DIPLOMITYÖ

Jarmo Kortelahti

2003

LAPPEENRANNAN TEKNILLINEN YLIOPISTO
Tuotantotalouden osasto

JARMO KORTELAHTI

DESIGN, IMPLEMENTATION AND USE OF AN INTERNET KIOSK AS AN INFORMATION SYSTEM FOR CNC-MACHINISTS

Master of Science Thesis

Diplomityön aihe on hyväksytty Tuotantotalouden
osaston osastoneuvostossa 12.03.2003
Tarkastajat: Professori Seppo Pitkänen
Professori Jorma Papinniemi

Päiväys: 25.08.2003

Jarmo Kortelahti
Lintulammenkatu 11 as 7
04250 Kerava
puh. 050 360 8717

Abstract

Author: Jarmo Kortelahti **Title:** Design, implementation and use of an Internet kiosk as an an information system for CNC machinists	
Department: Industrial Engineering and Management	
Year: 2002	**Place:** Cranfield
Master's Thesis. Lappeenranta University of Technology 84 pages; 21 figures; 4 tables and 9 appendices Supervisors: Professor Seppo Pitkänen, Professor Jorma Papinniemi	
Keywords: internet kiosks, task support systems, usability, information system design, shop floor information, ITSS, multimedia	

This project was sponsored by a large UK based aerospace company that recognised that with an increasing emphasis on a global manufacturing strategy and the increased use of electronic systems such as CAD/CAM, etc., they needed to understand what their shop floor information system requirements are and whether there are any benefits in improving these.

This report explains the construction of an Internet kiosk for providing manufacturing information on the shop floor for manufacturing engine components on CNC-machines. Kiosks have many characteristics that suggest they could be used in manufacturing environments as well. This report is a study on how the kiosk approach could be applied to manufacturing.

The thesis discusses the initial requirements gathering for the task support system, the design and development process of the system and finally analyses the successfulness of the kiosk through a usability study made once the kiosk had been implemented in the factory.

The conclusion shows that the kiosk indeed is applicable in a manufacturing environment and proves that providing manufacturing information in an electronic form is superior to that of paper. User comments show that the kiosk has been accepted and is considered to be an aid in their work. Additionally the kiosk provides benefits both to the shop floor as well as management levels.

Tiivistelmä

Tekijä: Jarmo Kortelahti

Työn nimi: Design, implementation and use of an Internet kiosk as an an information system for CNC machinists

Osasto: Tuotantotalous

Vuosi: 2002 **Paikka:** Cranfield

Diplomityö. Lappeenrannan teknillinen yliopisto

84 sivua; 21 kuvaa; 4 taulukkoa ja 9 liitettä

Tarkastajat: professori Seppo Pitkänen, professori Jorma Papinniemi

Hakusanat: internet kioskit, tietotukijärjestelmät, tietotekninen tuotannontuki, multimediajärjestelmät, käytettävyys, teollisuustyön vuorovaikutteinen tietotukijärjestelmä

Tätä diplomityötä sponsoroi suuri Isobritannialainen lentokoneteollisuudessa toimiva yritys, joka huomasi että globaalin tuotantostrategian ollessa painopisteenä ja tietoteknisten järjestelmien kuten CAD/CAM ollessa merkittävänä osana tuotantoa, on löydettävä ymmärrys siitä, mitkä ovat tuotannon tietojärjestelmien tarpeet ja onko niiden kehittämisestä hyötyä yritykselle.

Diplomityössä selitetään Internet teknologiaan perustuvan kioskin kehittämisestä tietotukijärjestelmäksi tuotanto-osastolle, jossa valmistetaan moottorin osia CNC-koneilla. Kioskeissa on piirteitä, jotka voisivat osoittautua hyödyllisiksi myös tuotantoympäristöissä ja siksi tässä työssä tutkitaan kioskiin perustuvaa lähestymistapaa tuotantoympäristöön sovellettuna.

Diplomityö kuvaa informaatiokioskin kehittämistä alkaen alkuvaatimusten keruusta tietojärjestelmää varten, tietojärjestelmän suunnittelu- ja kehitysvaiheen sekä lopuksi analysoi kioskin onnistuneisuutta tuotantoympäristössä käytettävyystutkimuksen avulla, joka suoritettiin sen jälkeen kun kioski oli implementoitu tehtaassa.

Johtopäätökset osoittavat, että kioski on hyvin implementoitavissa tuotantoympäristöön ja todistaa, että tuotantoinformaation jakelu sähköisessä muodossa on huomattavasti tehokkaampaa kuin paperilla. Käyttäjien kommentit osoittavat että kioski on sopiva heidän tietotarpeisiinsa ja siitä on hyötyä heidän työlleen. Kioski tarjoaa hyötyjä tuotantotason lisäksi myös johtotasolle.

Alkusanat

Haluan osoittaa kiitokseni useita tahoja kohtaan. Tärkeimpinä ihmisinä diplomityöni valmistumisen kannalta ovat Dr. Richard Greenough ja Tim Butcher Cranfieldin yliopistosta ja sponsoroivasta yrityksestä, jotka jatkuvasti opastivat ja neuvoivat työn tekovaiheessa. Heidän tukeaan en voi tarpeeksi kiittää. Cheers mates!

Yhtä oleellisena tahona kiitän Lappeenrannan teknillistä yliopistoa sekä työtäni tarkastanutta professori Seppo Pitkästä. Ilman korkeakoulun kattavaa ulkomaisten yliopistojen verkostoa, tämä työ tässä laajuudessaan olisi jäänyt syntymättä.

Akateemisten kiitosten lisäksi kenties suurempi kiitos kuuluu ystäväpiirilleni ja läheisille ihmisille jotka olen tavannut opiskeluni aikana. Elämänviisaus ja -kokemus mitä olen näiden ihmisten kanssa saavuttanut iltojen vietossa ja opiskeluponnistuksissa on korvaamatonta ja nämä kokemukset sekä muistot säilyvät vanhuuteni päiviin saakka.

Opiskeluaika on ollut löytöretki tieteisiin, ihmisyyteen, aikuistumiseen, oivaltamiseen sekä henkiseen kasvuun. Toverillisuus ja ihmissuhteet tämän löytöretken aikana ovat kasvattaneet minua ihmisenä suunnattomasti. Uljaasti ja jaloin aattein sekä akateemisin kannuksin voin nyt käydä kohti tulevaisuuden lukemattomia haasteita käyttäen hyväksi niitä tietoja ja taitoja joita olen viimeisen viiden vuoden aikana saavuttanut.

Lopuksi haluan kiittää vielä perhettäni ja läheisiä ihmisiäni. Ilman heidän tukeaan en olisi mitenkään voinut saavuttaa tätä pistettä.

Helsinki, 25.08.2003

Jarmo Kortelahti

Acknowledgements

I would like to thank Dr. Richard Greenough and Tim Butcher for their support, advice and help throughout the project, which will never be forgotten.

I would also like to thank Cranfield University and the sponsoring company for giving me the opportunity to work on such an interesting project.

Special thanks are due to my classmates in Cranfield for giving me a year that I will never forget.

Additionally, huge thanks are due to all the people I have met and shared experiences with during my time in Lappeenranta. Undoubtedly I have had an unforgettable time with you that as an old man I can reminisce with fondness. What the future holds for us is a mystery – with an open mind and heart let us go there.

And finally I would like to thank my family and friends for the support I have received from them, and without whom all this would not have been possible. You know who you are. I dedicate this thesis to the spirit of comradeship and thirst of knowledge that I have experienced for the last five years.

Helsinki, 25.08.2003

Jarmo Kortelahti

List of Figures:

List of Tables:

List of Appendices:

List of Notations:

ASP: Active Server Pages

AVI: Audio Video Interleave

BMP: Bitmap

CAD: Computer Aided Design

CAE: Computer Aided Engineering

CAM: Computer Aided Manufacturing

CAPM: Computer Aided Production Management

CAPP: Computer Aided Process Planning

CASFC: Computer Aided Shop Floor Control

CIM: Computer Integrated Manufacturing

CNC: Computer Numerically Controlled

CSS: Cascading Style Sheet

EDI: Electronic Data Interchange

ERP: Enterprise Resource Planning

HTML: Hyper Text Mark-up Language

IS: Information System

ITSS: Interactive Task Support System

JPEG (JPG): Joint Photographic Experts Group

MADE: Manufacturing Automation and Design Engineering

OCR: Optical Character Recognition

PDF: Portable Document Format

RMM: Relationship Management Methodology

SGML: Standardise General Mark-up Language

STL: Stereo Lithography

TAM: Technology Acceptance Model

URL: Universal Resource Locator

WWW: World Wide Web

XML: Extensible Mark-up Language

Table of Contents:

1. Introduction

This chapter is an introduction to the project. It explains the background of the company, the project and it's aims and objectives, the research methodology and the structure of the thesis.

1.1. Background to the project

As companies strive to increase productivity, lower costs, deliver better quality faster to their customers and increase supply chain integration, the importance of information technology and communication has become a very important issue. New ways of communicating within organisations, supply chains and even workstations have evolved.

ERP systems have become a standard for organisations and Internet technology has provided the tools for more efficient communication and information retrieval and viewing. Multimedia and hypermedia allow a completely new way of supplying information to workers for task support and training. They also provide a secure and usable way to provide the information.

Internet kiosks have many features that suggest that they might be suitable for use in factories e.g. in the automotive industry, especially now that many companies are using a web-based user interface to their manufacturing systems. A kiosk gives a new way to display manufacturing information directly to the operators at their work stations.

A large UK based aerospace company is investigating new ways for shop floor communication. The company recognised that with an increasing emphasis on a global manufacturing strategy and the increased use of electronic systems such as CAD/CAM, etc., it needed to understand:

A) What it’s shop floor information systems requirements are
B) Whether there is any benefit in improving these

Electronic documents seem to be the way of the future and new ways of supplying information to shop floor workers include the possibility of an Internet technology based kiosk.

The kiosk is intended to support the task of manufacturing airplane engine components for the CNC machinists on the shop floor at the company’s plant in the UK.

1.2. Research goals

The research goals of the project include developing an interface suitable for the manufacturing process, creating the web based manufacturing information - which includes engineering drawings, tooling sheets and part programs - and the possibility to view solid models and simulations for the manufacture of engine components for the engine. The usability of the kiosk-based approach will also be investigated by studying the use of a pilot system at the factory in the UK.

The design process was carried out by collecting and analysing feedback received directly from the operators. This allowed a task-centred information system to be developed and gave accurate user feedback for the usability study.

The goals of the project can therefore be said to include:

- Establishing shop floor requirements for a foundation on which to build the information system
- Create the web based information package and the user interface for the kiosk to form a manufacturing information system.

- Carry out a usability study to assess the success of the kiosk both in terms of usability of the system and usefulness for the task it is intended to support.

1.3. Thesis methodology

The methodology used in the project has several distinct steps. The initial phase consisted of a literature review to have an understanding of the evolvement and main issues of hypermedia, Internet technologies, kiosks and task support systems etc. This was needed to understand the possibilities of the kiosk to become a task support system in manufacturing. The development and design process of the information system also began in the early stages of the project.

The design and development process of the information system followed the methodology presented later in chapter 10. It included visits to the factory, establishing requirements, conducting task analysis and establishing the goals for the system. After the requirements etc. had been established the initial prototypes of the system were made and user feedback received. This was followed by several development cycles and additional prototypes to achieve what the users wanted from the system. After the final system version for the project was completed a usability study was done to establish the acceptance of the kiosk and to find out had the project reached the goals that were initially set for the project.

A sketch of the entire project including time lines can be found in appendix A. This thesis is part of a larger research project done by Tim Butcher an engineering doctorate student at Cranfield University researching new methods in shop floor communication to provide a vision of future shop floor information system requirements. The project activities continue after the development and usability study of the kiosk information system have been completed.

1.4. Report structure

The report structure is based on the thesis methodology described above. The structure and the contents of the chapters are as follows:

Chapter 2: Discusses the fundamental concepts of multimedia kiosks; their basic functions, their current applications and the development of kiosks.

Chapter 3: Deals with multimedia and manufacturing. How multimedia can be applied for manufacturing purposes, what multimedia applications exist in manufacturing and issues concerned with the development of multimedia applications for manufacturing.

Chapter 4: Discusses hypermedia information systems and the web languages that are involved. This chapter also deals with the application of hypermedia and the design of hypermedia applications for industry.

Chapter 5: Presents the various methodologies existing for information system design taking into account aspects that are relevant for this project i.e. hypermedia applications for manufacturing, general IS design issues, human aspects of information systems and technology acceptance. It also presents issues concerned with hypermedia documentation and the concerns of implementing hypermedia information systems in industry and issues on user interface design. Additionally it discusses the use of hypermedia systems in education and design.

Chapter 6:. Discusses the issues concerned with usability and usefulness and how to evaluate these.

Chapter 7: Discusses the project and issues concerned in developing the information system for the company.

Chapter 8: Introduces the design methodology implemented in the project and describes in large detail the phases of the development and design processes beginning from the establishing of requirements to the design of the final system and finally in creating a guidelines and procedures for future updates.

Chapter 9: Discussion and evaluation of the success of the project and the impacts of implementing the kiosk in the factory. Additionally the benefits of the kiosk are discussed.

Chapter 10: Final conclusions and recommendations on the project.

2. Multimedia Kiosks

This chapter explains the concept of multimedia information kiosks, their development and evolvement through the years and also the common applications of kiosks.

Information kiosks, or public access kiosks, are usually located in public thoroughfares, shopping malls, airports, railways etc. as a substitute or to complement customer service functions. Kiosks function 24 hours a day and are always accessible for anyone without the need for usernames or passwords. (Slack & Rowley, 2002)

Multimedia kiosks are workstations, which are specifically designed for public access. They may be standalone or networked through to a larger computer system. Multimedia kiosks present information in a variety of different media, including, for example, text, sound, graphics, images and video. The information inside a kiosk can be stored on a local disk or a database. In a number of environments in which it is useful to offer public access to a database, a kiosk format with the workstation just displaying a screen to the user is robust and attractive. (Rowley, 1995)

Kiosks are usually equipped with a keyboard and touch screen and often also with a printer slot to enable users to take information with them e.g. driving instructions or receipts etc. One difference between normal software systems and kiosk interfaces is the usability issues. Normally when a new software package is installed onto a computer it takes time for the user to learn how to use the different menus and tools provided. This means that the software is not possible to be used without at least some initial training. Kiosks however are meant to be intuitive. The interfaces on the kiosks should be easy and very logical and should be easy enough for anyone without any previous experience to use.

Kiosks also are secure and robust systems. They are operated on a software platform that is not possible to hack compared to if a software program is installed into a normal operating system without a security layer. The kiosk interfaces do not respond to keystrokes such as control-alt-delete or other shortcuts. Only the person with administrative level clearance on the system can actually change anything in the kiosk. This is a prerequisite for kiosk; they must be secure and usable to be able to make money. (NetShift)

Evolution of kiosks

As all things kiosks have also evolved much during the years of their existence. In Table 1 are shown the changes that have happened and are happening to kiosk from many different view points. As we can see the nature of kiosks has changed from just a source of static information to a multifunctional medium through which many different things can be performed from both the client and corporate point of view.

Dimension	**Early Kiosks**	**Kiosks today / future**
Physical characteristics	Uninteresting boxes, static displays	Eye-catching housings, consistent with corporate image. Moving images
Dialog design	Menu based access to a limited number of screens. Touch screen.	Web/Windows-like interfaces, with data-entry dialog boxes, dropdown lists, scroll bars, pointer and hyperlinks. Touch screen supplemented by keyboard.
Location	In-store, in a corner	In public thoroughfares, entrances and centrally positioned.
Philosophy	Task based.	Customer service based.

Originator	Service provider or retailer.	Infomediary or assembler.
Transaction	Single transaction.	Multiple transactions, communication and information provision.
Connectivity	Stand alone or connected to one proprietary database.	Internet enabled for real-time information provision and communication.

Table 1. The comparison of early kiosks and the kiosks of today and in the future

(Source: Slack & Rowley, 2002)

3. Multimedia and Internet Technologies in Manufacturing

This chapter covers the multimedia and Internet technologies that are currently used in manufacturing. It discusses the web and multimedia applications that have already been implemented in manufacturing and issues concerned with the development of these. This chapter also includes an example of a company that has implemented successfully these technologies in a manufacturing environment.

Internet technologies or web-based technologies have many features that have proved them useful in manufacturing environments. Product design and manufacture has been traditionally an area for intensive research and extensive application of computer systems. Computer numerically controlled (CNC) machines and other programmable machinery have delivered significant improvements in productivity and product quality.

The concept of computer-integrated manufacturing (CIM) arose in the 1970s to integrate the programmable machinery and devices in terms of communication. CIM has therefore achieved many advances and developed many so called computerised decision support systems. For example computer aided design (CAD), computer aided manufacturing (CAM), computer aided process planning (CAPP), computer aided shop floor control (CASFC) and computer aided production management (CAPM). These systems have evolved through several generations. (Huang & Mak 2001).

In order to maintain/improve the competitiveness of their business in the global market, manufacturing companies have to continuously improve their manufacturing environment through applying new technologies in various areas e.g. design/manufacturing tools, quality systems, control facilities and other systems which may benefit their business operations. Often this leads to a situation where the computer-based solutions are made by different vendors that may have proprietary systems.

In the long run this results in problems with management, communication and production with the system and makes updating the system even more difficult. (Cheng et al., 2000)

Internet technologies provide a promising way to approach these problems and allow manufacturers to achieve the agility in their manufacturing processes which is needed to answer to the growing demand of quality, cost, delivery and customer performance etc. Internet technologies enable companies to thoroughly integrate and extend their information systems on a platform independent architecture. This means that even though the computing environments in the organization can be very different the communication between them is done by the use of Internet-based techniques e.g. Java. (Cheng et al., 2000)

3.1. Web applications in product design and manufacture

One of the most important initiatives in the development and application of web-based systems in product design and manufacture is the US research project MADE (Manufacturing Automation and Design Engineering) program. This program supports research, development and demonstration of enabling technologies, tools and infrastructure for the next generation of design environments. Since the launch of the program many developments have been made in web applications, which can be categorised in three directions, (Huang & Mak, 2001).

1. Individual web-based decision support systems that are more conducive to product design and manufacture.
2. Individual web-based decision support systems that interact with each other.
3. Web applications that are especially designed and developed to facilitate and support group or team work in collaborative product development.

3.2. Issues of developing web applications

Although there are many HTML-based applications and the popularity of the World Wide Web is immense, the development of web applications is mostly ad hoc, lacking a rigorous and systematic approach. Most current practices in web application development rely on the knowledge and expertise of the individual developers rather than on systematic methodologies or approaches. Although methodologies exist on creating hypermedia applications that are systematic, the designer still has a large influence on the development. There are many reasons for this. First of all the web is a medium rather than an application platform to develop on. This has lead to a situation where the development of web applications is primarily an authoring problem rather than a software development problem to which systematic methods could be applied. Furthermore applications are very tailored for specific needs and no general approach in developing a web application for a specific task can be used. However the principles of software development can be applied on a higher level. (Huang & Mak, 2001)

3.3. Multimedia in Manufacturing

It is understood that today and in the future organisations need to be information-oriented, knowledge driven and many of the daily operations should be automated and connected to a network that links everything together. Internet technology has become a major enabler of this new way of thinking in manufacturing. Multimedia plays an important part in improving the communication of all levels of businesses and processes. In essence multimedia is understood to be text, pictures, moving images and sound but in fact in manufacturing terms it means more effective communication. The information provided is the same but multimedia provides a more focused, multidimensional and more effective and powerful way to communicate manufacturing information. (Rahman et al. 1999)

Multimedia and the Internet have been started to be used for example to connect manufacturers to suppliers and subcontractors, as a mechanism for shortening the development cycle of new products, for receiving feedback on software releases, and accessing super computers for industrial research and development. (Gunasekaran & Love, 1999)

3.4. Application of multimedia in manufacturing

Application areas of multimedia in manufacturing include marketing, design and engineering, production, distribution, personnel and administration. In fact all the essential areas of a manufacturing organisation have started to be involved with multimedia applications. The increasing use of enterprise resource planning (ERP) systems such as SAP R/3, Baan, Oracle etc. have in fact made multimedia a very normal part of business.

In Table 2 are classified the key multimedia applications of specific areas of an organisation.

Application areas in manufacturing	**Key multimedia applications**
Marketing	Electronic commerce, EDI (Electronic Data Interchange), on-line ordering, security systems, customer feedback, printing and
Design and engineering	Internet, WWW, CAD / CAE, CAM, 3D Software
Production	CAM, on-line production control, EDI, simulation
Distribution of information (communication) and goods	Transport network, on-line monitoring, security systems
Personnel (education and training)	A virtual reality, network facilities, tutorials, learning by simulation,
Administration (corporate management)	Tele-conferencing, meeting, printing and publications

Table 2. Application of multimedia in manufacturing and key applications
(Source: Gunasekaran & Love 1999)

By looking at the table we can see how cross-organisational the impact of multimedia is in an enterprise today. Kenard Engineering is a good example of a company that uses Internet technology throughout their manufacturing process.

Kenard Engineering

The following information was derived from a study tour during which the author visited Kenard Engineering.

Kenard Engineering is a subcontractor for machining parts for various customers. Currently their main customers are Rolls-Royce and Alcatel. Kenard is a very modern engineering company. They use IT systems very effectively throughout the manufacturing process.

When customer orders are received they come in drawings that are in electronic or paper form. Computer aided manufacturing (CAM) is used to verify the drawing. The drawing is then sent to be simulated on a CNC model simulation program called Vericut. When the program and drawing are confirmed the CNC program is sent directly to the CNC machines.

Production controlling and scheduling is done using a program called Preactor. Again the production schedule is sent directly to the machines so operators can see what needs to be done next. Orders are stored in a database from where the planning and scheduling is done by looking at process times. Unconfirmed orders are scheduled as ghost orders for 2 weeks and if not confirmed are then deleted from the schedule. From this an estimated due date for the customer can be extracted. Lead times on an average are 4 weeks, everything is made to order and no stock exists. Material lead times are the biggest problem at the moment.

The IT system controlling everything is built in-house. Every job has a batch tag with information of the batch. Inspection stamps are added electronically on the electronic job cards.

This is an excellent example of how information and Internet technology enables the manufacture of CNC machining parts.

4. Hypermedia information systems

This chapter introduces and discusses the main technologies behind hypermedia information systems. It explains the basic issues concerned and also studies the application of hypermedia in manufacturing.

4.1. Hypertext, hypermedia and multimedia

To have an understanding of hypertext, it is best to compare it with normal text in a book. A book is read in a sequential order; first one reads page one before page two, otherwise the book will not make much sense. The essence of hypertext is that it is non-sequential. There is no predefined order in which the text should be read and each section is on it's own a logical whole. In Figure 1, the logic is show by four pages that all link to each other.

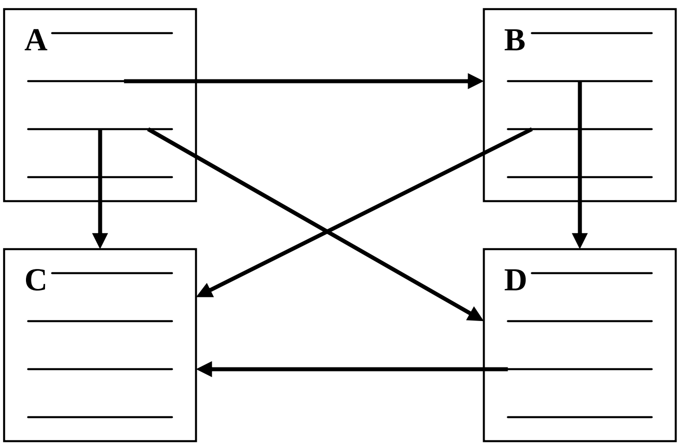


Figure 1. Simplified view of a small hypertext structure

(Source: Nielsen, 1995)

In this structure e.g. a part of text on page A links to page D and a part of text in document B refers to document C. This means there are several paths to read the four different documents. (Nielsen, 1995)

Multimedia is as the word states a combination of text, pictures, moving images and sound. Hypermedia is then the combination of hypertext and multimedia or multimedia hypertext. The Internet is full of websites that are examples of hypermedia. The main language to create hypermedia documents is called the hypertext mark-up language or HTML.

4.2. Application of Hypermedia within manufacturing

The use of hypermedia is particularly suited to engineering applications, as the information is normally organised into a large number of relatively small documents incorporating a significant amount of cross-referencing between the documents. At the same time the user may not require very much detailed information from these documents. This is to say that for example, an operator may require to view during a task mechanical drawings, electrical diagrams etc. only to extract a single piece of information e.g. a drawing issue number. (Crowder et al. 1999)

Paper based documents present problems, as systems get more complex. The more complex the system the more documents exists to support the system and the more cross-referencing occurs. This may lead to confusion because of inaccurate or out of date information and therefore decreases the efficiency of the user to perform the task. (Crowder et al. 1999). Engineering personnel are usually highly trained and therefore highly paid. Estimates have shown that over half an engineer's time is spent in searching for and retrieving information to undertake an activity (Hogbin & Thomas, 1994).

Implementation of hypermedia systems can hence improve the process of finding the correct information with the help of databases, search tools, efficient user interfaces, hypertext tools and EDI (Electronic data interchange) etc. (Crowder et al. 1999). Thus it can be said that hypermedia applications can deliver real benefits to manufacturing organisations in many ways e.g. the more efficient utilisation of work force.

4.3. SGML, HTML and XML

SGML

SGML, Standard Generalized Mark-up Language, is an enabling technology used in applications such as HTML. SGML has been the standard, vendor-independent way to maintain repositories of structured documentation for more than a decade, but it is not well suited to serving documents over the web. (http://cmit.edi.gatech.edu)

HTML

HTML, Hyper Text Mark-up Language, is the *lingua franca* for publishing hypertext on the World Wide Web. It is a non-proprietary format based upon SGML. HTML uses tags such as <h1> and </h1> to structure text into headings, paragraphs, lists, hypertext links etc. (http://www.w3.org)

XML

XML, Extensible Mark-up Language, is primarily intended to meet the requirements of large-scale Web content providers for industry-specific mark-up, vendor-neutral data exchange, media-independent publishing, one-on-one marketing, workflow management in collaborative authoring environments, and the processing of Web documents by intelligent clients (http://xml.coverpages.org). Technically XML differs from HTML so that the tags used in the code can be generated by the user and do not have to follow standardised procedures.

For example FIAT have decided to record, archive and manage all manufacturing, testing and assembly data for the Bravo/Brava replacement's seats by using XML. They have also based their new tracking system on the extensible mark-up language (XML), which can describe the content structures of all kinds of documents and data - from complete websites to tables or graphics - in the most appropriate way for each application. (http://www.e4engineering.com)

4.4. Developing an industrial hypermedia application

When developing a hypermedia application, the design methodology needs to be flexible to accommodate current and any future philosophies within manufacturing, for example agile manufacturing. (Crowder et al. 2000)

There are several known design methodologies in literature to design a hypermedia application e.g. the Hypermedia design model, the Object Orientated Hypermedia design model and the Relationship Management Methodology (Isakowitz et al. 1995), which will be explained in more detail in chapter 5.4. All of these approaches however are limited when they are being applied to industrial environments.

Hypermedia applications can also be categorised into process-oriented and content-oriented. Process-oriented are aimed to support organisational processes and content-oriented applications focusing on information services. (Suh, Lee, 2000)

Suh & Lee (2000) also propose a methodology for designing a content-oriented application, which aims on satisfying the users’ cognitive processes. This relates closely to the RMM model described later.

5. Information system design methodologies

In this chapter the various methodologies of information system design and development will be introduced. As this is a core issue in the thesis project, much detail is paid to explain the structures of these methodologies. A thorough understanding of information system design for industry is essential to be able to later to explain how the system was designed and developed. This chapter also deals with the issues concerned in developing an industrial hypermedia application. This includes the conversion of documents into electronic format and the issues related with user interface design. Additionally in this chapter the use of hypermedia in training and learning are discussed. Also the differences between task support systems and training for a task are covered and the concept of a hypermedia system for education *Microcosm* is introduced.

Information and hypermedia application development and design methodologies are very similar in many senses. In this chapter the different types of design methodologies that were relevant for this project are introduced and the logic behind them brought forth. As this project concerns a multidisciplinary approach to design it was important not only to look at methodologies of information system design, but also to look at methodologies that involve human factors because information systems are ultimately designed for people so this aspect is of relevant importance.

5.1. Information system design by Nielsen

Although it was noted before that web applications cannot easily be developed under a systematic approach, the aim of this project is to develop an information system based on web technologies. Several design methodologies however exist. This gives the advantage of creating a systematic information system while using web enabled tools to create a tailor made web based application.

An ideal scenario in developing an information system for a specific use is to completely make the system into what the end users want it to be. However some issues in developing a novel system cause the fact that users do not always know what the want and they are not always correct in their requirements for the system.

This places a lot of attention in trying to find out an optimal solution by listening carefully to the users but also keeping in mind the technical and practical aspects of the project. As Nielsen (1993) states, "*users are not designers and designers are not users*."

The information system design process that Nielsen (1993) suggests comprises of the following eleven stages of development. These are:

1. Know the user
2. Competitive analysis
3. Goal setting
4. Parallel design
5. Participatory design
6. Co-ordinating the total interface
7. Guidelines and heuristic evaluation
8. Prototyping
9. Interface evaluation
10. Iterative design
11. Follow up studies of installed system

Know the user

When beginning to design a new system the main focus must be on understanding the user. What the user is like, what his/her knowledge is on the process, computers, the tasks, education etc. In this project the main emphasis was to understand the task because this information system is designed to be a task support system.

Therefore the initial task analysis was the main basis in the construction of the product – the information system.

Task analysis

The objective of task analysis is to study the users' overall goals as well as how they currently approach the task, what their information needs are, and how they deal with exceptional circumstances or emergencies. The users' model of the task should also be identified, since it can be used as a source of information for the user interface. (Nielsen, 1993)

The task analysis is done by interviewing the people involved and observing what they do. One typical way to conduct a task analysis is basically to observe what the operators do when performing a task. The user typically says, "then I do this", and the interviewer then asks, "Why do you do it?" or " How do you do it?"

The task analysis gives a clear picture of the entire process involved. It identifies sub tasks and issues concerned in completing a task. What needs to be done before something else can be done and so on.

Competitive analysis

Comparing alternative systems to the intended task is always a good way of evaluating the best possible alternative. Looking at existing products gives ideas and guidelines on how to construct an optimum system e.g. on user interface solutions, layout proposals, structural functionality etc.

Goal setting

Goal setting in this case refers to usability issues of the system. Many different aspects of usability can be evaluated and goals can be set on how the intended system should perform when it is implemented.

For example the number user errors could be set as a goal. If the case was that currently on average there are 5 user errors per hour, a usability goal of 2 user errors per hour could be set as a requirement of the system.

As usability goals set also the financial impacts of the system, they should also be analysed carefully.

This analysis could be done based on time savings of the employees and therefore converted into money based on salary levels. The investment on an information system can easily be justified by the annual cost savings in the time that workers save on their jobs.

Parallel design

Parallel designing is the process of simultaneously developing several proposals of the system. Therefore the first prototypes would be the combination of several different concepts. This relates to iterative designing as shown in Figure 2. Parallel designing is at it's best when there is a team of designers working. It is important that the designers work independently on their drafts to create as much diversity as possible. (Nielsen, 1993)

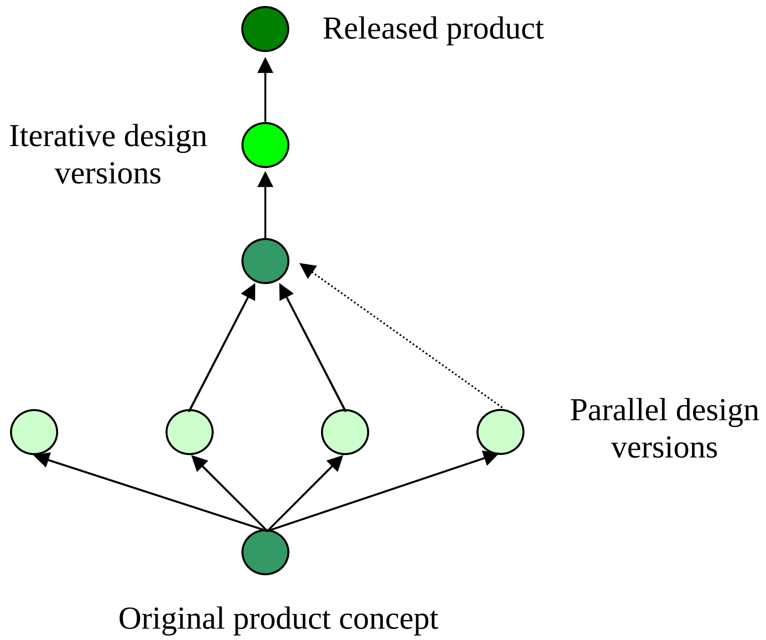


Figure 2. The relation between parallel and iterative design

(Source: Nielsen, 1993)

Participatory design

In participatory design the issue of listening to users is at it's best. In this designing method the intended users are very closely involved in the designing process. It is not just asking users what they think of a solution but to listen to their ideas and then work on them. (Nielsen, 1993)

Co-ordinating the total interface

The co-ordination of the interface is important to have consistency in the system. Consistency is one of the most important usability aspects and should be applied in every part of the system. If some part of the system or interface looks different to the others, some users will be discouraged to use it because they perceive it to be a different system and may have a feeling of not knowing how to use the system. (Nielsen, 1993)

Guidelines and heuristic evaluation

Heuristic evaluation is the process of looking at the system and trying to evaluate what is good and what is bad in the system, interface etc. It is a systematic way to assess the usability of a system. The guidelines to perform heuristic evaluation need to be set. These guidelines are categorised in general guidelines, category-specific guidelines and product-specific guidelines. They determine user related issues such as providing feedback on navigational issues from the user. Several general guidelines to user interfaces exist such as Brown (1998), which has 302 guidelines and Mayhew (1992) with 288 guidelines. These can be used as a basis on the heuristic evaluation. (Nielsen, 1993)

Prototyping

After the system has been developed to a trial version the users should test it. There can be several trial versions that can be experimented with to see which solutions are the best for the users. It is very useful and time / cost saving to create a trial version very early on in the project (Nielsen 1993). If the users see the system unfit for them it will have to be redone or redesigned and the more that has been done before the trials the more will have to be changed. This can be very time consuming and costly for obvious reasons.

Prototypes of the system can be made that are reduced versions of the full system. This can be done in two ways: either by cutting down the number of features in the prototype or reducing the level of functionality of the features so that they seem to work but do not actually do anything. Cutting down the number of features is called *vertical prototyping* and reducing the level of functionality is called *horizontal prototyping*. Horizontal prototyping keeps the features but eliminates depth of functionality, and vertical prototyping gives full functionality for a few features. These are depicted in Figure 3. Finally one can reduce both elements to arrive at a scenario that is like a simulation of the system following a predetermined path. This is done to illustrate and simulate the final system. (Nielsen, 1993).

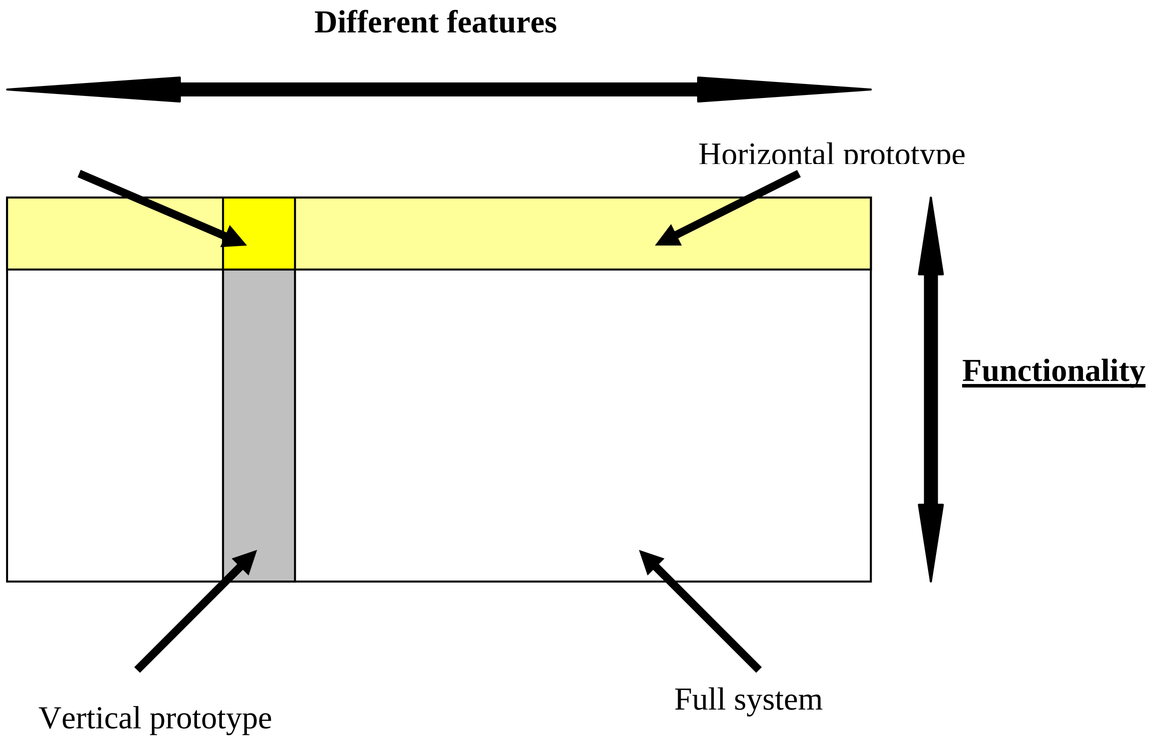


Figure 3. The two dimensions of prototyping: horizontal and vertical
(Source: Nielsen, 1993)

Iterative design

Empirical testing of the system many times produces feedback that helps to further develop the system in many respects. Iterative designing relies on receiving feedback to create new versions of e.g. the interface of the information system. Moreover many usability problems can be spotted.

Follow-up studies of installed systems

As in many cases involving project work it is essential to observe the results that have come forth from the project. This applies as well in software design. Studying results gives guidelines for new versions and future products. This phase is ultimately receiving feedback on how the system has functioned for its intended purpose.

5.2. Industrial hypermedia design methodology

A specific methodology exists that is intended to be used when constructing hypermedia applications of industrial strength. Through the literature research a very applicable and systematic design methodology was found created by Crowder et al. (2000)

Designing an industrial hypermedia application is an iterative process involving several different stages. The design process is shown in Figure 4. The first stage is to acquire the requirements of the application and conduct a feasibility study of the concept. The actual design process incorporates many different areas.

The authoring of an application consists of two main tasks, the collection of all the necessary information an its' conversion into electronic format, followed by the authoring process where links are added and the information is given its structure (Crowder et al., 2000).

This methodology also has a number of outputs that Crowder et al. call design outputs. These outputs consist of an implementation strategy for the application, customisation of the user interface, paradigms for navigation, templates and guidelines and procedures for producing electronic documentation and network resources. These all aim are a part of making the system fully functional and as effective as possible in the actual use of the system not just the designing of the system.

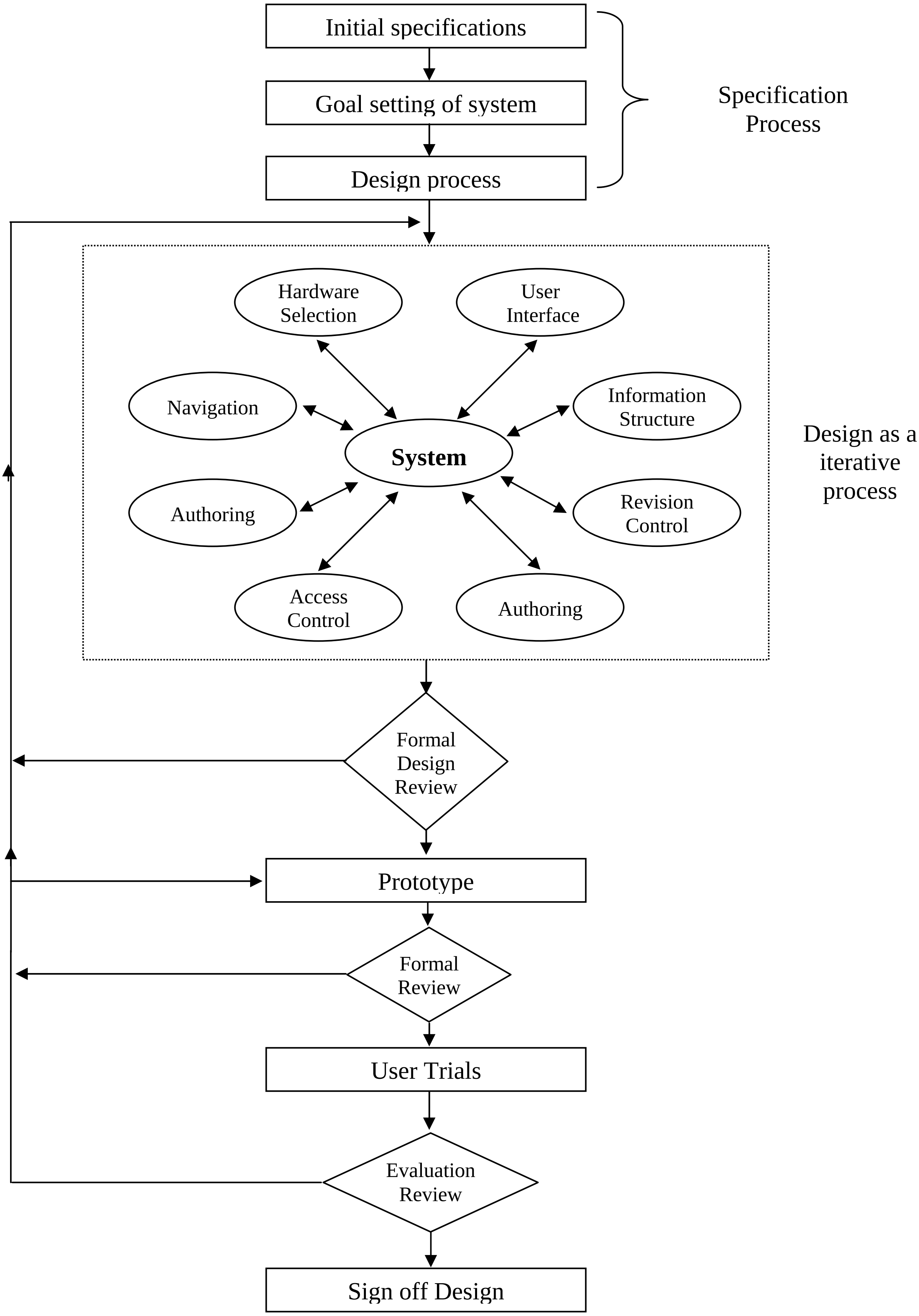


Figure 4. Hypermedia design process

(Source: Crowder 2000)

5.3. Information design and development

Coe (1996) emphasises the importance of involving users in information design and development. User-involvement is where the understanding of human factors theory becomes important. The human factors theory concentrates on the psychological and physiological needs and expectations of users. (Coe, 1996)

The methodology consists of eight phases of information design, which are:

- Site visits
- Competitive benchmarking
- Brainstorming
- Mind mapping
- Storyboarding
- Paper walks
- Draft and prototype reviews
- Usability testing

This methodology has the same idea of information system design as the previous introduced methodologies. However this approach is more focused on building user partnerships than actual system design. The methodology is shown in Figure 5. In this methodology each step is looked at from a human perspective rather than a system analysis perspective.

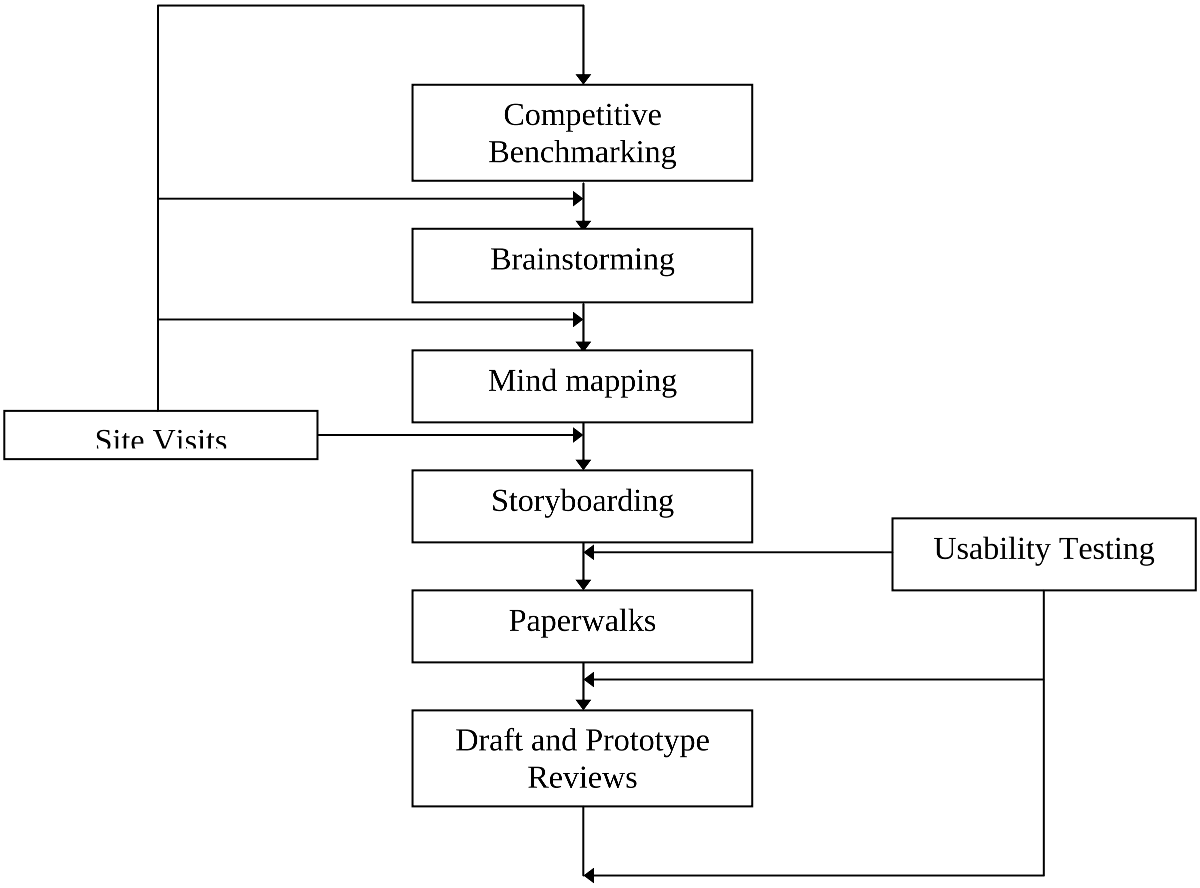


Figure 5. Systematic human factors approach to building user partnerships

(Source: Coe, 1996)

5.4. The Relationship Management Methodology

The relationship management methodology (Isakowitz et al., 1995) is a methodology for the design and development of hypermedia applications. The name relates to the fact that hypermedia is used as a vehicle to manage relationships between information objects.

The usefulness of the RMM approach to design and develop hypermedia applications is shown in Table 3.

The two axes in the table represent the structure and volatility of the information. The RMM methodology is most applicable in the areas where the applications have high structure and high information volatility.

Structure	Volatility of Information	Low	High
	High	Medium usefulness [e.g., Kiosk application]	High usefulness [e.g., Product catalog, DBMS interface]
	Low	Not useful [e.g., Literary work]	Low usefulness [e.g. Multimedia news sevice]

Table 3. Usefulness of the RMM approach

(Source: Isakowitz et al. 1995)

The RMM methodology itself has seven distinct steps (Isakowitz et al. 1995). These are:

1. *E-R (Entity-Relationship) design*: E-R design is a well-known and familiar concept to system analysts. In it are defined the relationships between all the information entities inside the application.
2. *Slice Design:* Unique to hypermedia applications, determines how the information in the chosen entities will be presented to users, and how they can access it.
3. *Navigational Design:* Designing the paths that enable hypertext navigation. Top-down or bottom-up approach in which the structure is studied either from a general level downward or from an individual level upwards.
4. *Conversion protocol design:* The remaining four steps are concerned with the design and construction process of the application. This step uses a set of conversion rules to transform each element of the model into an object in the application.
5. *User Interface design:* Involves the design of screen layouts for every object appearing in the navigational design of step 3.

6. *Run-time behaviour design:* Decisions on how links are done, the history, and backtracking and navigational mechanisms are to be implemented.
7. *Construction and testing:* Testing is done as in traditional software engineering projects. In hypermedia applications error tolerance is even lower than in traditional programs so thorough testing is necessary.

5.5. Website acceptance and perceptions by users

As the information system in concern is basically a website with an integrated user interface it is vital to examine the users' perceptions about it because they are main influence for the future development of the information system.

A method to study the users' perceptions of a web site is by applying the technology acceptance model (Davis, 1989; Davis, Bagozzi & Warshaw, 1989). TAM has been widely used to predict the acceptance of a new technology, such as the acceptance of new software packages. It deals with two main variables that have a great impact on the overall acceptance of a system. These are perceived usefulness and perceived ease of use. (Lin & Lu, 2000)

The technology acceptance model (TAM) is depicted in Figure 6. Although in this project the TAM was not directly implemented, many issues that it deals with correlated with issues in the project and these can be identified easily and are discussed in chapters 8.6 and 8.7.

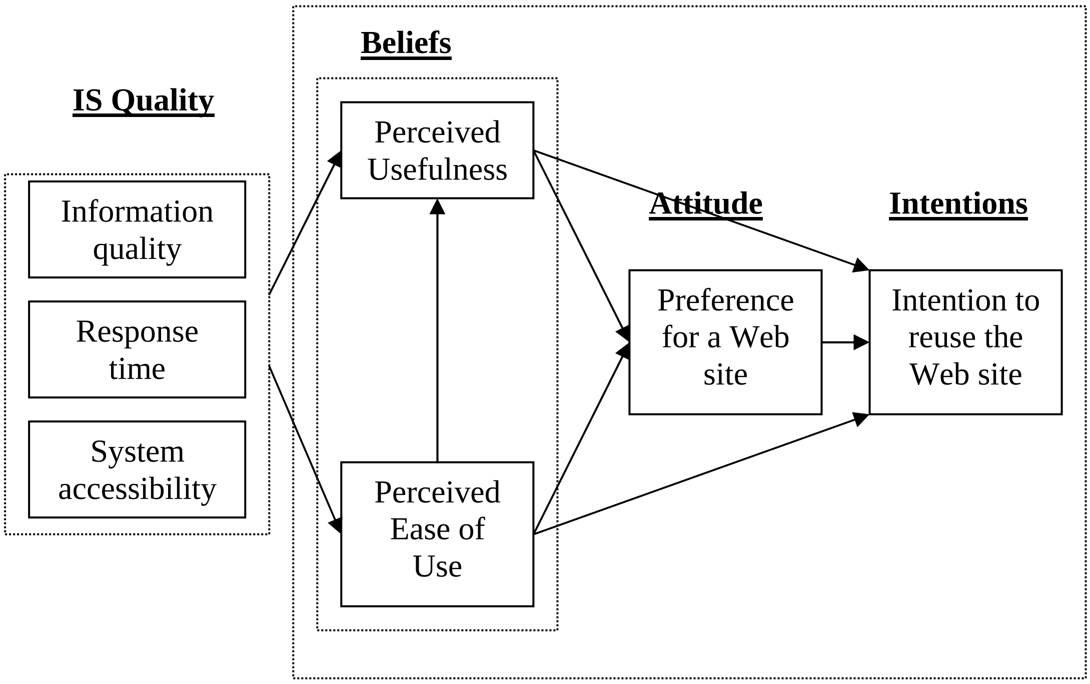


Figure 6. Research model for Web site acceptance

(Source: Lin & Lu 2000)

According to the TAM the perceptions that users have of websites are defined by beliefs, attitudes and intentions to use the website. Through this model it can be said that the actual technical quality of the website does not have a huge impact on the acceptance of the website. If the quality is perceived to be good by the users then it will result in better acceptance. Although it is notable that this is not the only factor involved.

The three variables that account for the information system (IS) quality in the TAM model are information quality, response time, and system accessibility. For example response time is very important. This is because despite the fact that the Internet has become very popular, many people resist using it because of low response time. There are many factors that contribute to low response times; among these are poor design decisions in the Web site, heavy traffic on the Internet and lack of system accessibility.

Again we return the issue of developing web applications and web sites mentioned before. As the development of a website is more of an authoring issue than of implementing a rigorous systematic approach as in other software development, the layout and logical structure of the site are of paramount importance. If the user sees a system that pleases the eye the user also perceives the quality to be good although the technical issues of the execution of the site may not be of a high standard. Nevertheless looks are not everything. One of the most important issues in a web site is the existence of a logical and robust navigation structure.

The TAM gives results on a micro or individual level but there is a definite link of system acceptance to a macro level or organisational level. If users are satisfied with the system this could result in the improved efficiency of workers. This naturally contributes to increase the efficiency of the entire organisation. As DeLone & McLean (1992) suggested in their IS success model shown in Figure 7.

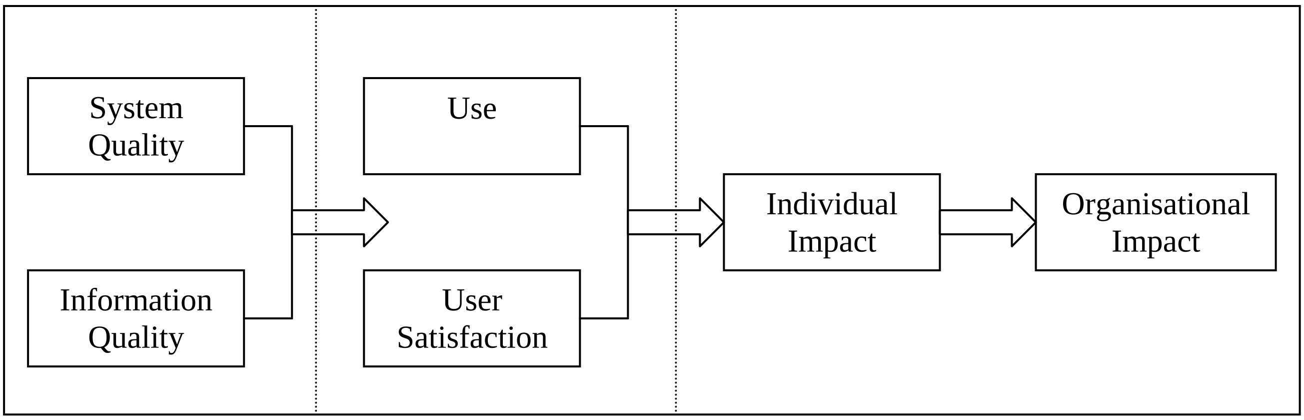


Figure 7. The IS success model

(Source: DeLone & McLean, 1992)

5.6. Designing an industrial hypermedia application

The basis of converting paper-based information into electronic information begins with scanning the existing documents to keep the original look of the documents. It is also possible to make a full conversion of the information using optical character recognition (OCR) for text or raster to vector conversion for drawings. (Crowder et al. 2000).

Especially engineering drawings present a challenge to convert into electronic format. The quality must remain at a very high level so that drawings are as clear as on paper. The bitmap (BMP) form of pictures has been used in many cases. However, when drawing sizes increase up to A0 size, BMP loses it's power due to the fact that file sizes become immense and they are no longer practical to be loaded onto computer screens (Greenough et al. 2000).

The Acrobat Exchange from Adobe System provides a file format called portable document format (PDF). This provides the possibility to view very large documents and drawings while taking up relevantly small amounts of disk space. The Acrobat Reader can be incorporated into a Web browser so PDF documents can be accessed globally via the World Wide Web or a company Intranet (Greenough et al. 2000)

PDF documents also are very easy and quick to create. They can also be viewed easily and zoomed into and have a very high picture quality.

Industrial user interfaces

As the user interface is used to access all the information inside an information system, it is imperative that the user interface is constructed in a holistic way. This means taking into account all the intended users, their experience levels, their computer literacy etc. If the interface is complex, hard to understand and not intuitive then most likely the users will discard the system and never use it once tried it and found it too difficult to use.

The industrial environment also brings together users of various backgrounds but who all need to use the same system. In practice, what is actually required is an appropriate interface for the task that has a common look and feel yet allows the different group of users, with different abilities, access to the appropriate information. (Crowder et al. 2001)

The kiosk approach adds another aspect into the interface. As the interface is not the one users are most common with, Windows etc., there is a challenge to create a system that is understandable and similar or comparable to systems users may have encountered before.

User interface standards exist and they state that consistency normally enhances the users' productivity by leading to higher throughput and fewer error because the users can predict what the system will do in any given situation and because they can rely on few rules to govern use of the system. (Nielsen, 1993)

5.7. Hypermedia and training

Hypermedia as discussed before is primarily meant to support a given task. Therefore it is considered to be a task support system. However there is also another purpose that task support systems can be used for which is training.

Kasvi et al. (1991,1993) have developed an Interactive Task Support System (ITSS) to provide all the task related information needed during the completion of a lightweight assembly task in the Helsinki Power Electronics Plant of ABB Industry Ltd. (Kasvi et al. 1996). The aim is to train new employees their future task in the factory without the need for them to be at the actual workstations. This is done with the ITSS's multimedia documents. The differences of training for a task and supporting are shown in Table 4. These include:

Training	Support
Delivered separately from the task	Delivered during the task
Medium to long range goals	Instant goals
Based on the assumed information needs of the employee	Answers to employee's actual information needs
You must not forget what you have been taught	You can always check what you have forgotten
Suitable for static work environments and basic skills	Suitable for dynamic, learning work environments and skill apply details

Table 4. Differences between training for a task and task support

(Kasvi et al. 1996)

Microcosm

Microcosm is an open hypermedia system developed at the University of Southampton in the early 1990s. Its objective is to provide a system to facilitate resource-based learning. From the beginning it's purpose was to create an information management and authoring environment that allowed users to customise the available multimedia resources into individual learning environments to cater for personal learning styles and abilities. (Hall, 2000)

The aim was to encourage staff to use this technology as a natural part of the tools they used for teaching. It is clear that not all teachers are willing or able to develop skills required to become multimedia/hypermedia application developers. Therefore the system was designed to reduce the authoring effort required to create hypermedia based learning environments. On the other hand this is a question also of evolution in teaching culture because computers have become a teaching aid replacing or supporting common textbooks. Twenty years ago not all teachers were computer literate but today it is almost a necessity. The same might happen to web authoring skills. Hypermedia could become the next replacement to overhead slides and blackboards. As Hall (2000) stated: "*It is all about changing the culture by evolution rather than revolution.*"

6. Usefulness and usability

This chapter discusses the two main issues of successful information system acceptance, which are usefulness and usability. The concepts of these two topics will be brought forth and the ways to evaluate and measure them as well.

Usefulness is the issue whether the system can be used to achieve some desired goal. This again can be broken down into to two categories, which are utility and usability. Utility is the functionality of the system i.e. can the system do what is needed and usability is the question of how well users can use that functionality.

Usability is a multi-dimensional issue that incorporates many features and issues. Traditionally usability is associated with five attributes (Nielsen, 1993):

- *Learnability:* The system should be easy to learn so that the user can rapidly start getting some work done with the system.
- *Efficiency*: The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.
- *Memorability*: The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.
- *Errors*: The system should have a low error rate, so that the users make few errors during the use of the system, and so that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.
- *Satisfaction*: The system should be pleasant to use, so that users are subjectively satisfied when using it; they like it.

The International Organisation for Standardisation (ISO) defines usability as: “the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments”.

6.1. Usability evaluation

Usability evaluation is the most fundamental usability method and is almost irreplaceable; because it provides direct information about how people use computers and what problems they are experiencing. (Nielsen, 1993)

Evaluation of the usability of a system is a part of the designing process of an information system. Faulkner (2002) presents that Hewitt (1986) suggests two forms of evaluation. These are formative evaluation and summative evaluation.

Formative evaluation is used to help the design process. It involves working closely with the users and gathering feedback about their opinions of the system. Formative evaluation concentrates on qualitative information on the system. For example, how the users like the system and what problems they have encountered. (Faulkner, 2002)

Summative evaluation is likely to require quantitative data. It is best to be used when the system is complete and the final product is trying to be evaluated. This means that summative evaluation contributes to the re-designing process of designing an information system (Faulkner, 2002)

6.2. Carrying out evaluations

Carrying out evaluations is discussed quite thoroughly in the existing literature. The basic structure of carrying out a usability evaluation consists of these steps (Faulkner, 2002):

- *Identifying the target group:* the target group can be very obvious, such as the intended users.
- *Recruiting users:* the stage to determine how many users are required for the evaluation and what the background and skills of these users should be

- *Establishing the task:* establishing the task is to specify what the users should do during the usability evaluation. The task should be extensive enough to test all the main elements of the system, but it is based on what the usability engineer hopes to establish with the evaluation.
- *Carrying out the evaluation:* the actual test stage which should be arranged in a comforting environment and so that the test subjects feel no pressure. They should have clear instructions and the test should follow out a pre-determined schedule.
- *Reporting on the findings:* any problems encountered during the testing should be reported so that findings can be accurately analysed.

Nielsen (1993) describes usability testing in four stages of *preparation*, *introduction*, *the test itself* and *debriefing*. These concur with the views that Faulkner (2002) describes.

6.3. Questionnaires

To capture the results of the evaluation tests, a questionnaire is a good tool. Data collection methods are various depending on the sample sizes the target groups etc. In this project the sample group is already known so the method for data collection is quite obvious. As there are only 6 users for the intended system, a questionnaire on usability and usefulness concerning functional issues based on an interview is the best answer.

Question types in a questionnaire are specified into open or closed questions. This means that in open questions the respondent can freely give an answer as where in closed questions the respondent is offered a choice of alternative replies (Oppenheim, 1996).

7. Design of the information kiosk for the company

This chapter discusses the actual development process of the information system. It presents constraints and the background of the system. It also looks at design methodology used and how the methodologies were adapted for the project.

This Master of Science thesis project was about the development of an Internet technology based information kiosk to be used as a manufacturing information system at the shop floor level.

Internet kiosks have many features that suggest that they might be suitable for use in factories, especially now that many companies are using a web-based user interface to their manufacturing systems. A kiosk gives a new way to display manufacturing information directly to the operators at their workstations.

The project includes developing an interface suitable for the manufacturing process, creating the web based manufacturing information - which includes engineering drawings, tooling sheets and part programs - and the possibility to view solid models and simulations of the manufacture of engine components for an airplane engine. The usability issues of the kiosk-based approach were also investigated by studying the use of a pilot system at the company's factory in the UK.

The design process was carried out using a structured approach of designing an industrial hypermedia application. The actual methodology was developed by Crowder et al. (2000), but it has been revised for this purpose by incorporating the methodologies of Nielsen (1993) and Coe (1996). These methodologies were described in chapter 5.

The designing process includes collecting and analysing feedback received directly from the operators. This allowed a task-centred information system to be developed iteratively and gave accurate user feedback for the usability study.

The methodology used is described in chapter 8 and the detailed explanations of each step in the methodology are also presented in the following chapters.

Design Methodology

The design of the information system for the company was done by using the hypermedia application development methodologies found in the literature of hypermedia information system development for industry as well as methodologies intended for general information system development with focus also on usability theories.

While the methodology introduced by Crowder et al. (2000) is a very holistic approach to hypermedia application development for industry it lacks certain issues that were essential to this particular project. The purpose of task support of the system was best tackled by also taking note and integrating the views and methodologies of Nielsen (1993) and Coe (1996).

Nielsen's methodology introduces many usability issues that were a concern in this project. These were evaluations of the intended users and parallel and participatory design. Coe on the other hand concentrates on the human factors of developing technical information systems for users. By creating an adaptation of these three methodologies a multidisciplinary approach could be taken in the design of the information system. The main emphasis was on creating an industrial hypermedia information system but also this way the aspects of usability and human factors, which are essential in successful implementation of an information system, were also taken into account.

8. The adaptation of design methodologies

In this chapter the design and development methodology used is discussed thoroughly. Also the process of design and development is covered step-by-step explaining problems raised, technical choices taken and many practical issues related with the phases of the design process. It covers the design of the system from initial requirements to the final version and the usability study made.

As proposed before the existing methodologies could all be more or less used in the development of the information kiosk for this project. However it is more appropriate to use parts of all the methodologies described. Therefore an adaptation of the three main methodologies was chosen to be implemented in the development of the information system.

This adapted methodology has nine distinct steps that best describe the development of the information system and is described in Figure 8 in more detail. Each step will also be described in greater detail in the following chapters.

- *Initial specifications:* The first step naturally is the initial specification. In this step the task analysis of the shop floor workers was performed. From this the detailed requirements of the system could be pointed out.
- *Goal setting of the system:* In this stage the purpose of the system was defined based on the task analysis; what where the specifications required to make the information system a task support system.
- *Design process:* The design process comprised of both parallel and participatory design. However it was more focused on making it a system for the users so participatory design had more emphasis and also was done in an iterative manor. In the design process the issues of *hardware decisions, user interface, information structure, functional structure, authoring* and *navigation* were addressed.

- *Prototype:* Several prototypes of the system were done to receive initial user response to the system.
- *Evaluation and re-design:* After having the prototype ready, user feedback was used to evaluate weaknesses and re-design the system. After this the full content was added.
- *User trials:* Once the system had been evaluated to have a logical function and structure the fully functional system was given to the users for testing and evaluation. Feedback was received from the user trials and much knowledge gained on what needs to be improved and which parts are weak and need improvement.
- *Final project version:* The final system version of the project was finished after the changes rising from the received feedback had been made to the system
- *Usability study:* The usability study was done to evaluate the successfulness of the kiosk and it’s impact on the shop floor by making a survey with the users.
- *Guidelines & procedures for future updates:* As some parts of the kiosk were specially designed for a purpose, guidelines for future changes are good to be done to remove possible errors or malfunctions that could occur. Suggestions and procedures in implementing further changes are also suggested. A manual dealing with these issues was made.

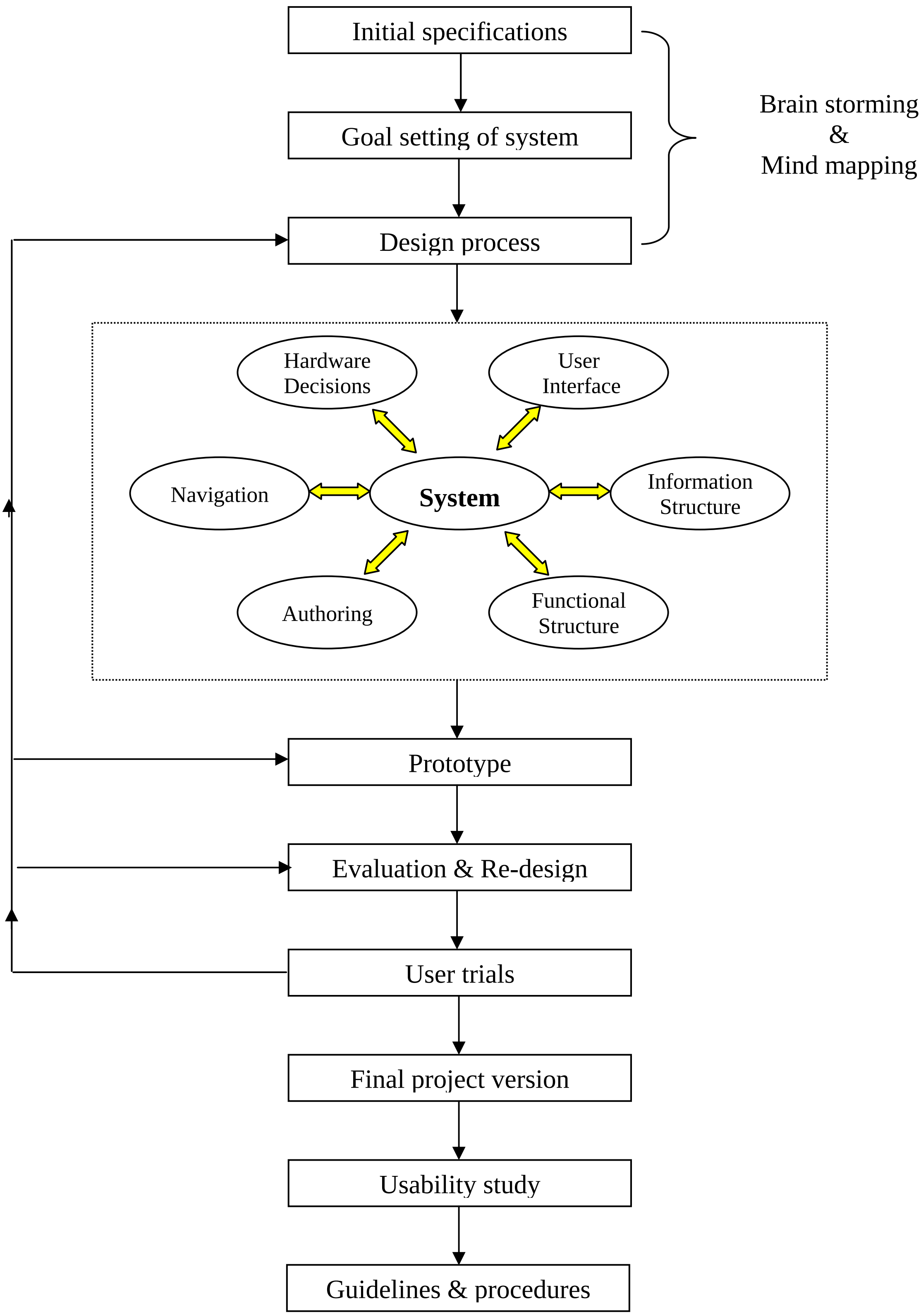


Figure 8. The adaptation design methodology

(After Crowder et al. 2000)

8.1. Initial specifications

To have an understanding of how to design and develop a task support system it is essential to have an understanding of the task that they system is developed for. A task analysis of the workers on the shop floor in the factory was done. Tim Butcher, as part of his research work, conducted the task analysis.

The task analysis began in February 2002 and included interviewing and observing and then transcribing these. The objectives of the interviews were:

- To determine the tasks performed by operators of the studied machine tools as to document and model the process/system
- To determine information use for improvement assessment
- To determine operator roles in the production system

The questions asked consisted mainly of ‘what, why, where, when, who and how’ questions specific to the task and were typically only required when the operator forgot to inform the interviewer of his actions at a point in time. With the interview a total understanding of the operator tasks was ascertained.

A task model was then constructed based on the interviews. This shows in a flow chart everything an operator has to do to perform a task: the core manufacturing process, component selection, datum setting, inspection and tool replacement. The preliminary task model and the following iterated task model can be found in appendix B.

Through the crucial first step of task analysis a basis for the project was created. The interviews allowed the information needs to be identified and therefore gave an appreciation of what information was required from the kiosk i.e. the information system.

The task, which the kiosk is intended to support, is the manufacture of engine components on CNC-machines. There are four parts or engine components that are included in the kiosk and there are three major sources of information that are needed by the operators while machining these parts and that are suitable for the kiosk. These are:

- Engineering drawings (CAD generated)
- Tooling sheets (CAD generated)
- Part programs for CNC machines

The way that the operators perform their task is in appendix B, but is summarised as follows. First the operator needs to look at the part program of the CNC-machine. This program includes e.g. information of tools that are needed for the process and when the tool needs to be changed on the machine. Therefore after consulting the part program the operator needs to view the tooling sheet of the tool. Additionally the operator needs to refer to the engineering drawing and then again to the part program and the tooling sheet. Therefore these three documents are the basis of the information system.

Current practice

Currently the information needed for manufacturing by the operators is all on paper. The documents are located in filing cabinets close to the CNC machines. Every time an operator requires information he needs to go to the cabinet, find the appropriate folder and then look for the correct drawing, tooling sheet or part program. This presents many issues that make current practice inefficient and time consuming.

Searching through many different pieces of paper takes time. Also due to the fact that the working environment is not very clean, due to machining, the papers can get easily dirty, damaged and even lost. Organising the documents and keeping them in the correct order also is a problem with the current practice.

8.2. Goal setting

The current practice shows many areas of improvement and there are many ways that a kiosk based system could prove to be useful and more appropriate. The objective was not to produce an entirely different system from current practice, but to create a system that would be a natural supplement to the current one and ultimately a replacement for it. Therefore the issues of duplicating what is done currently into an electronic form of information were a main objective of the project.

In terms of goal setting for the information needs, the information system had to have the same manufacturing information available as currently exists. Therefore the main documents it needed to have were the engineering drawings of the parts and components, the tooling sheets of different tools used by the CNC machines in the manufacturing process and the part programs that the CNC machines use. However the kiosk provided also an opportunity to test the usefulness of solid models of the components and also simulation programs generated by Vericut. The last two features have previously been unavailable to the shop floor directly due to the technical requirements to view such documents. The usability of these two features was therefore also studied.

Therefore the goals of the project could be outlined as follows:

1. Establishing shop floor requirements for a foundation on which to build the information system
2. Create the web based information package and the user interface for the kiosk to form a manufacturing information system.
3. Carry out a usability study to assess the success of the kiosk both in terms of usability of the system and usefulness for the task it is intended to support.

Other goals in the research project also include the development of a communication tool to study the issues of knowledge management and to study the effects of the kiosk on quality in the long term.

8.3. The design process

As stated previously the design process is an iterative process with many factors influencing it. In this project the design decisions will be described in the following chapters and the choices made are explained as well as the background issues affecting these choices.

The design process involves designing or sketching out the initial design and structure of the information system. After the requirements of the users are understood this initial design can be shown to the users to confirm that it is what they want. Much responsibility is on the designer to use his/her imagination to construct the system into what satisfies all the end users.

8.3.1. Hardware

The kiosk approach seems to provide many characteristics that suggest it would be good for use in factories. A kiosk gives many benefits over installing a normal computer system i.e. a PC. Mainly durability of the hardware is better in possibly hostile environments and mice and keyboards may get easily damaged as well as normal monitors. The kiosk provides a robust solution.

The actual kiosk comprises of a PC CPU, mouse and keyboard, which are housed in a lockable steel cabinet with a touch screen monitor built into the cabinet provided by Armagard. The control devices and the CPU are only accessible by having a key to the cabinet. The users use the touch screen to navigate on the screens and a virtual keyboard that is provided in the interface to insert text. The PC has Windows 2000 as an operating system on which the actual user interface platform, NetShift, operates from.

The steel cabinet is a very secure and robust housing for the kiosk as the kiosk is to be placed in a “hostile” environment where it may need to stand heat changes, accidental hits, exposure to swarf etc.

The touch screen on the kiosk is made of heat-strengthened glass, which is durable, stable and is not activated by dust or dirt. Moreover it is very easy and quick to clean. The total cost of the kiosk (hardware and software) was £ 4300 of which the touch screen monitor comprised £2730. It is also notable that this is the price for an 18-inch monitor. Smaller screens are much cheaper e.g. a 17-inch touch screen monitor costs ca. £760.

8.3.2. User interface

A large part of the designing of the kiosk information system was the development of the user interface. NetShift – a UK based company that claims to be the world's leading supplier of such software, provided the public browser interface software chosen. NetShift is a software package that runs on Windows. It uses Internet Explorer from Microsoft to display the contents of the kiosk in a browser window. The NetShift environment is actually a security layer on top of the Windows operating system and cannot be hacked without passwords.

NetShift

NetShift v5 is a complete solution to providing Public Internet or Intranet Access via a Windows/PC based device, often called a Kiosk or a Deployed Device. (ww.NetShift.com). The software allows creating a user interface needed for a kiosk. This includes buttons, a virtual keyboard, banners, a clock etc. The NetShift interface uses the Internet Explorer in a browser window to present the content. The content itself comprises of web pages that can be created a number of ways using e.g. HTML editors like FrontPage or Dreamweaver. NetShift also has a built in function to view PDF documents on it's own browser.

The user interface

The user interface developed for the kiosk is twofold. On one hand there is the user interface of NetShift and on the other the user interface of the content pages.
The content pages are constructed as a website with an internal navigation structure.
While designing the interface it was important to understand that these two interfaces supplement each other so it was not necessary for example to build a complete navigational structure into the website, but the NetShift interface was possible to be used for the highest level of navigation within the system.

8.3.3. Information structure

The information content of the kiosk consisted of engineering drawings, tooling sheets, part programs, solid models and simulation movies. The drawings, tooling sheets and part programs only existed in paper format so therefore they were all first scanned as images. After scanning the documents they were converted into Adobe's PDF file format. This format proved to be the best solution to display the documents in an electronic format. The PDF allows the document to be panned around, zoomed into etc. while still maintaining a very high level of quality. An example of an engineering drawing is shown in
Figure 9.

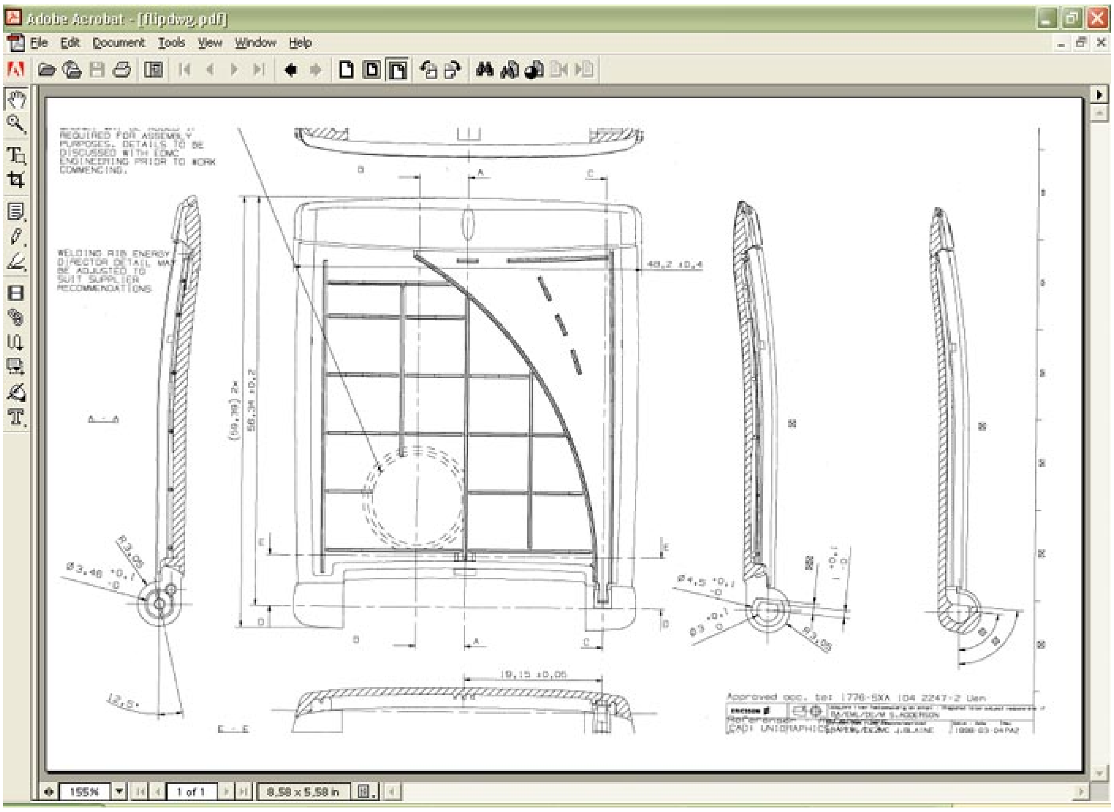


Figure 9. An example of an engineering drawing in PDF-format

PDF documents are also very useful for this instance because they cannot be altered or changed. The document is an exact copy of the original drawing and has no distortions or errors on it.

NetShift has a built in viewer to view PDF documents on the screen of the kiosk. This differs from the way that PDFs are traditionally viewed on Internet browsers. One point is that the toolbar that Adobe Acrobat has is not shown, so no one can try to alter the PDF in any way. A screen shot of NetShift's PDF browser is shown in Figure 10.

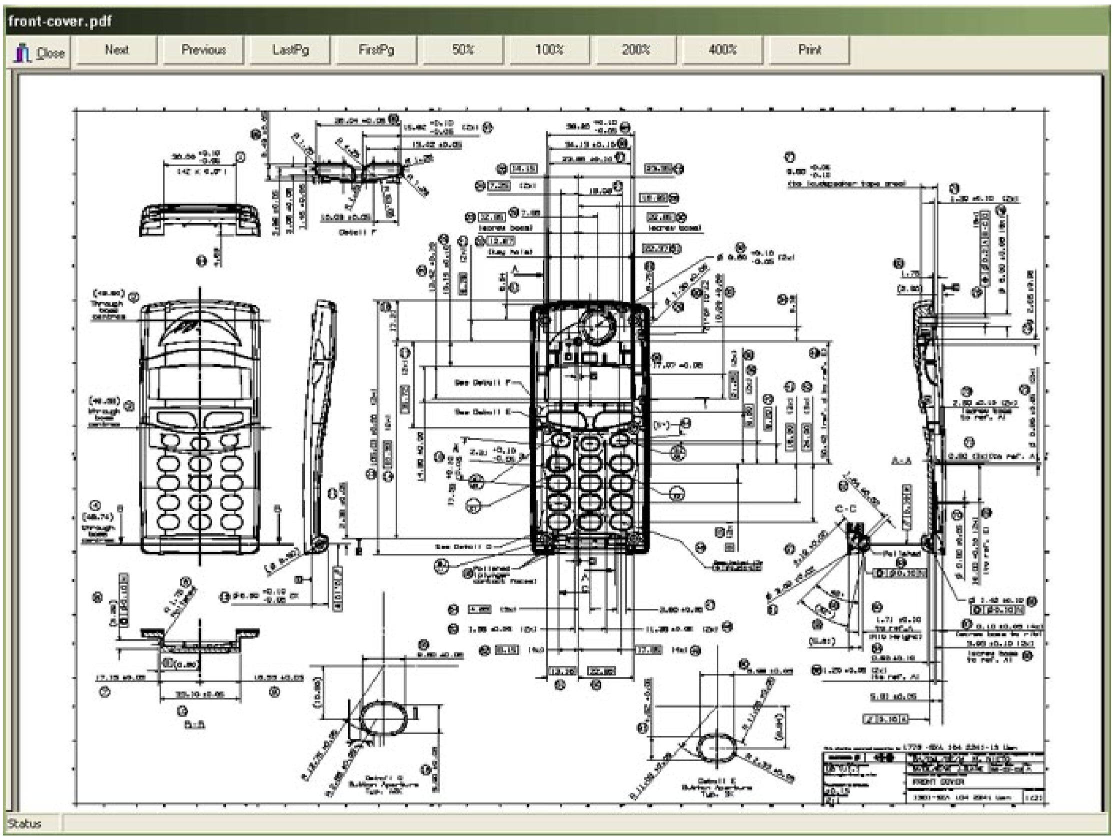


Figure 10. NetShift's PDF browser

The company uses CADDS, a software package, to generate the solid models of the products that are manufactured on the CNC-machine. The models are made directly from the drawings themselves. This software package enables AutoCAD models to be converted to STL file format. There were many options on how to view the solid models on the kiosk.

Many software packages exist that can view solid models or STL files, but all of them have the same problem when trying to integrate them into the web based system. They all required that the program itself be run. This presented a problem because it would take the user away from the interface into a totally new environment. This could not be acceptable because the intention was that everything could be viewed in the browser as embedded into the system. After going through the various means of viewing STL models a solution provided by ActiveX STL viewer control v2.0 was found.

This was an Active-X protocol for Internet Explorer, which enabled the STL file to be viewed directly in the web browser so that nothing else is shown on the screen except the model.

This was an excellent way to implement the solid models into the system. The only remaining issue was that one could not zoom into the model by using the touch screen. However the model could be panned and turned around on a 360-degree radius. An example of a solid model can be seen in Figure 11.

Figure 11. A solid model STL-file as viewed on the browser.

The visualisation of solid models can be an important issue. MCAD-magazine states that a widely used industry assessment says that for every part designed, there are upward to ten people who need to visualise the part as it makes its way through the supply chain. (Dean, 2002)

The simulations used are movies taken from the simulation program called Vericut. It shows an animated movie of the process performed on each part. The movies are in AVI (Audio Video Interleave) format and were integrated into the system as embedded files on the pages.

Because the current operators in the factory are highly skilled and have years of experience on the job, one could argue that there is no value in providing solid model viewing or simulations of the parts to support the task. However for training purposes these are excellent tools to give a visualisation of what is actually being done in the factory.

8.3.4. Functional structure

The content of the kiosk is a website consisting of several pages. As there were four major components whose manufacture the system was intended to support, four identical websites were created; one for each component. Each website has the same manufacturing information for each part and also the solid models and simulations accordingly.

The user interface was done by creating large images that functioned as buttons on the screen. These images were inserted on the pages and then hyperlinked. The idea was to create a very simple and intuitive interface. One issue on this was to reduce the amount of information on each page and also by not having dozens of buttons on each page.

The NetShift interface is shown in Figure 12. This shows the different areas of the information system. There are three main areas: the NetShift interface, the browser window and the banner window. The NetShift interface is visible at all times and has the main functions of the system. From this area the different websites to each part can be accessed. The interface also has the navigational buttons such as back, home, help and the virtual keyboard.

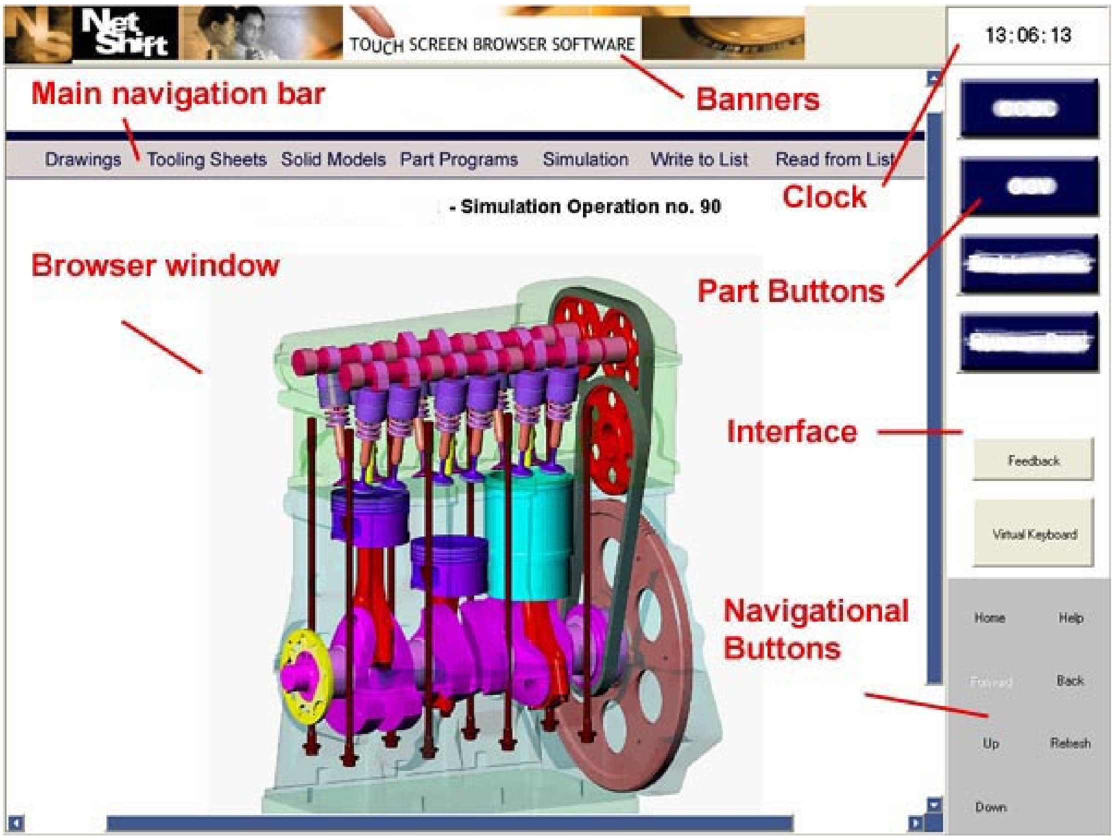


Figure 12. The NetShift interface

The browser window takes up a large part of the screen. This is where all the information is viewed through Internet Explorer.

The banner window has a set of banners that circulate and give general information about the kiosk to the users.

Additionally a communication tool was constructed as a part of the larger research project by Tim Butcher and this was then integrated into the system. The tool was made by using ASP pages that were linked to an Access database. This tool acted as a notice board for the operators so they could read and insert messages on specific tasks or tools and discuss problems etc.

This knowledge list communication tool acts as a virtual notice board, where operators can insert their comments on specific tasks, issues, problems risen etc. This list exists for each engine component separately and can be accessed from the main navigation bar. With this notice board more effective communication can exist between the operators. For example, a problem with a machine can be reported to the next shift operators via the kiosk.

8.3.5. Authoring

Concerning the visual image of the pages, not many graphics are used but still a very powerful image of design is portrayed by the use of curved shapes in the main navigation bar, which pleases the eye. Few colours are used to keep the pages clean. No background colour is used to keep the text readable. There are also no contradicting colours used on the pages e.g. blue and red. A screen shot of a page in the kiosk can be seen in Figure 13.

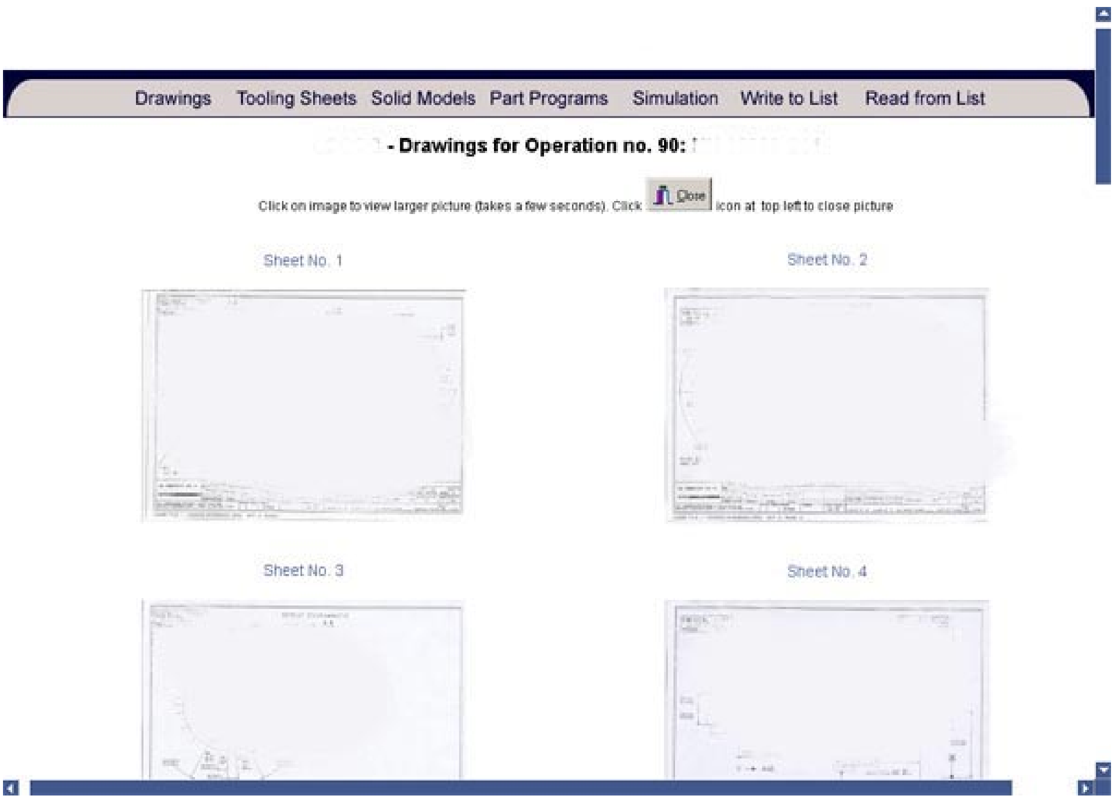


Figure 13. An example of a content page in the Kiosk

The font that is used is Arial, which is a good choice because the letters do not have ends on the letters as compared to e.g. Times New Roman. For example the differences are compared in the following sentences. "This is Arial. This is Times New Roman." Arial does not have ends on letters like the capital T vs. T. This is important when reading electronic documents because "plain" letters are faster and easier to read on the screen.

To enhance the updating and changing of the content of the page a Cascading Style Sheet (CSS) is used to determine the style on each page. This is a very important feature for many reasons. First of all it eases updating and changes. If a change in font colour is needed for 20 pages one need only to change the colour specification in the CSS document instead of changing the font on 20 pages. Secondly CSS-documents diminish the amount of code needed for the page. The HTML-code is now very compressed with no reference to style tags, apart from where the text is bold, underlined or italic in the text. The CSS-file can be found in appendix E.

Microsoft Frontpage was used to generate the HTML code for the pages. There are also many other HTML-editors, but Frontpage was chosen as a personal preference of the author.

8.3.6. Navigation

The navigation structure of the information system has been tried to keep as simple as possible. Where possible, the structure of the site has been tried to be kept on as few levels as possible, to avoid users getting confused or even lost inside the system. The navigational structure is shown in Figure 14 explaining the different levels of the system.

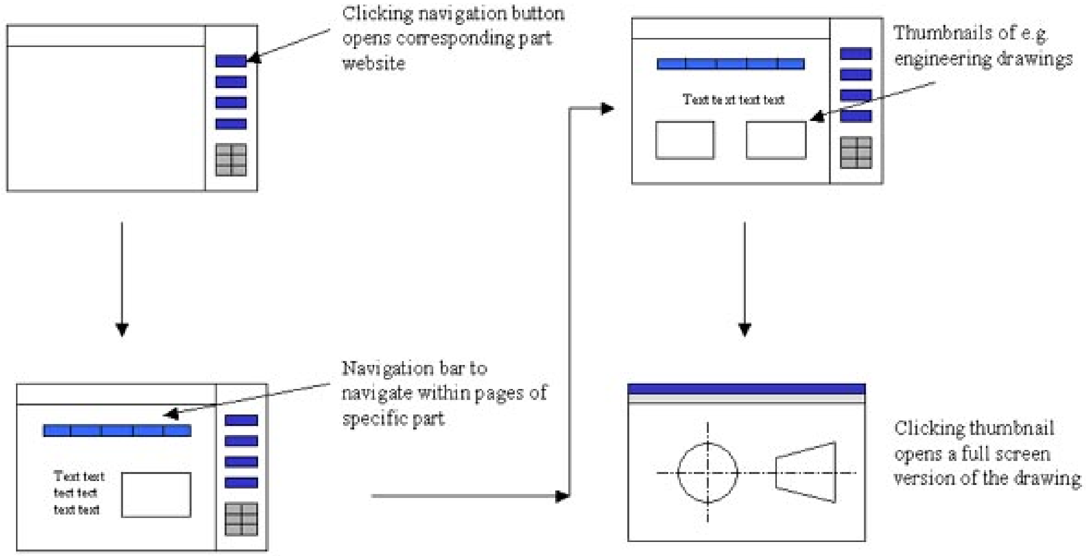


Figure 14. The navigational structure and levels of the information system.

The main navigation is done by clicking the desired part on the right hand side of the screen. By clicking the part that the user wishes to view the link opens the specific website in the browser area of NetShift. When the website opens in the browser the main navigation bar for the website can be seen. This is visible at all times and on all pages so that users can quickly move to the section of information that they wish to view.

The main navigation within the individual part websites is done through the main navigation bar shown in Figure 15. This navigation bar is always visible on each page so that one can move from anywhere in the system to the section desired.

Figure 15. The main navigation bar

8.4. Prototype

According to the methodology used to design the hypermedia information system, several different prototypes of the system were produced. In total there were three different types of prototypes that were created. The first one was a scenario-based prototype in which the first draft version of the system was developed. This had no actual relevant content and was designed to portray an example of what the system could look like. The first version of the system can be seen in Figure 16.

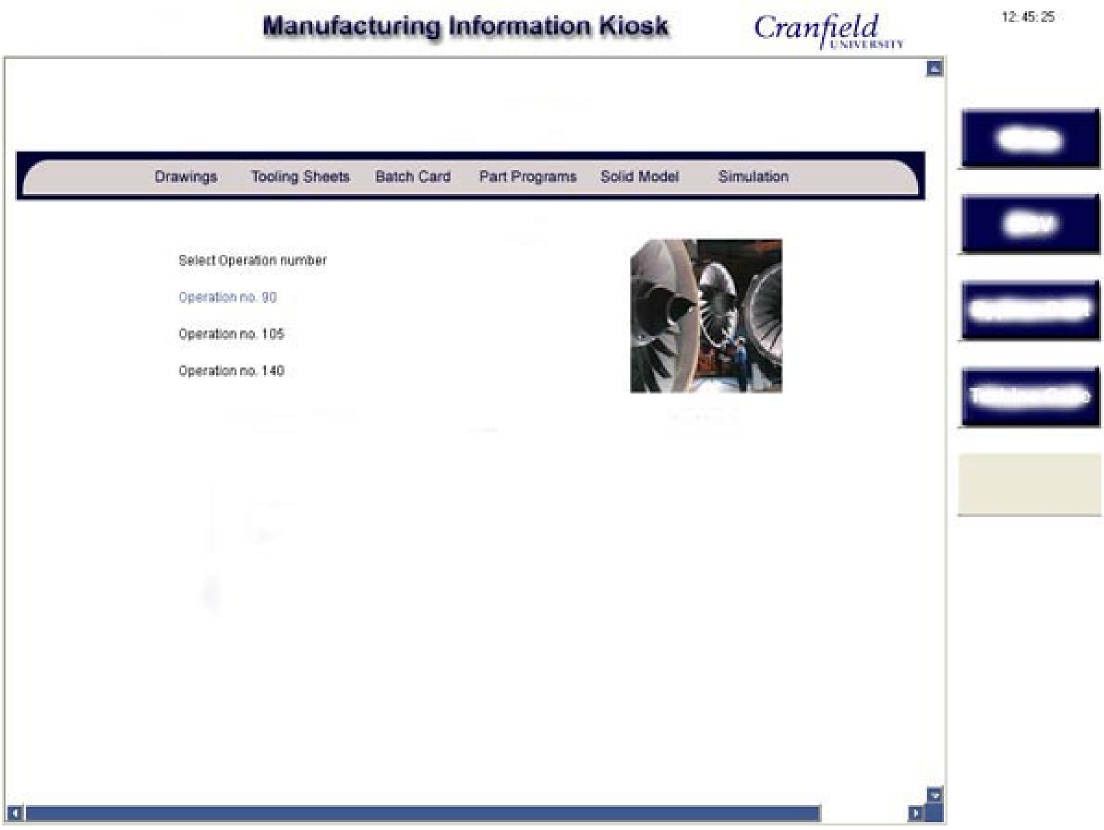


Figure 16. The first prototype of the Information System

As it was a scenario based prototype it was missing most of the functionality but gave a good idea of what the system could be like. There was an example of every type of information on it. This was done to give the users a grasp to what was to be expected of the system. As no current information system existed yet, the only thing that existed was ideas and expectations.

Although the system was very rough it gave a huge amount of feedback on what was good and what was bad. This was a good example of participatory designing where the users are closely involved in the development process. Many suggestion were made that had not had been thought of. Also many new ideas were generated and the development took a huge leap during the introduction of the prototype.

8.5. Evaluation & re-design

By creating prototypes of the information system it was possible to efficiently evaluate many aspects of the system. For example the first prototype proved not to be the best way to navigate on the website. The links were too small; they were located on the page at a place where the users did not spot them at once. The text size was also too small to allow efficient viewing of the pages. Also the main navigation bar buttons proved not to work very efficiently on the touch screen. It is notable none of the design decisions taken were actually wrong or bad ones, but carrying out the ideas into practical, working elements required re-evaluation and re-design.

In the prototype several ways of viewing information was also tested. For example the main elements of the system, the PDF drawings, were tested as embedded files on the pages and also as opening in NetShift's browser. The latter proved to be most accepted by the users. Another issue that was found out was that as there are tens of drawings, tooling sheets and part programs, the operators could not always remember the correct number of the e.g. the drawing they required. Therefore as the links were based on the drawing numbers they sometimes had to go through many drawings before finding the correct one. A solution to this was to add a "thumbnail", a small image of the drawing, next to the text link, because the operators could more often remember what the actual drawing looked like, rather than the number of it.

Various other issues were raised that required re-designing. For example, as the task required the operator to view the part program for the next process in the task, there was a specific sequence in which the machining tools were needed in the task. Hence the tooling sheets were sequenced on the page in the same order, as they were required in the part program.

Most of the problems in the system were noticed and pointed out by the users. This meant that participatory design was key in the development. If the users suggested something that was not technically possible due to constraints an alternative way to satisfy their needs was sought out.

After the evaluation of the prototypes and re-designing the system, the full version of the information system was constructed so that all the required content was added on to the kiosk. The kiosk was then submitted for full use in the factory for a period of time. Minor mistakes that came apparent in the test period were also corrected.

After the users had used the system for a while a big issue concerning the use of the kiosk was noted. Although the operators found the information system to be a success and an aid in their work, they could still not solely use the kiosk as the source of their manufacturing information. The operators were still using the paper documents as reference and the explanation was very simple. It was not sufficient that one could only view one document at a time. The task required that the operator first looked at the part program to see which tool they needed, for this they needed to have the tooling sheet viewable. After this they needed to refer back to the engineering drawing and again to the part program. This meant that the operator was actually viewing three documents at one time. The kiosk was designed to allow the viewing of one document at time and viewing an other document required the user to navigate on the website again and find the correct document needed.

Again a solution to this was suggested by one of the users themselves. A concept of having a split screen where all three documents could be viewed simultaneously was suggested.

This however while being a logical and valid idea had some technical restrictions. The screen size was only 18 inches so having three documents open at the same time would noticeably limit the viewing space on the screen.

However to test this possibility a split screen version was developed. In Figure 17 is shown a screen shot from the split screen alternative. Here it can be seen that on the left hand side of the screen is the main navigation structure. The operator chooses the correct operation number, which opens a new screen.

In this screen Figure 17, the part program that is the main source of information is on the left. On the top right hand side are the engineering drawings for the part and on the bottom right are the tooling sheets that are required for each specific part program in the sequence they are needed.

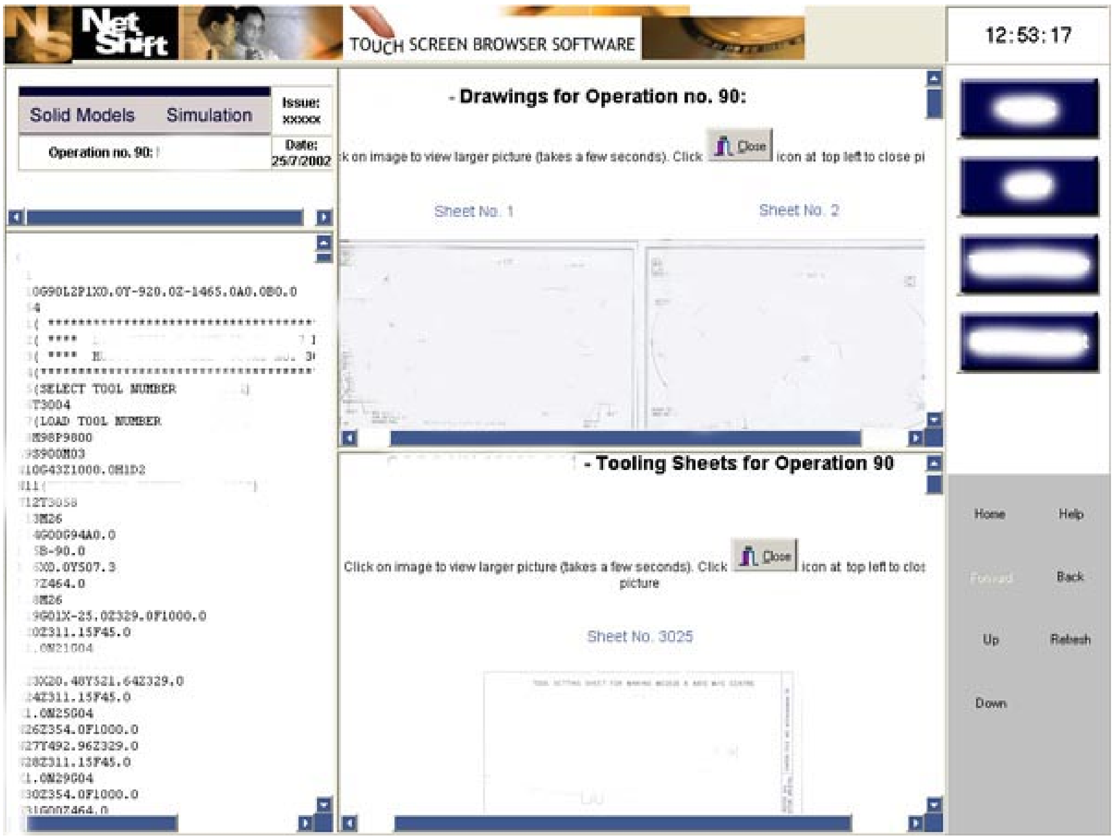


Figure 17. The "split screen" alternative interface

In Figure 18 the logic of the navigational structure of the split screens is shown. As it can be noted a larger amount of information can be displayed in this way and the requirements of the user request are fulfilled. However it is also notable that in the split screen alternative the space on the display is crammed and does not allow as much information to be viewed as in the original version. Nevertheless the usefulness of this alternative may be better and therefore replaces the need of usability.

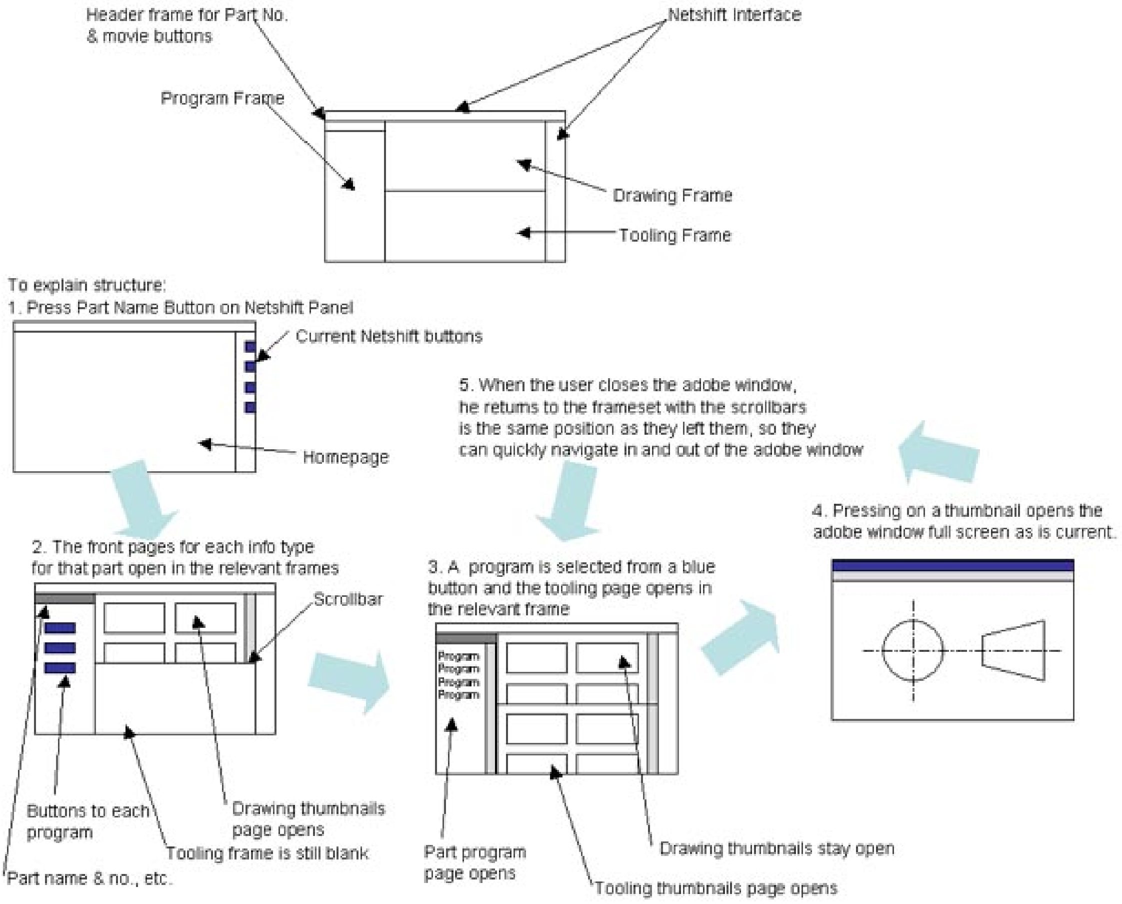


Figure 18. The manufacturing information portrayed in the "split screen" version

8.6. User trials

For the usability trials there now were two different versions of the system that could be compared between each other for usability and usefulness. The usability trials were conducted according to usability trial methodologies found in the literature.

As there were only 6 users for the system the data analysis was judged best to be done as a qualitative analysis instead of quantitative due to the size of the sample. A questionnaire with questions on usability and usefulness was constructed.

Concerning the collection of feedback from the users the kiosk has an online questionnaire that stores user answers into an Access database. However, although encouragement, instructions and help were given to the users to fill out the questionnaire the total feedback received through the online questionnaire could not be considered to be valid. There was only one fully completed answer with comments on the system, so no analysis could be done on the basis of this questionnaire. Therefore the usability study was conducted by directly interviewing the users after giving them simple tasks to perform on the system and then asking their response to both usability and usefulness issues.

To get an understanding how the system has been accepted by the users two main areas needed to be studied according to the technology acceptance model mentioned in chapter 4.5. These are the perceived usefulness and perceived usability of the system. Thus a series of questions concerning both areas was asked.

The test was conducted in a way that first the users were given tasks i.e. to find a certain engineering drawing for a certain part. The tasks were such that all the main areas of the system were taken into account. After a number of tasks were performed a series of very specific usability and usefulness questions were asked and in the end a series of more generic questions.

The questions were closed and could be answered based on the Likert-scale from 1 to 5, where 1 means “I strongly disagree” and 5 “I strongly agree”. The total questionnaire can be found in appendix C. All operators were asked the same questions and the trials were conducted over a two-day period.

The actual questionnaire consisted of questions covering both areas of usability and usefulness. The usability questions were dived according to the usability parameters by Nielsen (1993) explained previously of *learnability*, *memorability*, *efficiency,* *errors* and *satisfaction.* The usefulness questions were focused on finding out if the kiosk fulfilled its aim as supporting the task, and how the split screens are perceived compared to the original system.

The usability trials were a very efficient and effective way of measuring the successfulness of the system. However in the results it must be noted that the operators used the original system for a much longer time than the version with split screens. The data analysis method can be found in chapter 8.8.

8.7. Final project version

The final version of the information system kiosk was left in the factory for use for the operators. In Figure 19, the kiosk is shown in use inside the factory. As this thesis is a part of a larger research project in factory information and knowledge management that still continues the development of the kiosk is not fully complete. However the kiosk is fully functional and has all the manufacturing information needed to support the task of manufacturing engines.

The final version of the system has two versions of the user interface. One is the original interface and website structure and the other one is the version that has the concept of split screens implemented. The split screen development can be said to be at a prototype level even though user feedback and the usability survey was done. This is due to the fact that not all of the content has been converted to the split screens.

Figure 19. The final version of the kiosk in use in the factory

8.8. Usability study

Feedback was received constantly through out the project and aided the design and development in countless ways. However the feedback from the usability survey was the most crucial in determining the success of the kiosk.

A more thorough analysis and breakdown of the usability study and the impacts of the kiosk are in the next chapter (chapter 11). The following explains the qualitative data analysis method.

The method used to analyse the data collected from the usability survey was to assess each of the usability parameters that were presented before: learnability, efficiency, memorability, errors and satisfaction. These were weighted by a scoring system. This scoring system is based on the Likert-scale where as the scale suggests 1 as strongly disagree and 5 as strongly agree. It could be said that the amount of answers for each question would give a total amount of points to this area.

Thus if a number of answerers seem to disagree with a question, the question will receive a low score and therefore suggests that the total score will give an idea of the average opinion of the answerers.

Then as each parameter has a different amount of questions the total weighted score is divided by the number of questions to give an index value to each parameter of usability i.e. this will be the mean value of the answers.

This will very realistically portray the opinions of the users; the higher the score of the parameter the better the parameter has been addressed by the system. For example, for the question is "the system is easy to use?" if 2 people answer 1 - strongly disagree and 3 people answer 2 – disagree, then the score for this question will be 2*1+3*2= 8. The total score reflects the users' opinions that the system is not very easy to use. In this case the maximum score would be 5*5=25, which would indicate that the system is very easy to use. An example of the scoring system is shown below in Figure 20, and the total usability analysis and corresponding scores can be found in appendix D.

1. Learnability		**1**	**2**	**3**	**4**	**5**	**Weighted total**
	1. It was easy to find each destination				3	2	22
	2. I understand the structure of the kiosk, and could explain it				5		20
	3. The design of the kiosk is consistent				5		20
	4. The kiosk is easy to learn				2	3	23
		Mean of weighted totals, index value					**21,3**

Figure 20. An example of the scoring system and index value

This method basically depicts the total opinions of the users in the form of a number that in some cases can be easier to understand than simply saying that something seems to be easy or difficult to use. It simply states that if an area of usability gets a score of 20 out of 25 this would suggest that this area is very well addressed by the system. In words it would mean that a large number of the users agree with the statement that the system is usable.

8.9. Guidelines and procedures

There are many issues concerning the future updates of the kiosk that require some form of prior knowledge of the system and technical issues concerned. As most of the technical solutions and authoring decisions of the information system were done by the author himself it is necessary to create a manual of some kind with guidelines and procedures to be followed in the future development of the system. Otherwise it might prove difficult or even impossible in some situations to understand some aspects of the system.

Thus a small manual was made with explanations of the structure of the system, the file structures, navigational elements, the file formats and restrictions and possibilities. As the kiosk is an intuitive system it does not require a user manual but it does on the other hand require an administrator manual to ease the future development and updates. The manual consists of general guidelines and explanations of the file structure, the specifications of screen sizes etc., the logic of the navigation logic and so on. This manual must also be updated with the system because it is only applicable to the system version that was produced for this thesis project.

9. Evaluation of kiosk and usability study

This chapter evaluates the success of the kiosk and what its main impacts were after it had been implemented in the factory environment. It also analyses the user comments on specific areas and suggests possible solutions to encountered problems.

The usability study provided valuable information on how the users had accepted the kiosk and had it proven to be successful. The qualitative analysis method was described before in chapter 8.7. and now the results of the study are evaluated. A total of 5 users answered the questionnaire. Only one intended user was not interviewed for the survey. However the results show that the users have a consensus in their opinions. The scoring of the qualitative data results of the survey is shown in Figure 21. The more detailed survey analysis with individual question scores can be found in appendix D.

Usability		Index value
	1. Learnability	21,3
	2. Efficiency	17,3
	3. Memorability	20,5
	4. Errors	16,3
	5. Satisfaction	20,7
	6. General usability	19,7
	Total average*	**19,3**
	Total without errors**	***19,9***
Usefulness		
	General usefulness	**20,5**
Split screens		
	Split screens	**22,3**
TOTAL RATING		**20,7**

* Errors calculated as reversed value of 25-7,7=16,3

** Errors, include mistakes users made in tasks and do not give a realistic impression

Figure 21. The results of the usability survey

As we can see the kiosk has very efficiently addressed the issues of usability and usefulness. The different parameters of usability were individually studied and the total rating of the kiosk calculated from the means of the different areas gives the kiosk a rating of 20,7 points out of a total maximum of 25 points. This would suggest that the kiosk has been a success according to the users. The usability survey produced comments on the system relating to specific areas. These are discussed below:

Interface:

The interface and touch screen are good generally, but there are some issues of concern. There is no visual or audio confirmation that a button has been pressed. This results that the user stands and waits for the system to load and does not know if he has pressed the button or not. When pressing the button one must tap it gently and quickly. If you use e.g. your thumb to press the button it will probably not be acknowledged by the system.

Solution:

Perhaps adjusting the sensitivity of the touch screen would provide a solution to the problem.

Mistakes encountered during performing of tasks:

- Wrong drawing pressed because of uncertainty if text referring to drawing is above or below the thumbnail. Therefore the wrong drawing was opened.
- When filling in a comment to the list, the virtual keyboard hides the form and the submit button so the user must first realise that he has to hide the keyboard in order to reveal the submit button. (This happened on three occasions).

The virtual keyboard:

The virtual keyboard seems to be easy to use, although it has the same problem as the buttons; the touch screen does not always acknowledge contact. This is a bit of a contradiction between the answers on the usability of the touch screen and interface, as the same problems exist on the keyboard as on the buttons.

Efficiency of use:

One user pointed out that the kiosk would make him work more efficiently after he had learned how to use it fluently. The rest of the users agreed that the kiosk would make them work more efficiently. This one user however does not work frequently on the CNC-machine the kiosk was intended for, so being familiar with the task makes use of the kiosk more efficient.

Solid models:

The solid models would be useful for training purposes, but do not prove that useful for the current job. However some users said that it is good to see the final part on the screen.

Simulations:

The simulations are good because they show what is being made. It was also pointed out that it would be good to see a simulation of the entire engine. This was due to the fact that the operators cannot see the “bigger picture” as they only manufacture certain parts of the engine. A suggestion was also given of a possibility to see simulations of both the individual component and the entire engine on the split screen.

Split screens:

The split screens seem to have received a very enthusiastic response. The split screens seem to be considered generally as a much better, usable and useful system than the original one. The users also see the split screens as much more useful and appropriate for their task.

Other issues:

It was pointed out that there would be a considerate amount of savings in paper through the use of the kiosk. When e.g. the part programs are in electronic form, there is much less waste of paper and storing space. As part programs are generally very long and have several issues, there can be a considerable amount of savings in storage space and printing costs.

The users pointed out the problem of issue control of the manufacturing information documents. The updates to programs, drawings, sheets and files in general should be done "upstairs" by the design office itself. This would require the kiosk to be networked into the intranet and therefore make possible for updates to be made centrally and the kiosk would basically read from this database instead of always making changes locally. However electronic access via network is an improvement over paper when considering issue control.

9.1. Impacts of implementation of kiosk

The impacts and benefits of implementing the kiosk are various. The benefits arising from the project can be categorised into two areas, which are: shop floor and management level benefits. As the technology acceptance model and the IS success model presents, the acceptance of the system by the users will provide individual benefits, which lead to organisational benefits as well.

9.2. Benefits for the shop floor

The implementation of the kiosk has already introduced several benefits for the operators on the shop floor. These benefits include time savings – the operators find the information they need very quickly on the kiosk. They operators also have no need to go through filing cabinets and folders of documents to find a specific piece of information but can find the information by touching the screen a few times. The interface is considered to be very easy and quick to understand and to use. As the documents exist electronically on the kiosk, there is no need to store the paper documents near the machines. The users themselves have said they are comfortable with the kiosk and would not resort to paper any longer as everything is on the kiosk and can be conveniently accessed.

Additionally, by having simulations and the knowledge list on the kiosk, the kiosk provides an effective way to communicate. The operators can communicate with each other and the simulations provide them an understanding of the “bigger picture”. This means, that they could now have a larger understanding on where the parts they manufacture are going to and used rather than just working without knowledge of what the components are used for.

9.3. Benefits for management

Benefits for management become also very apparent when looking at the impact of the kiosk on the shop floor. Currently there are several departments and people that are responsible for the updating of the manufacturing information documents. This leads to communication problems and errors very easily. The kiosk integrates all of this together by presenting a centralised way of managing manufacturing information. It makes possible that all the manufacturing information documents are stored centrally and allows them to be managed by one person instead of having several people and departments in charge of keeping the paper documents up to date.

The users raised the problem of issue control. In many cases when e.g. a part program is reissued, the new issue of the program does not reach the shop floor i.e. the operator does not see it until some time. Therefore a component may be manufactured to wrong specification. By having centralised control, the reissue can be updated on the kiosk and the operator will immediately see the change. This would how ever require a change in the networking infrastructure and hooking the kiosk into the network. Nevertheless the potential gains of doing this may result in huge savings in rework, scrap and time. The quality of both product and documentation is also controlled more efficiently through a database type of approach that the kiosk presents.

Additionally time savings on the shop floor result in cost savings, as the operators spend less time looking for specific information and more time on the job. This means more efficient utilisation of the work force.

10. Conclusions and recommendations

This chapter concludes the project by presenting the key findings and discuss recommendations for future work on the kiosk.

10.1. Conclusions

This thesis project's aim was to design and evaluate the possibility of delivering manufacturing information to the shop floor through an information kiosk. Throughout the project the kiosk has proven to be a success based on the all the comments, suggestions and enthusiastic response coming directly from the users. The kiosk has not just become a toy to play around with, but an actual aid to the operators.

The kiosk development has followed a methodology that has proven to be very effective in reaching results that were expected. Continuous improvement and design of the system has made every update more usable and more useful and has shown that kiosks can truly function as manufacturing information systems.

The usability study shows that the kiosk is considered to be a success from the user point of view. There are several benefits that have been already gained both the shop floor and management point of view. Many other benefits will occur also in the long term.

The kiosk has been built to support operator tasks. These tasks include information and knowledge tasks. Hence, through the kiosk usable & useful information to support info tasks and a communications tool to support knowledge have been provided.

Key findings

The key findings of this project are:

- It was confirmed that the usability of a kiosk is suitable in a manufacturing environment as a task support system
- While usability issues of interface development are paramount the usefulness of the system is still more valuable and users may discard a more usable system for a system that offers more value for their purposes
- Kiosks are intuitive to use even when the content is highly technical i.e. when the system is easy to use and usable, the content has no effect on the ease of use of the kiosk
- Data management is important to keep the contents up to date. In this case issue control of the documents is the most important matter for long-term use of the kiosk.
- Hypermedia is an acceptable medium for manufacturing information.
- The operators save time on finding the correct documents and document management is more efficient with the use of the kiosk.
- Although hardware changes may become relevant in the future the flexibility of the content allows the transfer of the system without any changes to a new generation of PCs.

10.2. Recommendations

The implementation of the kiosk in a factory environment proves to be a successful venture. The kiosk is a good communication tool and can be used not only to display information but also to allow communication between the workers. This suggests that two-way communication with the e.g. the design department and the shop floor could be carried out via the help of the kiosk.

The split screen alternative allows a more efficient and usable way to present the manufacturing information on the shop floor.

Thus the conversion of the entire current version into the split screen format is required. Additionally the simulations of the all the components should be added onto the kiosk, as they do not all exist there yet.

The Internet technology kiosk gives a new way of communicating on the shop floor. It presents information faster, quicker and in more detail to the users. The usability of the kiosk is perceived to be good and proves to work in a manufacturing environment and the users have already demonstrated the usefulness of the system by adapting it to their job. Further investigation on how to successfully manage the information and have efficient issue control of the documents is the next challenge as well as looking to see if the kiosk could be integrated into the networking environment of the company.

References

Cheng, K., Pan, P. Y. and Harrison K. (2000). The Internet as a tool with application to agile manufacturing: a web-based engineering approach and its implementation issues. *International Journal of Production Research*, vol. 38, no. 12, 2743-2759

Coe, M. (1996). *Human Factors for Technical Communicators.* John Wiley & Sons, Inc., New York.

Cover Pages: Extensible Markup Language. [WWW document] Accessed: 6th August 2002, Available: http://xml.coverpages.org/xml.html.

Crowder, R. M., Hall W., Heath I., Wills G., Humphreys D. and Ash J. (2001) Hypermedia information systems in industry. *Computing & Control Engineering Journal*, February 2001.

Crowder, R. M., Hall W., Heath I. and Wills G. (2000). Industrial strength hypermedia: design, implementation and application. *International Journal of Computer Integrated Manufacturing*, vol. 13, no. 3, 173-186.

Crowder, R. M., Hall W., Heath I. and Wills G. (1999). Integration of manufacturing information using open hypermedia. *Computers in Industry*, vol. 38, 31-42.

Dean A. (2002). OpenHSF initiative – the future of 3D viewing over the web? *MCAD*, vol. 22.

Delone, W. H. and McLean, E R. (1992). Information systems success: the quest for the dependent variable. *Information Systems Research*, vol. 3, no. 1, 60-95.

Faulkner, D. (2002). *Usability Engineering*, Macmillan Press, London.

Gay, P. (2002). *XML gets foothold with FIAT seat production*. [WWW document from Integrated Manufacturing Solutions] Accessed: 6th August 2002, Available: http://www.e4engineering.com/item.asp?id=45069&type=Features&pub=ims

Georgia Tech Centre for Manufacturing Information Technology (2002). *What is XML?* [WWW document]. Accessed: 5th August 2002, Available: http://cmit.edi.gatech.edu/ITS/xml_description.htm

Greenough, R., Fakun D. and Kay J. (2000). Development of a digital manual for a manufacturing system – a case study. *Integrated Manufacturing Systems*, vol. 12, no. 6, 387-393.

Gunasekaran, A. and Love, P.E.D. (1999) A review of multimedia technology in manufacturing. *Computers in Industry*, vol. 38, 65-78.

Hall, W. (2000). As we may learn, the application of hypermedia in education. *Computing & Control Engineering Journal*, August 2000.

Hogbin, G. and Thomas, D. (1994). *Investing in Information Technology*, McGraw-Hill.

Huang, G. Q. and Mak, K.L. (2001). Issues in the development and implementation of web applications for product design and manufacture. *International Journal of Computer Integrated Manufacturing*, vol. 14, no.1, 125-135.

Huang, G. Q. and Mak, K.L. (2001). Web-integrated manufacturing: recent developments and emerging issues. *International Journal of Computer Integrated Manufacturing*, vol. 14, no. 1, 3-13.

Isakowitz, T., Stohr E. A., Balasubramanian, P. (1995). RMM: A methodology for structured hypermedia design. *Communications of the ACM*, vol. 38, no.8, 34-44.

Kasvi, J.J.J,, Vartiainen M., Pullkis A. and Nieminen M. (1996) Information tools for the shop-floor. *AI and Society,* vol. 10, 26-38.

Lin, J. C. C., Lu, H. (2000). Towards and understanding of the behavioural intention to use a web site. *International Journal of Information Management*, vol. 20, 197-208.

NetShift-website. Available: www.NetShift.com

Nielsen J. (1993). *Usability Engineering.* Academic Press Limited, London.

Nielsen J. (1995). *Multimedia and Hypertext: The Internet and Beyond.* Academic Press Inc., London.

Oppenheim, A.N. (1992). Questionnaire Design, Interviewing and Attitude Measurement. Pinter Publishers Ltd, New York.

Rahman, S.M., Sarker, R. and Bignall, B. (1999). Application of multimedia technology in manufacturing: a review. *Computer in Industry,* vol. 38, 43-52.

Rowley, J. (1995). Multimedia kiosks in retailing. *International Journal of Retail & Distribution Management*, vol. 23, no. 5, 32-40.

Slack, F. and Rowley, J. (2002). Kiosks 21: a new role for information kiosks? *International Journal of Information Management*, vol. 22, 67-83.

Suh W. and Lee H. (2001). A methodology for building content-oriented hypermedia systems. *The Journal of Systems and Software*, vol. 56, 115-131.

World Wide Web Consortium. Hypertext Mark-up Language. [WWW document], Accessed: 6th August 2002. Available: http://www.w3.org/MarkUp/

Bibliography

Carroll, J.M. (2002). *Human-Computer Interaction in the New Millenium.* ACM Press, New York.

Fakun, D. (2000). The development of successful industrial hypermedia applications, Thesis (Ph.D.) Cranfield University.

Huang, G. Q. and Mak, K.L. (1999). Design for manufacture and assembly on the Internet. *Computers in Industry*, vol. 38, 17-30.

Lee, H., Lee, C. and Yoo, C. (1999). A scenario-based object-oriented hypermedia design methodology. *Information & Management*, vol. 36, 121-138.

Leung, R.F., Leung, H.C. and Hill, J.F. (1995). Multimedia/hypermedia in CIM: state-of-the-art review and research implications (Part I: state-of-the art review). *Computer Integrated Manufacturing Systems*, vol. 8, no 4., 255-260.

Leung, R.F., Leung, H.C. and Hill, J.F. (1995). Multimedia/hypermedia in CIM: state-of-the-art review and research implications (Part II: research implications). *Computer Integrated Manufacturing Systems*, vol. 8, no 4., 261-268.

Mandal, P. and Baliga B. (2000). MIS-user interface design for job shop manufacturing environment. *International Journal of Operations & Production Management*, vol. 20, no. 4, 468-480.

Miles, M.B. and Huberman, A.M. (1994). *Qualitative Data Analysis*. SAGE Publications Inc., Thousand Oaks.

Nicholas, D., Huntington P. and Williams, P. (2000). Establishing metrics for the evaluation of touch screen kiosks. *Journal of Information Science*, vol. 27, no.2., 61-71.

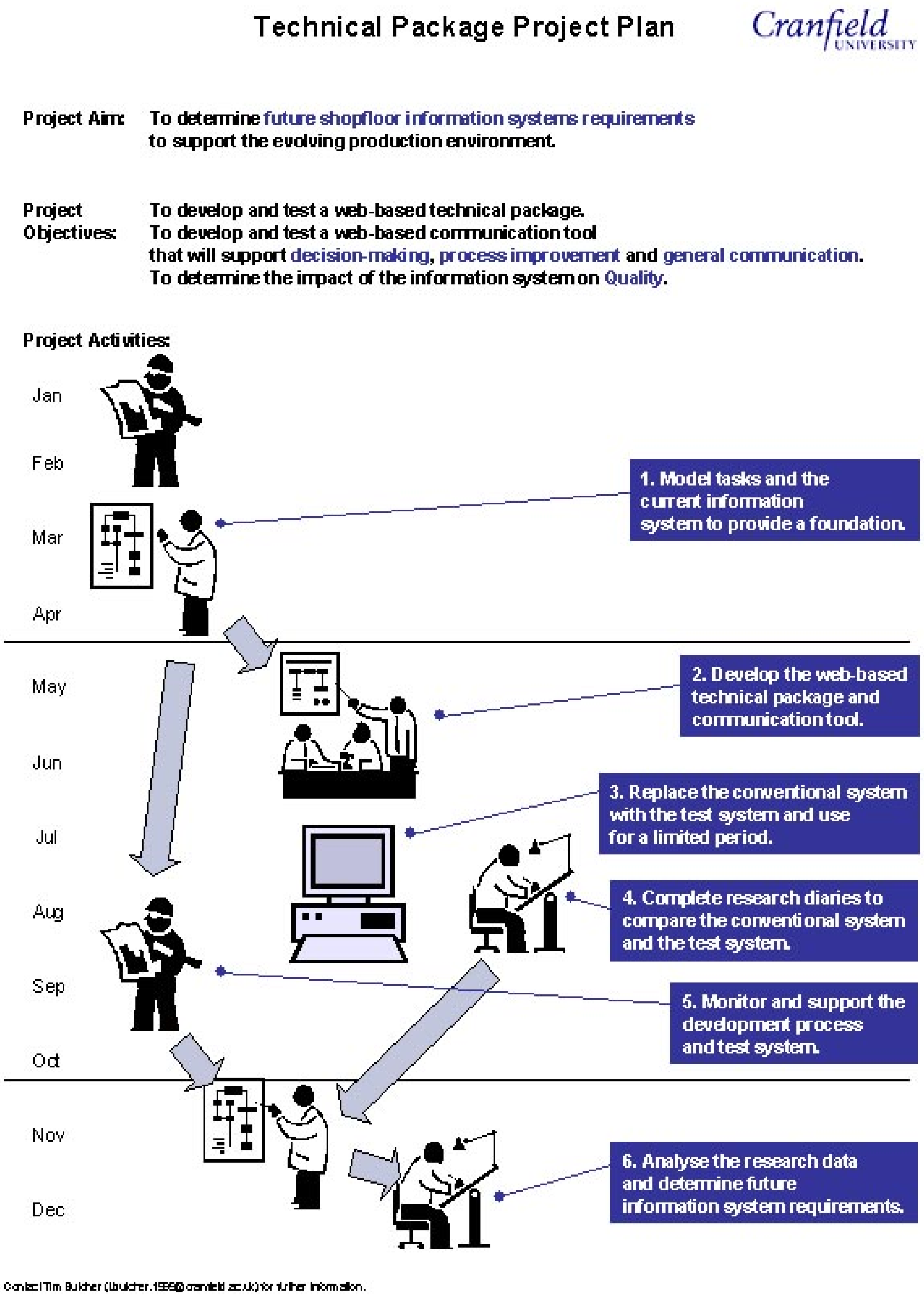
Reynolds, A. and Araya, R. (1995). *Building Multimedia Performance Support Systems.* McGraw-Hill, Inc., New York.

Smith, C.S, Wright P.K. (1996). CyberCut: A world wide web based design-to-fabrication tool. *Journal of Manufacturing Systems,* vol. 15, no.6, 432-442.

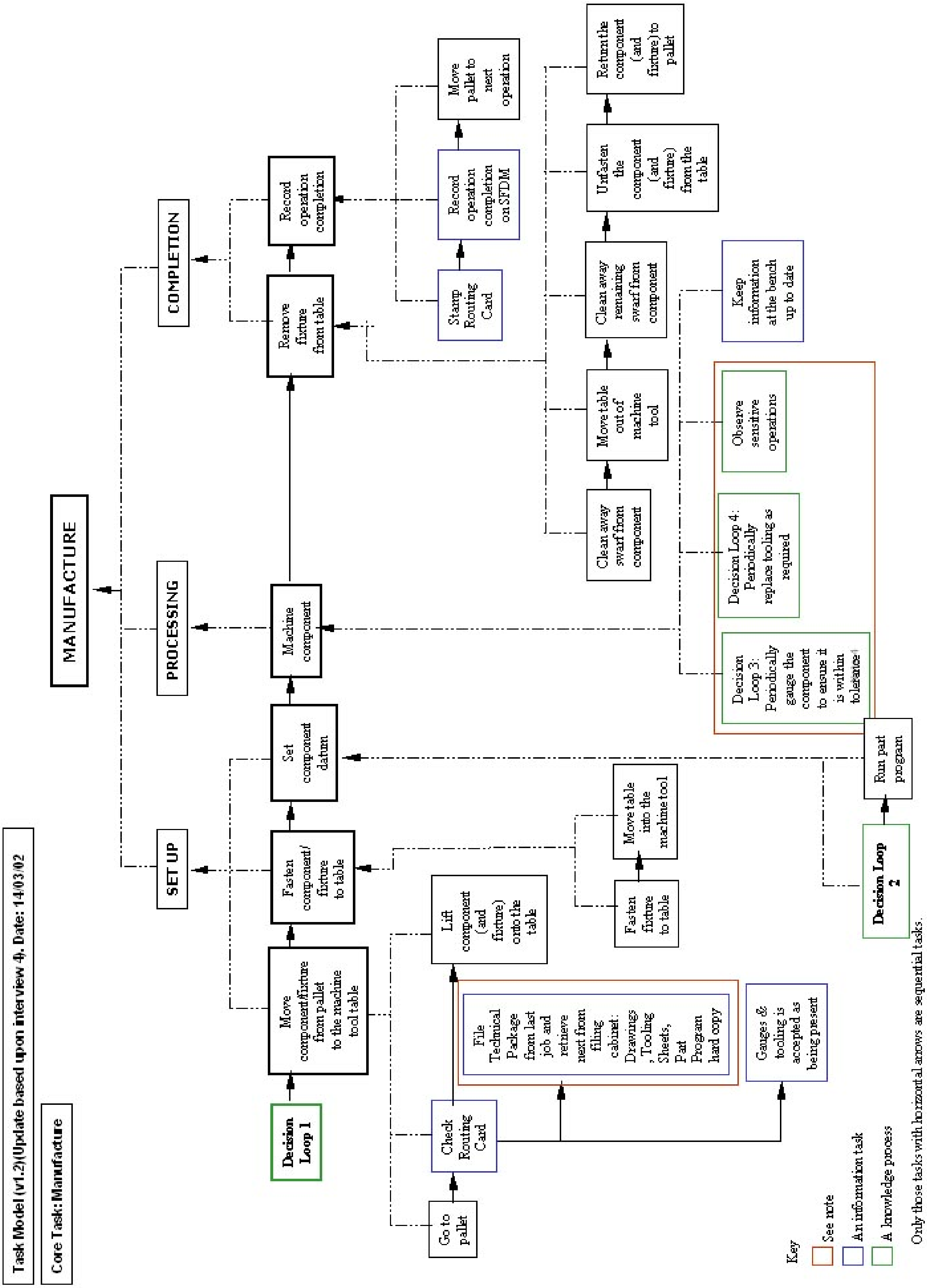
Tjahjono, B. and Greenough, R. (2002). Using collaborative authoring to develop a hypermedia performance support system. *Performance Improvement*, vol. 41, no. 6.

Appendices

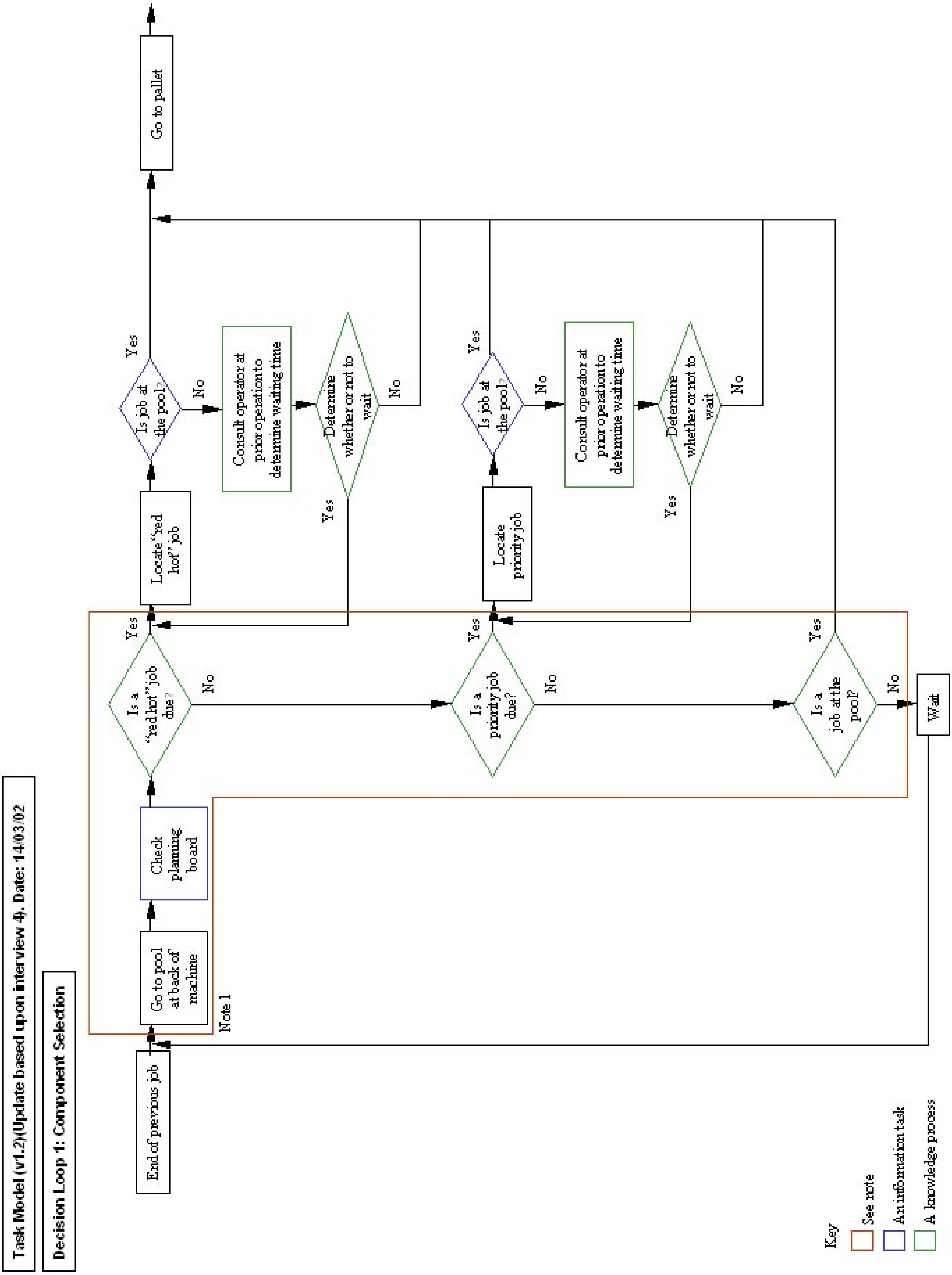
Appendix A - Technical Package Project Plan



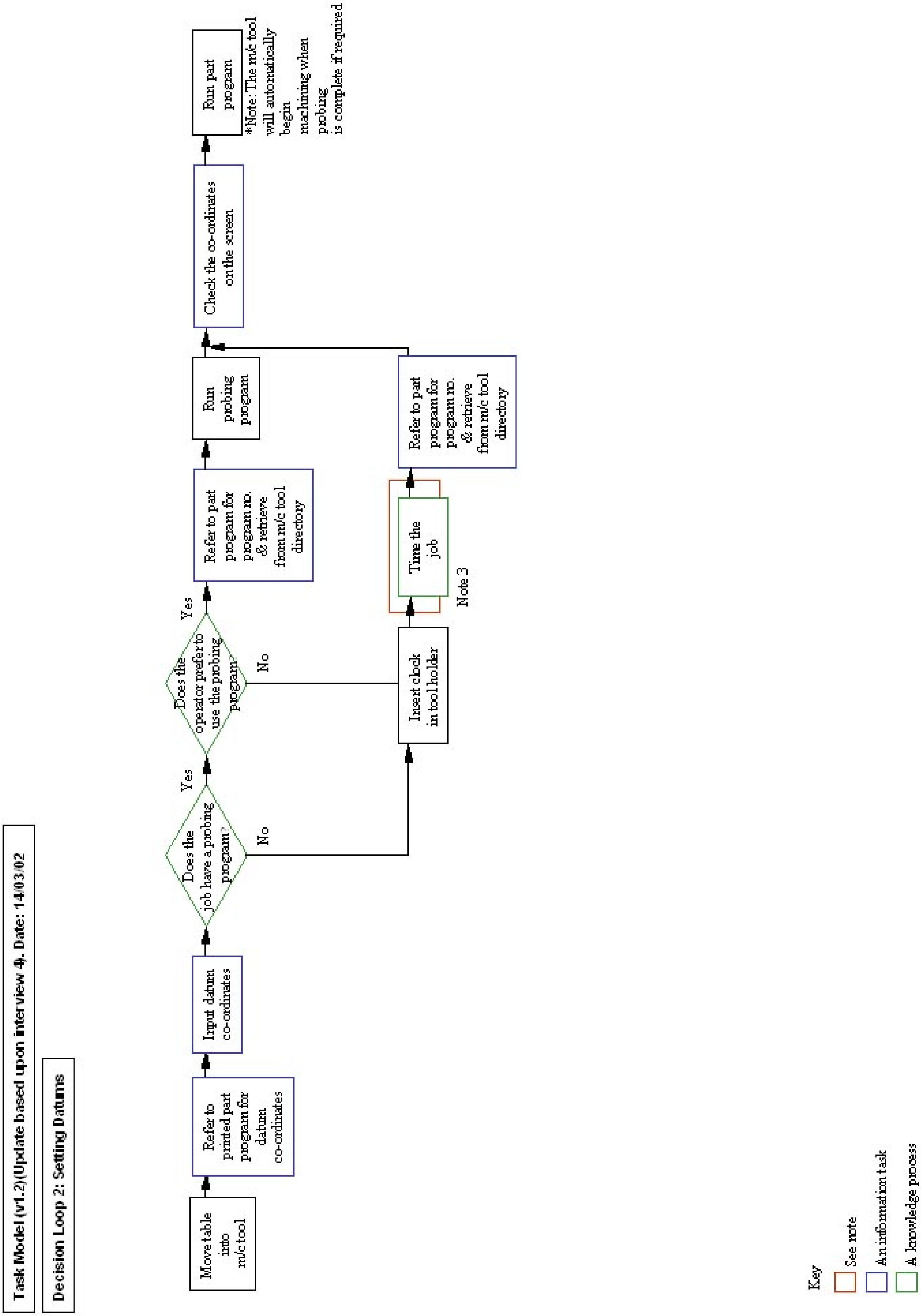
Appendix B1 Task model – Core Manufacture



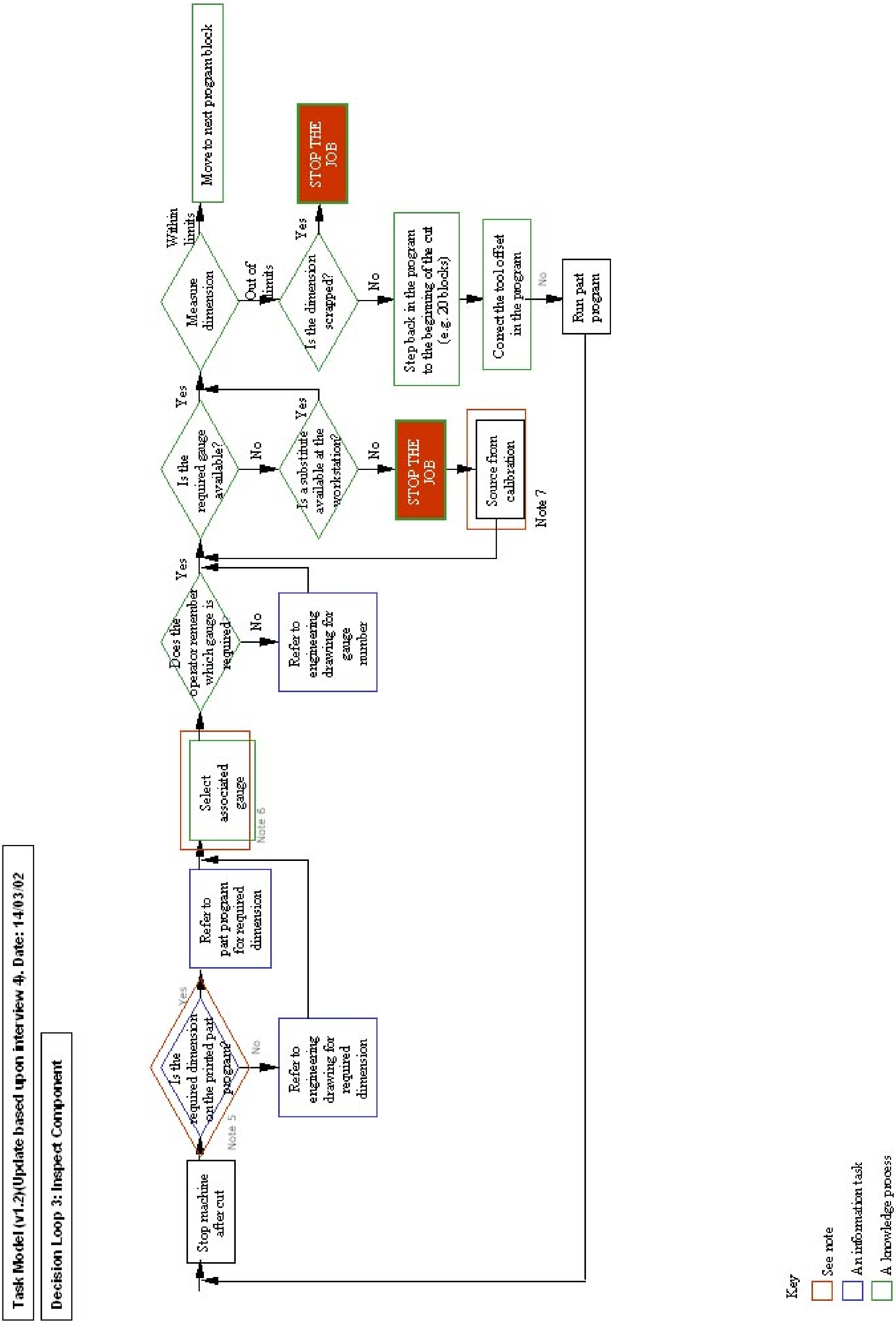
Appendix B2 Task model – Component Selection



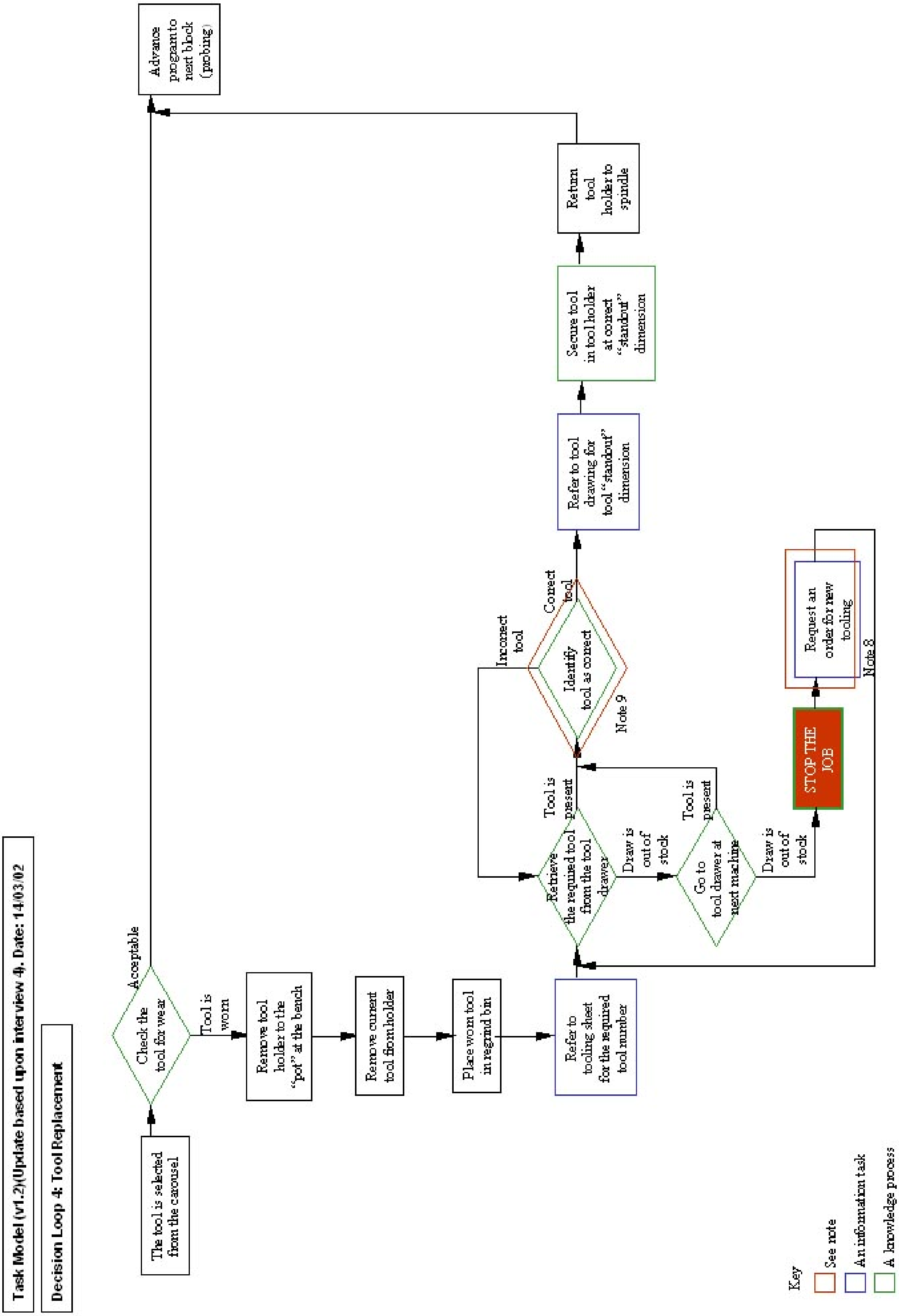
Appendix B3 Task Model – Setting Datums



Appendix B4 Task Model – Inspect Component



Appendix B5 Task Model - Tool Replacement



Appendix C - Usability Study Questionnaire

Usability Questionnaire

Tasks:

1. Find the xxxxxx engineering drawing xxxx
2. Find the part program for xxx for the XXX
3. Open the solid model for the XXXXX
4. Open tooling sheet XXXXX
5. Open the tooling sheet XXX for the XXX, program XXXX
6. Open the simulation for the XXXX
7. Open the 'Write to List' page for the XXX and write & submit a note (that says "test").
8. Open the Knowledge List for the XXX to find your note.

Questions:

1 Learnability

1.1 It was easy to find each destination.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

1.2 I understand the structure of the kiosk, and could explain it.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

1.3 The design of the kiosk is consistent.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

1.4 The kiosk is easy to learn.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

2 Efficiency

2.1 It was quick to find each destination.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

2.2 The interface is easy to use / the buttons are easy to press.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

2.3 I can get the kiosk to do what I want it to do.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

3 Memorability

3.1 I remember how to find e.g. a specific drawing and could tell someone how to do it.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

3.2 The next time I use the kiosk I would already know how to find the information I need.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

4 Errors

4.1 I made a mistake while trying to find a specific piece of information

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

4.2 I got lost in the system.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

4.3 There was a system error during the test

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

5 Satisfaction

5.1 I feel comfortable with the kiosk.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

5.2 I'm satisfied with the quality of the content.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

5.3 I would like to use the kiosk in the future for my work.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

6 General usability

6.1 The touch screen is easy to use.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

6.2 The virtual keyboard is easy to use.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

6.3 The pages are clear and logical

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

7 Usefulness Questionnaire

7.1 The kiosk helps me do my work.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

7.2 It is quicker to find information on the kiosk than from the paper documents.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

7.3 The kiosk makes me work more efficiently

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

7.4 The solid models are useful for my job

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

7.5 The simulations are useful for my job

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

7.6 I think the kiosk replaces the paper documents

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

7.7 I think I will still use the paper documents in the future

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

7.8 I still need to refer to the paper documents with either version of the system.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

8 Split screen questions

8.1 The split screens are easier to use than the other system.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

8.2 The split screen version is more understandable than the other version.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

8.3 The split screens are more useful for my job.

Strongly disagree	Disagree	Don't know	Agree	Strongly agree

Appendix D - Usability survey data analysis

Usability survey data analysis

Usability

Likert-scale 1 to 5 (1 = Strongly disagree, 5 = Strongly agree)

1. Learnability		1	2	3	4	5	Weighted total
	1. It was easy to find each destination				3	2	22
	2. I understand the structure of the kiosk, and could explain it				5		20
	3. The design of the kiosk is consistent				5		20
	4. The kiosk is easy to learn				2	3	23
		Mean of weighted totals, index value					**21,3**

2. Efficiency		1	2	3	4	5	Weighted total
	1. It was quick to find each destination				5		20
	2. The interface is easy to use / the buttons are easy to press		3	1	1		12
	3. I can get the kiosk to do what I want it to do				5		20
		Mean of weighted totals, index value					**17,3**

3. Memorability		1	2	3	4	5	Weighted total
	1. I remember how to find e.g. a specific drawing and could tell someone how to do it				5		20
	2. The next time I use the kiosk I would already know how to find the information I need				4	1	21
		Mean of weighted totals, index value					**20,5**

4. Errors		1	2	3	4	5	Weighted total
	1. I made a mistake while trying to find a specifc piece of information	1	1	1	2		13
	2. I got lost in the system	5					5
	3. There was a system error during the test	5					5
		Mean of weighted totals, index value					**7,7**

5. Satisfaction		1	2	3	4	5	Weighted total
	1. I feel comfortable with the kiosk				5		20
	2. I'm satisfied with the quality of the content				3	2	22
	3. I would like to use the kiosk in the future for my work				5		20
		Mean of weighted totals, index value					**20,7**

6. General usability		1	2	3	4	5	Weighted total
	1. The touch screen is easy to use			2	3		16
	2. The virtual keyboard is easy to use				4	1	21
	3. The pages are clear and logical				3	2	22
		Mean of weighted totals, index value					**19,7**

Usefulness

General usefulness		1	2	3	4	5	Weighted total
	1. The kiosk helps me do my work				5		20
	2. It is quicker to find information on the kiosk than from the paper documents				4	1	21
	3. The kiosk makes me work mor efficiently			1	4		18
	4. The solid models are useful for my job		3		2		14
	5. The simulations are useful for my job				5		20
	6. I think the kiosk replaces the paper documents					5	25
	7. I think I will still use the paper documents*				4	1	21
	8. I still need to refer to the paper documents with either version*					5	25
		Mean of weighted totals, index value					**20,5**

Split screens

		1	2	3	4	5	
	1. The split screens are more useful for my work than the other system					5	25
	2. The split screens are easier to use than the other system				3	2	22
	3. The split screen version is more understandable than the other				5		20
		Mean of weighted totals, index value					**22,3**

The maximum amount of points for each area is 25. This is from 5 users giving 5 to all questions of an area. **Errors** is the only area where a low score is best, because it would mean that a few errors exist.

* The scoring of this question is reversed due to the nature of the question i.e. low answers give a high score and low answers a high score

Appendix E – CSS-Style sheet

```
A {
	TEXT-DECORATION: none;  style: bold; color: #41588E; font-size: 14;
}

A:hover {
	FONT-WEIGHT: bold; COLOR: #41588E;
}
Table { align: center;
}

BODY{
scrollbar-face-color:#41588E;
scrollbar-arrow-color:#ffffff;
scrollbar-track-color:#ffffff;
font-family: arial;
font-size:12;
}

p {
font-family: arial;
font-size:12;
}

table {
font-family: arial;
font-size:12;
}
```