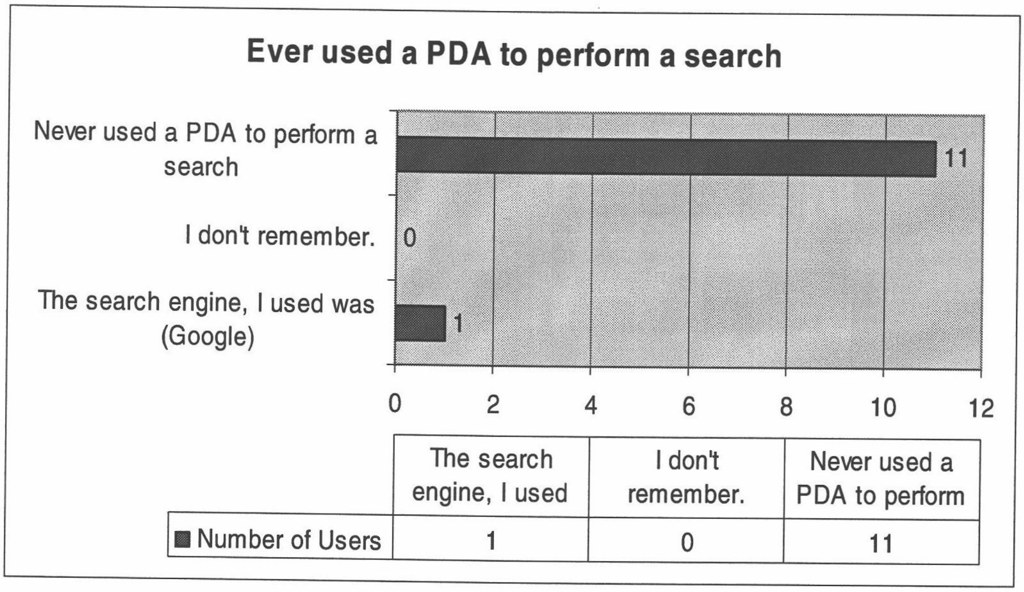
	Never	Once a week	Once/Twice a week	Daily	Heavily	Other
Number of Users	1	0	0	5	2	4

Question 10 addressed whether participants used a PDA to perform a search before. Out of twelve participants, eleven indicated that they had never used a PDA to search before.

10.Have you used a PDA to perform a search before? If No, skip to question 12
If yes, which search engine did you use?

The search engine, I used was (Google)	1
I don't remember.	0
Never used a PDA to perform a search	11

Table and graph showing Previous experience using a PDA to perform a search.

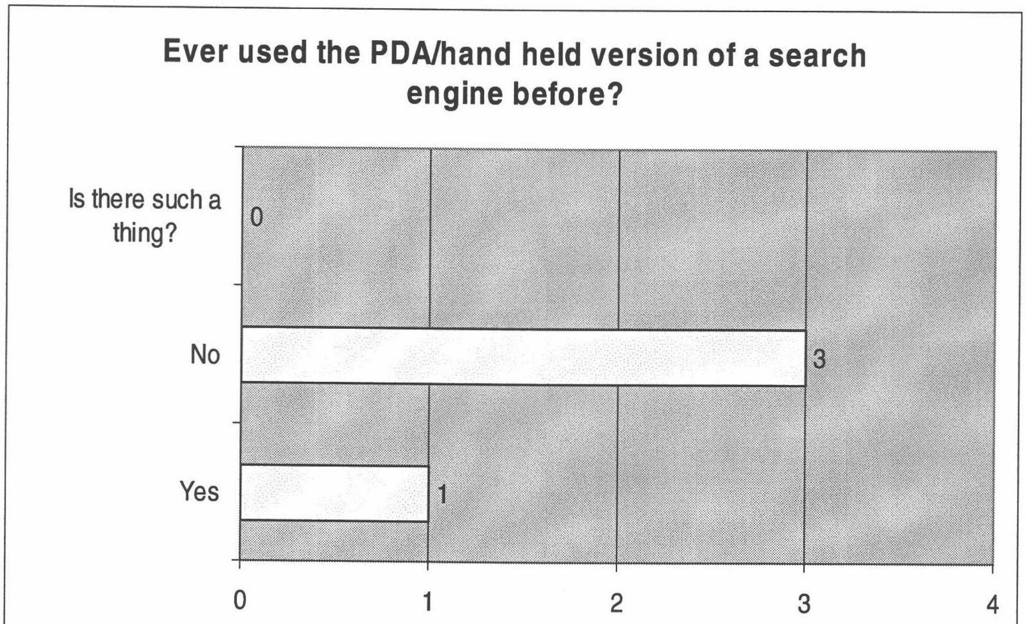


Question 11 addressed the issue of participants used the PDA or handheld version of the search engine before. Out of four participants who responded to this question, three had never used the PDA version of the search engine.

11.Did you use the PDA/hand held version of the search engine? If No, skip to question 12

Yes	1
No	3
Is there such a thing?	0

Table and graph showing PDA/handheld version of search engine to perform a search.



	Yes	No	Is there such a thing?
Number of users	1	3	0

5 Discussion

The experimental results (4.3) did not provide statistically significant results and were thus disappointing. It did not make much difference who (PDA/Non-PDA user) used what (Google PDA/Google Desktop). Based on just the analysis of the experimental results, it may be assumed that Google PDA has no clear/definite advantages over the Google desktop version.

So, did Google really come up with a PDA version or did they simply scale down the Google desktop version? The reasons may be numerous, but based solely on the results of this experiment, Google failed to impress in producing a search engine built exclusively for the SSDs. Although getting a clear convincing result would have been ideal, the usability engineering approach that Google adopted may have had several deficiencies. A closer look at the usability engineering approach from a system engineering perspective may reveal several deficiencies, which may have hitherto gone unnoticed. Use cases were identified as a possible usability engineering shortcoming, which may require the stricter regimen that the systems engineering approach provided. (2.5.3)

Figure 6, shows how some of the key components of Systems Engineering were integrated into the usability engineering approach. Google can similarly scrutinize their current usability engineering approach and try integrating systems engineering into the approach.

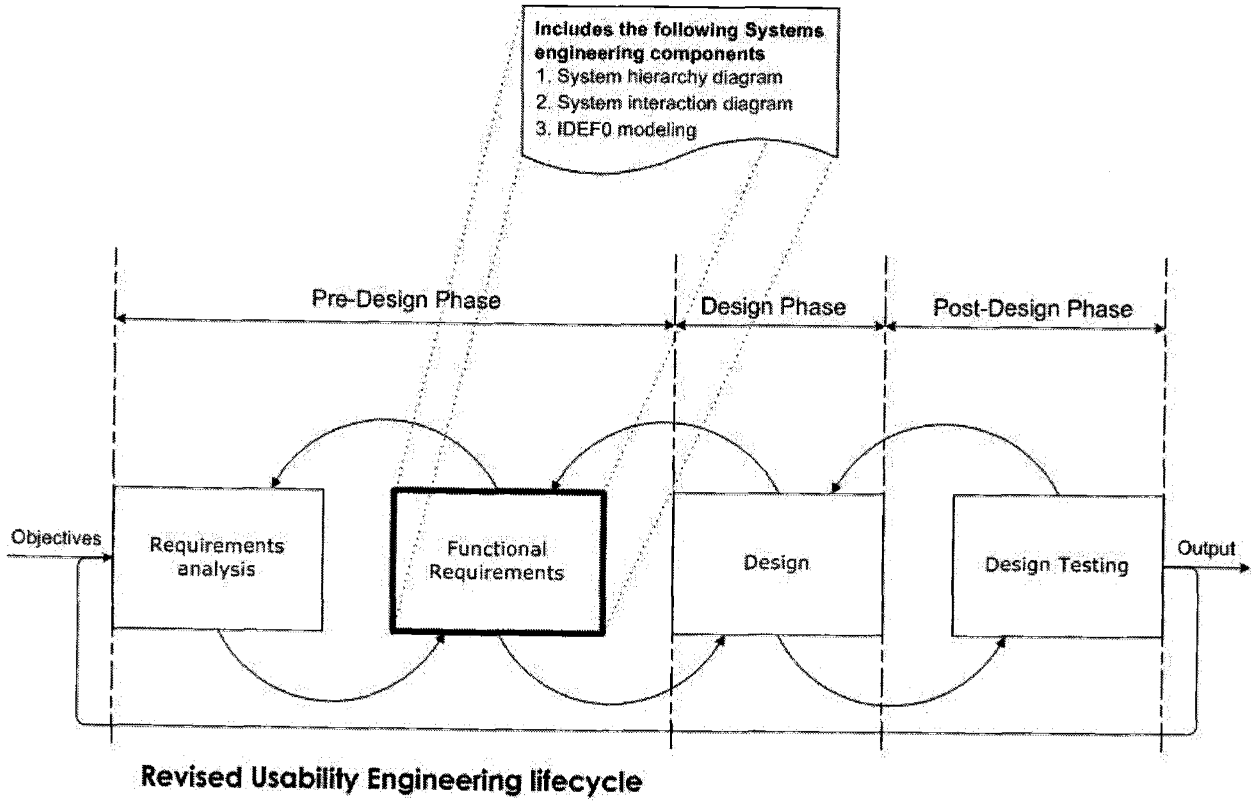


Figure 23: Figure shows the revised usability engineering lifecycle with key components of the systems engineering included in the functional requirements stage of the usability engineering lifecycle.

To reiterate, some of the inherent advantages of systems engineering are:

- It offers a structured way of thinking about complex problems. It is able to handle such problems by subjecting them to a formal series of analytical techniques - 'structured' approach.
- It provides a means of representing and documenting the results of analysis and design so that they can be communicated effectively.
- By working systematically through analysis and design, it claims to be more accurate and complete.

While relating general observations about generalizing desktop usability principles, guidelines, and/or standards to SSDs is beyond the scope of this thesis, it is certainly a worthwhile topic to pursue in future research. Some of the general usability principles that have been violated by Google are discussed in the next section.

5.1 Conclusions and Implications

Although the experiment itself did not quite make a clear case as to which of the search engines was better, several interesting observations were recorded during the experiment.

Some of the users' observations of the Google PDA version follow:

"How do I go on to the next page?"

"Why is this version so different from the desktop version?"

"The level of detail is just not good in this version"

"Results are definitely slower in this version"

"I just don't feel comfortable with this version"

"I think the PDA version takes more time to load"

"The search button is more visible on the desktop version than this version"

"This version of Google had fewer search results than the desktop version"

"PDA version has cleaner interface but more confusing display of results"

"Some of the key features are missing in this version"

"The PDA version should stay away from giving users the ability to search for images"

Though an equal number of positive remarks were made about the Google PDA version, the ones that can be considered negative are taken into consideration for this section because, although fairly basic, these remarks had serious implications. Some of the implications discussed with reference to the user remarks follow:

Users were accustomed to using the Google desktop version for a long time, but the PDA version was quite different from the desktop one. Naturally, users complained about feeling uncomfortable with the PDA version, missing several key features, not having enough details as the desktop version, and not getting a feel of the PDA version being a Google product.

Usability principle violated: Interface consistency. (Allen, Eckols, 1997)

When a user questions about going on to the next page, this indicates that the concept of navigation is missing or hidden. A generic search usually yields lots of results. There should be a clear indication of how to navigate through the results pages.
Usability principle violated: Designing logical, natural interfaces for computer interactions. Provide feedback wherever applicable. (Allen, Eckols, 1997)

A search button is the only thing the user has to click to get search results. Users complained about not being able to see the search button clearly on the PDA version.
Usability principle violated: Don't overload users' working memory. (Allen, Eckols, 1997)

There were other concerns about the PDA version taking a longer time to load, but that could have been a slow wireless connection. On the other hand, the PDA version home page could have been large, and it may have taken a longer time to load than the desktop version. Faster-loading pages are definitely the answer.
Usability principle violated: Make your page fast loading. (Allen, Eckols, 1997)

Users were confused by the search results that were displayed as a result of clicking the search button. Some of the results had strange icons at the end of the search result link, and they didn't have a mouse-over to know what it actually stood for. Clicking these icons took the user to a new page. As a result, several users were frustrated. Provide easy and intuitive icons, and do not aggravate users by making them open new pages, especially in SSDs.
Usability principle violated: Use words readers can easily understand. (Allen, Eckols, 1997)

The PDA version gave the user the ability to search for images. Several tried this option, and they commented on not being able to see images clearly on the PDA. SSDs not being particularly friendly for displaying images, why give the user the option to search for images?

Usability principle violated: Use graphics and illustrations to supplement and support the text. (Allen, Eckols, 1997)

Users also commented on the number of search results that were displayed upon clicking the search button, which they noted were lesser than the desktop version. This may have had more to do with the search engine technology than anything else.
Usability principle violated: Use intuitive graphics and illustrations to supplement and support the text. (Allen, Eckols, 1997)

5.1.1 Other factors that may have affected results

5.1.1.1. Variability of Participants who had used a PDA before and PDA used

24 participants were recruited for the study. 12 had never used a PDA before, and 12 **claimed** to have used a PDA before. Out of the 12 participants who claimed to have used a PDA, a few used a PDA on a daily basis, others used it occasionally, and the rest had used it only for three or four times. Having participants who had the same level of experience using a PDA may have given a better and different set of results. The author's assumption that participants who had used a PDA before would outperform those who had not could have been realized if participants having similar levels of PDA experience were involved in the experiment. By doing so, the author would not have had to take into account the variability of participants,

and would have had a more straightforward analysis since all the participants would have been at the same level.

The PDA used for the experiment was a Compaq 720. Out of the 12 participants who claimed to have used a PDA before, none of the participants had ever used a Compaq model before (section 4.2 – Q8). Although the operating system is the same on most of the PDAs today, there is a possibility that not having used a Compaq PDA may have affected the participants' performance. Having participants use a PDA similar to the one with which they were accustomed would have provided a better way to asses the participants' performance based on using a similar PDA, rather than assessing them on different PDAs.

5.1.1.2. Sample Size

Since the study involved participants who had used a PDA/hand-held, the sample size was very limited due to the fact that the author had to rely solely on available Oregon State University campus resources to get participants. Since the project was not funded in any way, hiring participants from outside the campus who had PDA/hand-held exposure/experience was not feasible. Due to the very small sample size, the margins of the end results were very close. A larger sample size may have made a difference and yielded statistically significant results.

5.1.1.3. Statistical Experiments

The only statistically significant fact was that Non-PDA participants took more time to complete the tasks, which was hardly surprising.

Comparing 2 independent variables on 2 different platforms, a PDA and a desktop with different search engines, may have provided more data and the results may have been easier to analyze. This would certainly have added more value to the experiment, since the experiment failed to reveal the superior of the two search engines.

5.1.1.4. Age, Ethnicity, and Gender

Age, ethnicity, and gender were not taken into consideration in the study. Further classifying PDA and Non-PDA participants on the basis of age, ethnicity, and gender would have provided a larger set of dependent variables, thereby providing more data available to asses the participants' performance. For example, an experiment could have been conducted to see if the age of the participants had something to do with choosing the better between the two search engines, or whether there was a correlation between the age of the participants and one of the dependent variables, and so on. The same would apply to ethnicity and gender as well. These factors would certainly be something to look at if the whole experiment was replicated, and they would broaden the scope of the study as well.

5.1.1.5. Search Engines

The search engines used in this thesis were two different variants of Google. Comparing different types of popular search engines on the PDA would have added more value to the experiment, as it would have resulted in certain key search engine characteristics to asses the interface. Some characteristics that would have really made a difference would have been the way search results were displayed, how participants navigated through the list of search results, how the search results page provided feedback to participants, and so on.

The author generalizes that the end results would be applicable to any search engine, irrespective of being a PDA or desktop variant. This is still an assumption that sets the path for future work.

5.1.1.6. Learning and Learning Effect

Participants who had never used a PDA before were given a few minutes to familiarize themselves with the PDA before the experiment actually began. Participants may still have been learning how to use a PDA during the experiment due to insufficient learning time.

A learning effect takes place when participants are subjected to several repetitions of similar experiments, usually between varying time intervals. Participants may or may not show a marked improvement between experiments.

In this experiment, there might have been a learning effect, since participants were subjected to two runs with slightly different scenarios and there was a time interval between the two runs. The author, however, made an assumption that there would be no significant learning effect, and after looking at the data during the analysis, the author was right to assume that participants didn't show a marked improvement after they completed run one. Therefore, it seemed reasonable to affirm the author's assumptions that, although there would be a learning effect, its effect would be minimal.

Had there been a significant learning effect involved across participants, there would have been more data available to asses the participants' performance.

5.1.1.7. Usability and Systems Engineering – Did the Combination Work?

Although a very thorough and analytical approach was used to limit the number of usability metrics, there is a possibility that one or more than one metric from the complete list of metrics was not taken into consideration, which may have altered the experiment altogether. The author assumed that the final list of usability metrics would be sufficient for this study. No assumptions were made for the functions/tasks from the systems engineering aspect. All the functions/tasks were put in the final table, which compared the systems engineering part (functions/tasks) with the usability engineering part (attributes/metrics) (see section 3.3 – Table 3).

The usability metrics were sufficient to the point of providing reasonable results. A much more detailed analysis of the metrics may have resulted in providing more concise results.

5.2 Recommendations for Future Research Work

For a search company that is so reputed and controls nearly 50% of the search engine market-share, Google's attempts at making a search engine targeted at the SSD segment are dismal. It is also surprising, considering the exponential growth of SSDs, that Google seems half-hearted about capturing market-share, as it normally captures market-share aggressively with its products.

Based on the remarks of the participants and the author's personal experience in this field, Google seems to have gone wrong with regard to a very important thing – usability testing. Google needs to conduct iterative usability testing—as they normally do with most of the products that they bring out—do a thorough analysis of the data, and only then think about releasing the product in the market.

Google has often been praised for the simplicity of their design. Transferring some of the simple design concepts onto the SSD version would certainly be beneficial.

Coming out with a set of standards and guidelines is fine, but applying them time and again across all products would be even better. The Google SSD version seemed a lot different from the desktop version. Re-applying the standards and guidelines may help Google a lot. The key is to stay consistent throughout the entire range of products and try to not violate guidelines that have been set.

Introducing systems engineering would greatly help in the process, as it would help in understanding the search process in the context of SSDs even better. Systems engineering processes would also help in understanding what really makes the whole search system work smoothly.

Systems engineering is still thought to be a complex and time-consuming process. While this thesis makes an attempt to integrate systems engineering with usability engineering, there are many areas in usability engineering that can benefit from the numerous facets of systems engineering. Enforcing stricter and more refined systems engineering approaches can ensure that products will achieve higher levels of usability. Companies can benefit from this by selling usability and user friendliness as their main focus.

Information architecture, defined as the science and art of organizing and representing information in a structured and orderly manner, traces its roots to core human factors. Compared to usability engineering, information architecture has a closer relevance to systems engineering and can benefit greatly by following a systems engineering approach.

Overall, both usability engineering and information architecture, which again have overlaps in their lifecycles, can benefit from systems engineering methods. How they can benefit would be the start of a whole new era of integrating systems engineering methods and processes.

Bibliography

Ackermann, E. & Hartman, K. (2000). Searching & researching on the Intemet & The information specialist's guide to searching and researching on the Internet and the World Wide Web.

Allen, B.S., & Eckols, S.E. (Eds.) (1997). Principles for one-stop information & training: Handbook of usability principles (print version available as a PDF file). San Diego, CA: Center for Leaming, Instruction, and Performance Technologies, San Diego State University (35,000 words; Bibliography entries). Retrieved October 22, 2001, from: http://clipt.sdsu.edu/posit/POSIT_PDF_Files/UsabilityPrinciplesHandbook.pdf

Alpert, M. (2004). Gadget Envy, Scientific American, Vol. 291, Issue 4

Barnum, C(2002) Usability testing and research. Hillsdale, NJ: Erlbaum

Berry, M., & Browne, M (2002). Understanding search engines : mathematical modeling and text retrieval. Cambridge, MA: Harvard University Press.

Bloomberg News (2001) "Sharp to challenge Palm, Pocket PC with Linux PDA." Retrieved July 16, 2004, from http://www.techweb.com/wire/26801726

Bruijn, O., Spence, R. and Chong, M.Y. RSVP browser: Web browsing on small screen devices, in Proceedings of HCI with Mobile Devices Workshop (IHM-HCI, Lille, September 2001)

Buyukkokten, O., Garcia-Molina, H., Paepcke, A. & Winograd, T. (2000). Power browser: efficient Web browsing for PDAs. Proceedings of the CHI 2000 conference on Human factors in computing systems, pp430-437. Amsterdam

Dumas, J. S. & Redish, J. C. (1999). A practical guide to usability testing. New York, NY: Pergamon Press

Fulk, M., (2001).Improving Web Browsing on Handheld Devices, GVU Center & College of Computing, Georgia Institute of Technology, in: ACM CHI 2001, pp. 395-396.

Gabbard,J.,Hix,D.,and Swan,J. "User-Centered Design and Evaluation of Virtual Environments", IEEE Computer Graphics and Applications, 19(6), Nov / Dec 1999, pp.51-59.

Gabbard,J.,Swan,J.,Hix,D.,Lanzagorta,M.,Livingston,M. "Usability Engineering: Domain Analysis Activities for Augmented Reality Systems," in Proc. SPIE Vol. 4660, pp. 445-457

Hill,S., and Robinson, L.(1995) A Concise Guide to the IDEF0r Technique: A Practical Technique for Business Process Reengineering. Enterprise Technology Concepts, Inc., Puyallup WA.

Hix, D. and Hartson, H.(1993) Developing User Interfaces: Ensuring Usability through Product & Process. New York, John Wiley and Sons.

Holmquist, L. (1999): Will Baby Faces Ever Grow Up? In: Bullinger, H.-J., Ziegler, J. (eds.): Ergonomics and User Interfaces. HCI International Conference Proceedings, Munich, Germany, 22-26 August, Lawrence Erlbaum Associates, Vol. 1, 706-709.

Huberman, B. A., Pirolli, P. L. T., Pitkow, J. E., & Lukose, R. J. (1999).
Strong Regularities in World Wide Web Surfing. Cambridge, MA: Harvard University Press.

ISO 9241-11. Ergonomic requirements for office work with visual display terminals (VDTs) Part 11: Guidance on usability (1998).

Jones, M., Buchanan, G., Thimbleby, H. & Marsden, G., User Interfaces for Mobile Web Devices, W9 Mobile Workshop Position Paper (2000)

Kawachiya, K. and Ishikawa, H. Improving Web interaction on Small displays, in Proceedings of 8th International WWW Conference, 51-59, 1999.

Kirakowski, J. and Corbett, M. (1993). SUMI: The software usability measurement inventory. British Journal of Educational Technology 24, 3 (1993), 210-212.

Kossiakoff, A., and Sweet, W. (2003) Systems engineering: principles and practices Publisher: New York: J. Wiley

MacKay, B. (2003), The Gateway: A Navigation Technique for Migrating to Small Screens. In Proc. of ACM SIGCHI Conf.(Doctorial Consortium Session), Fort Lauderdale, Florida .684-685

Marcus, A. (2001). Baby face Design for Mobile Devices and the Web. In Proceedings Human-Computer Interface International (HCII) 2001. pp. 514 - 518.

Martin, J. Systems Engineering Guidebook. CRC Press, Boca Raton,Florida, 1996

Munusamy, M., & Leang, H. (2002). Characteristics of Mobile Devices and an Integrated M-Commerce Infrastructure for M-Commerce Deployment. In Proceedings of the second International Workshop on Internet Computing and E-Commerce (ICECE 2002).

Nielson, J.(1999), Predictions for the Web 2000, Retrieved January 16,2003, from http://www.useit.com/alertbox/991226.html

Nielson, J.(1994), Ten Usability Heuristics, Retrieved January 16,2003, from http://www.useit.com/papers/heuristic/heuristic_list.html

Oliver A. McBryan. GENVL and WWWW: Tools for Taming the Web. First International Conference on the World Wide Web. CERN, Geneva (Switzerland), May 25-26-27 1994.

Pascoe, J., Ryan, N. and Morse, D. Using while moving: HCI issues in fieldwork environments. ACM Transactions on Computer-Human Interaction, 7 (3), 2000, pp417-437.

Perry, J. (2004, April). Smart phones or PDAs: which type of mobile device is winning the hearts and minds of business users? Communicate, 66(3), 178-181

Reding, E. (2001). Building an E-Business from the Ground Up. New York: McGraw Hill

Ruuska-Kalliokulju, S., Schneider-Hufschmidt, M., Vaananen-Vainio-Mattila, K. and Von Niman, B. Shaping the future of mobile devices - results of the CHI2000 Workshop on: "Future Mobile Device User Interfaces". Proceedings of Mobile HCI 2001: 3rd International Workshop on Human Computer Interaction with Mobile Devices, at IHM-HCI 2001, Lille, France, 10 September 2001.

Rooney, P. (2003) "Gates: Microsoft Will Invest $6.8 Billion In FY '04 On Research." Retrieved July 16,2004, from http://www.techweb.com/wire/26801726

Spencer, D. (1999). History of Computers: A Chronology of the Most Important People and Events in the History of Computers. Berkeley: University of Califomia Press.

Strategy Analytics (2000). Strategy Analytics Forecasts $200 billion Mobile Commerce Market by 2004. Retrieved January 23,2004 from http://www.wow-com.com/newsline.press_release?press_id=862.

Spence, R. (2001). Information Visualization. Addison-Wesley, Reading, MA, 1998

Schneiderman, B (1998). Designing the User Interface: Strategies of effective Human-Computer Interaction, third ed., Addison-Wesley, Reading, MA, 1998

Appendices

Appendix 1 - Scenario 1 and 2

SC1

John Smith works in a big computer firm in Austin, Texas and is presently in Corvallis for fixing some major flaws in the computers at their Corvallis unit. After his work is done, he decides to visit his friend in Eugene. Help him find his way to Eugene and to the Portland airport from where he catches a flight to take him to Austin, Texas.
For the tasks coming up, imagine yourself to be in John's shoes and carry out ALL the tasks John thinks would help him get to his destination

On to the next page...

John is unsure of the best & cheapest way to get to Eugene. He opens his favorite search engine on the computer and finds out. Flying and taking the train are out of question since they are either expensive or do not fit his schedule. Left with no other option he decides to drive.
What does John do next?

- Looks for 1 or more than one popular **rental car companies** in **Corvallis (**Find a List**)**

- Makes a **comparison** of **prices** and settle for the cheapest rental car

He meets his friend in Eugene and they catch up on old times. Their pleasant conversation is interrupted by a phone call from John's boss asking him to come to Austin ASAP. His tickets have already been purchased and he has to collect them from the Portland airport. But since the earliest flight leaves Portland airport in the next hour, he has no option but to fly from Eugene airport.
What does John do next?

- Looks for information about **Eugene airport**

- Looks for **flight options and pricing** for a **1way trip** from Eugene to Portland (Find a List)

- Looks for **maps** showing Eugene airport

Leaving the car at Eugene airport, John finally arrives at Portland airport and gets his flight tickets. Checking the flight schedule reveals that this flight has been cancelled and the next flight is in 3 hours. Cursing his luck, he decides to check the art galleries in the city. He rents a car from the airport and heads to the city. Before heading out he decides to find out about the galleries in downtown and how he would get there.
What does John do next?

- Looks for 3-4 **art galleries** in the **Portland city area (**List them)

- Looks for **Portland city** area maps

The art galleries turn out to be impressive. Getting to and fro from one gallery to another is no problem, since there are in close proximity of each other, till he realizes that he is lost. He retraces his steps and heads back to the last gallery where the manager generously offers to let John use the gallery computer. He also decides to check the flight schedules while he is online
What does John do next?

- Re-confirms his flight schedules from the **Portland airport (**Just find a list of schedules of <u>any</u> airplane**)**

SC2

Susan Johnson just got promoted to a senior position in a major consulting firm in Detroit, Michigan. Currently she is spending her last days in the firms San Jose office. Due to the current economic problems, the company is not paying for her relocation expenses. They are however paying for a brand new car (within a price limit), with a hitch. She has to buy the car herself. Help Susan buy a car, look for plane tickets, look for temporary accommodation before she moves to Detroit, Michigan.

For the tasks coming up, imagine yourself to be in Susan's shoes and carry out ALL the tasks Susan thinks would help her get her stuff done

--

On to the next page...

Excited as she is about her new job, she is even more excited about the prospect of buying a new car. She has been an ardent Jaguar **X3** fan and has therefore put buying a Jaguar as her # 1 priority.
What does Susan do next?

- Looks for 2-3 Jaguar dealerships in and around **Detroit, Michigan (**Find a list**)**

- Makes a **comparison** of Jaguar **X series prices** and settles for something that fits her budget **(**Find 2-3 prices**)**

Her next priority is to look for airplane tickets, temporary accommodation and places to shop and eat.
What does Susan do next?

- Looks for **flight options and pricing** for a **1way trip** from San Jose to Detroit **(**Find a list**)**

- Looks for **places to eat** in the Detroit area **(**Find a list**)**

- Looks for **places to see** in the Detroit city area **(**Find a couple**)**

Since she is moving to a new place she plans to look at some places where she can shop for groceries. She also likes to shop for clothes & accessories too
What does Susan do next?

- Looks for places to do her **groceries** in the **Detroit city area (**Find a couple**)**

- Looks for **Detroit city** area **maps** to take her around the city **(**Show maps**)**

- Looks for places to **shop** for women's clothing **(**Find a couple**)**

Appendix 2 - Questionnaire

1. How long have you been using the Internet? (Please Circle one)
a) Less than 6 months
b) 1-2 years
c) 2-3 years
d) 3-4 years
e) 4 or more years

2. In an average week, how often do you use the Internet? (Please Circle one)
a) Never
b) Once a week
c) Once or Twice a week
d) Daily
e) Heavily (More than once per day)
f) Other. Please specify ______________________

3. In an average week, how often do you use a search engine? (Please Circle one)
a) Never
b) Once a week
c) Once or Twice a week
d) Daily
e) Heavily (More than once per day)
f) Other. Please specify ______________________

4. Please circle each search engine you have used in the past year?
a) AltaVista
b) AOL.com
c) AskJeeves
d) Dogpile
e) Excite
f) Go
g) Google
h) GoTo
i) HotBot
j) Lycos
k) MSN
l) Netscape
m) Northern Light
n) WebCrawler
o) Yahoo
p) Other. Pls specify
____
____

5. When did you first start using your primary search engine? (Please circle one)
a) Never used a search engine
b) Within the past 3 months
c) More than 3 months to 6 months ago
d) More than 6 months to 1 year ago
e) More than 1 year to 2 years ago
f) More than 2 years ago
g) Don't Remember

6. How often are you able to find the information you are looking for on your primary search engine? (Please circle one)
a) Every time
b) Most of the time
c) Sometimes
d) Never
e) Other

7. Have you ever used a PDA before? (Please circle one) Yes No
If No, skip to question 12
If yes, please circle one OR more of the following
a) I own one

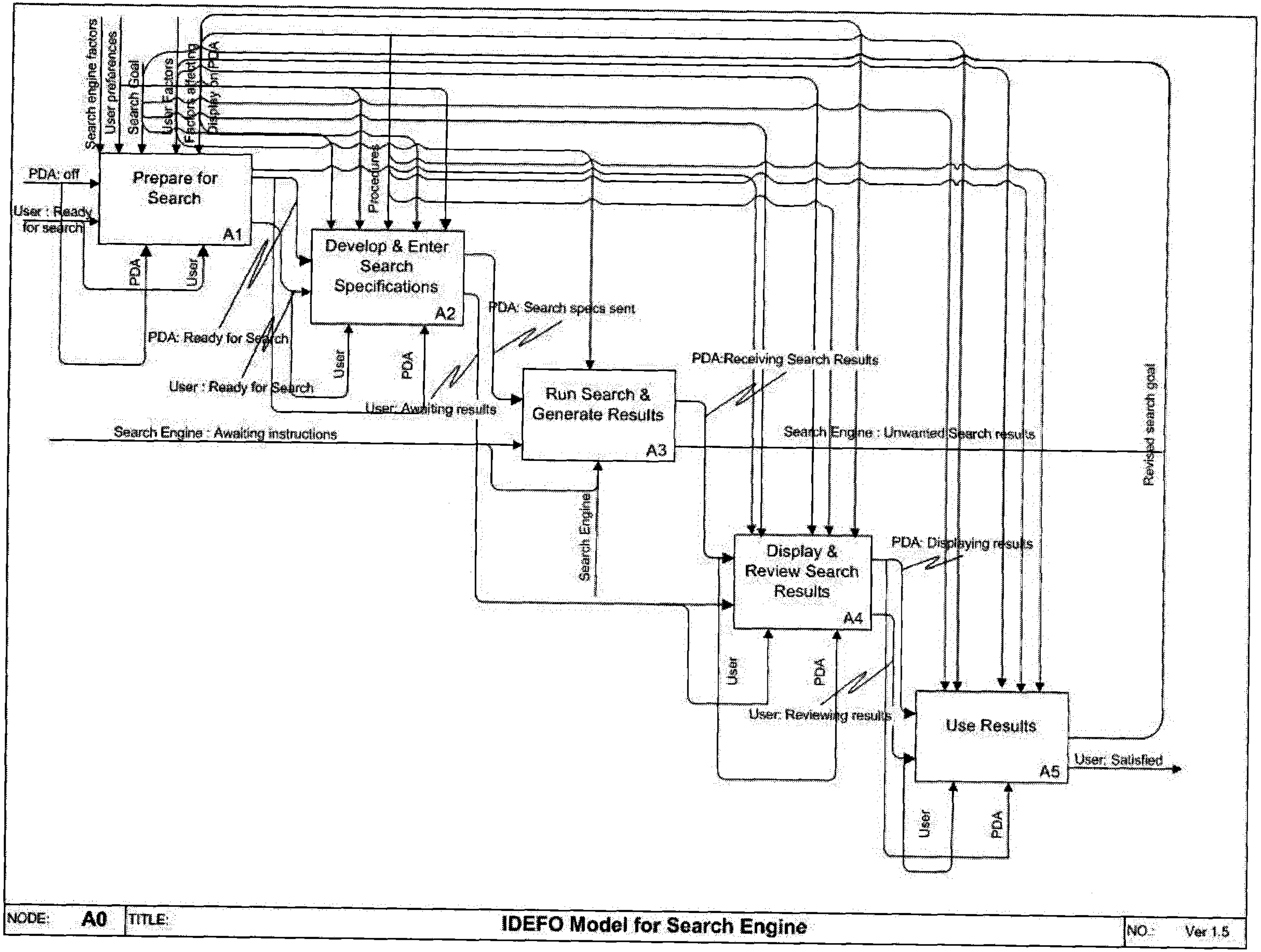
b) I have used it for a class
c) I have used it once OR twice

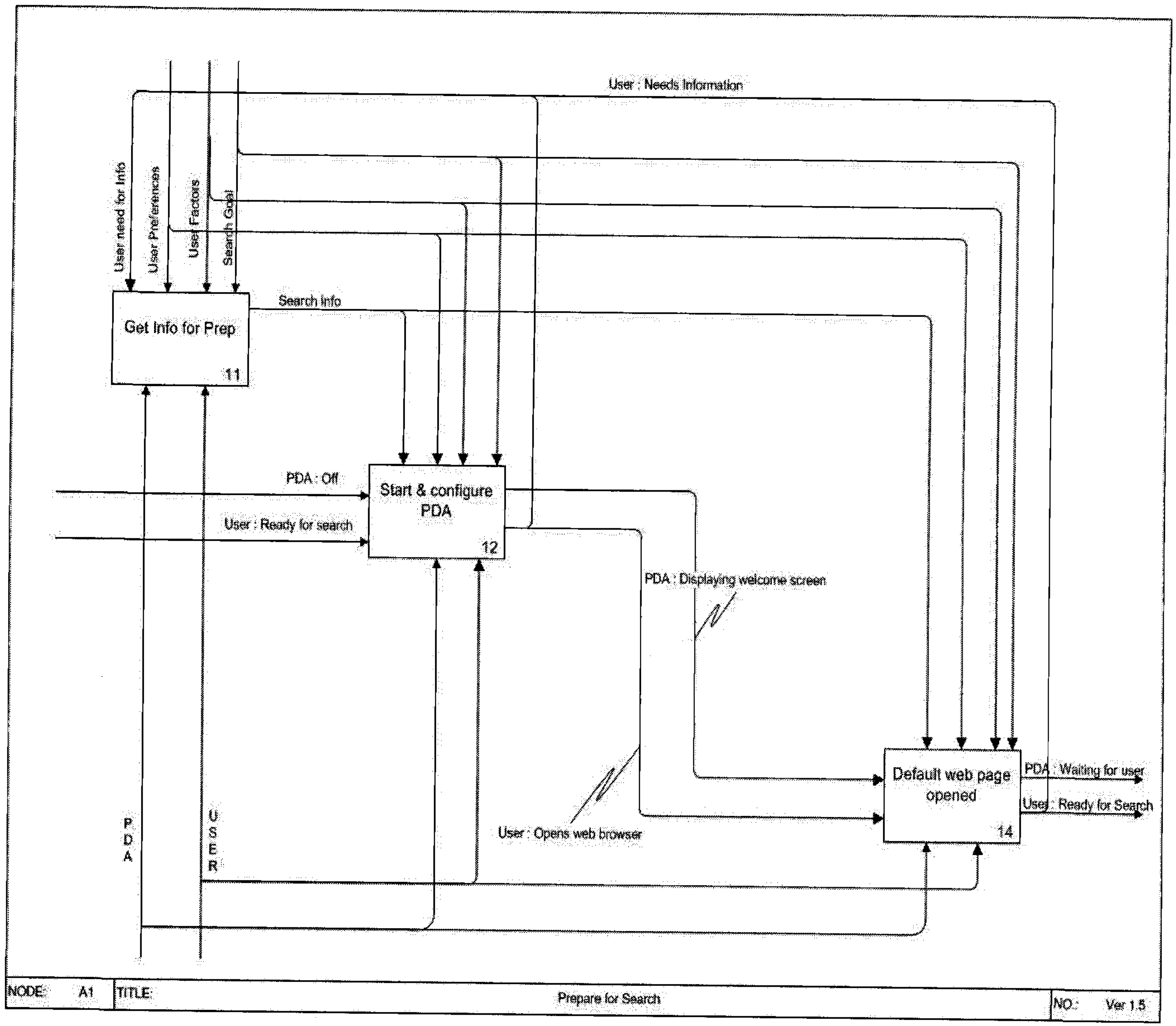
8. Which PDA (manufacturer) have you used before? (Please Circle one)
a) Hewlett-Packard
b) Compaq
c) SONY
d) Palm
e) Handspring
f) Dell
g) Toshiba
h) Casio
i) Kyocera
j) Other (Please specify)

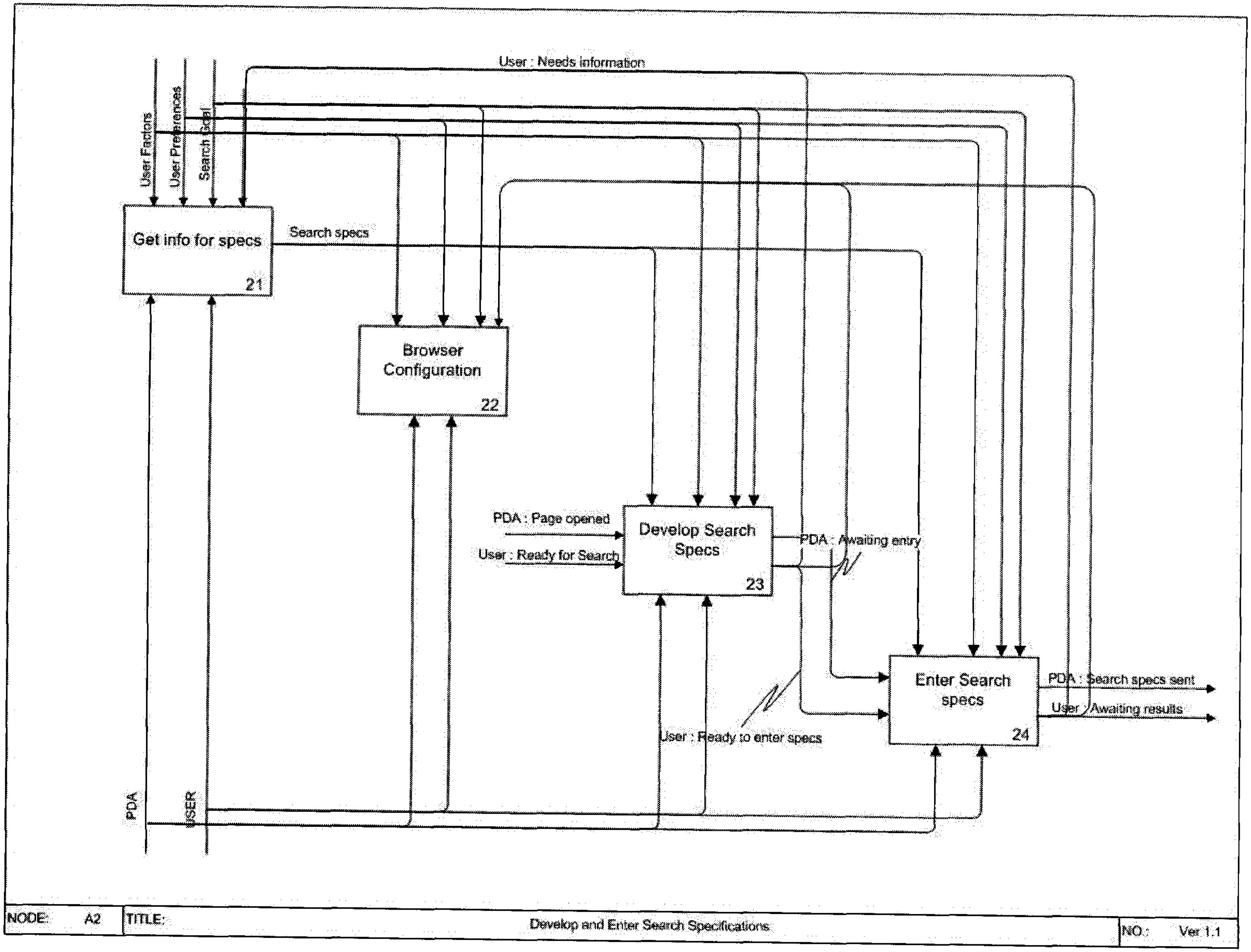
9. Please indicate your PDA usage (Please Circle one)
a) Never
b) Once a week
c) Once or Twice a week
d) Daily
e) Heavily (More than once per day)
f) Other. Please specify ______________________________

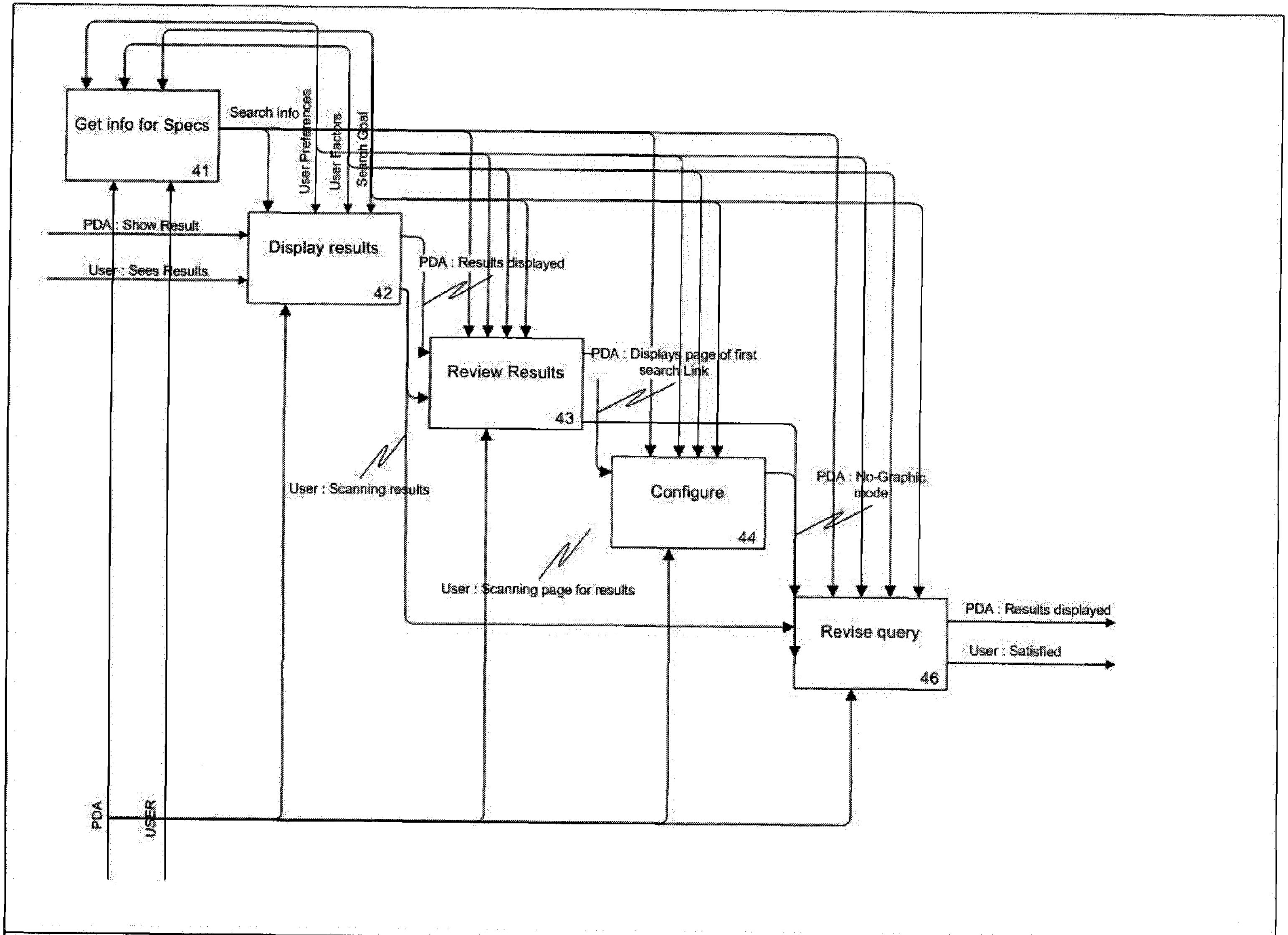
10. Have you used a PDA to perform a search before? (Please circle one)
Yes No
If No, skip to question 12
If yes, which search engine did you use?
a) The search engine, I used was ______________________________
b) I don't remember.

11. Did you use the PDA/hand held version of the search engine?
a) Yes
b) No
c) Is there such a thing?

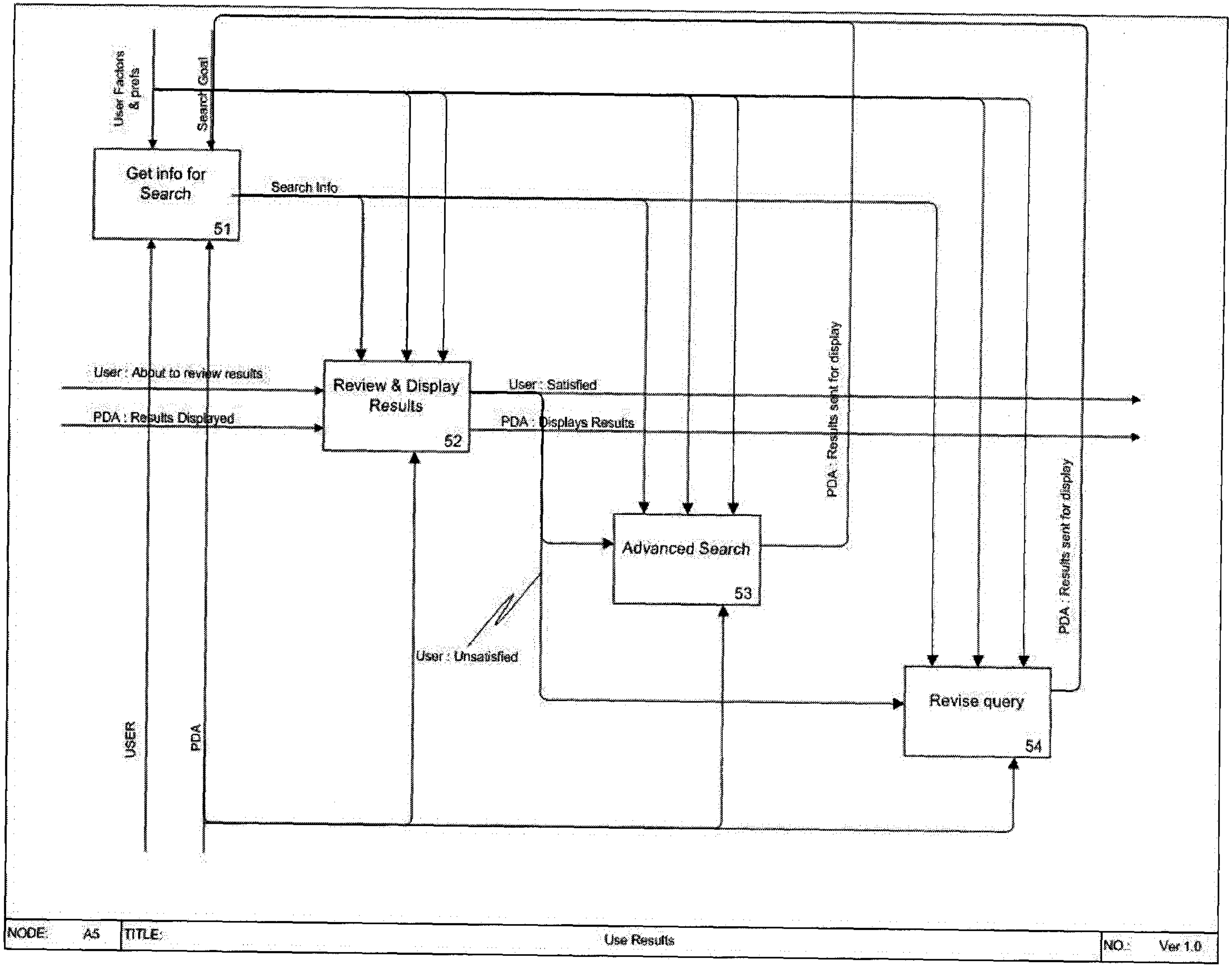

Search engine factors
User preferences
Search Goal
User Factors
Factors affecting Display on PDA
Procedures
PDA: off
User : Ready for search
Prepare for Search
A1
PDA
User
PDA: Ready for Search
User : Ready for Search
Develop & Enter Search Specifications
A2
User
PDA
PDA: Search specs sent
User: Awaiting results
Search Engine : Awaiting instructions
Run Search & Generate Results
A3
Search Engine
PDA:Receiving Search Results
Search Engine : Unwanted Search results
Revised search goal
Display & Review Search Results
A4
PDA: Displaying results
User
PDA
User: Reviewing results
Use Results
A5
User: Satisfied
User
PDA
NODE:
A0
TITLE:
IDEFO Model for Search Engine
NO.:
Ver 1.5


User : Needs Information
User need for Info
User Preferences
User Factors
Search Goal
Get Info for Prep
11
Search Info
PDA : Off
User : Ready for search
Start & configure PDA
12
PDA : Displaying welcome screen
User : Opens web browser
Default web page opened
14
PDA : Waiting for user
User : Ready for Search
PDA
USER
NODE: A1
TITLE: Prepare for Search
NO.: Ver 1.5


User : Needs information
User Factors
User Preferences
Search Goal
Get info for specs
21
Search specs
Browser Configuration
22
PDA : Page opened
User : Ready for Search
Develop Search Specs
23
PDA : Awaiting entry
User : Ready to enter specs
Enter Search specs
24
PDA : Search specs sent
User : Awaiting results
PDA
USER
NODE: A2
TITLE: Develop and Enter Search Specifications
NO.: Ver 1.1



NODE: A4 | TITLE: Display & Review Search Results | NO.: Ver1.1


User Factors & prefs
Search Goal
Get info for Search
51
Search Info
User : About to review results
PDA : Results Displayed
Review & Display Results
52
User : Satisfied
PDA : Displays Results
PDA : Results sent for display
Advanced Search
53
User : Unsatisfied
PDA : Results sent for display
Revise query
54
USER
PDA
NODE:
A5
TITLE:
Use Results
NO.:
Ver 1.0