Abstract

This master thesis consists of two major objectives.

The first objective is to describe how to achieve usability in the user interface of the “next generation” TPOP (Tetra Pak Operating Panel), used for the filling machines. The assignment has been conducted with studies in literature and on Internet resources, which resulted in the suggestion to apply the usability engineering process to the development of the next generation TPOP. This report suggests focusing on the following features in the design process:

- Iterative design
- Studies of user-centred issues
- Continuous prototyping and evaluation
- User derived feedback
- Usability metrics (measurable usability goals)
- Establish a vision based on overarching goals
- Establish a project plan with a pronounced start and finish
- Involving all parties who have an interest in the TPOP (users, programmers, assigners, market department etc) in the design process
- Apply the four levels of design (design of system services, conceptual design, interaction design and graphical design) to the process

The second objective is to perform a competitive analysis. The competitive analysis takes two altered directions.

The first direction can in principle be described as benchmarking and consists in comparing the TPOP user interfaces with other operating panel user interfaces. The motive of doing so is to find high quality solutions that could be applicable on the TPOP and to give inspiration for new design ideas.

The benchmarking included field studies at Elanders Novum, Klippan AB and Volvo Cars Body Components, with regard to user profiles, working procedures, system services, graphical layout and interaction of user interfaces. The analysis gave ideas about a number of issues to consider when designing the user interface of the next generation TPOP.

The second direction involved looking into the system services offered by Tetra Pak’s competitors and by other companies within the automation industry. The purpose was to find out how well Tetra Pak manage in competition, with regard to the system services, with other companies, and to find support for new ideas on the subject. Also looking into other companies’ information management can give rise to ideas for new solutions.

The gap analysis was conducted through conferring the Internet to find information about the system services offered by Tetra Pak’s competitors and by other companies considered to be leaders within the area of system service design. Only the competitors that provide information about their system services on the Internet were included in the analysis. They are APV-Systems, Elopak, KHS, Krones, Miteco, SIG-Combibloc and Van der Molen. The companies being identified as leaders in the area are ABB and Westinghouse Process Control.

Drawing any certain conclusion based on the information found on the Internet was not feasible, since it was far from complete. Also much of the features mentioned on the Internet were not explained in a pronounced way. Neither were the actual intents of a specific system service made clear, the quality of the system services could not be estimated, and, finally, it is not a matter of course that the system services offered are in fact requested by the customers and usable to them. Owing to this argumentation it was not possible to draw any conclusions about Tetra Pak’s position in comparison to their competitors with regard to the system services. However, it can be established that many of the companies in the study offer their customers system services, which are not available for Tetra Pak’s customers. A summary of those follows below:

- on-line help and documentation as supporting the installation of a system
- simulators to be used for production planning, performance optimisation and training
- on-line training programs
- tool for planning, scheduling and manufacturing of end products
- batch management
- monitoring of production, process, machine, and system status
- remote control
- remote access
- feedback checks on values, variance analyses against specification
- evaluation of plant or process parameters, equipment status and recommended actions, analyses of performance trends – advice plant engineers, technicians and operators
- general messages
- automatic calculation of required maintenance intervals, maintenance triggers
- remote diagnostics and remote trouble shooting
- on-site cameras for live dialogues
- monitoring the quality of the units produced
- access to a website with searchable tech tips and answers to frequently asked questions, software release notes, access to customer and field engineer problems reports and resolutions, user manuals in downloadable pdf file format, on-line software updates

1 Introduction

1.1 Tetra Pak

Tetra Pak is a supplier of processing, packaging and distribution solutions for the liquid food industry. Operating in 165 countries, delivering around 85 billion units of equipment every year, makes Tetra Pak the largest producer of packaging and processing systems in the world[1].

Tetra Pak is also a provider of packaging materials, service and maintenance, and education for production and service personnel. Since the lifetime of a machine is 10-20 years, Tetra Pak has a long-term relationship with their customers.

1.2 Tetra Pak Operating Panel

Among other products, Tetra Pak manufactures and distributes filling machines for liquid food. These machines are equipped with operating panels, TPOP (Tetra Pak Operating Panel), to support the operators, service technicians and other production personnel in their work.

The TPOP consists of a touch screen and a set of hardware buttons. The operator uses the TPOP to control and monitor the machine and its production. The TPOP display presents a picture of the machine, the machine status, the production status and alarms. In addition to this machine settings are controlled via the TPOP and production data is collected.

As the complexity of the filling machines is increasing there is a wish to improve the usability of the TPOP. Also a new type of information and new system services are requested to better support the decision-making called for by the operators and the technicians in their daily work.

1.3 Customer Technical Information Platform

A project has been initiated to create a concept for technical information that meets the customers' needs and desires in a better way than the information management of today. This concept is called CTIP (Customer Technical Information Platform). The CTIP consists of an extranet solution and aims at providing relevant information and support in every situation. The CTIP enables the opportunity of presenting new types of services and the possibility to continuously updating machine related information based on customer needs.

Including several different working stations, suitable for different situations, is an essential part of the CTIP concept. These are:

- The "next generation TPOP", fulfilling the requests for an increased usability and a new type of information.
- A desktop PC providing information in an office environment.
- The e-TV supplying customers with on-line training.
- Mobile devices, such as a pocket PC or a hand computer.

[1] Tetra Pak intranet, http://151.183.33.121/, 2002-05-27

1.4 Objectives

This master thesis includes two parts that are both relevant to the further development of the CTIP concept. The task formulation is:

1. Describe how to improve the TPOP with regard to the usability.
2. Perform a competitive analysis.
   1. As a part of increasing the usability of the TPOP, a set of keywords have been drawn up by the developers in the Machine Information department:

- Intuitive – a study of the TPOP user interface (Lützhöft, 1998) has shown that it is learnable but not intuitive.
- Communicative – the interface should communicate with the operator in order to facilitate operation of the machine as well as the interaction with the operating panel.
- Common standard – exertion of e.g. Windows standard on the TPOP user interface. The conception common standard here also includes common user interface practice, like e.g. use of symbols, design of controls, etc.

The aim of this part of the thesis is to describe how to attain these specific qualities and how to improve the usability of the TPOP in general.

2. One of the major issues concerning the CTIP development is to determine what information and services are needed, who (what category of personnel) needs them, and where within the CTIP concept they are optimally made available. As a part of this work Tetra Pak wishes to perform a competitive analysis. The competitive analysis takes two altered directions. One is to compare the system services (including information management and functions) offered by Tetra Pak for the filling machines, specifically, but also for the entire production of a plant, with the ones offered by competitors and other industries. Tetra Pak refers to this as a gap analysis. The aims of the gap analysis are to get a notion of where Tetra Pak stands in comparison to their competitors. The other direction of the competitive analysis is to compare the TPOP user interface with other interfaces. The aims of such a study are to find ideas and solutions of how to design a user interface to ensure its usability. Within the product development faculty this type of competitive analysis is referred to as benchmarking (Ullrich and Eppinger, 1999).

2 Next Generation TPOP Usability Improvement

As an introduction to the commission of giving an description as how to improve the TPOP with regard to the usability, I would like to have a closer look at the key words set up to characterise the resulting user interface.

Intuitive
The next generation TPOP should be intuitive. But what does the expression intuitive in fact signify? According to dictionary.com[2] intuitive means *"Knowing, or perceiving, by intuition; capable of knowing without deduction or reasoning."* Dictionary.com further states that intuition means *"The act or faculty of knowing or sensing without the use of rational processes; immediate cognition."*

There are different approaches to what we call intuition. One is the spiritual approach, implying that intuition is some sort of divine gift. Another one is to equal intuition with instincts. Finally, intuition can be looked at as the consequence of pattern recognition, insinuating that intuition in the end is the result of a logical reasoning after all – only, the reasoning has occurred earlier, in a similar situation.

Ultimately, the question in this context is whether there are distinctive features that are intuitive for all TPOP users or, at least, for a larger group of users. Assuming that instincts only has an inconsiderable effect on user interface design and that intuition is not a divine gift, but the result of pattern recognition this necessitates that the TPOP users have similar frames of reference and experiences. That is not likely to be the case considering that the users are of widely different cultural, linguistic and educational backgrounds. Yet, it is reasonable to presume that some features are common to all human beings. For example everyone can tell black apart from white, or a round item apart from a square one. Colours, formations and locations can be utilised to make a user interface more straightforward.

However, creating an operating panel that is all through intuitive based on knowledge like the above is not feasible. In contrast to intuitive the user interface will have to be more or less learnable. Still, the term intuitive function well as a characteristic for the next generation TPOP – not as a reachable goal, but as a utopia to strive for.

Communicative
The essence of the CTIP concept extends over the idea of a communicative operating panel. Communicative includes the conception of supplying the right information in each situation, i.e. providing the operators with relevant feedback and instructions to assist them in decision making, guide them through activities and inform them when to proceed with specific activities.

Communicative also includes having an exchange of thoughts or ideas. The next generation TPOP should also respond to the input of the operator.

The question is what information is relevant in each situation and what kind of responses do the operators request?

Common standard
The reason for exerting a common standard, such as Windows or the standards of for example kitchen devices, in a user interface is to utilise the knowledge, which the users have retrieved operating other systems. However, the developer must be aware

[2] http://www.dictionary.com/, 2002-06-20

that the system used as a reference is not optimised for the specific conditions valid for the new system being designed.

The aim of this part of the thesis is to describe how to attain these specific qualities and how to improve the usability of the TPOP in general. Since the characteristics above are a part of the over all usability of a user interface, I will concentrate plainly on the usability conception. Because of the very broad formulation of the task I have chosen a theoretical approach, seeking the answers in literature available. The questions I have tried to answer are:

- What is usability?
- How is usability achieved in a user interface?

Finally, I have drawn up a suggestion of how the findings of the theoretical studies can be implemented in the work of developing the next generation TPOP.

2.1 What is Usability?

The term usability addresses the relationship between tools and their users[3]. A usable system is favourable to the needs or purpose of the user. The abstract concept of usability can be defined through the more precise and measurable characteristics relevance, efficiency, learnability and satisfaction (Löwgren, 1993):

- The *relevance* of a system corresponds to how effective the system is, i.e. how well it suits the user's needs and how well it supports the user in accomplishing a task.
- The *efficiency* refers to the performance time required to complete a task. This includes the aspect of how frequently errors occur and how quickly the user is able to recover from an error.
- *Learnability* is a result of with what ease a novice user learns work the system and how well the skills are remembered over time when a system is not used regularly.
- *Attitude* reflects the subjective feelings or attitude that the user has towards a system.

A system that has a high degree of usability will be save money by diminishing the operating training time, speeding up performance time and decreasing the error rates. Furthermore the cost for maintenance is lowered. Other benefits of a well-designed system are the chance of avoiding accidents and the prospect of increasing the customer's appreciation of the system.

So how is a high degree of usability in a system achieved? Jakob Nielsen (1993) makes the following comment on this issue:

"What makes an interface good? Unfortunately, so many things sometimes make an interface good and sometimes make it bad that any detailed advice regarding the end product has to be embellished with caveats, to an extent that makes it close to useless, not least because there will often be several conflicting guidelines. In contrast, the usability engineering *process* is well established and applies equally to all user

[3] www.usabilityfirst.com, 2002-06-14

interface designs. Each project is different, and each final user interface will look different, but all the activities needed to arrive at a good result are fairly constant.”

2.2 The Usability Engineering Process

Usability engineering is a systematic approach to user interface design that provides structured methods to attain usability in a system. In short the usability engineering process ensures that a product corresponds to the user’s needs by:

- Studies of user-centred issues
- Exerting user-derived feedback within the design process
- Iterative design

To produce a system that fulfils the demands for usability, it is essential that the designer is familiar with the users, their goals, their tasks, and their environment. The work performed gathering and interpreting information about the users will have a great impact on the success of the resulting user interface design.

The objectives found studying the users and their tasks, together with known general design principles, is formulated into a usability goals specification defining the demands, which must be fulfilled in the system. The findings of a competitive analysis – a study of other companies’ systems – can also contribute to the usability goals specification and can be a source of design ideas.

To facilitate and structure the actual design work, it can be managed on four levels: design of system services, conceptual design, interaction design and graphical design. When the design process of each level is initiated it is recommended to produce several different ideas simultaneously. Jakob Nielsen (1993) refers to this parallel design. The parallel design versions are evaluated in consideration of the usability goals. The designers can thereafter continue working with the version proved to be most suitable or a combination of several design versions. Based on the usability problems and opportunities found when testing, the user interface can be changed for the better. A cycle of design, evaluation and redesign is continued until the usability goals are met. This is referred to as iterative design.

The usability engineering process is presented in Figure 1.

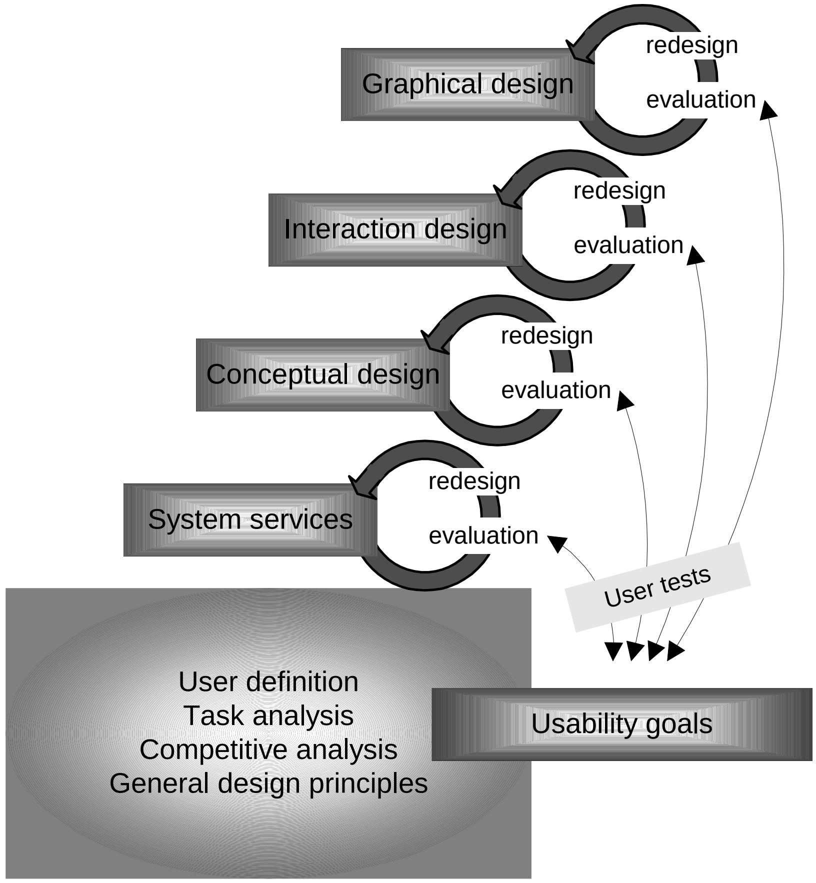

Figure 1. The usability engineering process.

Usability experts emphasise that one should not rush straight into design. The development costs will be lowered if as much as possible is done before the actual design work is started, since there is a greater chance of producing a relevant and adequate system that does not have to be changed to meet the demands for usability

Ben Schneiderman (1998) points out an important part of the usability engineering; "it involves the development of partial and interim solutions that may ultimately play no role in the final design" and that "design intrinsically involves the discovery of new goals".

The design process is not a top to bottom or bottom to top procedure. Decisions made at one level of design might affect other levels. During the design process the designers will have to revalue and change decisions made earlier in the progression.

2.2.1 User Definition

As Xristine Faulkner (2000) points out that a good system is not to supply the easiest design, but the most appropriate design for a specific group of users. Of course, this is a result of the fact that "easy" is a subjective notion. Different people have different experiences, frames of reference, and hence different ways to relate to an interface design. Therefore it is vital to get to know the users, and the organisation and environment they work in. Information should be gathered concerning the age range, educational background, skills, cultural and linguistic background, physical abilities, motivation, goals and personality of the users. Also details about the job are of interest, such as the main tasks and responsibilities. Other observations to make are whether the users are novice, intermittent or experts in their work and whether they are used to working with computers. Finally, one should be aware of how the system will be used – often or seldom, obligatory or optional.

A few methods for gathering information about the users are: observation, interviews, questionnaires, focus groups and participatory design.

Simply *observing* users working can be very useful, especially if the users are able to ignore the observer. It should be noticed that people being watched might act differently than they normally do.

Interviews can be managed in different ways. An unstructured interview aims to get the users to lead the interview to the issues important for them. A structured interview attempts to find a more general representation of the user. When interviewing people it is important to pay attention to the fact that they sometimes describe their job in a way that does not agree with what they actually do (Löwgren, 1993). Reasons for this might be that they do not trust you or that they say things they believe to be "correct". Also, people seem to have difficulties to remember their tasks in detail, when being away from work (Faulkner, 2000).

There are *questionnaires* of different types, e.g. multi-choice questions, checklists and scalar questionnaires, meeting different needs. According to Xristine Faulkner (2000) questionnaires are suitable for subjective responses, but are less dependable for collecting objective data. She also remarks that questionnaires are time-consuming to create and need to be thoroughly and accurately tested before they can be used.

Discussions in *focus groups* can be an excellent source of information. A suitable size of the group is between eight and twelve users or potential users[4]. A moderator facilitates the discussions following a script that leads the dialogue.

Participatory design means that one or more users actively participate in the work of the design team. The idea is to offer the designers an opportunity to get more accurate information about the users and their tasks. Also users tend to ask questions, which the developers would never think of asking.

2.2.2 Task Analysis

A system that does not support the users' tasks in an accurate way is, obviously, useless. Therefore it is essential to have a clear picture of what the system must do. A task analysis involves learning about the users' tasks and analysing the components of these tasks (Faulkner, 2002).

It is important to be aware of the difference between the users' tasks and the users' goals. The tasks are human actions that will reach a goal. When designing an operator system the designer should focus on the goals and try to work out the processes involved in achieving those goals. Xristine Faulkner (2000) points out that this is not always practicable, thus the users' tasks are analysed and often replicated in the system.

The result of a task analysis is knowledge about what the users want to achieve with the system (the goals), what information is needed to reach these goals, what problems are likely to occur, what criteria is used to evaluate the quality and

[4] http://usability.gov/methods/data_collection.html#relevant, 2002-06-1

acceptability of the work, how often is a task done and when, and the communication needs for the users when they exchange information with others.

Information about the users' present tasks, workflow patterns and underlying goals can be collected through observation, interviews and focus groups.

Another approach, recommended by Jakob Nielsen (2000), is to identify the weaknesses of the current situation. These weaknesses offer openings to improve the new operating system.

Knowing the current tasks, the designer might want to reengineer the workflow patterns, suggesting new tasks that better support the goals of the users.

2.2.3 Competitive Analysis

In a competitive analysis, user interfaces or other applications and devices are examined to find ideas and solutions that are applicable to the system being developed.

2.2.4. General Design Principles

General design principles include design principles, style guides, guidelines and patterns.

Design principles are found in HCI (Human-computer-interaction) and usability textbooks. Among the most commonly applied design principles are the heuristics of Jakob Nielsen and Ben Schneiderman (Appendix A). The design principles are constructed to be general enough to cover different applications in different contexts. They are often concise and easy to remember. However, their lack of specification sometimes, in fact, makes them hard to interpret and to apply[5].

Style guides are particularly produced sets of guidelines that cover applications for specific contexts. Style guides usually give descriptions of specific interface elements, detailing both appearance and behaviour, with guidance on how and when to use them. Commercial style guides are available, but often organisations and companies create their own style guides.

Guidelines collections consist in tried and tested knowledge, derived from research and practice[6]. Guidelines are typically concise, numerous and delivered out of context, making the procedure of handling them rather tricky.

Sidney L Smith and Jane N Mosier (1986)[7] discuss how to apply guidelines in the article *Guidelines for Designing User Interface Software.* They argue that the designers must first choose what guidelines to employ and then translate them into specific design rules. In order to do so the designers must have a comprehensive understanding of the users' characteristics and tasks. When all relevant guidelines have been identified they have to be reviewed. Since some guidelines might conflict the designers must prioritise and decide which ones to actually apply. Also economy and time restrictions may require a reduction of the number of guidelines to employ.

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[5] Lyn Pemberton ,*The Promise of Pattern Languages for Interaction Design,* School of Information Management, University of Brighton, http://www.comp.it.brighton.ac.uk/~lp22/HF2000.html, 2002-06-17

[6] Ibid

[7] http://hcibib.org/sam/, 2002-06-17

Patterns offer a solution to some of the problems using guidelines. Patterns distinctly concentrate on context and tell the designer when, where and how to use them[8]. Whilst guidelines consists of small rules, based on design knowledge, patterns aims at capturing design knowledge and describe it in terms of problem, context and solution, offering the designer a more usable tool for user interface design.

Pattern languages are today under development and only a few collections are available.

2.2.5 Usability goals

In the light of the user and task analyses, the usability goals are set up. The usability goals include user requirements and desires as well as general design principles. The usability goals ratify just how "usable" a system needs to be.

Deborah Mayhew (1999) writes about qualitative and quantitative goals. Qualitative goals are general characteristics that guide the design in a certain direction. Quantitative goals are associated to the so-called usability metrics.

Since the usability attributes - relevance, efficiency, learnability and satisfaction - do not have an assertive and quantifiable meaning in the real world; they need to be explicated as measurable design objectives. For example:

- The efficiency of a system can be measured by the time required to perform a specific task, the number of actions needed to perform a task, time spent looking for information related to a task or time spent dealing with errors.
- Learnability can be measured by the time required to reach stated performance criterion, frequency of errors, and time spent in search of help.
- The user's attitude towards the system can be measured by how comfortable the user feels or what feelings the user has towards the system.

Usability experts refer this to as usability metrics. The usability metrics simplify the evaluation of future design proposals and guarantee the usability to a degree set by the developers.

There are many possible ways of going ahead with the quantitative goals. Jonas Löwgren (1993) recommends creating a table where the usability goals are summarised, what to measure is determined, how to measure it is specified, the current level today is stated, and the planned target level is set.

Table 1. Example of a table for quantitative goals. The usability goals are summarised, what to measure is determined, the method to do the measure is specified, the current level for the measure is stated and the planned target level is determined.

Usability goal	Measure	Method	Current level	Planned target level
Efficiency: A novice user shall be able to start the machine	Time dealing with errors	Video of task	12 min	3 min
Attitude: Subjective assessment of usability and appeal.	Rating 1-5 1 is worst 5 is best	Questionnaire	3.0	4.5

[8] Martijn van Welie , *Patterns as Tools for User Interface Design*, http://www.cs.vu.nl/~martijn/gta/docs/TWG2000.pdf, 2002-06-17

When the usability goals have been drawn up they should be structured and organised. The aim is to produce a list of requirements and desires that is foreseeable and easy to manage. Usability goals that are related to each other are grouped together. Finally, the requirements should be graded according to how important they are relative one another.

2.2.6 System Services

Jonas Löwgren (1993) explains the relation between the user, the system services and the user interface in a pronounced way: "the services of a system determine what the user can do with it, and the user interface determines how he can do it".

Designing the system services involves deciding what assistance and support the system shall offer and what information and functions to include. The user definition and the task analysis compose a foundation for the decision-making. Things to consider are: what are the goals with the system, what are the users going to be able to do with the system, what information is needed. Note that on this level of design no effort is made to define how the services are going to be made available.

A convenient way to approach the design of system services is to perform a functional analysis, which is a method to express what the system is going to do. The purpose is to explicate and structure the needs found studying the user and the task, and to formulate them as functions. As a rule each function is described with two words: a verb and a noun (Löwgren and Stolterman, 1998). A function that is of vital importance for the system is classified as necessary. If a function is not absolutely necessary, but still useful it is labelled as desirable. If a function proves to be superfluous it is classified as unnecessary. Finally, it is advisable to organize functions that are related to one another in groups. A reliable way to produce ideas for functions is to carry through a brainstorming session.

Table 2. The table below is an example of a functional analysis for a system that will be designed to manage X-rays. The table is replicated from Jonas Löwgren's and Erik Stolerman's Design av informationsteknik (1998).

Function	**Classification**	**Comments**
supply X-rays	Main function	the system's fundamental idea
seek X-rays	N	
manipulate X-rays	D	contrast, light etc
store new X-rays	N	

2.2.7 Conceptual Design

Donald Norman defines conceptual, or mental models as "the models people have of themselves, others, the environment, and the things with which they interact" (Norman, 1998). People's mental models do not always agree with reality. Alan Cooper (1995) gives a good example of this: "Many people imagine that when they plug their vacuums and blenders into outlets in the wall, electricity travels up to them through little black tubes." This is not an adequate model of how electricity actually works, but it is a perfectly acceptable model for using household appliances.

A system's visual representation of the conceptual model must agree with the user's conceptual model of how the system works. If not, it will not be easy to use. Thus, the user interface design must be consistent with and represent the operations and processes in accordance with the user's conceptual model.

Conceptual design involves only the highest level of design. The aim is to establish the system's overarching structure and to ratify the user's conceptual model. Issues to consider are:

- Grouping of services into natural groups.
- Overview, orientation and navigation
- Language usage and terminology
- Metaphors and analogy
- Overarching way of interaction

Grouping of services
When grouping services into natural groups the card sorting method can be applied. Each function and category of information is written on a separate card. Participants representing the users are asked to organise the cards in a way that makes sense to them. A lot of additional information can be detected if the participants are asked to think aloud while sorting the cards. This information can also be valuable when it comes to language, terminology, metaphors and analogy.

Orientation and navigation
A good way to proceed with the orientation and navigation of a system is to work with scenarios. Scenarios are replications of workflow patterns. An understanding of the users' tasks and goals gives a comprehension of which order the functions and information should be presented in.

Language usage and terminology
It is important that language usage and terminology of a user interface corresponds to the user's language. The user's language and terminology is identified when working with the user definition and task analysis.

Metaphors and analogies
Using metaphors and analogies is a way to benefit from the users' previous knowledge about everyday things. Jonas Löwgren (1993) points out a few inconveniences about metaphors. Metaphors say too much and too little at the same time, he says. Too much, because they might activate insignificant background knowledge related to the analogy. And too little, because functions within the system may not be represent able within the framework of the metaphor. The designer must, accordingly, be very cautious when applying metaphors, and make sure that the intention of the analogies complies with the users' interpretation of them.

Overarching way of interaction
Finally, on this level of design, the overarching way of interaction is settled. Different interaction styles are menu selection, form fill-in, command language, and direct manipulation.

Menu selection consists of a list of items representing different functions. If the terminology of the items is appropriate, the user can easily pick the proper function to accomplish a task. An advantage of menu selection is that the functions available are displayed reminding the user of what actions and commands are accessible.

Form fill-in is used when data enter is required. The field labels must be understandable and it must be clear what values are permitted. A good thing about forms is that many people have experience with paper forms.

Command language is foremost applicable for frequent users. Command language is rapid and inspires a feeling of control, but the rate of error is relatively high and excessive training is necessary to manage the interaction.

Direct manipulation implies that the actions are represented as visual objects. The user performs a task by manipulating the objects. The greatest benefit of direct manipulation is that the user can see which functions are available without having to remember any syntax. It is easier to recognise than to remember. A disadvantage is that some actions are difficult to support in a direct manipulation design. As an example Jonas Löwgren (1993) mentions the action “change all italics to bold”.

2.2.8 Graphical Design

Screen design involves a detailed draw up of the dialogue structure. On this level the form and content of the process windows, dialogue boxes and message boxes is determined. Also standards for controls, feedback and input interaction is set. One objective of the graphical design is to ensure consistency and simplicity throughout the user interface.

Donald Norman’s “seven stages of action” (Norman, 1988) can be of help on this level of design. The seven stages of action is an outline of the elements included in the process of reaching a goal. These are:

- Forming the goal
- Forming the intention
- Specifying an action
- Executing the action
- Perceiving the state of the world
- Interpreting the state of the world
- Evaluating the outcome

2.2.9 Evaluation

Continuous user tests and evaluation of the different design versions makes sure that the design activities proceed in accordance with the usability goals. There are a number of different evaluation methods suitable for different types of feedback. Before deciding on a method the examiner needs to be clear about the aims of the evaluation.

The evaluation process includes the activities prototyping, expert reviews, user tests, and analysis.

Prototyping

Prototypes are developed to illustrate design ideas and are objects that can be used for evaluation. Löwgren (1993) talks about the hi-fi and lo-fi prototyping. Hi-fi prototypes are realistic prototypes with a lot of functionality implemented using technology close to the real thing. A lo-fi prototype can for example consist of a simple paper model. The benefits of lo-fi prototypes are that they are cheap to develop and it is easy to create and evaluate several user interface designs. Creating a hi-fi prototype requires more work, but for an advanced design concept it yields more reliable evaluation results.

Expert Reviews
Expert reviews can be conducted as soon as an early prototype is produced. Different methods are:

Heuristic evaluation
The conformance of the interface is tested to a set of broad-based principals, so called heuristics. The most commonly used heuristics are “the eight golden rules of interface design” by Ben Schneiderman and “the usability heuristics” by Jakob Nielsen (Appendix A).

Cognitive walkthrough
Using scenarios the developers go through the interface step by step estimating what cognitive load the user will be subjected to and what difficulties can be expected. Does the user find the control for an action? Does the user understand the feedback connected to an action?

Consistency inspection
The user interface is checked for inconsistency in terminology, colour, layout, input and output formats, feedback etc.

Guideline review
The interface design is checked with regard to general and company specific guidelines.

User Tests
When user tests are performed the examiner needs to be clear about who the real users are, and seek to realise the tests with individuals who correspond to the range of real users in a satisfactory way. Furthermore, relevant tasks or scenarios have to be prepared.

Having an observer attending the test can be eye opening. The observer might perceive unspoken reactions that the examiner does not catch. Another possibility is to video tape the tests and to evaluate them at another occasion.

During the tests the examiner needs to be careful about interacting with the test users. The test users must not be influenced to act in a specific way or to give particular answers to questions. However, in some circumstances it is necessary to guide the test users to be able to carry through the tests at all. The examiner must be sensitive to when interacting contributes to an accurate test result and when it does not.

A few of the most common user tests are:

Scenarios
In the light of scenarios interviews, questionnaires and focus groups can give ideas about usability problems and user attitudes.

Focus groups
Focus group sessions can be performed to discuss the different designs.

Thinking aloud
The user is given a task or a scenario to perform and is asked to think aloud while doing this. The evaluation gives the experimenter a very direct understanding of how the user is affected by the task and what problems occur interacting with the interface.

Data logging
Logging user activities, such as errors, time to conclude a task, time used searching for help etc.

Analysis
Once the tests data has been collected it needs to be analysed. Are the results of the tests relevant? Are they valid for a large number of the entire user population? Have the usability goals been meet? What can be done to improve the usability problems found?

2.3 International User Interface Design

Working with international user interfaces involves numerous issues to consider including linguistic and cultural aspects, such as organisational structure, communication, metaphors and symbols. There are several ways of approaching this problem.

International inspection means having people of different countries examining the interface looking for components that will possibly cause usability problems in their country. Nielsen (del Galdo et al, 1996) points out that such an inspection only results in educated guesses, since the examiners are not real users. An expensive variant, which ought to generate a higher quality of the result, is to involve usability experts from different countries.

A more reliable outcome is retrieved involving real users in the development process. A company that is established in a large number of markets might choose to include only a few countries that are representative for a larger business area. Another decision that has to be made is whether to perform the studies oneself or to outsource the commission to someone else. Usability experts in the countries of interest can be hired. A usability expert will probably originate a high quality report, but involving local staff from the company in the process has some significant benefits; it is cheaper and the staff will feel positive about having an influence.

Performing user tests in a foreign country involves some difficulties, like for instance travelling and travelling costs. As an alternative to travelling, user tests can be conducted over the Internet. However, the lack of visual feedback means a deprivation of a significant source of information. This can partially be avoided using a web camera, but a web camera is not an absolute replacement of actual nearness.

However, the biggest obstacle to overcome is the language barrier. A lot of information can be lost in a translation. Engaging a translator means introducing a third party, whose interpretations of what is said will colour the outcome. When employing a translator the designer must make sure that the aims of the study are made clear to the translator.

There is also the possibility to apply to test users who speak a language known by the designer. Doing so, it is important to be cautious with making sure the test users represent the real users in an accurate way, and to be attentive to the fact that speaking a second language can sometimes be intimidating, causing the test users (or the test executer) to hold back on information.

Finally, a multinational design team can be established to ensure that cultural differences are regarded in the design process.

When working with a system that will be used internationally, it is of weight to produce an application, which is translatable. As Jakob Nielsen[9] puts it: "The user interface and documentation must be translated into the user's native language in a way that is understandable and usable".

Elisa M del Galdo (1996) calls attention to the importance of not introducing international user studies to late. Many products, she states, are not exposed to international usability tests until the development is close to its end, and no major changes are possible.

2.4 Applying the Usability Engineering Process to the Next Generation TPOP

This chapter aims at giving suggestions as how to apply the usability engineering process to the next generation TPOP.

It should be mentioned that only the TPOP fraction of the CTIP concept is discussed below. However, the next generation TPOP is in fact a part of CTIP that cannot always be distinctly separated from the entirety. This is for example true for some of the system services, in which cases it is not always obvious where about within the CTIP concept they are best applied.

2.4.1 Background

The user interface of the TPOP is not a sells argument that is of importance for the filling machines today. Also the conventional design of the existing TPOP interface is very well established among people at Tetra Pak R&D. Thus, improving the usability of the TPOP is not a highly prioritised activity.

When the existing TPOP was developed several years ago a number of user-centred activities were employed. The developers interviewed the real users and took part in their tasks. Iterative design was performed and the prototypes were discussed with service technicians at Tetra Pak, who are familiar with the operators in various countries. However, the real users were not included in the design process and no further development has taken place since the existing TPOP standard was determined.

There are several strong arguments for developing a new, improved system that better supports the operators and that corresponds to the customer's needs and desires. The most vital is the customers' satisfaction with the system. Factors that will contribute to the satisfaction are:

- Decreased training time for operating the machines.
- Increased performance due to well-directed tools supporting the daily decision-making
- Decreased frequency of errors.
- Decreased confusion of languages and terminology.

2.4.2 A Vision

The first step in a design process is to formulate a vision, describing the future product, including overarching usability goals, clearly.

[9] http://www.useit.com/papers/international_usetest.html 2002-05-29

2.4.3 Project Plan

The user interface and usability activities should be planned and roughly scheduled. When the project is planned it would be a good idea to include all the people who are involved, e.g. programmers, assigners, CCUPD (Customer and Consumer Understanding and Package Design) and future users. That way all the participants will have a greater understanding for the process and have the opportunity to influence the work.

2.4.4 User and Task Analysis

A number of potential user groups and their main responsibilities have been identified:

Machine operators – operation, supervision, maintenance, troubleshooting
Local service technicians – maintenance, troubleshooting, repair
Tetra Pak service technicians - maintenance, troubleshooting, repair
Process personnel – quality assurance, performance
Laboratory personnel – quality assurance
Production supervision – performance, quality assurance, production planning
Customer management – production planning, quality assurance
Tetra Pak service management – performance, repair, trouble shooting

The backgrounds of the user groups in various countries and within various companies are extremely differentiated. There are cultural, lingual, educational, professional, and organisational aspects to consider. It is not an easy assignment to form an understanding of such a widespread group of people.

My suggestion is to concentrate on the users that are within reach of Tetra Pak in Lund initially, i.e. Swedish and possibly Danish customers. Pay visits to the plants and conduct interviews with the future users of next generation TPOP.

One should also investigate whether the CCUPD (Customer and Consumer Understanding and Package Design) have information that can contribute to the user analysis. Also other corporations within Tetra Pak might have valuable information to share. Other sources of information that can be utilised are experiences of for example the service technicians. However, if conferring service technicians the designers must remember that they are not representatives of the entire user population.

Continuing with user and tasks analyses in other countries would perhaps be the most accurate way of conducting the usability engineering, but would certainly be expensive. Therefore, the multi-cultural and multi-lingual problematic should be kept in mind, but be dealt with later, when early prototypes have been produced. This will be further discussed in Section 2.4.8.

2.4.5 Competitive Analysis

Competitive analyses have been performed and are described in Chapter 3-5.

2.4.6 General Design Principles

Sources of design principles are:

The heuristics (Appendix A)

User interface guidelines on the Internet:

- Usable Web (http://usableweb.com/topics/000529-0-0.html, 2002-06-17) provides a set of links to what they call "comprehensive guidelines".
- HCI Links (http://www.hcibib.org/hci-sites/GUIDELINES.html, 2002-06-17) offers guidelines links.
- HCI Resources (http://www.ida.liu.se/~miker/hci/guidelines.html, 2002-06-17) present links to guidelines, style guides and standards.

Deborah Mayhew (Mayhew, 1999) suggests the following books on general design principles and guidelines:

- The Design of Everyday Things, Donald Norman
- Designing User Interfaces for International Use, Jakob Nielsen
- *Developing User Interfaces,* Deborah Hix and H. Rex Hartson
- Envisioning Information and Visual Explanations, Edward Tufte
- The Essential Guide to User Interface Design: AN Introduction to GUI Design Principles and Techniques, Wilbert Galitz
- *The GUI Style Guide,* Susan Fowler and Victor Stanwick
- *The Icon Book,* William Horton
- Principles and Guidelines in Software User interface Design, Deborah J. Mayhew
- *Readings in human-Computer Interaction: Towards the year 2000,* Ronald Baecker, Jonathan Grudin, William Buxton, and Saul Greenberg

Pattern resources on the Internet are:

- Uidesign.net (http://www.uidesign.net/links/newlinks.html, 2002-06-17) offer links to pattern language sites.

Company specific guidelines are:

- Tetra Pak's operator panels general HMI guidelines (http://151.183.8.67/mainframe.asp, Tetra Pak's intranet, 2002-06-17)
- Operator panels TPOP Maxi HMI guidelines (http://151.183.8.67/mainframe.asp, Tetra Pak's intranet, 2002-06-17)

Both these resources thoroughly describe the design of the TPOP user interface of today. The idea of the next generation TPOP is to improve this interface design, meaning that the design standards of these resources are not to be considered as definite rules. However, it is possible that some of the features of today's TPOP deserve to live on in the next version.

If it is decided to incorporate Windows standard in the TPOP guidelines are found in *Macintosh Human Interface Guidelines*, 1995, Apple Computer Inc. (http://developer.apple.com/techpubs/mac/pdf/HIGuidelines.pdf, 2002-05-30).

2.4.7 Usability Goals

In the light of the user and task analyses a session of idea generation should be carried through to find suggestions of usability objectives to consider. If possible it is, in my opinion, advisable to include some representatives of the user groups in such a sitting.

Doing so would with great probability increase the quality of the suggestions drawn up. This is, however, a question of time and cost and might not be achievable.

Once the usability objectives have been outlined they need to be organised, prioritised, and the measurable levels for the usability metrics have to be determined. I suggest that the existing TPOP is used as a reference to decide upon the explicit values to set for the usability metrics. User tests based on scenarios can be utilised for this purpose. Employing real users in the evaluation of the existing TPOP could be favourable. The real users have all the background information necessary to run the TPOP. However, engaging test users who have no experience of the TPOP or the work around the filling machines will give a more appropriate idea of how the novice user reacts to the user interface. Since many users around the world are not skilled workers this might give a better replication of the actual circumstances. When testing the existing TPOP the possibility to include test users of different cultural and lingual backgrounds ought to be exploited.

Evaluating the existing TPOP has a few additional advantages. Firstly the usability problems found can give ideas of things to improve and where usability activities will yield the most effect. Secondly, the designers will have to think through how the usability goals can be evaluated.

2.4.8 Design and Evaluation

Parallel and iterative design, carrying through early prototyping and evaluation is an approach, which I believe will give the best result in the end. Working on the four levels design of system services, conceptual design, interaction design and graphical design offers a manageable structure to the design process.

Involving real users in the design process to ensure the usability is essential. Initially only users in Sweden should be employed, since it is quite expensive and might be time consuming to perform tests abroad. When real users are not available other test users will have to be engaged. In some cases, involving people who are not real users might even be beneficial, e.g. to give a picture of how novice users interact with the user interface.

Real users can be recruited in the dairies in Sweden and Denmark, who are customers of Tetra Pak. Other test users can be enlisted through adds in a magazine or through personal contacts. Yet, the examiner needs to be careful to ensure that the test users are tolerably representative for the future users of the user interface.

Once the looks of the user interface have been outlined international inspections should be carried through. There are several people from different countries working at Tetra Pak in Lund, who could be involved in the evaluation process. Another possibility is to apply to international organisations, like for example the Finnish Organisation or the Assyrian Association, to find test users of differing cultural and lingual backgrounds.

Later in the design process it is possible to engage local staff in the countries where Tetra Pak has offices to conduct usability tests with real users. Such a procedure needs to be carefully prepared. The people conducting the tests must be clear about the aims of the tests and how to perform them. Also the test results need to be reported in a consistent and manageable way.

The advantage of including local staff instead of usability experts in the user test process is that it will inspire a positive feeling of involvement and possibility influence. It is also less expensive.

Yet, sometime during the design process it could be beneficial to involve usability experts in the main markets of the filling machine to perform expert reviews of the interface.

3 Competitive Analysis

In the light of the market study *Customer Technical Information Need* (Eliasson et al, 2001) the desire to perform a gap analysis arouse. Originally the objective of performing an analysis was to compare the TPOP user interface with operating panels from Tetra Pak's competitors and from other industries. However, during the course of proceeding with the assignment, it has undergone some alterations, and can be divided into two subtasks, which I have chosen to call "benchmarking user interfaces" and "gap analysis of system services".

Benchmarking user interfaces
The first subtask can in principle be described as benchmarking and is more or less equivalent to the original task formulation – namely to compare the TPOP user interfaces with other operating panel user interfaces. The motive of doing so is to find high quality solutions that could be applicable on the TPOP and to give inspiration for new design ideas. The main factors to be examined are the system services, the graphical layout and interaction. Since it is not quite simple to get access to the competitors' operating panels the benchmarking will be limited to other companies within the manufacturing industry. The main focus will be on the machine operators, but also other types of personnel interacting with the system will be considered.

Gap analysis of system services
The second subtask involves looking into the system services offered by Tetra Pak's competitors and by other companies within the automation industry. The purpose is to find out how well Tetra Pak manage in competition with other companies, with regard to the system services, and to find support for new ideas on the subject. Also looking into other companies' information management can give rise to ideas for new solutions.

These two directions of the competitive analysis are different in several ways, but some items are overlapping, e.g. the system services are looked at in both cases.

3.1 An Organisation of the Information to be collected

Seeing that a lot of information related to the benchmarking and gap analysis will be collected, this information needs to be organised in a way that is manageable. A suitable approach to finding a structure is to start out from the processes, which the system services are to support. The processes involved in the production of every manufacturing plant can be divided into: installation, training, production planning, operation, maintenance, troubleshooting, repair, quality assurance and performance. The processes are described below.

Installation includes the help and documentation and possibly other forms of support needed to install a machine or a system.

Training involves the material and assistance necessary for the staff to learn their tasks and the tools provided to support their work. Training also includes refreshing skills.

Production planning is the planning and scheduling of production activities, such as order handling (external and internal), inventory control and production steering.

The **operation** procedure includes the functions and information needed by the machine operator to run the machine.

Maintenance includes the assistance and tools needed to perform planned care and overseeing.

Troubleshooting and **repair** concerns unplanned maintenance.

Quality assurance refers to the procedure of assuring the quality of the product manufactured.

Performance concerns the analysis of the data collected during operation, maintenance and quality assurance and how it is utilized.

In addition to this, I have added three more factors related to the information management. They are:

Reports including tools for producing reports based on production data.

Web based services including services available over the Internet or an Intranet.

System management including services such as language handling or integration of systems.

3.2 The TPOP

3.2.1 The Users

Since the TPOP is used in a large number of countries all over the world the user profiles are extremely differing. Cultures and languages may furthermore differ within a country, making the user spectra even larger. A number of different alphabets are represented within the markets where Tetra Pak is active. Examples are Latin, Japanese, Arabic, and Thai. Another aspect, further complicating the picture, is that the reading skills of some users are not highly developed; in some cases the users might even be illiterate. Today the user interface only supports the languages represented in the EU (Pettersson and Rosén-Lidholm, 2000).

Another area carrying large differences is the user skills. In some places the staffs stay employed in the same company for a long time. In other cases staff is hired to help out during temporary intense periods that may last for only a couple of weeks.

The company policy and organisation also influence the staff's skills. For example, a company with a hierarchic organization will be more inclined to want to preserve power structures, and hence not invest largely in advanced training for some groups. Others are anxious about the over all competence, offering their staff extensive training opportunities.

The user groups who are concerned with the TPOP today are: machine operators, local service technicians, Tetra Pak service technicians, and laboratory personnel.

3.2.2 Working Procedures

This description of the working procedures around the filling machines is based on the operating manual (OM TB/19 020V), the master thesis *"An Information analysis of operators, technicians and their requirements with an e-business approach"* (Pettersson and Rosén-Lidholm, 2000), and conversations with Lars Lindmark, User Interface Designer. The text does not refer to any specific producer, but is a general outlining of the working procedures around the filling machines. It should also be noted that widespread variations in the working procedures of different companies might occur.

The production management typically performs production planning. The information about what to produce on each machine is usually forwarded to the machine operators on a paper sheet.

Before the production of a new product is begun the machine needs to be cleaned. Cleaning programs are started on the TPOP. Once the cleaning is done the operators proceed with starting the machine. Starting the machine involves going through a number of program steps, e.g. preheating, spraying (disinfection) and motor start. When a step is completed the TPOP will request a confirmation from the operator before continuing with the next activity (the operator pushes a button on the operating panel).

Once the machine has reached the production mode, the operators main tasks are to attend to alarms and to refill filling material. Also the operators are to check that the packages are of good quality on a few occasions during production.

In addition to this the operators perform daily and weekly care. Daily care involves internal and external cleaning of the machine. Weekly care involves going over the machine more carefully, checking certain components and filling some items with oil. Directions of how to perform daily and weekly care are provided in the operating manuals supplied by Tetra Pak. However, interviews conducted with operators at Kivik's Musteri (Pettersson and Rosén-Lidholm, 2000) shows that in this dairy they have their own checklists for care taking of the machines, since Tetra Pak's recommendations are considered to be to extensive and time consuming. Maybe this is a common view among other filling machine customers as well?

Another operator task is to fill out reports and keep records of features, such as peroxide values, preparation time, production time, temperatures etc. The reports are foremost paper based, and tend to be left untreated until some sort of problems with the production occurs. They are than used for troubleshooting.

In some companies operators perform a little maintenance, including failure diagnosis and repair, beyond the daily and weekly care. Yet, the operators usually do not have the authority to carry out any complicated maintenance, even if they have the knowledge to do so. When complex problems occur local technicians are called to perform troubleshooting and repair. If the local technicians need help they turn to Tetra Pak technicians. Tetra Pak technicians also visit the customers on a regular basis to execute preventing service on the filling machines. This typically occurs a couple of times a year, according to the agreement between Tetra Pak and each of their customers.

The laboratory personnel are responsible for quality assurance of the products contents, i.e. the liquid food.

3.2.3 Working station

The TPOP is attached to the machine and consists of a touch screen and a set of hardware buttons.

Figure 2. The TPOP consists of a touch screen and a set of hardware buttons.

The operating panel is used in a noisy industrial environment. Light environment, space planning, and other factors affecting the working environment are presumably different in different plants.

3.2.4 System Services

The TPOP supports the following processes:

Operation

- Operation (control, machine settings, system settings)
- Alarm handling
- Data collection[10]
- Monitoring (machine status, production status)
- Help texts

Troubleshooting

- Data collection

3.2.5 Graphical Layout and Interaction

The main features of the touch screen display (see Figure 3) are a picture of the machine (centre), the so-called ladder (right side) showing which status the machine is in, and a number of software buttons (bottom). The header, in the top, shows the time, the name of the active window and the machine status in writing.

[10] Refers to the manual input requested by the system, e.g. package waste.

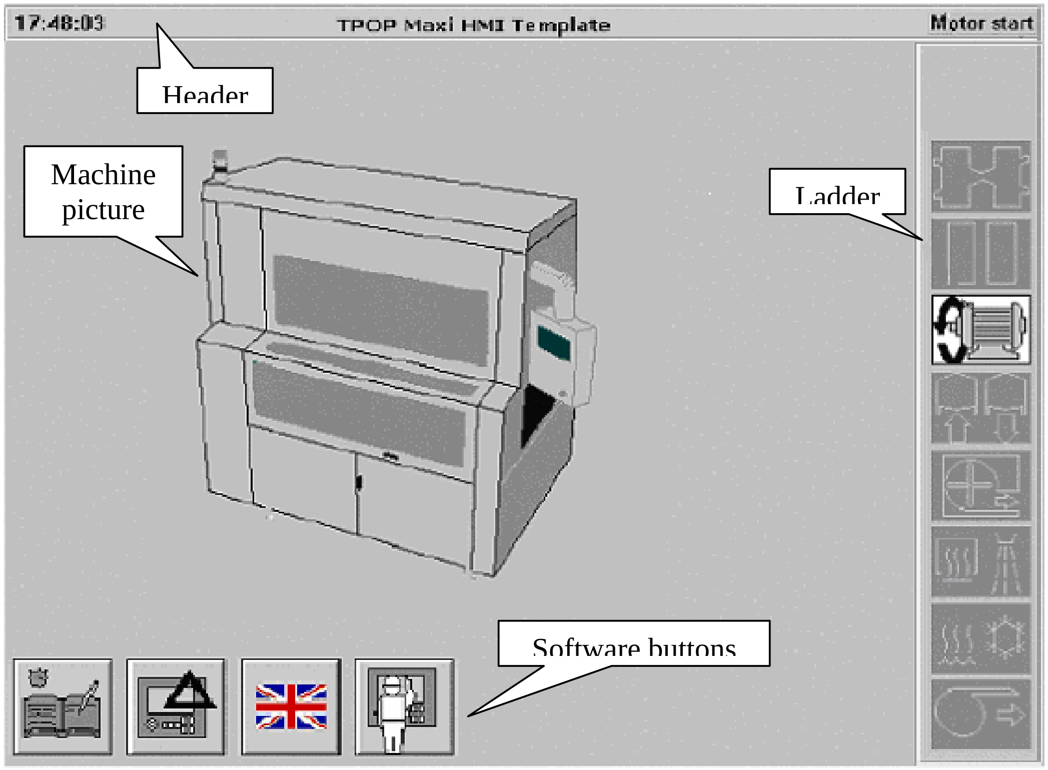

Figure 3. The default page of the TPOP and its main features.

Before starting the production a number of programs, such as preheating, tube sealing, cleaning, motor start etc, have to be carried through. These programs are prompted using the hardware buttons. The ladder shows which program is active lightening up the symbol representing that program step. When a new program step is to be started the symbol in the ladder will begin to flash prompting the machine operator to activate the program using the hardware buttons.

The software buttons represent the data collection menu, the alarm menu, the system settings menu and the machine settings or manoeuvre menu. Touching one of the buttons a subwindow will appear on the screen. The windows are organised in a hierarchic fashion and the user moves in between them by touching objects and buttons displayed in the windows. Within the subwindows information can be retrieved and settings can be made.

The alarms are sorted in groups. When an alarm is activated the alarm window representing the alarm group will appear on the screen. A help text is available in the window.

When troubleshooting is called for, the data collected in the TPOP has to be downloaded to a diskette and examined on a separate computer.

Figures 4-7 illustrate some of the features of the TPOP user interface.

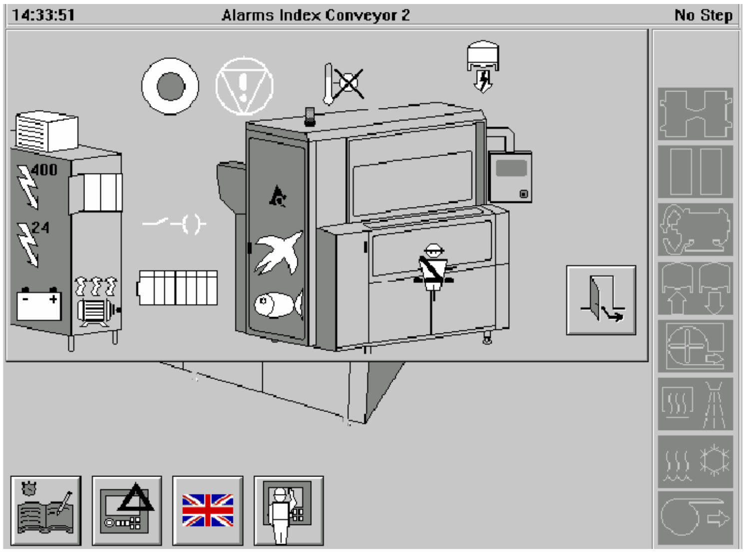

Figure 4. The alarm window. All alarm group symbols are displayed. When no alarm is present the operator can pick the alarm menu button to display all alarm symbols. Information about the alarm groups is available by selecting the symbols, displayed in white, representing them.

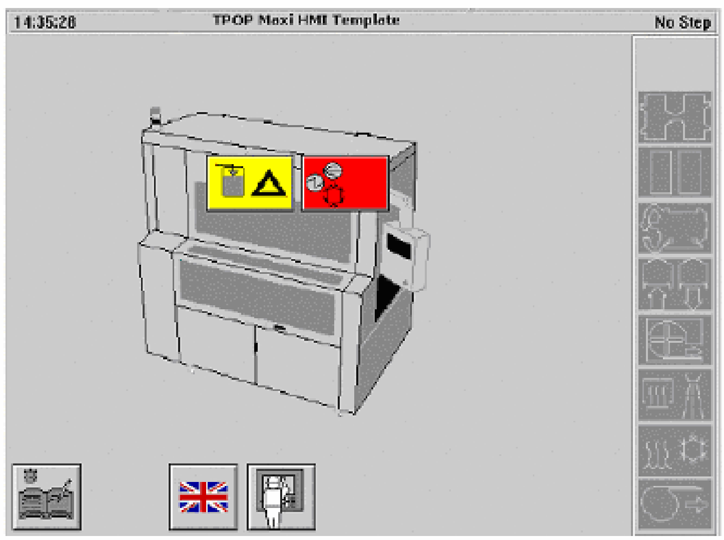

Figure 5. Activated alarms. When an alarm occurs the symbols representing that alarm group appears and the alarm menu button disappears (since it cannot be selected). Selecting the symbol representing an alarm opens the alarm group sub window.

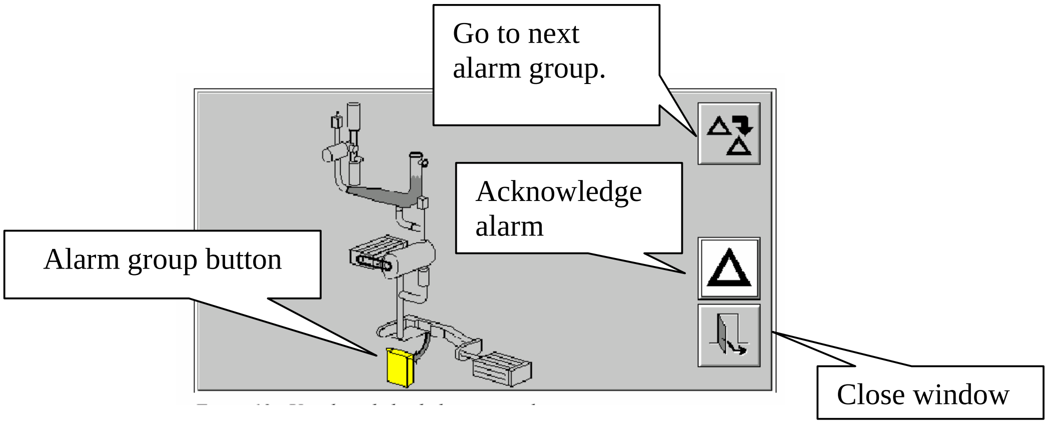

Figure 6. Alarm group subwindow. The alarm group button is coloured red, yellow, or blue according to its severity. Selecting the alarm group button retrieves a help text.

Figure 7. Help text window. The help text window consists of concise instructions.

4 Benchmarking User Interfaces

The first step in performing the benchmarking was to look for user interfaces suitable for an analysis. Different possibilities were investigated. In the end three companies were willing to accept a visit, and to show and discuss their user interfaces. They were: Eleanders Novum, Klippans AB and Volvo Cars Body Components.

The visits were accomplished in a more or less unstructured way. Discussions around the users, the users' tasks and the user interfaces were conducted. Questions to be answered were:

- Who are the users?
- What are the users' tasks?
- What processes (confer chapter xx) are supported by the user interfaces? Which are the system services?
- How do the users interact with the user interface?

The result of the visits is presented in Sections 4.1,4.2 and 4.3.

4.1 Elanders Novum

Elanders Novum is a printing company located at Tetra Pak in Lund, mainly in the business of printing manuals and drawings for Tetra Pak.

My visit to Elanders Novum lasted for only about an hour, during which Lars Oscarsson, manager, showed me the user interfaces and told me about the routines of their every day work.

4.1.1 The Users

The operators have no specific education when starting to work for Elanders. Their colleagues introduce them to the machines and their work tasks. In addition to this the supplier of the machines offers an education on how to work the machines.

The operators' tasks are to prepare and make adjustments for printing a document, attend to alarms and refill material during production, and documenting when a job is finished.

The suppliers' technicians perform all service of the machines. They are called on about once a week.

4.1.2 Working Procedures

The work to bring forth a production plan is performed on a weekly basis. The purchase orders are printed on separate paper sheets and organised in the order of priority.

Every purchase order has an id-number. The information about what to produce is forwarded to the operators on paper sheets marked with the id-numbers. The document that is to be printed is found stored under that same id-number in a computer separate from the machine. The paper sheet tells the operator what kind of paper to use and what settings to make. However, the sheet does not say this straightforward, but the operator can interpret the information by experience. There is also a crib sheet, made by Elanders, to guide the inexperienced user.

The printing machine is started on a user interface placed on the machine.

When necessary the operator fills paper and toner in the machine. The operator must also be prepared to attend to paper jams.

If the machine is disabled for any other reasons one of the machine supplier's technicians will be called. The operators are not to perform any advanced machine service.

When a job is finished the operator will acknowledge this by signing the purchase order.

4.1.3 Working station

The machines used at Elanders are digital printers. The operators have two working stations - one on the machine and one on a separate table nearby the machine. They are both ordinary pcs with keyboards and mouses

The separate computer has a windows environment. This is where the documents to print are found and settings, such as number of copies and paper size, are performed.

The other computer displays an interface on which the machine is operated.

4.1.4 System Services

The computer separate from the machine supports the following processes:

Operation

- Operation (control, machine settings, production status)
- Help

The computer attached to the machine:

Production planning

- Change the order of documents in line to be printed

Operation

- Operation (control, machine settings, production status)
- Alarm handling
- Proactive event handling[11]
- Help

Troubleshooting

- Data logging (alarm lists)

4.1.5 Graphical Layout and Interaction

The user interface of the working station separate from the machine is a common Windows environment. The documents to print are found in the Document manager. Settings, such as number of copies and paper size, are adjusted in the Print window.

Some of the features of the Print window are illustrated in Figures 8-11.

[11] The system informs the user of upcoming events, e.g. little paper in container two.

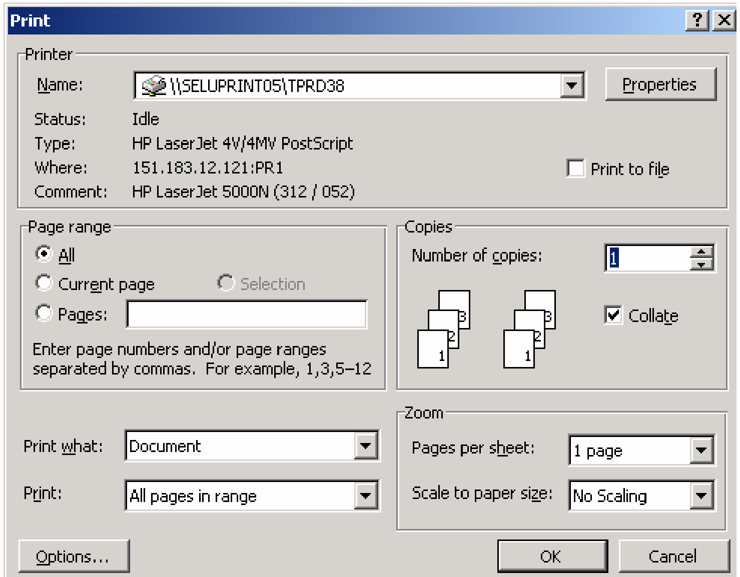

Figure 8. The Print window in the user interface of the working station separate from the printer at Elanders.

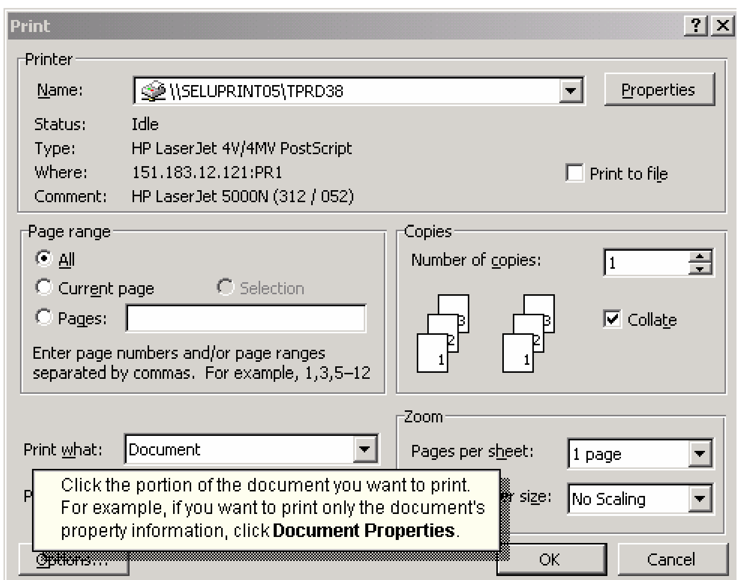

Figure 9. Help texts are retrieved by choosing the question mark and thereafter clicking on an item.

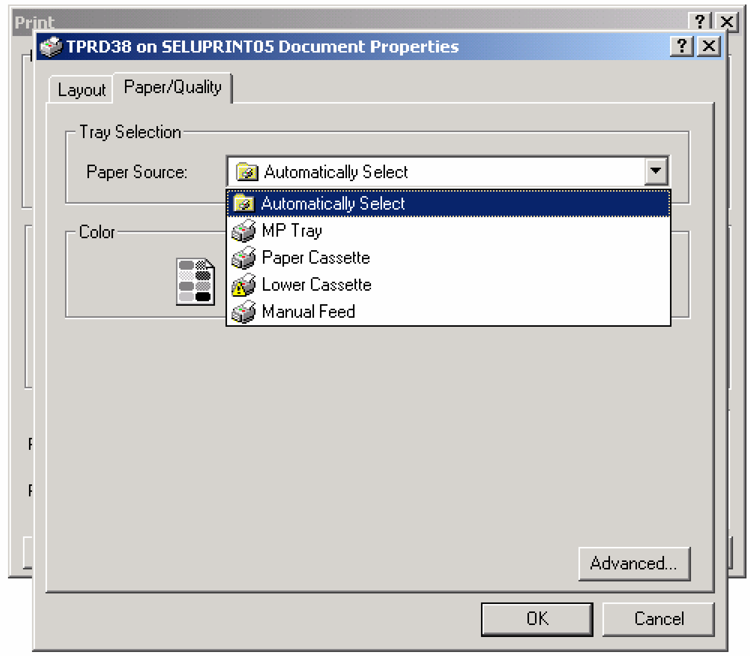

Figure 10. Further settings can be made, e.g. in the Properties windows.

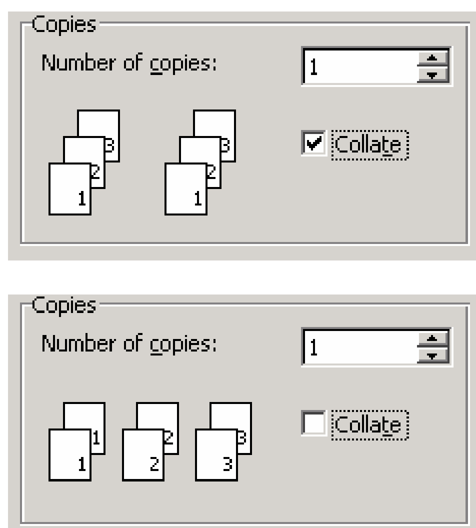

Figure 11. The user interface in many cases offers direct visible feedback on chosen settings.

The other computer displays an interface on which the machine is operated (see sketch, Figure 12).

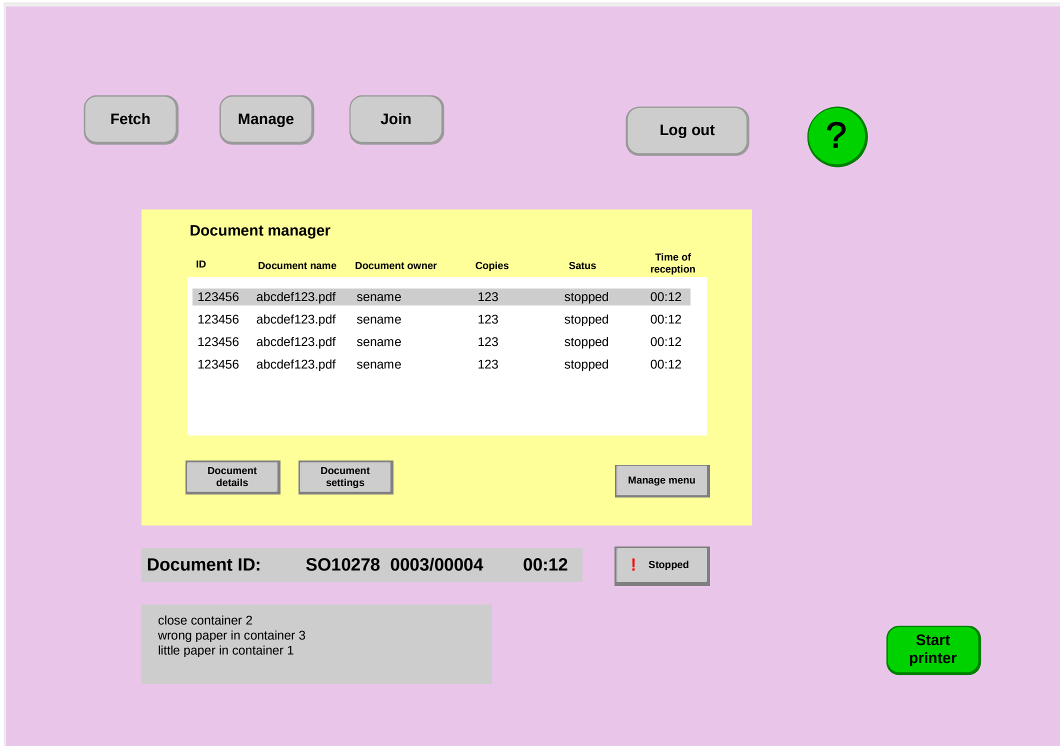

Figure 12. Sketch of the user interface of the working station on the printer at Elanders.

On this interface the machine can be started and stopped. The settings made at the first working station can be altered, but usually that is not necessary.

The status of the document being printed and the documents standing in line to be printed is displayed in the box called document manager in the middle of the interface. Under the document manager there is a text showing, which document is printed and how much time is left until the job is finished. There is also information about how many copies to print and how many have been printed.

At the bottom of the display there is a box showing actions, such as close container x and refill container x, that need to be performed. Current events are displayed, as well as events coming up.

When an alarm occurs the machine stops. The cause of the alarm is displayed on a button under the document manager. Information of how to solve the alarm is retrieved by selecting the button.

The system automatically logs the alarms.

4.2 Klippan AB

Klippan AB is a company manufacturing graphical paper, office paper and special paper.

Lars Lindmark, User Interface Designer, and I visited Klippan AB, one afternoon, to have a look at the operating system of their plant. We were welcomed there by Lars Tornevall, Electrical Technical Department Manager, and Jan Mauritzson, Instrument Engineer, who introduced us to the system and to the plant.

Klippan AB started to work on a new operating system about two years ago. The system is used to supervise the production, manipulate machine settings, write reports, and for troubleshooting. Lars Tornevall and Jan Mauritzson and other instrument engineers involved in the system's design are continuously working to improve it.

4.2.1 The Users

The system is worked by a number of different user profiles: operators, technicians, production supervisors, and laboratory and quality personnel. In the future there will also be services included in the system to support the purchase personnel with matters such as inventory control and storage status.

The operators typically stay in the company for a long time, which means that they know their job thoroughly. Since the rotation of employees is insignificant there are always experienced operators at hand when a problem occurs.

A new employee starting to work in the factory will work side by side with an experienced operator for a long period of time to learn the working procedures and how to work the machines. This is considered to be the best way of training a novice operator at Klippan AB because of the complexity of the machines and processes. The high risk of severe accidents and, as a consequence of this, the need to be familiar with security directives are factors that supports this assessment.

The software system supports the operator in manoeuvring the machines and supervising the process. Lars Tornevall and Jan Mauritzson estimate the training time required to learn the user interface to a couple of hours, depending on what degree of computer experience the user has.

Technicians and quality personnel mainly use the system for troubleshooting, whilst production supervisors are concerned with data collected by the system.

4.2.2 Working Procedures

The operator's main tasks are to manoeuvre and supervise the production process. There are, in general, two operators working on each machine.

The coordination and prioritisation of purchase orders from customers is performed by planning personnel and is forwarded on paper sheets to the machine operators. These paper sheets make it clear what type of paper is to be manufactured and what amount to produce. The operator types the recipe values (number of bales, amount of colour, chalk etc.) into the system and makes sure that the material needed is filled up. The system keeps track on how much material is used up and alarms when refill is necessary.

The service technicians continuously carry through maintenance.

4.2.3 Working station

The environment in the factory is very rough, dirty and noisy. Since the machines are rather large, the production cannot be overviewed from one point. The software system used to supervise and manoeuvre the machine and production is placed in a control room nearby each machine. In the room the level of noise is lower, but it is far from quiet. In spite of this, my impression is that it is possible to work in the room without experiencing any greater disturbance or stress due to the din.

The working station comprises several computers with different user interfaces – some older systems for manoeuvre and supervision, the new system and a system for automatic regulation of parameters concerning the quality of the paper, e.g. weight, moisture and the surface profile. Around the machines there are further operator panels, which the operators must understand and work with.

The system is also used in an office environment.

4.2.4 System Services

The system supports the following tasks:

Operation

- Operation (control, machine settings)
- Monitoring
- Alarm handling[12]

Troubleshooting

- Data logging (alarm lists, history)

Reports (data is retrieved from the system and is manually summarised in excel sheets)

System management

- Integration of systems
- Monitoring of all machines and processes – read only access

There are plans to include more services in the future. As mentioned above the system will have functions to support the work of the purchase department. It is also an ambition to make the system available at home for on-call duty staff and to transmit alarms to the operator's cellular phones for when they are not close to the operator interface.

4.2.5 Graphical Layout and Interaction

Klippans operator system is based on the product FIX MMI/SCADA, which is created and distributed by Novotek. FIX MMI/SCADA is an open system for Windows NT/98/95 constructed around standards. Being an independent system FIX leads to an improved integration of different control systems. With FIX as the platform and with support from Novotek the user interface has been design by Klippan to suit the needs of their plant.

When starting to work with the user interface the first page displayed consists of an overview with buttons representing the different parts of the plant divided into separate machines and processes (see sketch below, Figure 13)

[12] The system also alarms when a problem has arisen somewhere behind or ahead in the production line.

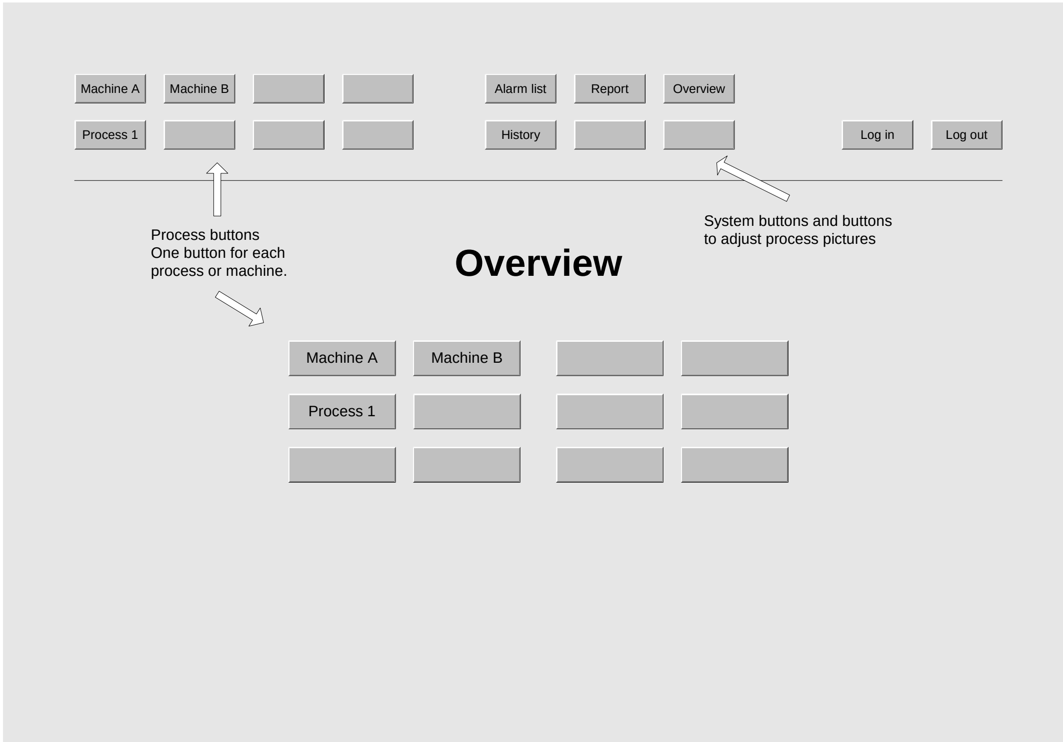

Figure 13. Sketch of the default page of Klippan's operating system.

On the top to the left there are a number of buttons each representing a machine or a process in the plant. The same buttons are displayed in the middle of the page.

On the top in the middle there is a section for buttons covering data collection, report writing and manipulation of the process pictures (described in Figure 14).

The data collection referred to includes history (process values), and alarm list and status. This is mainly used by technicians for troubleshooting and by the laboratory and quality personnel for follow-up on discharge and quality issues.

All personnel can retrieve information about all processes in the plant by clicking on the buttons representing them. However, it is only the operators working on a machine who can perform manoeuvres and set values on that specific machine.

On the pages concerned with specific processes or machines there are schematic pictures outlining them (Figure 14). On the left side there are buttons to manoeuvre the machine and to set values. In the bottom of the page there are buttons to retrieve pages of sub processes involved in the process. The section in the top of the page is always the same, which means that it is notably easy to navigate between the system's pages.

It is also possible to retrieve the pages of sub processes by clicking on the corresponding sections of the process picture. The same goes for making manoeuvres and setting values; it can be done by clicking on the objects in the picture signifying the items wished to manipulate. Instructions about an item can also be recovered this way.

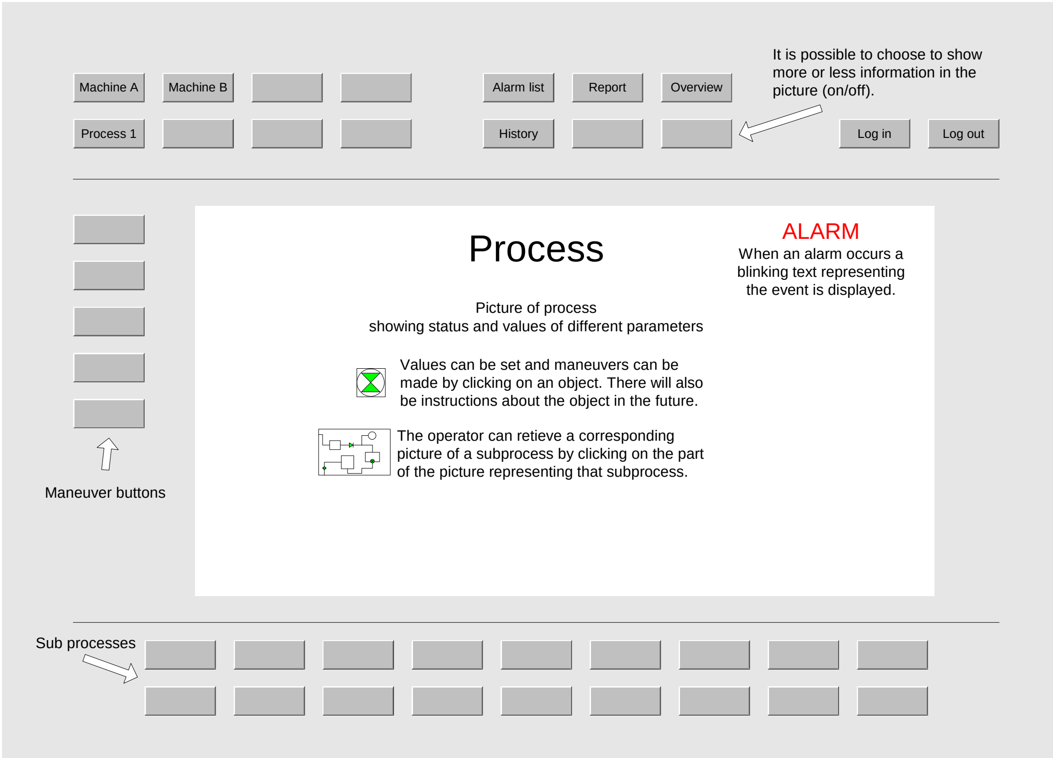

Figure 14. Sketch of the pages concerning a specific machine or process at Klippan.

When an alarm occurs a blinking text indicating the event is displayed in the right corner on the top of the picture. Also alarms, that do not directly concern the specific process an operator is working on, are displayed revealing events happening before or ahead in the production chain when this affects the work on the machine.

There is a lot of information about the process in the pictures. Real values and desired values presented in numbers and bars with percentage marks illustrate the status of different objects.

When clicking on an object to manipulate it a window pops up where values can be set and manoeuvres can be made. The new settings must be confirmed for the changed values to be activated.

Information about the object's settings is available here and there are instructions to be retrieved about it.

Clicking on a cross in the upper right corner closes the window.

4.3 Volvo Cars Body Components

Volvo in Olofström presses and assembles car body components for Volvo cars. The components are delivered to Torslanda in Sweden and Gent in Belgium, where the cars final assembly is carried out. There are about 1000 people working within the production in Olofström.

Helena Helm, User Interface Designer, Lars Lindmark, User Interface Designer, and I visited Volvo in Olofström for one whole day. We were met by Ove Jösok, Electrical Engineer, who told us about the control systems of the plant and gave us a concise introduction to some of the operating interfaces used in the production. Thereafter we were shown around in the factory.

Since the production lines of Volvo in Olofström are automatized to a high extent, the operator interfaces are almost only used when the machines stop to get information about the problem or for trouble shooting. Therefore the user interfaces are not very complicated or sophisticated. Also there were several different interfaces in use. Because of this it was not relevant to perform any careful study of a specific interface, but some interfaces were briefly looked at and are presented below.

Also the information below about the user and the work procedure is somewhat scanty, since there was not much time allocated to discuss these matters. Still I have tried to summarize what was brought up during the visit to get a general picture of how they work in the production lines and how the operating systems support the operators tasks.

4.3.1 The Users

The personnel working within production typically stay in the company for a long time and are regarded to be very skilled workers. Machine operators, technicians and storage personnel have a varying educational background. Since there are many immigrants working in the plant, sometimes confusion of languages arises. The most prominent linguistic groups, besides Swedish, are Finnish and languages from former Yugoslavia.

New machine operators are trained for one or two days before they start working independently. Since there are many experienced operators in the plant there are always knowledgeable people to ask when a problem occurs.

4.3.2 Working Procedures

The production planning in the assembly division is performed daily. Purchase orders received from Torslanda and Gent are coordinated with material supply and other production related factors. The production planning personnel forwards production orders to the machine operators on paper sheets. These orders typically comprises of two or three different kinds of products per working shift.

The kind of product to be produced is typed into the operator panel of the first zone in the production line. The robots are programmed to change tools themselves according to what product name is typed in. The remaining zones are then automatically adjusted to produce that product. The operators' main tasks are to supply the robots with the pressed parts that are to be assembled and to examine the final products to see that they are not defect in any way.

The system automatically signals the industry truck drivers when material needs to be refilled.

4.3.3 Working Stations

The plant can be said to comprise of two divisions, one where parts are pressed and one where they are assembled.

In the press division there are lines with machines placed alongside each other making a striking din. Operating interfaces covering one or more machines are positioned between sections of the lines.

The assembly division is crowded with robots welding and gluing parts together. The noise is less obvious than in the press division, but is still at a disturbing level. The lines of robots are divided into so called operation zones, which are equipped with an operating interface apiece. There is also an interface for the whole line, used mainly by technicians, and an interface specific for each robot.

Three different user interfaces are presented below. One is the so-called GOT (General Operation Terminal), which is used in the assembly department. This system has been developed by Volvo in Olofström and was introduced about 13 years ago. The GOT working station comprises of a computer with a dashboard and a mouse. In addition to this there is a set of hardware keys, which are, among other things, used to activate automatic or manual operation

Today the GOT-system is used parallel with another, newer system, which has been adopted from Volvo in Torslanda. The newer working station consists of a display surrounded by buttons facilitating interaction. The same set of hardware buttons existing on the GOT is used here.

Finally, a system used in the pressing department is briefly mentioned. This working station also consists of a display surrounded by buttons.

4.3.4 System Services

The services provided by the GOT system are:

Operation

- Operation (control, programming)
- Alarm handling

Troubleshooting

- Data logging (alarm lists)

4.3.5 Graphical Layout and Interaction

The interface of the GOT is based on Windows standard. Different functions are available through a folder system. It is also possible to double click on objects to recover information. When navigating through a chain of commands the hierarchic path is shown on the right side of the display. The path is illustrated by showing the folders, through which the user has passed to reach a specific page, in a decreased size.

The system supplies a picture of the process. The process is represented by a flow chart showing the status of the transmitters, where green means clear and red means not clear. When the robots stop the operator can see which transmitter is concerned, but there is no further information to be retrieved unless the user understands the programming language used for the control system. Programming can also be performed at each working station.

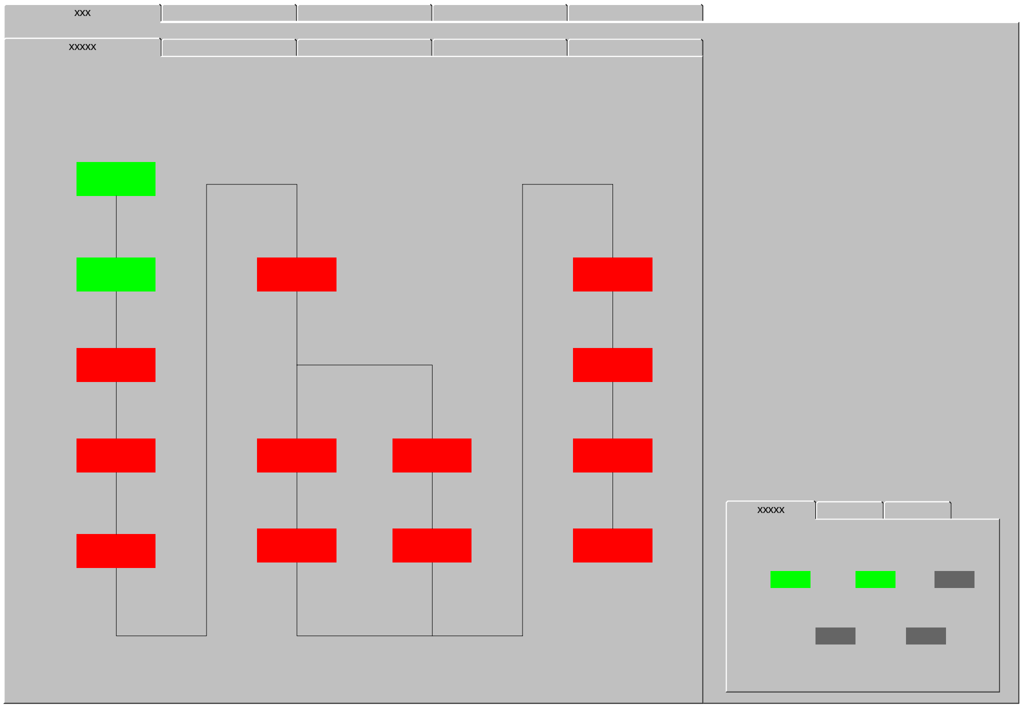

Figure 15. Sketch of the GOT interface at Volvo in Olofström.

The newer terminals provide essentially the same services. The main difference is how the information is presented and how the user interacts with the interface.

On the display photographs of each robot are available, showing where the transmitters are located, their id-numbers and their status. When an alarm occurs, there is no information supplied about how to solve the problem. The operators need to know this by experience. Many of the buttons surrounding the display are not in use. The buttons that are in use do not seem to state clearly what services they support and the system status is not illustrated in any way. As a result of this interacting with the interface appears to be rather complicated.

Ove Jösok and his colleagues made an interesting observation when introducing the new system. They then had the ambition to move the function of manual operation from the hardware buttons to the buttons on the computer, but the machine operators, who apparently felt safer interacting with the hardware buttons, did not appreciate this. Therefore it was changed back.

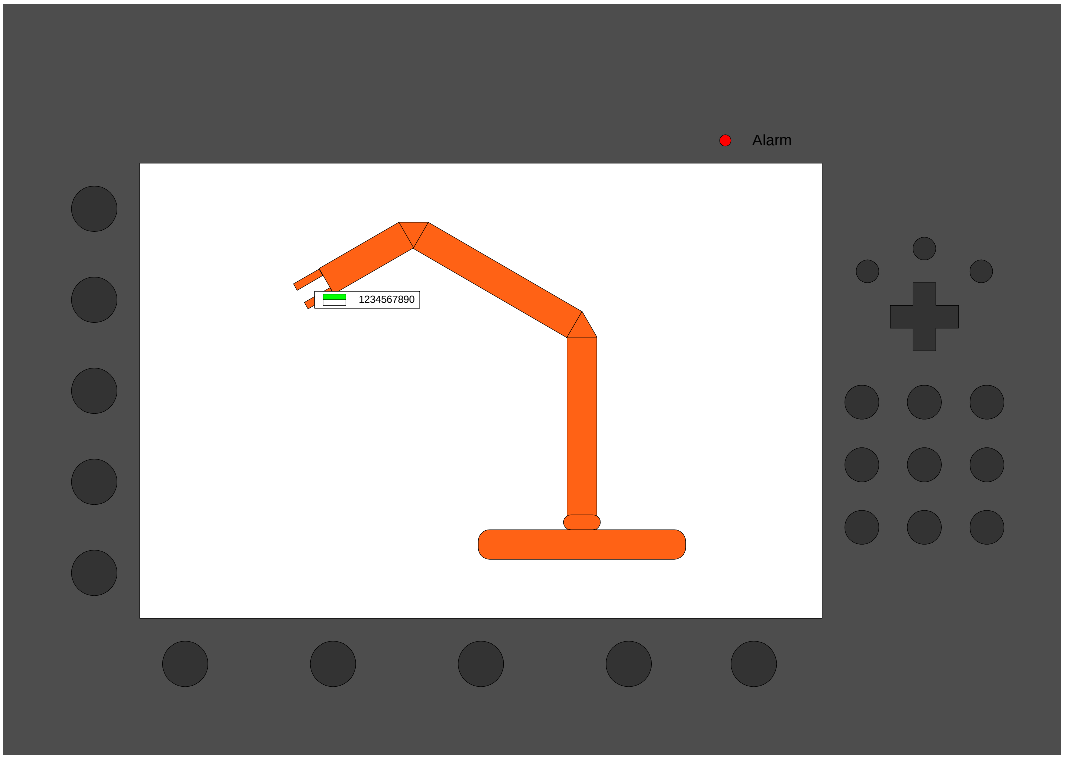

Figure 15. Sketch of the new operator interface at Volvo in Olofström.

Finally, I would like to mention a user interface, that we did not have a good look at, but which is interesting in contrast to the interface with photos. In the press division a system was in use where the process was illustrated by an animation of the machine and its moving parts. The pictures of the machines were very uncomplicated, and, Helena Helm, Lars Lindmark and I were all of the opinion that they were easier to comprehend than the photos (Figure 16).

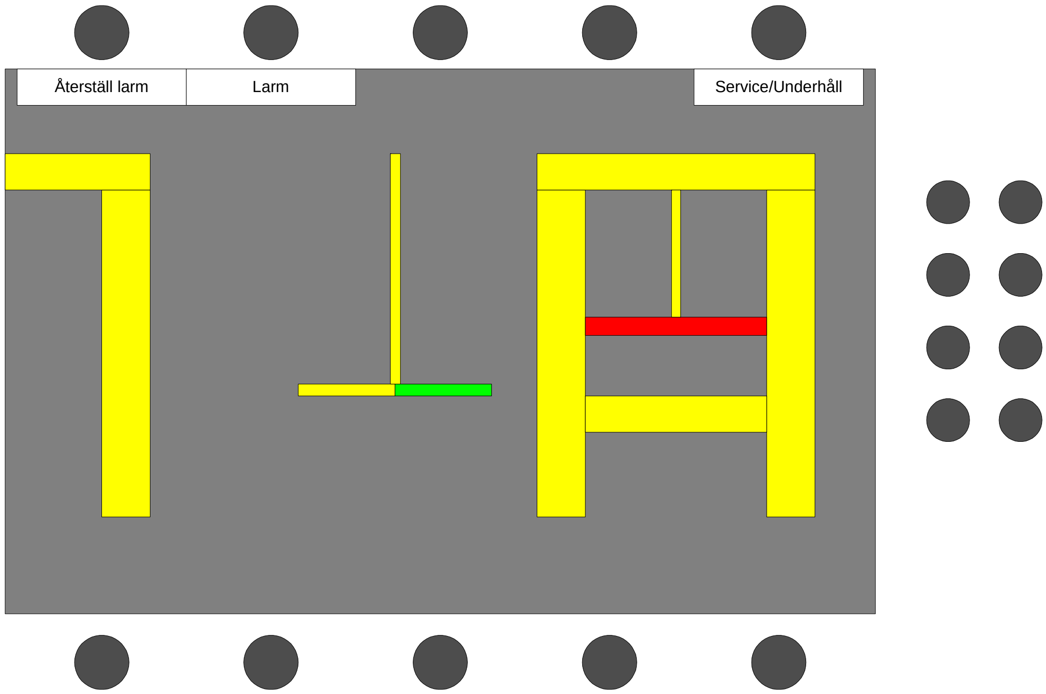

Figure 16. Sketch of user interface in the press division at Olofström.

4.4 Analysis

As an introduction to the analysis I would like to point out an important observation of the differing conditions for the TPOP user interface design and the design at Klippan and Volvo. The operating systems at Klippan and Volvo are developed for a limited group of staff within a specific company. The designers of the system work at the same site as the operators and have regular contact with the users. Thereby the developers get direct feedback on their designs.

4.4.1 The Users

The user profiles differ a lot between Tetra Pak's customers and the users at the companies looked at. The TPOP has a widespread range of operators including many different language groups, cultural and educational background and varying degrees of skill. The users at Elander, Klippan and Volvo are a much more homogenous group and they usually stay employed for a long period of time.

4.4.2 Working Procedures

In spite of the differences in the products being produces the working procedures involved in the production and the operators tasks are in fact very similar. The operators' main responsibilities are to refill material and to attend to alarms.

However, the machines and processes are more complex at Tetra Pak and Klippan, which make greater demands upon the operators' abilities. The operators of Tetra Pak's filling machines also have the responsibility of performing maintenance. Taken together this increases the needs for assistance.

At Volvo the work is automated to a high degree, simplifying the responsibilities of the operators. This way the work gets more effective and less demanding. However, the drawback is that the operators' prospect of developing their skills decreases. Also the tasks get less alternating and perhaps the work more boring.

4.4.3 System Services

The systems looked at in the benchmarking essentially provide the same, or at least similar, services. On some points the TPOP offers a better assistance. However, it is more interesting to look into the objectives, which offers ideas for new solutions. An account of those is presented below.

One of the operating systems at Elander offers the users what I have called "proactive event handling". The system informs the users about events coming up, e.g. paper in container three needs to be refilled, before they disrupt the production. This allows the operators to plan their work better, and increases the efficiency of the production.

The system at Elanders provides more information about the production status than the TPOP. Knowing how many items have been produced and the time estimated to finish the job is beneficial. In the case of the filling machines the time needed, and the left could be displayed for each program step to simplify the planning of the work.

The document manager on the operating interface at Elanders allows the operator to change the order of the documents to print, if necessary. The final decision-making is moved from the production planning personnel to the operator, allowing a greater flexibility.

Is this a system service that would be usable and desired in the case of the filling machines and is it applicable under the specific circumstances concerning the production of the filling machines?

With a similar concept it would be possible for the production planning personnel to directly import the production plan into the TPOP, making the paper sheets handling this communication today superfluous.

At Klippan the all systems are integrated allowing the operators and other users to monitor the processes and production of the entire plant. The advantage of this approach is, once more, that it can offer the operators increased possibilities to plan their work. On the other hand, a to extensive flow of information might also complicate matters and make the user interface more difficult to work. In the end it comes down to one of the prerequisites of the CTIP concept; providing the right information in each situation.

Another service at Klippan that is of help planning the work, is the information supplied about alarms further back or ahead in the production line.

4.4.4 Graphical Layout and Interaction

One of the most obvious differences between the TPOP user interface and the other user interfaces is that the TPOP to a large extent is based on a symbol language, whereas the others rather employ texts. The advantages of using symbols are that they are recognised quickly amongst a large amount of information (Marcus,1996) and they are easy to remember. Often a picture says more than words in less space (Löwgren, 1993). Also, symbols are appealing and attractive. On the other hand it is sometimes difficult to find a symbol that is meaningful and recognisable for a large group of people. This is especially true when it comes to multi-cultural, multi-lingual, and multi-professional groups (Marcus, 1996). However, coming up with an appropriate text to label the contents of a feature is also associated with hardship. One solution that has proven to be serviceable in many cases is to combine symbols with text. In any case it is important to test symbols and text labels on users to produce the best result.

All systems possess a hierarchical structure. The GOT system at Volvo has a folder-based organisation, whereas the others are constructed of windows.

When designing windows or folders the contents need to be clear to the users. The system services have to be grouped together in sections and follow sequences that are natural to the users. It is beneficial if the services available are visible to the users; the user needs to know what actions can be performed using the system. Furthermore the navigation paths should be pronounced so that the users know where they are located within the system and how to continue to where they are heading.

The GOT system at Volvo shows the navigation paths replicating each view went through in the form of a small window displayed in the right corner of the screen. This technique is very clear, but it certainly takes up a lot of space.

At Klippan the navigation is made simple by including the buttons representing the most important windows in every view. Also the orientation within each window is straightforward since the button bars are constantly placed on the same location.

Nevertheless, the orientation of the process overviews at Klippan is complicated, because of the large amount of information included the picture gives a muddled impression. Since the operators at Klippan stay employed for a long time and are skilled at their work it is possible that they want and need all this information to perform their tasks. For a novice user, though, it must be confusing.

The operator system of the printers at Elanders is in sharp contrast to the information-overloaded interface of Klippan. It is easy to overview, but still seems to provide all the necessary services. Of course, the complexity of the processes at Klippan contributes to the need of an extensive information handling.

The print window at Elanders allows easy access to the help function using the question mark to retrieve information. This solution could be applicable to TPOP user interface.

Another interesting objective of the print window at Elanders is the direct and distinct feedback provided. This is something that should be kept in mind when designing user interface of the next generation TPOP.

Finally, I would like to emphasize the experience made at Volvo attempting to move the function of manual operation from the hardware buttons to the buttons on the computer. The workers did not appreciate this new fashion of operating an apparently important function, and it had to be changed back. This indicates the significance of user centred usability activities and user tests.

4.4.5 Further Benchmarking

The systems analysed in this study have given ideas about a number of objectives to consider when designing a user interface. Would further studies conducted in the same way contribute to the results of the benchmarking with additional objectives of interest? I am sure it would, but the results yielded will most likely not compensate for the time needed to perform the benchmarking.

However, further looking into solutions for specific features, like for example start and stop functions, or presentation of machine status, and evaluating them, I believe would contribute to the success of the user interface.

In addition to this it could be beneficial to study user interfaces developed at other corporations within Tetra Pak. Since they have a user population much alike the users of the filling machines and are directed to the same countries, companies and types of organisation as the TPOP, they could with certainty offer solutions that are applicable to the TPOP.

5 Gap Analysis of System Services

The aim of the gap analysis is to find out how well Tetra Pak manage, with regard to the system services, in competition with their competitors and with other companies, and to find support for new ideas on the subject. Also looking into other companies' information management can give rise to ideas for new solutions.

In order to find out what system services are supplied by other companies the Internet resource was utilised.

Apart from getting an idea of what system services are supplied by other companies, it would be interesting to know to whom (what user profile) they are directed and how or where they are made available. It would also be of interest to make out whether the system services are appreciated and usable to the customers. A simple Internet search, however, could not answer any of these questions.

The competitors of Tetra Pak, with regard to process equipment, were identified on the site Competitor Intelligence on Tetra Pak's intranet ORBIS. Not all of the companies listed on ORBIS provide information about their system services on the Internet. Only the ones that do have been included in the study. They are:

APV Systems
Elopak
KHS
Krones
Miteco
SIG Combibloc
Van der Molen

To find other companies suitable to be included in the study I looked among actors on the automation market that are possibly leaders in the area of developing operating interfaces and designing system services. The companies I choose were:

ABB
Westinghouse Process Control

The reasons for including ABB and WPC (Westinghouse Process Control) in the analysis are that they both possess a high ranking in the Fortune Most Admired Companies list[13] and they are winners of the Editor Choice Awards of the magazine Control Engineering[14]. This does not verify that ABB and WPC in fact are leaders in the area, but at least it gives an incitement to assume that they might be.

[13] For the industry rankings, the Hay Group consultancy took the ten largest companies (by revenues) in 58 industries, including large subsidiaries of foreign-owned companies. They then asked 10,000 executives, directors, and securities analysts to rate the companies in their own industries based eight criteria: Innovation, financial soundness, employee talent, use of corporate assets, long-term investment value, social responsibility, quality of management, and quality of products and services. To arrive at each company's final score, which determines its ranking in its industry group, we averaged the scores that survey respondents gave it on these eight criteria, www.fortune.com, 2002-06-24,

[14] Control Engineering is a magazine cover the global control, instrumentation, and automation marketplace. The Editors' Choice Awards contestants were judged on technological advancement, service to the industry, and impact on the control market. The competition covers the areas process and advanced control, instrumentation and process sensors, software and information integration, machine

A brief outlining of the companies included in the gap analysis is presented in Section 5.1.

Apart from the TPOP there are a number of systems supplied by Tetra Pak to support the production of a plant. It is reasonable to assume that also the companies looked at in the gap analysis offer their customers a number of different applications that include different types of services. To be able to form a reasonably accurate notion of Tetra Pak's position in comparison to the other companies it is convenient to have a look at all of the systems offered by Tetra Pak that are relevant to the study.

5.1 The Companies

APV Systems
APV Systems delivers high quality process engineering solutions, automation, products, and performance improvement services to food, brewery and beverage, pharmaceutical and healthcare industries (www.apv.invensys.com, 2002-06-18).

APV Systems is a part of the engineering and electronics company Invensys. Invensys is a group of companies active within the divisions software systems, automation systems, control systems and powerware. Some of the Invensys companies working with the automation systems of APV Systems are Wonderware, Foxboro and Eurotherm.

The system services that are mentioned on the Internet and that are associated with APV System's products were found on www.apv.invensys.com and www.wonderware.com.

Elopak
Elopak is a supplier of packaging systems for liquid food products (www.elopak.com, 2002-06-18).

There is not much information about Elopak's system services on the Internet, but the computer based system Elo-vision is briefly described. The Elo-vision system consists of a camera connected to a computer, which learns to distinguish and identify the characteristics of a product, such as type, size and design. The computer analyses the information.

KHS
KHS is a supplier of production equipment for the beverage, food, chemistry, cosmetic, and pharmaceutical industries (www.khs-ag.com, 2002-06-18).

Krones
Krones provides solutions for the packaging industry for beverages and food (www.krones.de, 2002-06-18). Krones group comprises of several companies. Syskron is an IT-company within the group (www.syskron.com, 2002-06-18) and is involved in the development of system services.

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control and discrete sensors, human-machine interface, motors, drives and motion control, embedded control, networks and communications, and control components. www.controleng.com, 2002-06-24

Miteco
Miteco is a supplier of mixing and process technology for producing of liquid food (www.miteco.ch, 2002-06-18).

SIG Combibloc
The SIG Combibloc group is a manufacturer of carton packaging and filling machines for long-life food products, such as juice, milk, soups, and sauces (www.combibloc.com, 2002-06-18).

Van der Molen
Van der Molen is a supplier of specialised process systems for the beverage and food industry (www.van-der-molen.com, 2002-06-18).
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ABB
ABB is a provider of power and automation technology solutions (www.abb.se, 2002-06-18). Some of the industries that ABB works with are paper, mining, metals, chemicals, refining, marine, oil, gas and petrochemicals. ABB offers their customers a wide range of products and services, e.g. voltage products, robotics, transformers, instrumentation, control products and systems, technical support, optimisation, environmental services, financial advice etc.

The product that I consider to be the most relevant for the gap analysis is called Industrial IT. Industrial IT is a solution designed to provide integration of real-time automation and information. It consists of a large number of compatible "blocks" supporting different aspects of the activities within an industry. There are about 20 blocks consisting of various services. The customers choose what blocks to include in their system solution.

The system services included in the summary below are all related to the production of a plant. System services supporting for example financial issues (such as equity, insurance, and treasury operations) have been left out.

Westinghouse Process Control
Westinghouse Process Control Inc. engineers and supports process control technology to improve the performance and efficiency of power plants, wastewater treatment facilities and water treatment facilities (www.westinghousepc.com, 2002-06-18). As part of the Emerson Process Management group, Westinghouse Process Control offers complete control and instrumentation solutions.

Emerson Process Management is a leading global supplier of products, services, and solutions that measure, analyse, control, automate, and improve process-related operations

In this context, the most interesting series of products and services provided by WPC are called Ovation® and SureService. Ovation® consists of a large number of products including process controllers, network designs, communication servers, etc.

5.2 Systems Supplied by Tetra Pak

Since the TPOP has already been described earlier in this paper it is not included in the presentation of the systems provided by Tetra Pak to support the production of a plant.

PLMS
The PLMS is a system for collecting, analysing and monitoring the operational performance of Tetra Pak filling machines and packaging lines. The PLMS consists of three subsystems. One is integrated in the TPOP and collects production data from the filling machine. PLMS off-line analyses downloaded data from the filling machines and creates graphs and reports. PLMS on-line produces the same information in real-time. The information retrieved form the PLMS is above all used for troubleshooting, but also to increase the performance of the packaging lines.

e-Parts
The e-Parts system offers web based spare parts catalogues and order placement.

PlantMaster
The PlantMaster is an application, which integrates the process control and management system of a plant. The system gives an overview of production status and ongoing activities. Based on operator commands, the process is controlled by activating the necessary valves and pumps.

PIMS
Part Inventory Management System is an application that handles the spare parts stock, including spare parts catalogue, order placement and inventory control.

There are also systems that support Tetra Pak staff in supplying the customers with machine related information.

WebMon
WebMon is a system for storing, analysing, distributing and reporting machine performance figures for specific machines as well as entire production lines or plants. The data includes information about maintenance, service and repair performed on the machines. The information is displayed in the form of tables and graphs on a web page. The system also generates reports.

TPMS
The Tetra Pak Maintenance System provides the customers with carefully prepared maintenance recommendations. The Service on-line system enables the service technicians to fill in reports on-line. Checklists for maintenance are also available on-line.

Table 3. Summary of the system service that Tetra Pak offers their customers.

	TPOP	PLMS	eParts	PlantMaster
Installation				
Training				
Production planning				Recipe handling
				Trends Historical trends
Operation	Manoeuvre			Manoeuvre
	Monitoring			Supervision of production for whole plant or individual processes/ machines
	Data collection	Data collection		
	Alarm handling			
Maintenance				
Trouble shooting	Data collection			Historical trends
				Alarm list
		Statistics, trends and calculations		
Repair				
			E-parts order E-parts catalogues Spare parts lead-time and order status	
Quality assurance				
Performance		Statistics, trends and calculations		Trends
Reports		Generate graphs and reports		
Web-based services				
			E-parts order E-parts catalogues Spare parts lead-time and order status	
System management				Integration of process control and management systems
				Different log in access for different user profiles
	Handles a number of languages			Handles a number of languages

Table 4. Summary of the system services that support Tetra Pak staff in supplying the customers with machine related information

	TPMS	WebMon
Installation		
Training		
Production planning		Trends
		Performance data
Operation		
Maintenance	Checklists On-line checklists	
Trouble shooting		On-line data collection
Repair		Service data collection
Quality assurance		
Performance		Trends
		Performance data
Reports	Reports	Generates graphs and reports
Web-based services	On-line checklists	On-line data collection
System management		

5.3 Results

The search on the Internet yielded a varying result for different companies. Most companies do not communicate a lot of information about their system services and user interfaces on the Internet. For those who do, the information is generally not detailed enough to draw any conclusive conclusions.

The information is organised according to the grouping described in Section xxx. Since the description of the systems is generally not explicitly specified, which means that it is not feasible to know for sure in what context they are actually used, I have chosen to express the services with the same words used by the companies on the Internet and to site every service on each possible location in the table.

An account of the information found for Tetra Pak's competitors is presented in Table 5.

An account for the information found for ABB and WPC is presented in Table 6.

Table 5. A summary of the system services of Tetra Pak's competitors based on information found on the Internet. The information is organised according to the grouping described in Section xxx. Since the description of the systems is generally not explicitly specified, which means that it is not feasible to know for sure in what context they are actually used, I have chosen to express the services with the same words used by the companies on the Internet and to site every service on each possible location in the table.

	APV-Systems	Elopak	KHS	Krones	Miteco	Van der Molen	SIG Combibloc
Installation							
Training	On-line training						
	On-site training programs		Video films, CDs				
Production planning	Production planning			Reports and records of production figures, consumption values and operation levels			
	Recipe formulation						
	Specialised application software for batch management and resource tracking	The entire production of a dairy can be identified and registered, an item or a product batch can be followed directed, from ready product to storage and distribution.					
Operation	Monitoring	Monitoring Quantities of stock produced within cerain timeframes. Length of time left to complete a run		Monitoring	Monitoring	Supervision	Overview of important processes and components
				Operation	Operation	Operating	
	Data logging Event handling		Data logging	Data storage	History	Historical data storage	Data logging
	Alarm handling						
	Recipe formulation						
	Trends						

	APV-Systems	Elopak	KHS	Krones	Miteco	Van der Molen	SIG Combibloc
Maintenance	Data logging		Data logging	Data storage	History	Historical data storage	Data logging
	Feedback checks on values Variance analysis against specification.		Prerequisite for quick pinpointing of weak points				
	Analysis of alarms						
	Trends						
			Automatic calculation of required maintenance intervals recording of line status information				
							Detects possible sources of faults.
							On-line maintenance
Trouble shooting	Data logging		Data logging	Data storage	History	Historical data storage	Data logging
	Remote diagnostics Remote troubleshooting		Remote diagnose Direct transmission of information from the machines to KHS Live dialogue with on site camera or MHD				
			Detailed self-diagnosis of machines and modules				
	Analysis of alarms			Fast malfunction analysis Detailed analyses of the duration and frequency of disruptions.			Detects possible sources of faults
Repair	Web-enabled parts order placement		Spare parts tool Link to e-Commerce	Spare parts inquiry and order on the internet			

	APV-Systems	Elopak	KHS	Krones	Miteco	Van der Molen	SIG Combibloc
Quality assurance	Data logging		Data logging	Data storage	History	Historical data storage	Data logging
	Reporting and analysis tools			Reports and records of production figures	Reporting and analysis tool		
	Trends						
	Feedback checks on values Variance analysis against specification	Monitoring the quality of output - recognition of product blemishes.		Monitor and documents the quality of the units produced			
	Specialised application software for batch management and resource tracking	An item or a product batch can be followed directed, from ready product to storage and distribution.					Takes notes of products Check which station a product has passed through and when
Performance	Data logging		Data logging	Data storage Reports and records of production figures, consumption values and operation levels	History	Historical data storage	Data logging
	Trends		Documentation and comparison of all line performance data over extended periods				
	Operational efficiency Analysis of downtime Analysis of alarms			Monitoring production flow and machine efficiency Detailed analyses of the duration and frequency of disruptions.			
	Reporting and analysis tools			Reports and records of production figures	Reporting and analysis tool		
				Inspection parameters optimisation.?			
	Variance analysis against specification						
	Feedback check on values						
Reports	Reporting and analysis tools			Reports and records of production figures, consumption values and operation levels	Reporting and analysis tool		

	APV-Systems	Elopak	KHS	Krones	Miteco	Van der Molen	SIG Combibloc
Web-based services	Web-enabled parts order placement		Fast identification for required spare parts Link to e-Commerce	Spare parts inquiry and order on the internet			
	Remote troubleshooting						
	Remote viewing over the internet or company intranet Remote access	Can be connected to the Internet for remote on-line interrogation of staff off-site.			Possibility of remote control	Several visualisation and operation stations via network-connection Remote control possible	
	Remote diagnostics Technical support via the internet		Remote diagnose Normal identification of trouble areas via modem				
			Live dialogue with on site camera or MHD Direct transmission of information from the machines to KHS				
	On-line upgrades			Program updates			On-line maintenance
	On-line training						
System management	Integration of process control and management systems			Whole plant in overview	Monitoring and operation of the complete production plan in whole/ partial pictures	Complete visualisation of the whole production unit in partial interlaced pictures	
				System access and varying access privileges			
				Choice of languages	Many languages	Easy surveyable visualisation in most languages	

Table 6. A summary of the system services of ABB and WPC based on information found on the Internet.

	ABB	WPC
Installation	On-line help and documentation	
Training	Simulator	Simulator
	eLearning solutions	Online Tutoring module
Production planning	Planning, scheduling, and manufacturing of end products	
	Comprehensive recipe management	
	Batch control	
	Monitor, analyse, schedule, control and optimise their production assets	
	Simulator	Simulator
Operation	Control and management of plants and processes Remote control	Control graphics Standard function displays Plant status
	Advanced alarm management system	Alarms Alarm management
	Comprehensive historian Data collection, storage and tools for analysis	Historical data Event logging Mass storage and retrieval of historical data viewing, sorting and data analysis
	Trends	Trending Diagnostics
	Evaluation of plant or process parameters, equipment status, and recommended actions	Automatically provides optimal PID parameter values Analyses performance trends - advise plant engineers, technicians and operators

	ABB	WPC
Operation	Comprehensive recipe management	
	Batch control	
	On-line help and documentation	
	WAP phones	
		General messages
Maintenance	Trends	Trending
	Maintenance trigger	Fault tolerance System diagnostics
	WAP phones	
	On-line help and documentation	
		Analyses information
Trouble shooting	Historian Data collection, storage and tools for analysis	Historical data Mass storage and retrieval of historical data - viewing, sorting and data analysis
	Trends	
		Provides connectivity via the Internet or company intranet - read-only access
	On-line help and documentation	
		Analyses information System Diagnosis module
Repair	Spare parts inventory management and automatic web-based parts purchasing	

	ABB	WPC
Quality assurance	Historian Data collection, storage and tools for analysis	Historical data Mass storage and retrieval of historical data - viewing, sorting and data analysis
	Trends	Trending Fault tolerance
	Batch control	
		Provides connectivity via the Internet or company intranet - read-only access
Performance	Historian Data collection, storage and tools for analysis	Historical data Mass storage and retrieval of historical data - viewing, sorting and data analysis
	Trends	Trending
	Evaluation of plant or process parameters, equipment status, and recommended actions	Analyses performance trends - advise plant engineers, technicians and operators
	Tuning, improving, and optimisation	Automatically provides optimal PID parameter values
	Batch control	
	Simulator	Simulator
	WAP phones	
		Provides connectivity via the Internet or company intranet - read-only access
Reports		Easy-to-use report definition
		Flexible report generation
	Reporting and compliance with regulatory agencies for environmental, safety, and more	

	ABB	WPC
Web-based services	Internet integration	
	eLearning solutions	Online Tutoring module
	On-line help and documentation	
	Spare parts inventory management and automatic web-based parts purchasing	
	WAP-phones	
		Provides connectivity via the Internet or company intranet - read-only access
	Remote control	
		Password-protected web site contains searchable tech tips and answers to frequently asked questions, software release notes, access to customer and field engineering problem reports and resolutions, user manualsin downloadable pdf file format, online software updates
		System Diagnosis module
System management	Integration of systems	Integrate plant control systems with corporate networks
		Remote file storage system
		Software Updating module
	Scaleable	
	Internet integration	

5.4 Analysis

As mentioned before it is difficult to draw any certain conclusion based on the information found on the Internet, since it is far from complete. Also much of the features mentioned on the Internet are not explained in a pronounced way. Neither are the actual intents of a specific system service made clear, the quality of the system services can not be estimated, and, finally, it is not a matter of course that the system services offered are in fact requested by the customers and usable to them. Owing to this argumentation it is not possible to draw any conclusions about Tetra Pak's position in comparison to their competitors with regard to the system services. However, it can be established that many of the companies in the study offer their customers system services, which are not available for Tetra Pak's customers. An account of those is presented below.

ABB provides on-line help and documentation as support for the installation of a system. This service could be extended to the installation of a machine.

ABB and WPC offer simulators to be used for production planning, performance optimisation and training.

APV-Systems, KHS, ABB and WPC provide on-line training programs.

ABB offers a tool for planning, scheduling and manufacturing of end products. (APV-Systems mention the system services production planning. It is not feasible to know what they include in that concept, but it could be a similar tool.)

APV-Systems, Elopak and ABB provide batch management implements.

All companies offer monitoring or supervision (except for KHS, according to the Internet, but it is reasonable to assume that they do have some sort of monitoring service). Monitoring and supervision possibly includes production, process, machine, and system status.

The monitoring services of the TPOP today comprises of the ladder showing what status the machine is in. It is also possible to check what machine and system settings have been chosen and in a few cases a time bar is provided to display down times for a specific activity. There is certainly scope for improving the support of the operation process by increasing the monitoring services of the TPOP.

Operation is also offered by most companies. Operation might refer to manoeuvre, control and machine settings.

Elopak, Miteco, Van der Molen and ABB provide remote control.

APV-Systems and WPC offer remote access.

Data logging, data storage and history is another system service provided by almost all companies. This service might consist of logging of alarms, interruption (cause and time), events, production data, process data, machine settings, and waste (cause and number of items). However, it is likely that some companies only offer a small selection of those possibilities.

APV-Systems, ABB, WPC and Tetra Pak provide trends. In the case of Tetra Pak the trends are used for performance optimisation, production planning and trouble shooting. The possibility to communicate the trends to the machine operator in order to facilitate direct actions is not utilised. Whether APV-Systems do or not is not made clear. However, the services "feedback checks on values" and "variance analyses against specification” imply that do. ABB offers an “evaluation of plant or process parameters, equipment status and recommended actions” and WPC offers “analyses of performance trends – advice plant engineers, technicians and operators”.

ABB offers on-line help and documentation. The advantages of on-line documentation are that it is easy to upgrade and the upgrades are immediately available to the customers.

WPC provides the service “general messages”. General messages can possibly be a system for exchange of information in between shifts or different categories of personnel.

KHS and ABB present “automatic calculation of required maintenance intervals” respective “maintenance triggers”.

APV-Systems, KHS and WPC supply remote diagnostics and remote trouble shooting. The WebMon system of Tetra Pak facilitates remote trouble shooting for Tetra Pak staff. Remote troubleshooting is, however, not available for customers.

KHS also present on-site cameras for live dialogues, offering the possibility of direct assistance by KHS technicians.

Elopak and Krones have systems for monitoring the quality of the units produced.

Many of the companies, including Tetra Pak, provide tools for reports and analysis. Yet, it is common that the customers of Tetra Pak fill in large amounts of paper based reports, with for example production figures or quality values. Tetra Pak should look into the possibility to create a computerised tool to manage these reports and investigate whether there is a need for such a tool.

WPC offers their customers availability to a website with “searchable tech tips and answers to frequently asked questions, software release notes, access to customer and field engineer problems reports and resolutions, user manuals in downloadable pdf file format, on-line software updates”.

5.4.1 Further Analyses

Further search of information on the Internet will most likely not contribute to a more extensive outlining of the system services offered by the competitors and by ABB and WPC. If Tetra Pak wishes to achieve a more accurate idea of how the system services are designed the possibility to acquire information directly from the companies looked at should be examined.

6 Conclusions

To ensure a high degree of usability, based on the usability attributes relevance, effectiveness, learnability and attitude, in the next generation TPOP user interface the developers should apply usability engineering to the design process. The essentials of the usability engineering process are:

- Iterative design
- Studies of user-centred issues
- Continuous prototyping and evaluation
- User derived feedback
- Usability metrics (measurable usability goals)

In order to structure the design process the developers should consider to:

- Establish a vision based on overarching goals
- Establish a project plan with a pronounced start and finish
- Involving all parties who have an interest in the TPOP (users, programmers, assigners, market department etc) in the design process
- Apply the four levels of design (design of system services, conceptual design, interaction design and graphical design) to the process

The benchmarking of Elanders Novum's, Klippan AB's and Volvo Cars Body Components' user interfaces gave rise to a number of issues to consider when designing the user interface of next generation TPOP. They are:

- A highly automated process simplifies the responsibilities of the machine operators. However, the drawback is that the operators' prospect of developing their skills decreases. Also the tasks get less alternating and perhaps the work more boring.
- Services that increase the possibilities for the machine operators to plan and schedule their work are: "proactive event handling", feedback on production status, and providing information about events before and ahead in the production line.
- The document manager on the operating interface at Elanders allows the operator to change the order of the documents to print. The final decision-making is moved from the production planning personnel to the operator, allowing a greater flexibility. This solution could be extended to directly import the production plan into the operator system, making the paper sheets handling this communication today superfluous.
- The TPOP user interface is based on symbols, whereas the others rather employ texts. In any case it is important to test symbols and text labels on users to produce the best result.
- The navigation of a user interface is simplified by displaying the navigation paths and by offering ways to reach main window in each view.
- The orientation within a window is simplified when items are consistently placed on the same location.
- The orientation is made difficult if the window is overloaded with information.
- Provide direct and distinct feedback on actions taken.

- The print window at Elanders allows easy access to the help function using the question mark to retrieve information. A solution that is applicable to the TPOP.
- User centred studies and user tests are significant in order to produce a user interface that is usable.

The gap analysis shows that Tetra Pak's competitors, ABB, and WPC provide their customers with a number of services, which are not offered by Tetra Pak. They are:

- on-line help and documentation as supporting the installation of a system
- simulators to be used for production planning, performance optimisation and training
- on-line training programs
- tool for planning, scheduling and manufacturing of end products
- batch management
- monitoring of production, process, machine, and system status
- remote control
- remote access
- feedback checks on values, variance analyses against specification
- evaluation of plant or process parameters, equipment status and recommended actions, analyses of performance trends – advice plant engineers, technicians and operators
- general messages
- automatic calculation of required maintenance intervals, maintenance triggers
- remote diagnostics and remote trouble shooting
- on-site cameras for live dialogues
- monitoring the quality of the units produced
- access to a website with searchable tech tips and answers to frequently asked questions, software release notes, access to customer and field engineer problems reports and resolutions, user manuals in downloadable pdf file format, on-line software updates

References

Books:
Cooper Alan, About Face: *The Essentials of User Interface Design*, (1995), New York: Hungry Minds Inc

del Galdo Elisa M and Nielsen Jakob (editors), *International User Interfaces*, (1996), John Wiley & Sons Inc

Eliasson Martin, *Customer Technical Information Need*, (2001), internal market study at Tetra Pak

Faulkner Xristine, *Usability Engineering*, (2000), New York: Palgrave

Löwgren Jonas and Stolterman Erik, *Design av informationsteknik*, (1998), Lund: Studentlitteratur

Lützhöft Margareta, *Utvärdering av gränssnitt för Tpop,* (1998),internal report at Tetra Pak R&D AB

Löwgren Jonas, *Human-Computer Interaction*, (1993), Lund, Studentlitteratur
Mayhew Deborah J, *The Usability Engineering* Lifecycle, (1999), San Francisco: Morgan Kaufmann Publishers Inc

Marcus Aaron, *name of chapter missing*, (1996), In: Elisa M del Galdo and Jakob Nielsen (editors), *International User Interfaces*, John Wiley & Sons Inc

Nielsen Jakob, *Usability Engineering*, (1993), London: Academic Press

Norman Donald, *The Design of Everyday Things*, (1988), New York: Doubleday

Pettersson Tobias and Rosén-Lidholm Eric, *An Analysis of Operators' and Technicians Information Requirements – with an e-business opportunity approach,* (2000), master thesis conducted at Tetra Pak R&D

Schneiderman Ben, *Designing the User Interface,* (1998), Addison Wesley Longman Inc

Ulrich Karl T and Eppinger Steven D, *Product Design and Development*, (1999), London: McGraw-Hill Publishing

Internet (as of 2002-06-24):

www.usabilityfirst.com

http://usability.gov/methods/data_collection.html#relevant

Lyn Pemberton ,*The Promise of Pattern Languages for Interaction Design*, School of Information Management, University of Brighton, http://www.comp.it.brighton.ac.uk/~lp22/HF2000.html

Martijn van Welie , *Patterns as Tools for User Interface Design*, http://www.cs.vu.nl/~martijn/gta/docs/TWG2000.pdf

www.apv.invensys.com

www.wonderware.com

www.elopak.com

www.khs-ag.com

www.krones.de

www.syskron.com

www.miteco.ch

www.combibloc.com

www.van-der-molen.com

www.abb.se

www.westinghousepc.com

http://151.183.33.121/, Tetra Pak intranet

http://www.useit.com/papers/international_usetest.html

http://hcibib.org/sam/

http://www.dictionary.com/

Appendix A

Ben Schneiderman's (1998) eight golden rules of interface design:

1. Strive for consistency – sequences of actions, terminology, colour, layout etc.
2. Enable frequent users to use shortcuts – decrease number of actions, increase pace of interaction
3. Offer informative feedback - for every user action, modest response for frequent and minor actions, substantial response for infrequent and major actions
4. Design dialogues to yield closure – sequences of actions should be organised into groups with a beginning, middle and end, feedback at the completion of a group gives satisfaction of accomplishment, a sense of relief, a signal to drop contingency plans and options from their minds, an indication that the way is clear to prepare for the next set of actions
5. Offer error prevention and simple error handling – design the system such that serious errors can not be done, if an error is made offer simple, constructive and specific instructions to recover
6. Permit easy reversal of actions – relives anxiety, encouraging exploration of unfamiliar options
7. Support internal locus of control – make users in charge, the system responds to their actions, the user initiator of actions rather than the responder to actions
8. Reduce short-term memory load – rule of thumb: humans can remember seven plus-minus two chunks of information

Jakob Nielsen's (1993) usability heuristics:

- **Simple and natural dialogue** – simplify, every additional feature or item of information is one more thing to learn, one more thing to possibly misunderstand, and one more thing to search through
  Interfaces should match the users' task in as a natural way as possible, such that the mapping between the computer concepts and user concepts becomes as simple as possible and the users' navigation trough the interface is minimized, present exactly the information the user needs and no more at exactly the time and place it is needed
  Graphic design and colour – "mumble screen", gestalt rules, colour coding should be limited to 5 to 7 different colours, colour blind (8% of males),
  Less is more – extraneous information not only risk confusing the novice user, but also slows the expert user down, also applies to the choice of features and interaction mechanisms for a program
- **Speak the users' language** – the terminology in the user interfaces should be based on the users' language not on system oriented terms, as far as possible use native language
  Mapping and metaphors
- **Minimize user memory load** – in general, people have a much easier time recognising something that is shown to them than they have at having to recall the same information from memory without help, the computer should display dialogue elements to the users and allow them to choose from the items generated by the computer or to edit them, menus
- **Consistency**

- **Feedback**
  Response time – rule of thumb; use percent-down progress indicators for operations taking more than 10 s
- **Clearly marked exits** – user feel in control, offer an easy way out
  Interrupt the computer and cancel operation
- **Shortcuts** – perform frequently used operations especially fast
- **Good error messages** – phrased in a clear language, understand error message without having to refer to any manuals or code dictionaries, constructive advice, precise rather than vague or general, polite, not intimidate the user, avoid abusive terms like *fatal, illegal*
  Multiple-level message – use shorter messages that will be faster to read, offer more information
- **Prevent errors** – e.g. select an item form a menu rather than typing it in, errors with especially serious consequences can be reduced by asking user to reconfirm
- **Help and documentation** – model of documentation use: Searching, understanding, applying, on-line help available at site, search tools, task oriented, the sequence in which it should be carried out, each section should be as self contained as possible, should be possible to keep any on line help system visible in a separate window, step-by-step procedures, mention how the user might check whether the operation has been a success