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DOCTORAL THESIS

"Is the Machine Directive not enough?"

-A study of integrating work environment design in an international production development project

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Abstract

This thesis deals with the importance and the processes of integrating work environment design when developing new production systems in international collaborative projects.

During recent decades, organisations have developed systematic approaches to deal with work environment design, often as parts of management systems. This is commonly limited to a specific context, consistent of an organisation with a well-developed way of working with work environment. However, developing production systems in international collaborative projects has become more common, implying new conditions for work environment design.

The qualitative study of an EU-project, conducted between 2002 and 2005, constitutes the empirical base in this thesis. This EU-project aimed to develop new ways of manufacturing large non-rigid structures through innovative production systems. Partners from five European countries participated: England, France, Germany, Spain and Sweden. The partners consisted of persons from institutes, consulting companies, universities and manufacturing enterprises.

Within the study, semi-structured interviews were conducted together with observations and to some extent action research. When the companies collaborated together, the normally well-structured development procedures to integrate work environment design became unclear. The temporary structure of the project group did not have a specific overarching approach to these matters and the different perspectives from different companies both collided and reinforced each other simultaneously. The analysis, based on a socio-technical approach, showed that the organisations participating in the EU-project had major differences in handling work environment design. Some of the differences, as for example how to refer to work environment issues, are possible to derive from different discourses and different national contexts. There were also differences depending on what roles people had and were given in the project organisation. Participants generally tended to have a narrow focus where, for example, most engineers focused mainly on the technical questions and did not erect a holistic perspective in which work environment factors were included. Further, the experts on work environment factors, of which I was a part, focused mainly on these questions and not on the technical innovation aspects. This seclusion of roles and the organisation of the project is described and analysed. The analysis showed that the organisation of the project was divided, where the work package concerning the work environment became detached from the rest of the project.

This thesis illuminates the problems with work environment design issues that appeared when the different companies collaborated in the international project. The solutions of the problems were quite obvious and the most important task was to grasp the need of a holistic view of the work environment and the need of a structure to handle these issues in project organisations. In this thesis, the need of a systematic approach is stressed and an outline of a conceptual design model is presented, whose main points are awareness and easily measurable goals. This awareness can include different cultures, contexts, body of knowledge, perspectives and way of speaking about these matters. A future development of the model is sketched to make it applicable for practitioners in future projects and not only for scholars.

Keywords: *production system development, work environment design, socio-technical development, different perspectives, holistic perspectives*

Appended papers

Paper I

Lindelöf, P. (forthcoming) *The significance of national contexts regarding work environment functions when developing new production technologies*. Submitted for publication.

Paper II

Lindelöf, P. Abrahamsson, L. Johansson, B. (forthcoming) *Management of work environment design when developing new technologies of production in international cooperation projects -Learning from an EU-project*. Submitted for publication.

Paper III

Lindelöf, P. (forthcoming) *The presence of socio-technical perspectives in the development of future production processes – Experiences from an EU-project within the aero structure industry*. Submitted for publication.

Paper IV

Lindelöf, P. Sandberg, M (forthcoming) *Knowledge on work environment design in an international collaboration project - Experiences from sharing the concept of work environment design*. Submitted for publication.

The author's contributions to the appended papers

	Paper I	**Paper II**	**Paper III**	**Paper IV**
Planning	2	2	2	2
Data collection	2	2	2	1
Analysis	2	1	2	1
Reporting	2	1	2	2

2= Personal responsibility; 1= Shared responsibility

Other publications by the author

Lindelöf, P., Sandberg, M. (2003). *State of research in the field of work environment*. Report in the EU-project.

Lindelöf, P., Sandberg, M. (2003). *Technology renewal with respect to the work environment-Examples from the aircraft aviation industry*. Paper at the 35th Annual Conference 'Mind and Body in a Technological World', Nordic Ergonomics Society, Reykjavík, Iceland, 10-13 August, 2003.

Lindelöf, P. (2004) *How to develop a general ergonomic guideline for new ways of automated manufacturing of large non-rigid structures*. Paper at the 9th International Conference 'Human & Organisational Issues in the Digital Enterprise', Haamaha 2004 Galway, Ireland, 25-27 August, 2004

Lindelöf, P. et al (2005). *Guidelines for implementation of the new production system concepts in industry*. Report in the EU-project.

Table of contents

List of Figures

List of Tables

"*There is nothing more difficult to take in hand, more perilous to conduct or more uncertain in its success than to take the lead in the introduction of a new order of things." Niccolo Machiavelli*

1. Introduction

Many are those who believe work environment problems were something we dealt with 20 years ago and that was it. All problems were solved and everyone lived happily ever after. Would it not be great if that was actually the case? Unfortunately, there is always the word 'but'. No doubt that we have taken a large step both nationally in Sweden and internationally towards a better quality of life for operators and in general speaking terms for the industry. It is important to remember that every company is influenced by its surroundings, and this force companies to adopt more or less systematic ways of handling both physical and psychological aspects of the work environment. The focus of these procedures is due to what context the company finds itself in. This means that one of the problems today is how to work with work environment design when a more complex context is present.

Between 2002 and 2005, I had the opportunity to study and participate in an EU-project within the Fifth Framework Programme with the aim to develop new production processes for manufacturing large non-rigid aero structures. The project enclosed five different nationalities. This was where the empirical data for this study was collected, and where this thesis had its starting point. The empirical data and the comprehension of overcoming the problems of work environment design when working together in an international collaborative project revealed a field of research that had not yet been fully explored. In the project several national contexts shared the space and fought for domination. Problems such as different contexts of end users, discourse belonging, different experiences, different bodies of knowledge, and an unstructured way of working with these matters called for a systematic way to deal with work environment design. As a typical example of the differences, a question heard at the initial EU-project meeting asked whether the Machine Directive (98/37/EC) was not enough regarding work environment design, as mentioned in the title of this thesis. The Machine Directive, effective January 1st, 1995, deals with safety demands in the constructing and manufacturing of new machines. The directive consists of one product directive (98/37/EC) and one user directive (89/655/EEC). The user directive lays down the guiding principles for users of the machines and aims to prevent accidents when the machines are used. The problem is when different machines should be used in a production system, and that the work environment is not just to prevent accidents.

Even though all companies in this study worked with work environment factors and design, they did it in their own specific way. Some of the respondents interviewed during my research state that the money spent on work environment issues in their companies has decreased during recent years. This could be due to either fewer problems because the engineers took care of these matters themselves and prevented the problems at an early stage, or the fact that it was easy to cut costs in this field in the short-term. However, in the long run it can backfire and the costs may instead increase. Ergonomics offers a valuable vehicle for management and employee collaboration, in which both can reach considerable benefits (Butler, 2003). However, there are not only economical incentives. Society, organisations

and foremost individuals are also driven by a humanistic thinking in which ethical and moral issues play an important role. We ourselves do not want to work in an unsuitable environment for human work and we try not to create such jobs for others. The scientific evidence that a good work environment is the major enabler for high productivity involving human work is still to come, even though I am convinced there is a connection. Attempts have been made, but until all involved universally establish this reasoning in the development of future production systems, we have to place some of our confidence in human values.

Today, companies can find themselves in a completely different field of force than 30 years ago. The companies discussed in this thesis are part of the aero structure industry, which is today very global. Companies do not simply need to comply with what the surrounding society and authorities consider is the main objective of the activities. This should not be misunderstood, since it is foremost a question for the shareholders to manage the strategy of the company, but to be successful a company must comply with its surroundings to run everything as smoothly as possible. Historically, this was fairly easy, since every company's market was partly local and focused on the nearby society. Nowadays, multinational companies, of which the aircraft industry was one of the pioneers, need to combine these local forces with national and international forces. This implies a balancing act between the national and international context. Some companies are international in nature, with affiliated companies in several nations. In this type of organisation international collaboration is fairly common, taking place within the same company. Various parts of the organisation are forced to collaborate and are rather used to it. In contrary, work in, for example EU-projects, sometimes 'forces' companies and organisations from different nations to collaborate in different constellations. When these companies collaborate, the balancing act becomes even more intricate when they fight with each other what forces to consider. This fighting should only be seen as figuratively speaking, since they sometimes seem to have the same type of basic values that make it easier to cooperate, at least in some aspects. Some companies have their special way of handling work environment factors, often strongly influenced by national laws and regulations. They also focus differently on this work, making how it is done when these different methods collide interesting and necessary to study.

Operators in the different contexts have to trust that those developing the new systems will consider that whatever they develop, i.e. not automated to a hundred per cent, will affect the operators' work. In addition, even though the process is to a hundred per cent automated, the new system will affect someone else's job, e.g. those who are supposed to manufacture or maintain the machines. People participating in the development process need to consider, for example, the connection between work organisation and adverse physical exposure, which according to Hägg (2003) is generally overlooked. If they fail to consider these factors, adverse effects may arise. For example, Bullinger et al (1997) showed that unsatisfactory conditions lead to a high turnover rate among specialists in assembly work and thereby a shortage of specialists in areas producing technically superior products with high standards of quality. This is especially true for the aero structure industry, which is strongly associated with a need of high quality.

In general, trying to change the basics of something is not easy. A natural resistance is often present and questions as to why should organisations change at all arise. One answer is that there is no choice. Society, competitors, the company itself, and sometimes the workers force this change. The question is not whether we should stop the pace of change, but how we change, especially regarding systems, both deliberately and inadvertently. It is not possible

to please everyone, but when trying to innovate new ways of production that will include automation of some parts of production, it is essential to adopt some sort of system thinking. As Pulat (1992) states, automation can lead to job fragmentation, supervisory control, training, changing role of labor, decreased autonomy, increased dependence on others, safety, displacement of workers, boredom and stress, etc. At the same time, as a consequence, it is common for designers to believe that the most effective work designs are those that minimise the skills and involvement of users in the production process (Das, 1999). Whether automation is good or bad in regards to the work environment is disputable. Both Braverman (1977) and Blauner (1964) agreed that some negative aspect could be a consequence, while Blauner stated that under specific conditions it could lead to greater responsibility and thus a form of work upgrade. This perspective is also adopted in this thesis.

Organisations implementing new technology usually tend to disregard human and organisational issues (Axtell et al., 2001). This is a problem for projects such as the EU-project studied in this research, since the most common consequences of organisational change, which is one part of a socio-technical change, is how it affects people in redundancy, changes in job content, etc. (Sadler, 1996). One way to take care of these issues is to use tools and methods to help design and evaluate new work organisations. However, it should be remembered that particular forms of work organisation should not be presumed to fit all scenarios even though the new technology may be the same (Axtell et al., 2001).

Interestingly, within this type of reasoning is that even though major trends in production planning and organisation in recent decades have originated from Japan, or some would say Boston, USA (Furusten, 1999), Japanese reports of ergonomics programmes in the Euro-American sense are sparse (Hägg, 2003). Once more, this highlights how nationally influenced is work with work environment. According to Das (1999), an interdisciplinary perspective on industrial work design is needed, since the problems of industrial work design and worker productivity are complex and multivariable, and I can only agree. As stated in several types of research the need for an interdisciplinary approach is vital.

This thesis may tend to build on the fact that performance and quality of working life walk hand in hand. Some researchers have shown a connection between investments in preventive measures and productivity (Jensen and Roos, 2005), while others state that this can be one of many reasons for increased productivity. Pruijt (2000) as an advocate of critical theory, states that this congruence is the base for most management and scholarly works. My belief is that performance in a short-term perspective is attainable in ways other than boosting the quality of working life, but when it comes to a long-term perspective, quality of working life is essential. Because most changes at industrial facilities aim to improve production to obtain better productivity and product quality, problems in the work environment could be treated as production problems, since they affect the outcome of the production (Lovén, 1997). The way to involve economical mechanisms in OSH-management is questioned by, for example, Dorman (2000), who admits that they have a role to play. Dorman states that there is no good reason to place economic values above all others and that the economic mechanisms are already here, but it is more up to how organisations use accounting systems, where causes of a bad work environment can hide today. Harms-Ringdahl (2004) states that there exists a fundamental thought within the work environment discussion, that if there are economical advantages with a specific act, both companies and individuals will choose that alternative. However, a problem when assessing organisational changes is the difficulty in interpreting results, since people feel the potential of the change as well as its excitement and euphoric

(Abrahamsson, 2004b). This can create many positive statements and imply a feeling of over enthusiasm in the assessment. This is one of the reasons why Abrahamsson (2004a) states that it is difficult to scientifically back up the direct connection between the good work environment and growth or between multitude and profitability. The economical mechanisms and the human values and regulatory approaches can be said to supplement each other. It is questionable if quality of working life can be singled out as THE factor that sets performance, but one out of many is likely. However, Das (1999) states that many shortcomings in industrial work design can be traced to inadequacies of the minimum cost criterion. Even though evidence for the connection between performance and quality is still questioned, the humanity of people has to be appealed to, especially the management of organisations and not to forget, the shareholders. Together, they can conclude that investing in these issues will benefit all with an interest in the organisation.

Employees and entrepreneurs from different contexts around the world seem to regard work environment related questions with different kinds of dignity. They tend to define the concept of work environment differently and focus on various areas inside the concept of work environment. Combined with the ongoing internationalisation of industrial production, this will eventually lead to a situation where each nation's traditional ways of viewing and handling work environment issues are challenged. Work units with members from different contexts share the common goal of producing high qualitative products or processes within specified time frames and tight economical conditions. The common goal is obviously related to produce and, in the long-term perspective, to generate a profit for the company and for the implementation of rational production concepts are examples of strategies aimed to enhance the outcome of production.

The above-mentioned problems call for attention to work environment design in international projects and, primarily due to access to empirical data, to European Union collaborative projects, where organisations with different origins attempt to collaborate. These projects need to consider the end user of the technologies even though they work in different contexts. This is the reason for my research.

1.1 A need for a method of integrating work environment in early stages of production development

Some of the above problems in development projects plus additional problems will be further described throughout the thesis. Who is responsible for or owns these problems is a question of how we define them. I am of the opinion that a problem cannot be owned, but a solution can. Some people are affected by problems, especially their effects, more than others and some have greater possibilities to prevent them. If we divide the problem into three parts, they are; technology centered ergonomics, the leftover approach to function and task allocation, and a failure to integrate the socio-technical characteristics of the system into its organisational and work system design (Hendrick, 1995). All of these problems affect the end user, and it is the people participating in the development project who have the biggest opportunity to prevent them, by analysing the problems and making them visible before a search for a solution can begin.

According to Johansson (2004) the lack of financial support in the research field during recent years has implied an academication of it. Instead of producing practical results, the

focus has shifted to becoming more accepted in the academic field. Instead of helping companies with hands-on solutions, the focus has been on getting the field accepted in the scientific world. The fundamental problem is that the main production task should be effective and not to take care of humans, which may be hard enough (Johansson et al., 2004). Hence, when companies are faced with the question of choosing between creating a better work environment or improving productivity, if they are not demonstrably connected, they often chose productivity.

Further, it is obvious for all profitable organisations that they cannot be driven by only social considerations and employees needs, rights and demands, since the most important thing is to produce goods and services for the market (Abrahamsson, 2004a). However, even if this is the major objective, we have to consider how we achieve this production. Work environment factors have to be somehow acknowledged and this should be adapted to the specific way an organisation produces their products and services. We cannot have a collective approach with assumptions such as one size fits all when it comes to, for example, psycho social work environment. As a matter of fact, this approach is not suitable for any aspect of the work environment.

In a two part evaluation of the research in mechanical engineering design, Finger and Dixon (1989) state a need for better analytical tools in the early stages of design when critical decisions are made based on qualitative information. Although this statement is directed at mechanical engineering design, the same need might be found in the field of work environment. In this field, tools and methods would help designers exploring alternatives fully and efficiently. Moreover, designs must be evaluated and analysed at every stage from conception to detailed design. Hence, if the need is out there, why has such a method not already been developed and used? Two answers to this question is that people have not looked at the causes of bad work environment in the outcomes of collaborative projects, and that there is no one best way to organise work, whatever the management gurus say (Hofstede, 2001, Hofstede, 1982, Trompenaars, 1994). This implies that a solution must be flexible enough to adapt to specific circumstances. Today, there are no suitable solutions available and little research is published in the field.

1.2 Aim of the research

The aim of this research is to describe, explain, and enumerate obstacles and opportunities regarding work environment design when developing new production systems in an international collaborative project. The intention is to generate knowledge regarding these issues and, by doing so, improve the conditions for future international project organisations to improve the outcome of work environment issues in the finalised project or production system. The aim is also to present an outline of a comprehensive design model for these projects, including as many relevant aspects as possible into a single model and thus provide a broad picture of the design process concerning the work environment.

1.3 Research questions

There is a need to enhance the multidisciplinary research whose purpose is to better understand and develop methods of steering the work environment (Harms-Ringdahl,

2004). New methods and models have to be developed, and that is one of the objectives of this thesis. In a project, the earlier the work environment factors are considered the less costly they will be (Ranhagen, 2004).

The specific research questions formulated are all based on an understanding that, as Bullinger et al. (1997) state, a properly designed technical setup can offer a considerable degree of freedom in organising work procedures for serial assembly.

This thesis consists of four submitted papers intended for publication. In each paper, questions have been raised and answered, creating the foundation for the doctoral thesis summary, which contains further analyses. Some of the questions return in several papers because they are closely related, and others appear only once. Apart from that, the questions are together essential to the whole thesis. They form the main thread in the thesis and theories described, methodologies chosen, results presented, and the discussions held are permeated by the questions presented. The first three questions are of a descriptive character and the last of an analytical.

Research question 1

The design and management of the work environment has come a long way the last hundred years, and companies have developed certain ways to handle these issues. When these companies come together and work in international collaborative projects, e.g. EU-projects, problems that have not been noticed for a long time in the companies' head organisations appear. These problems form the basis of the first research question and the following questions.

What are the problematic elements regarding work environment design when working in an international collaborative project aiming at developing a new production system?

Research question 2

When working in international collaborative projects, it is important to remember that even though the project aim is the same for all companies involved, their way of looking at work environment issues may differ. If there are fundamental differences between the wishes of how to tackle future work environmental problems, awareness is essential to avoid it becoming a problem for the outcome. Maybe it is sometimes just a different way of speaking about these issues, and maybe there are sometimes more substantial differences. These problems form the basis of the second question.

How does the way of looking at work environment design issues differ between involved partners?

Research question 3

Work environment design issues can be tackled differently and the outcome may be the same no matter what. Methodological models used in specific organisations have often been developed for a long time. The timeframe is essential, since how these issues are handled often evolves through time and with pressure from the surroundings and inside the organisations. This pressure originates from society, managers or competitors, customers, and workers. Grouping these companies together in a project outside their ordinary context, at least abstractly, may imply that in the newly developed organisation, the project organisation,

there is no history of dealing with these issues. Hence, the management of work environment design tends to be built from the ground up. Therefore, the third research question is addressed in this thesis.

How is work environment design handled when developing new production technologies in an international collaborative project?

Research question 4

The socio-technical perspective is an important base in the field of work environment, both research and practice. The perspective is regarded as a good way to simultaneously accomplish both the 'good' work environment and profitability for an organisation. It becomes interesting when project participants have a perspective in their own company that is sometimes dissolved in the cooperation with other companies, especially in international collaborations. This implies that to look at work environment issues, research question number four is important.

How can a socio-technical perspective be said to filter through in the manufacturing companies studied and in the collaborative project they participated in?

Research question 5

When working in an international collaborative project, people from different organisations participate. As they enter the project they bring knowledge of how to deal with work environment issues in their specific organisations. They posses tacit knowledge about possible solutions to work environment problems and they may have suggestions on how to manage these issues in collaborative projects. This knowledge is not always taken advantage of and people do not know what sort of knowledge the project as a whole possesses regarding work environment. This can be a problem, since some knowledge has to be acquired through experts outside the project. These thoughts have led to the fifth research question.

How is the knowledge of work environment issues and work environment design used in the project?

Relevant outcome

The sixth question is mainly a development question. I will try to demonstrate that the problems during the project and some found in the literature are surmountable if dealt with systematically, and if work environment questions are considered early as a part of the design process. The five presented research questions try to find out in what way. It is important to bridge over from 'grounded' research to applied, where there are possibilities to improve the outcome of future development projects. During the whole project this step has been kept in mind and it should be present when describing the structure of the thesis.

How can the procedures of working with work environment design in international collaborative development projects be improved with regards to stringency, transparency, and the results of the five research questions?

1.3.1 Connection between research questions, studies and appended papers

The research questions all respond to different papers included in this thesis, based on the studies done in the EU-project, and are dealt with in the doctoral thesis summary. The

relationships are displayed in Figure 1. Each research question is addressed in some of the reports written in the EU-project. These reports are confidential to the public. Although they deal with some of the research questions, the connection between them and the questions are omitted.

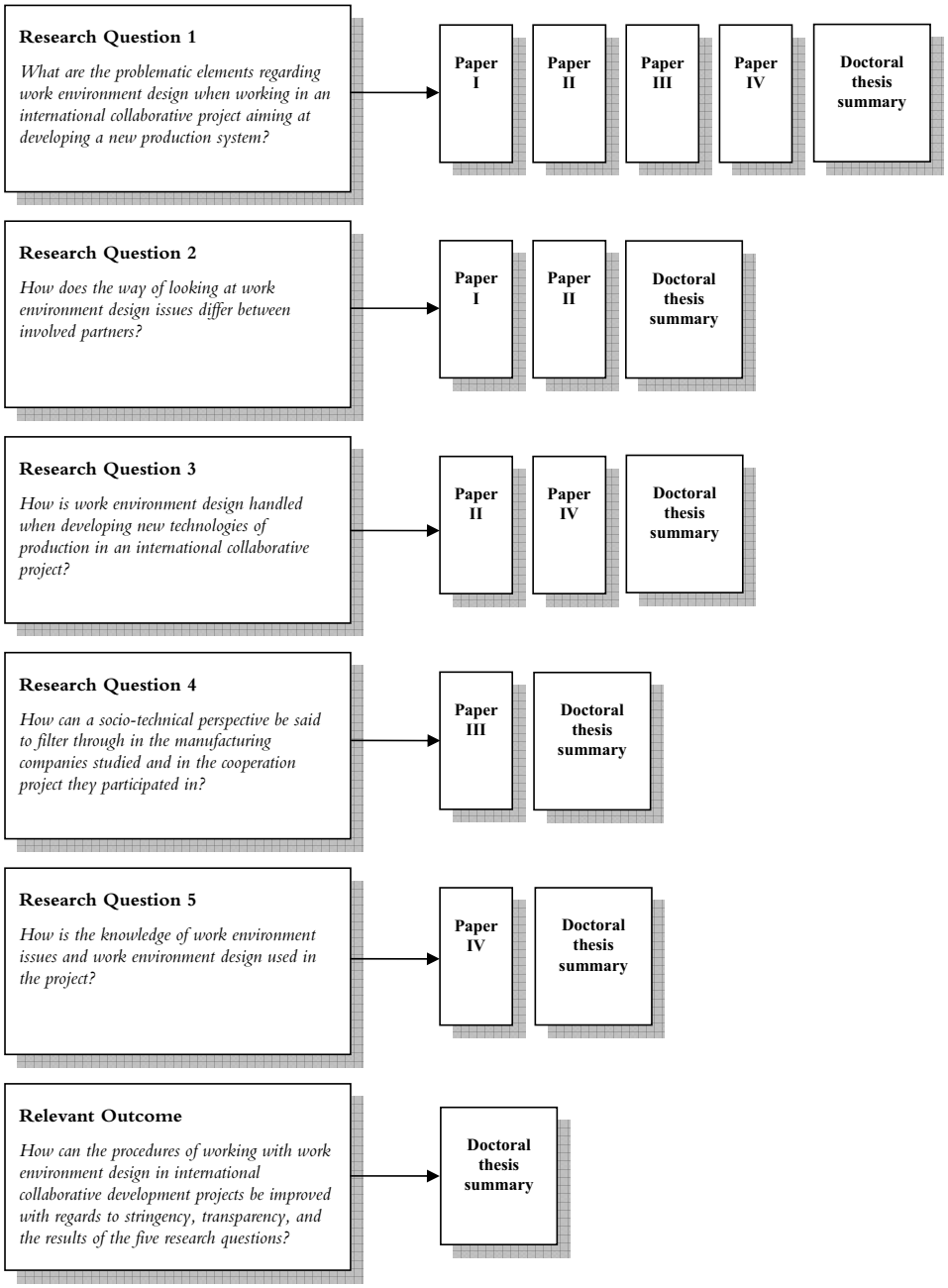

Figure 1 The connection between the research questions, relevant outcome and the appended papers in this thesis.

1.4 The design of this thesis

There are different ways to structure a doctoral thesis. As a matter of fact, it is similar to handling work environment design in international collaborative projects. It has to be noted what context you find yourself in. As a graduate in engineering of Swedish origin, I find myself in a specific context and with a certain perspective on issues regarding work environment design. Further, different universities, departments and divisions have their own way of structuring a thesis. It is about balancing and taking the most basic characteristics from those institutions that influence me in specific way and structure the thesis in a way that suits me and my readers best. Hopefully, this will make it easy to follow the way of reasoning in the thesis and make the reader able to understand the results in its right context. The way to design a thesis is important, but only to justify the results. One must not forget that it is possible to develop life jackets of lead according to all the recognised rules of production, but the result would not function as a life support when in the water. The research presented in this thesis should be seen as applicable research in which the results can be used to overcome problems of work environment design caused by different origins and perspectives.

Early in the research process, I decided to write a thesis with appended papers. Ideas and a structure of a future thesis were set up early in the EU-project, which in minor aspects was altered along the way. The most important reason why I stuck with the idea to write papers for journal publication was because I consider writing papers and thus distributing understanding a central element of being part of the scientific community. However, the introductory doctoral thesis summary is written to stand for itself and is supported by the appended submitted papers. The appended papers bring a deeper analysis in some fields.

1.5 Conceptual definitions

When speaking about work environment in industry, the concept of ergonomics is well known. A problem is this does not mean the same for all people. To overcome this issue, some of the most important conceptual definitions are presented and explained to make sure that the thesis will be read with the same perspective as intended by the author.

When writing about factors affecting the health and wellbeing of operators, different words to express almost the same thing can be chosen. In this thesis the expression work environment is used. The word ergonomics is also frequently used, and has already been used several times in this thesis. The conception of work environment has today become slightly overused in certain quarters, according to Gröjer (2004). He states that today the conception stands for everything and nothing, and that the same thing is valid for ergonomics. The word ergonomics historically has many definitions, but in this specific thesis, that stated by the International Ergonomic Association (IEA) in August 2000 is embraced.

"*Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.*

Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people. .....

Practicing ergonomists must have a broad understanding of the full scope of the discipline. That is, ergonomics promotes a holistic approach in which considerations of physical, cognitive, social, organizational, environmental and other relevant factors are taken into account. ……

Organizational ergonomics is concerned with the optimization of socio-technical systems, including their organizational structures, policies, and processes. " (IEA, 2000)

Work organisation is an important part of the modern broad ergonomics concept. In particular, the opportunities for job variation, rotation and enlargement are of great importance for the prevention of MSD (muscoskeletal disorders) (Hägg, 2003).

Some problems also exist with using the word ergonomics. Lately, the field of ergonomics has been enlarged, though in Sweden many people still associate the word only with issues regarding musculoskeletal disorders (Ruth and Odenrick, 1994). When speaking to engineers in the industry this misconception is especially noticeable. To bridge this gap of conceptions, work environment will instead be used in this thesis, even though this may cause misinterpretations internationally (Ruth and Odenrick, 1994). The definition of work environment used in this thesis is that it involves all aspects of work that affects a person's health, but it also involves the human role in the technical production system. This implies that the connection is strong between things affecting the health and the productivity of a system. However, several of the references used refer to ergonomics in a wider form. A more thorough, but older description of the development of ergonomics and how it has developed in the US and Europe and then foremost in the UK is given by Singelton (1982).

It is important to point out that in the description of the EU-project, we were supposed to conduct a socio-economical evaluation, but due to our wider definition of work environment, it also involved discussions of the usefulness, profitability and the production system efficiency regarding the human involvement in it. Thus, in some ways it was a socio-technical system evaluation, which focused on the work environment design that was carried out.

2 Background

To understand the context in which this thesis is written and the field it discusses, a few areas have to be briefly described. The EU-project forming the empirical base of this thesis is described in a context of similar projects, to help the reader before they become engrossed in the methodology and analysis of the thesis and to further understand this specific EU-project. How work environment demands are handled in EU-projects today are briefly described, and because the project focused on the aero structure industry some main characteristics of this industry are mentioned. The two producing companies mainly focused upon in the EU-project and in the research, i.e. in the aero structure industry, are briefly described to an extent that retains their anonymity.

2.1 Earlier relevant work environment research in the aero sector

There is a striking contrast in the number of work environment studies conducted in, for example, the automobile industry compared to the aircraft industry. Research in this multi-national large aircraft industry is often confidential and unpublished, therefore contributing to the difficulty of conducting further public research. To keep up to date with new and developing technologies is a challenge for researchers hoping to influence the work environment for companies adopting the new technology.

Some of the developments within in the aero sector worth mentioning occurred during the 1980s when the development of new generation tools, such as ceramic, polycrystalline diamond, and ultra-hard coverings, led to the introduction of high speed machining (HSM) (Birch, 2003c). Another development taking place at the moment is the change from aluminium to composites. Today, it is not considered commercially viable to use composites because the manufacturing costs of composite structures are considerably higher than those of equivalent light-alloy structures. The reasons for this are threefold: higher cost of raw materials, unsuitable manufacturing methods, and non-optimised designs (Burley and Mills, 1998). However, most people involved in the industry see composites as a material of the future. These shifts of paradigms will have effects on future work environments.

Studies about producing aeroplanes with respect to, for example, ergonomics are conspicuous by their absence. Much can be found about technical achievements, i.e. production techniques, robots, and product development. It seems that the aero structure industry has an even stricter focus on technical aspects of production than, for example, the automobile industry. The constructor of techniques receives significant attention in research, but the manufacturing engineer receives much less.

2.2 EU-projects and work environment

Since the international development project studied and participated in was an EU-project, it is of interest to describe why development projects happen and what are their general

characteristics. Each EU-member state has its own material describing how to apply for economic support from the EU. A Swedish publication (Riksdagen. EU-upplysningen, 2005) and a publication describing research within the EU (*Med sikte på framtiden: vetenskaplig forskning i Europeiska unionen*, 2005) were of use when writing this section. These publications announce that to apply for economic support from the EU, the project has to have an outspoken European aim. One reason is that behind the EU funds and programmes, there is a political purpose that permeates the objectives, scope and direction of the economic support. Since several nations comprise the Union, so are the different politics.

No project can be conducted entirely based on financial support from the EU. EU-support seldom exceeds half of the project costs, and the projects are run as collaborations between partners from several member countries. A basic rule to be granted financial support is that companies, universities and other organisations from different countries collaborate within projects. The project is often demanded to be of benefit for more countries than those participating in the project. This means production processes developed in the EU-project studied in this research should also be available to organisations and nations that did not participate in the project. This is counteracted by the strict confidentiality applied in the EU-project, where companies and organisations try to protect themselves from competitors.

Economic assistance is given to research in several fields, e.g. IT, public health, renewable sources of energy, product development, and transportation. Economic support of research in the EU is mainly financed from the joint budget consisting foremost of EU-nation membership fees and value-added taxes. The membership fees fluctuate among the countries and are calculated from the gross national income. Sweden is estimated to pay SEK 28 billion in member fees in 2006, in an EU-budget containing SEK 1050 billion. The EU's long-term budget runs presently between 2000 and 2006. This means several of the funds and programmes expire after 2006.

The EU has been engaged in research for almost 50 years and its joint research centre was founded as a part of the Commission when the EU was grounded in 1958. The mission of the centre was to supply independent scientific guidance and technical support for the commission and other institutions within the EU, during the work of designing and conducting different political programmes. During the 1980s, the EU took on a bigger responsibility to stimulate and coordinate the scientific research within its member states. To take care of this task, the EU has run several Framework Programmes. Each Framework Programme runs for about four years and is updated continuously to represent the changing situation within technology and science, and the development of the EU's priorities.

In 1986, the Single European Act confirmed research had now become a question for the EU. The Treaty on European Union (TEU), signed in Maastricht on 7 February 1992 and entered into force on 1 November 1993, increased the EU's role of promoting research and technology development. In 2003, EU leaders agreed to increase the economical investments on research and development to 3 percent of GNP before 2010.

Economical research support by the EU is focused in a special framework of research. The First Framework Programme ran from 1984-1987. The present framework programme, the sixth, runs from 2002-2006, and the Fifth Framework Programme, including the EU-project studied in this research, ran from 1998-2002. The framework programmes are open for individual researchers, universities, companies and other organisations. Participants can originate from the different member states, nations having an association agreement with the

framework programme, and other countries outside the Union. Thus, the demands on the participant can differ between different types of research projects. A general principle is that the project should consist of at least three different partners from at least three different member states or associated countries.

The description of the Fifth Framework Programme states that a system approach is necessary, in which research activities support the development of coherent, interconnected and eco-efficient industrial and social systems, responding not only to market, but also to societal needs. This exemplifies a focus on some of the facets of work environment, at least rhetorically.

The trend that can be discerned is that work environment issues are brought up, but often not actively used. The projects focused on production techniques presented on the EU's web pages, though do not generally describe a strong work environment focus. The only project found is that described in this thesis. Thus, it is not common to have a strong focus on work environment design, at least not as a separate work package, and it is doubtful whether the focus has ever been there. Some projects are mainly concerned with work environment and health, but not with an aim to jointly optimise both technical and social aspects in production.

2.3 The aero structure industry

This section will give a brief overview of the industry sector of aero structures. The material forming this overview is mostly collected in newspapers, magazines, and in scientifically accepted reference work. However as this overview's objective is to shed some light on the industry discussed, and the fact that it will only serve as a background, this will not imply any problems for this thesis. Nevertheless, some scientific references can be found in the overview supplementing the other material.

The aerospace industry was born unofficially in 1903 when Wilbur and Orville Wright demonstrated an airplane capable of controlled flying. In March 1909, the British entrepreneurs Eustace, Horace, and Oswald Short set up the company Short Brothers Limited on the Isle of Sheppey, establishing the world's first aircraft assembly line (Aerospace Industry, 2004). We have come a long way since then, and over the last 20 years, data used in manufacturing has made its way from a Mylar medium to one that is digital. Engineering data has evolved into Cad, and manufacturing data to NC tapes (Bokulich, 2002b). Most basic metal-fabrication methods have been employed since World War II, but due to advancements in the capabilities of machines and tools, tighter metal-cutting tolerances are possible today (Aerospace Industry, 2004).

Aircraft manufacturing has been and is still a very complex process, and is often referred to as "a craft process with a mass production mentality" (Aerospace Industry, 2004). Because of the extensive range of skills and facilities required, no single company builds an entire flight vehicle these days (Aerospace Industry, 2004). Currently, the work is a labour-intensive process using manual drilling and fastening methods with dedicated jigs and fixtures (Rooks, 2001). There are different parts to the production and this thesis focuses mostly on the assembly process where structures are first milled, drilled and then riveted together. A typical example of this procedure can be found when producing wing boxes consist of four main stages (Whitehouse, 2003). In the first stage, the aluminium alloy wing components are

machined, treated and shot peened, and then painted. In the second stage, the stringers (longitudinal strengtheners) are joined to the wing panels to make a completed wing skin. In the third stage, the basic wing box structure is created as skins, and ribs and spars are placed in jigs and bolted and riveted together. During the fourth stage, the wing box is equipped with moving surfaces and its electrical, hydraulic and fuel systems. The structure is then tested before being shipped out to one of the final assembly plants, which can be located far away and therefore demanding special transportation for the large structures.

2.3.1 A globalised industry sector

A number of multinational actors are present within the industry. The two big elephants are Boeing and Airbus, which compete year after year to see who is the biggest, while Bombardier Aerospace and Embraer are the world's two leading regional aircraft companies (Newton, 2003). Boeing has historically been the biggest, but Airbus has gained ground recently. However, due to recent delays regarding the A380, Boeing seems to have the best position. In 2002, Airbus took orders for 300 aircraft representing 54% of the market (Whitehouse, 2003), and one of the reasons for this is that the European Union has realised the importance of excelling in this field. An example of this is the underlying objective of the EU-project described in this thesis, which has been to secure employment in the European market. Several European countries are owners of EADS (European Aeronautic Defence and Space), which comprises the activities of the founding partners: Aerospatiale, CASA, and DaimlerChrysler Aerospace AG and holds 80% of the shares in Airbus (Birch, 2003e).

While Europe and the US each maintain a high profile in aerospace technology, Asia's contribution is relatively modest (Birch, 2003d). However, Airbus has now opened a new engineering centre in Russia to benefit from their large, unexploited knowledge bank. In Japan, Airbus is on the march and have now expanded its partnerships with, for example, Bridgestone, Mitsubishi Rayon and ShinMaywa (Birch, 2003b). These few examples show the present industry that is already multinational and will become even more globalised in the future.

Collaboration efforts have naturally occurred between manufacturers and their suppliers in an effort to improve efficiency and reduce cost in the supply chain. Other partnerships were created to reduce risk or remain viable in a small market (Bokulich, 2002a). A typical Airbus project has between 1,000 and 1,500 suppliers. These multinational projects and teams represent a growing trend in the industry (Baird et al., 2000). In the past, collaboration has been seen by some companies as a way of avoiding consolidation when market volumes decrease. Others have seen collaboration as a way to keep in touch in several product areas that may not be their primary focus (Bokulich, 2002a). To form these alliances, several barriers have to be overcome, both internally and externally. These may consist of corporate cultures and attitudes that are not easily overcome, including "our way is the best way", critiquing your partner's participation, trusting your partner, and the need for absolute control of the program (Bokulich, 2002a). This conclusion is not only drawn by Bokulich, but will be returned to several times during this thesis.

Most products within the aero structure industry, e.g. the wing boxes, are modularised, enabling companies to share only information in regards to the interfaces and keeping much of the technology within the components proprietary (Bokulich, 2002a). However, problems occur when the modularised parts should be put together.

2.3.2 Present developments in the sector

One reason for the noticeably positive atmosphere in the aircraft industry during the time of this research was the boost of Airbus A380 to the level of employment. The A380 made its first flight in early 2005 and was supposed to enter service in 2006 (Birch, 2003e, Birch, 2002a), but has been postponed to 2007. This huge aeroplane will carry 555 passengers and be 79,8 m wide (Gesab, 2002), thus causing implications for the industry. Ideally, much of the processes involved in manufacturing the A380 will be carried out automatically, but among other things, the sheer physical size of the components involved and the accuracies of alignment necessary were and are a challenge for the industry (Rooks, 2001).

Since Airbus itself is a company of collaborating companies, various parts of the aeroplanes are produced in different European countries. For example, according to (Birch, 2003a), Airbus UK has produced the wings and fuel systems, Airbus France the nose, flight deck, and flying control systems, Airbus Germany the fuselage sections, and Airbus Spain the tail section, with each country designing, building, and installing all the structure and most of the systems in its allocated part of the aircraft. Final assembly is at Airbus' Toulouse facility. However, not all parts are manufactured in Europe. Regional evaluation of the vendor selection status shows that A380 procurement for equipment is equally divided between Europe and North America (Birch, 2003a). The scattered production of the different parts and sub-assemblies places heavy demands on transportation between the locations.

The aerospace industry has during recent years stumbled through some hard times. Even if the European industry does not appear to have been hit as hard as North America's following the 9/11 terrorist attacks (Newton, 2003), the future looked gloomy for those companies involved in the production of civil aircraft. But as people know, this kind of industry fluctuates whether there are terrorist threats or not. History shows a pattern of strong growth interrupted by a series of short-term downturns from which traffic has invariably rebounded to resume its growth trend (AECMA, 2003). Airbus forecasters are confident that long-term civil air transport will continue to grow strongly (Airbus, 2003), though according to the Federal Aviation Administration (FAA), regional jets will lead the recovery in commercial passenger traffic over the next decade (Newton, 2003). The Bureau of Labor Statistics' Occupational Outlook Handbook 2002-2003 Edition, states that employment of aerospace engineers is expected to increase 10-20 percent through 2010 (Gehm, 2004). This implies that the aircraft industry is still and will be very important for Europe. It employs more than 407,000 people and creates a turnover of about € 75 billion (AECMA, 2003). In addition, it is economically and politically prestigious for a country to possess an aerospace industry (Aerospace Industry, 2004). So, while corporations seek profit in a global market, governments will share the benefits domestically (Kremic, 2003).

Already in 1965, Turner, then Director of Production Operations at Northrop Norair in California, predicted the future of the manufacturing man in the aerospace industry. He said that the multitude of material choices, the vast potential in design concepts, and the advance in manufacturing technology would trigger the need for a higher level of knowledge and competence. He also predicted that we would see vehicles with 500 and more passengers, which is in fact coming true today in the A380 (Turner et al., 1965). However, the consequences with the advancement and development of technology have not only been positive; to prevent possible negative effects regarding the future work environment, the issues discussed in this thesis will be helpful.

2.3.3 Automation in the aero structure industry

In 1973, Trist stated that history had shown that automated plants were in fact nowhere near working automatically. There will always be a need for human involvement. An important point is that because almost every system operation can be automated, designers must decide which functions should be left for the human operator. The trend is clearly towards giving human operators more overseeing and decision responsibility and less moment-to-moment control of system processes (Howell, 2002). It is a misleading notion to think that any given whole task can best be accomplished by either a human or a machine without the aid of the other, because often some elements of both provide a combination superior to either one alone and other times it is not a recommendable solution to join them.

The increasing pace of automation that is attributable to the increased capabilities of digital computers (Hess, 2002) is causing effects on how organisations work with these kinds of issues and on the pace that they adopt and adapt new technologies. Certain ways of thinking state that it is the risk of running with a loss than the chance to make transitory profits that stimulate the development of new technologies (Kling, 1981).

The literature provides different reasons for automation, e.g. productivity, efficiency, quality, safety, flexibility, and cost (Hess, 2002). However, most automation today is not done for safety reasons, but rather cost is the primary motivation behind automating tasks previously undertaken partially or completely by humans. Chief among these cost savings are those associated with labour, including salaries, benefits, and training. This is somewhat of a short-term perspective of automation because it is necessary to consider not only the decision to adopt a new technology, but also the technology's implementation and impacts on OHS (Occupational Health and Safety) in the company (Carrière et al., 1998). So far, much of the allocation of functions in manufacturing environments has been technologically driven, leaving leftover tasks for humans to perform and failing to the consider socio-technical characteristics (Kleiner and Shewchuk, 2001). This is important because technology both influences and is influenced by the process of organisation design. To change technology inevitably results in changes to the social system, while to achieve desired changes to the social system it is usually necessary to make changes in the technology used or at least, in the way it is used (Sadler, 1996). This is one reason why it is strange, as Levi et al. (1991) remark, that organisations do not include the participation of production workers in the technological change process more often.

The automation movement is positive when dangerous tasks such as manual riveting are eliminated. It should be remembered that the use of new technology does not systematically eliminate industrial hazards (Carrière et al., 1998). An aspect of automation, positive or negative depending on perspective, is that the size of the human work force supporting such enterprises naturally shrinks and the skill requirements of the new work force increases considerably (Hess, 2002). For example, the majority of people interviewed within the aircraft industry agree, as Burley and Mills (1998) state, that the wing-box must be designed for ease of assembly, enabling the use of simplified tooling with reduced manual labour input. This attempt at automation has thus far not reached completion, but it has focused on reducing reliance on manual methods and dedicated fixturing (Rooks, 2001). The obvious result is the elimination and displacement of human labour. Once more, it is stated that the effect of technological change should be viewed as a multidimensional, non-deterministic

occurrence, largely influenced by decisions surrounding the specific implementation (Endsley, 1994).

Some factories within the aero structure industry have come a long way towards the flowing production line, despite manufacturing large structures. The A380 wing factory in Broughton has a moving production line that moves every 14 hours with each movement taking 7 minutes while at each workstation is a multi-functional team of 5 who remain fixed instead of moving between wings (Birch, 2002b, Whitehouse, 2003). This is a sign that in the foreseeable future, the involved partners will become more and more automated, though fully automated production lines in the aircraft industry is not plausible, since the series is still too small and the product is extremely expensive. As mentioned, very few examples of automation of these large structures exist. However, one of the manufacturing criteria used in a development project of automated processes for the manufacturing of cost effective composite wing-boxes was the design with a minimum of manual input. The opinion was that even though a human operator is more versatile than any conceivable machine system, he is also considerably more unreliable; automation results in more efficient control over the manufacturing processes leading to an improvement in Quality Control and Quality Assurance, and ultimately a more consistent product (Burley and Mills, 1998).

2.4 The two aero structure companies in the EU-project

The EU-project described in this thesis has two aero structure companies, where most of the empirical material was derived from. These two companies are briefly described below to give the reader some background information. The need for confidentiality, discussed in the methodology section, makes it necessary to give them fictitious names to be used throughout this thesis. These abbreviations are also used in the appended papers. The descriptions involve specific products that the companies are well known for, but cannot be mentioned. Instead, general characteristics are focused upon that can affect the understanding of the analysis conducted.

Swedish Aero Structures (SWAS)

The business domain SWAS belongs to the SWAS group operating in several fields, e.g. electronics, aviation, and aerospace. The group has approximately 13,000 employees and total annual sales of SEK 17,250 million. SWAS Aerospace develops entire aircraft and subsystems for the defence market and serves as a partner and supplier to manufacturers of large commercial aircrafts. SWAS Aerostructures is one of the producing companies in the business domain SWAS Aerospace. This company produces components and builds fighter jet bodies, as well as producing parts for the civil assembling of details for Airbus. The company has around 1,500-2,000 employees. SWAS Aerostructures processes have been studied and are presented in this thesis.

They began to produce for the civil market in 1944. The second civil aircraft was produced in 323 units and delivered to 21 countries. In 1980, SWAS started to collaborate with Fairchild Industries and together they developed and produced a civil aircraft. In 1984, Fairchild withdrew from the project and SWAS took full control, and the aeroplane was then renamed to reflect the company name. More than 400 units were produced to some 40 operators all over the world, followed by another civil aircraft of which the first was

delivered in 1994. SWAS established themselves as a world leader in the turboprop regional airliner market. Since 1997, SWAS has taken part in the development of the A380. Except from Airbus, SWAS delivers to BAE Systems, Boeing, Eurocopter and other SWAS companies/business units.

In 1998, SWAS received large orders from Aerospatiale of France to manufacture aero structures for the A340-500/600 series, and in 1999 SWAS stopped producing whole civil aeroplanes and concentrated on aero structures for larger companies.

Spanish Aero Structures (ESPAS)

The company named ESPAS Aeronáutica was when the EU-project started a company belonging to a holding group called ESPAS, mostly concerned with Aeronautics and Renewable Energies. Today, another holding group has purchased ESPAS Aeronáutica. The processes studied in the EU-project were part of the Aeronautic side of the old holding group, more specifically in the Aeronautical Structures.

The company has been in business for approximately 19 years. From the beginning, the main customer was CASA. But in 1993, ESPAS signed an agreement to be a risk-sharing partner with Embraer for a civil aircraft. The first prototype of the aircraft was delivered in February 1995. In 1995 and 1996 ESPAS signed contracts to manufacture parts for Sikorsky, fuselages and empennages for IAI, and wing and fuselage for another aircraft with Embraer. In 1999 ESPAS started its participation in the development of a new family of aircraft with Embraer, and in 2000 a contract with Bombardier to manufacture two aircraft was signed. ESPAS also has some parts contracted for the new Airbus A380. Today, ESPAS participates in several different segments of the market, e.g. Business Aviation, Regional Aviation, Medium Commercial Aircraft, Helicopters, Large Commercial Aircrafts, Defence and Military Transport Aircraft, and the main customers are Embraer, Bombardier, Sikorsky, Eurofighter, Eurocopter, and Airbus.

Net profit the last three years has been about € 21 million, and interestingly the total workforce has increased from 732 persons in 1997 to around 2,472 in 2004. Due to the downturn for the industry as a whole, ESPAS also had a downturn in 2002 until an improvement in 2004. Due to different circumstances, ESPAS has recently begun to lay people off again.

ESPAS has quite a few facilities around Spain along with one in Brazil from summer 2004. The facilities studied in this project have been demarcated to ESPAS facilities in Spain.

2.5 Work environment development in Sweden, Europe, and Spain

Historically, several major occurrences have transformed the way products and services are produced and manufactured. In particular, the industrial revolution, when we took a big leap from mainly craftsmanship to more machined-based production. This period of time known as the industrial era included the school of Scientific Management, a.k.a. the founder of what social scientists called 'machine theory of organisations' (Trist, 1973). During this time, technology was often deterministic, in line with how Braverman (1977) describes technical development overall, i.e. it is supposed to contribute to the workers degradation, since

knowledge and control are centralised. This contradicts Blauner (1964), who describes the technical development with a more positive perspective. Like this thesis, he had a more socio-technical perspective and stated there are several possible ways to organise work for the same choice of technical strategy. During the period of 'the machine theory', it was taken for granted that the cause and effect relationships were known and that all actions or tasks could be specified to obtain desired results (Davis, 1971). Management tended to organise people in the same way they organised machines, which was shown to not be the best solution. In this context the question of work environment was brought up on the agenda. Questions like the following were beginning to be noted: What is work environment? Where can the work environment be found? When does the work environment exist? Who is affected by the work environment? What sort of work environment can be found in our industry? What sort of work environment do we desire? Of course, these matters have come a long way since then, but it can be said to have started here. This era, i.e. the industrial era, was also influenced by a way to look at labour. A task force was seen as a commodity to be sold by the individual and purchased by the organisation (Davis, 1971). This created a situation were the work environment was not seen as a big issue by employers. Instead, unions mostly pushed for the development of these issues. If problems were noticed, it was not that hard to solve them, since the effects of a bad work environment could easily be traced back to the causes. Today, we know that this is not that easy. Work environment factors exist and are caused in a complex world where the effects of a bad work environment cannot always be traced back to a specific cause. Some effects can be traced, but not all, since a production environment consists of not only machines that are deterministic, also humans who bring a huge range of unforeseeable behaviours with them. Although we have this knowledge, there are still fragments of the Taylorism present in production theory and praxis of today (*Critical perspectives on work and organization*, 1992).

2.5.1 Work environment development in Sweden

When dealing with work environment, as shown in this thesis, it is important to be aware of the context. Hence, because my analysis and knowledge are based on how the conception of the work environment has been developed in Sweden, this can serve as a background for this thesis.

It can be stated that Sweden's 'official' focus on work environment started with the first work environment law introduced in Sweden in 1889, i.e. 'Yrkesfarelagen' (Hydén, 2004). Within the meaning of the 1977 Work Environment Act, the concept of the work environment is very broad encompassing the physical, psychological and social factors that make up the work situation. The Community Directives have been transposed through minor amendments to the Work Environment Act (last changed July 2005) (Vogel, 1998). Although earlier history may be interesting, the system of work environment present in today's Sweden was mostly created during the 1970s (Johansson et al., 2004). Within this timeframe the socio-technical perspective began to take root in Swedish society. Often cited and mentioned in the literature concerning the development of the Swedish way of dealing with a work environment is Volvo's experiment with the Kalmar site. This was a part of ÄAO (changed work organisation) and is often regarded as a failure, but one should remember that several positive aspects accompanied it (Jenkins, 1978). In the Kalmar experiment, the assembly line was eliminated, allowing some parallels to be drawn to the EU-project described in this thesis, since they can be seen as underlying goals to develop

assembly lines for the aero structure industry. This will take us in the opposite direction, back to a request for assembly lines and division of work. The development of the Kalmar site was also a result of the democratisation process that had already taken place in Norway. Sweden followed the developments in Norway, but the cooperation did not flow as smoothly as it did in Norway (Johansson, 2004, Vogel, 1998). Substantial opposition occurred and good results did not always appear.

During the 1980s, the development of computer-based production systems led the way from the Tayloristic formed work organisation (Oscarsson, 2004). The aim now was not only to protect health, safety and work satisfaction, but also to serve as a resource for the renewal of production life. The Swedish car industry led this development and gained international recognition. Working life research became more detached from the strong connection to directions, limit values and other regulations that dominated the 1970s (Oscarsson, 2004). This opened a way to reach company management and production management. It became evident that the psychosocial environment and work organisation would not be regulated in the same way as safety issues. Unfortunately, an increase in the focus of work environment and working life did not happen.

The 1990s, with its economic recession, also led to needed economic measures and hard profitability demands for work environment research. For example, Nordh (2004) states that we have gone now further from the traditional tayloristic principles. As mentioned before, this is a controversial question with many diversified opinions. Johansson, Frick and Johansson (2004) state that even though surveys conducted by the SCB (Statistics Sweden in English) show great improvement regarding the physical work environment, many of the old risks still exist. Johansson et al. (2004) argue that severe accidents have continuously decreased to such a low level that they can be able to compete with the best in world, e.g. the number of occupational deaths among men in Sweden is less than one-sixth of what it was in 1965 (Wegman et al., 2006). Signs that work environments in general should have improved during the 1990s are few (Lindqvist, 2004a). Johansson, Frick and Johansson (2004) agree that reliable evidence of whether the physical work environment has been improved since 1970s is lacking, but state that it is very likely.

What has changed is the way work environment problems are looked at. Abrahamsson (2004b) states that development has gone from considering work environment and work organisations as only a matter of cost or a health question for the individual to considering the work organisation as a field for strategic means of control for management. Even so, Johansson (2004) is of the opinion that the market has increased its signification and direct influence over the production elements in which the organisation plays a big part.

Lindqvist (2004b) states that monotonous jobs are increasing because of the level of automation. The first jobs to be automated in fact create new, monotonous jobs. It is not economically justifiable, at least not in a short-term perspective, to automate whole processes. This implies that tasks in between automated tasks are and will still be done by humans. Another reason monotonous jobs might be increasing is due to more production being done by networking and less by one single company these days (Johansson et al., 2004). By partitioning the manufacturing process only short cycle jobs remain at one specific shop floor.

In Sweden, the investment in research into work environment factors has decreased in recent years and Johansson (2004) mentions two possible reasons, i.e. work environment factors

have been integrated into the production techniques to such an extent that there is no need for one's own field of research and specific research no longer has any political driving force. This seems not only to be the case for Sweden, but Johansson (2004) concludes that working life research neither holds a high priority on the European agenda.

Research regarding the work environment is carried out in several different research centres in Sweden. Of note is the National institute for working life, which due a political decision taken during the autumn 2006, will close in 2007. Sweden and Portugal will be the only countries in the European Union who do not have a national institute of working life. Sweden also has strong tradition of research conducted at universities regarding work environment. Lund University, for instance, is famous for the Change@Work, a multi-disciplinary centre and network focusing on work life and change processes, and LUCRAM, focusing on risk management research. Linköping University has a department of Industrial Ergonomics with research groups of human machine interaction, work organisation and physical ergonomics. From Linköping , Jörgen Eklund can be mentioned as prominent in the field of relating ergonomics with quality and productivity. At Chalmers University of Technology, at the department of Product and Production Development, a division of Production Ergonomics is found. One of their research areas is on virtual product and production preparation and on virtual training for work situations. Often published names are Professor Roland Örtengren for ergonomic simulations and Johan Stahre for production systems. Finally, Luleå University of Technology and the Department of Human Work Sciences, comprises several disciplines important for work environment research, e.g. sound and vibrations, engineering psychology, industrial design, gender and technology, and industrial work environment.

It is might not be the lack of research that is the problem, but to spread it and get action. It is not only important to use available tools, but also how you use them and in what contexts. Johansson, Frick et al (2004) conclude that the lack of action is far more common as a cause of occupational risks than lack of knowledge.

The view of the problems of working life in Sweden are diversified (Johansson et al., 2004), since the unions paint a picture of a situation where there is much to do, and even though we have set an example in the past, we are today lagging behind. Fräjdin-Hellqvist (2004) in the management group of confederation of Swedish enterprises states, however, that the Swedish work environment stands up well when compared internationally. She states that the Swedish work environment is good, perhaps the safest one in the world.

2.5.2 Work environment development in Europe and Spain

The development of the work environment in Europe has been somewhat similar to the Swedish one. It is hard to distinguish a separate history within Europe before the European Union involved many countries. In the literature, such as Meister's (1999) description of the history of human factors and ergonomics, European history is delimited to the history of the UK. Whether this is because it is easier to find relevant information in English or if history in the UK is also significant to European history is doubtful. It is my personal conviction that there are many countries in the European Union that have a genuine tradition of this kind of work. Examples can be found in the socio-technical perspective described later in the thesis.

As mentioned already, it is of interest to describe the European Union's work with work environment factors. In the late 1980s, the EU initiated what can be called an offensive in

the field of work environment (Ekström and Olsson, 1994). The Single European Act in 1986 was the beginning, followed by several important directives, e.g. the Council Directive 89/391/EEC (Vogel, 1994) on the introduction of measures to encourage improvements in the safety and health of workers at work and the directive of Machinery 98/37/EC.

During the Maastricht meeting in 1991, 11 of the 12 EU members signed a protocol that the EU should have an objective to improve the work environment. The only nation that did not sign was the UK, which is interesting in relation to what was stated in the paragraph above.

Ekström and Olsson (1994) also state that the Swedish work environment law is more distinct in several different respects than the European Directive. However, in standardising the national laws with the European directive, the discrepancy is not mainly between employers and employees but rather between different nations (Vogel, 1994). The discrepancies are found between the northern and southern nations. Countries in the northern part fight for higher safety demands, whereas some southern countries state that they have competitive strength since they have lower demands (Ekström and Olsson, 1994).

Since one of the studied companies in this research project was from Spain, it is of interest to briefly describe the frame of Spanish regulations regarding work environment. According to the European Foundation for the Improvement of Living and Working Conditions (2005), the Prevention of Occupational Hazards Act of November 8 establishes the general framework of health and safety at work in Spain and covers all employees working in Spain in both the private and public sectors. The act brings European regulation in this field into the Spanish legal system, e.g. the EU Directive 89/391. It regulates the general obligations or duties of employers, employees and the manufacturers and suppliers of machinery and equipment with regards to the prevention of risk, etc.

The content of health and safety regulations is very varied in Spain: safety at work, industrial hygiene, occupational health and industrial medicine, training activities, etc. The obligations of employers, managerial staff and workers are also very diverse, since they cover design and maintenance of work premises, use of machinery and tools, training in new work methods and new technologies and medical examinations.

According to the European Foundation for the Improvement of Living and Working Conditions (2005), the total number of industrial accidents recorded in Spain was around 1 million per year between 1985 and 1994, but the actual number of serious accidents amounted to approximately 10,000 per year. Over the past few years, these figures have increased in industry, construction and the service sector, and decreased in agriculture.

"In theory, there is no difference between theory and practice; In practice, there is." Chuck Reid

3 Theoretical and analytical perspectives

The aim of the research project described in this thesis is to describe, explain, and enumerate obstacles and opportunities regarding work environment design when developing new production systems in an international collaborative project. To conduct this study scientifically, theories that helped to describe and explain the phenomenon had to be chosen, which expanded the research already conducted by others. Literature and theories with a direct and specific focus on the phenomenon studied are rare. Since the field of human work sciences is multidisciplinary, the theories are assembled in four overarching domains, viz. *the socio-technical perspective*, *work environment design*, *different perspectives regarding work environment design*, and *work environment design in project work*.

Das (1999) states three major approaches to work design, viz. *technology-centred*, *human-centred*, and *the socio-technical approach*. The most common is the *technology-centred*, which follows the linear sequence of system development, i.e. requirement analysis, functional specification, design, implementation, and test. This approach does not focus on the production system as a whole and will be exemplified by how the EU-project described in this study was run. However, it is in some ways contradictory to my own perspective on how it should be. The *human-centred approach* focuses on personal growth, the development of professional skills and social competence, and the use of human capabilities and skills as the main sources of productivity. This is the very opposite to the first approach, i.e. the extreme on the other side of the scale. The Hawthorn studies were one of the starting points for this era in organisational theory. In their studies Roethlisberger and Dickson (Boalt, 1950) showed an interdependency of the technological and human organisation. In the research presented in this thesis, both technical and human centred approaches are acknowledged and merged together in the *socio-technical approach*. It should be acknowledged that all theories described should be seen from a perspective based on production process development and work environment. Researchers belonging to other fields may say that the central point in the chosen theories is misplaced. Researchers in the field of production process theory may also object to why this field does not have a separate section in the presented theories. Instead, the field has a whole thesis permeated by its train of thoughts and its work environment aspects.

The socio-technical perspective has inspired me and led me to my starting point. Thus, this is one of the largest fields of theory presented in this section. In this field, which will be further described later on, contains several sub-theories. For example, the idea of worker participation plays an important role in the socio-technical perspective, while the theory is useful to explain the empirical material and conduct the right analyses. The socio-technical perspective is used due to the importance and efforts to optimise the social aspects and the technical aspects simultaneously, and thereby achieve a holistic approach on work environment. In reality, it is foremost about avoiding sub optimisations of any two and approaching a joint optimisation using a holistic perspective.

The concept of change frequently occurs in theories describing the work environment. Numerous shelves are occupied by literature trying to turn change processes inside out. This

thesis will describe change, since it is one important variable for the outcome of a collaborative project, and mostly about how people work with change and what sort of models are available and used. It will illuminate how these change models consider work environment design and if there is any models for change that simultaneously can be said to be conceptual models for work environment design.

Knowledge transformation is important when speaking about work environment design. Knowledge about work environment legislations, factors, and design were differentiated among the EU-project participants and it was of interest to study how this was coped with in the EU-project. In the section about project management and project organisation, projects in general are described as well as their characteristics. These characteristics imply certain conditions for knowledge transformation between different projects due to, e.g. different time perspectives and different project organisations.

3.1 The socio-technical perspective

The socio-technical perspective is a mixture of Sociology and Physics & Technology (Herbst, 1974, Herbst, 1965) as can be seen in Figure 2.

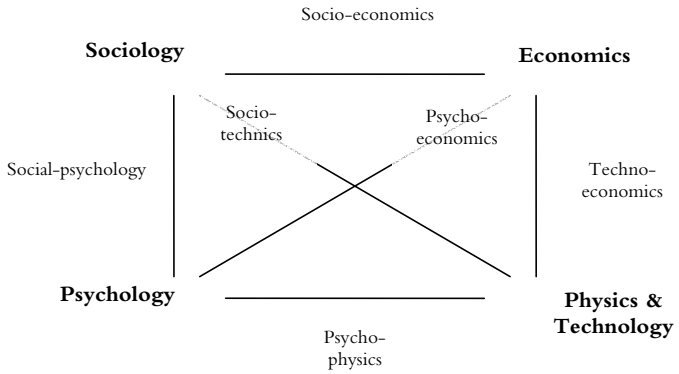

Figure 2 How the different basic disciplines of science are blended and creating new hybrids (Herbst, 1974, Herbst, 1965).

Since the socio-technical perspective permeates this thesis, this hybrid is of most interest. The socio-technical perspective was developed with much involvement in the field of Psychology, i.e. the classification cannot be as specific as in Figure 2. Although the socio-technical perspective, which is a cross disciplinary science, is built on Sociology and Physics & Technology, it contains other sciences as well, e.g. Psychology and Economics. It seems that if an approach is multidisciplinary, it tends to involve even more fields than just two. Thus, there are strong similarities between the socio-technical perspective and work environment science, which also can be regarded as a cross disciplinary science. These similarities will be strengthened within this theoretical framework.

3.1.1 The history of the socio-technical perspective

To understand the socio-technical paradigm and why it is still important, it is essential to realise what it answered back in the 1950s. Even though the school of Human Relations was one answer to Taylor's scientific management, in which the scientific motion studies by Gilbreth (1911) played an important part, there were still ideas about what the new paradigm, called a socio-technical perspective, was up against. To some extent, it also answered the critique of Human Relations, since it had gone from one extreme to another. The important notions of Human Relations were very different from those of Scientific Management, but they had no way near the same impact on industry as the Scientific Management notions. Trist (1973) describes the characteristics of Scientific Management, which he ascribe to his colleague Louise E Davis. The description can be summarised in:

- The man and his job are the essential building blocks of an organisation
- Man is an extension of the machine, useful only for doing things that the machine cannot do.
- The men and their jobs are to be glued together by supervisors who will absorb the uncertainties and variabilities that arise in the work situation. Every supervisor will also have a supervisor, which will implicate a strong hierarchy.
- The organisation is free to use any available social mechanism to enforce compliance and ensure its own stability.
- Job fractionation is a way of reducing the cost of carrying on the work by reducing the skill contribution of the individual who performs it. Man implies an extension of the machine, and obviously, the more you simplify the machine (whether it's a living part or not) the more you lower costs.

When Human Relations served as an antithesis to Scientific Management, some researchers began to realise the need to simultaneously take care of the technology and the organisation. Trist (1973, pp 104) states that *"…to optimize the technical system and hope the social system will somehow sort itself out, then sub-optimization is certain to result."* In the beginning of the 1950s, this statement could describe several of the outcomes of change projects; the case in the EU-project described in this thesis will be shown. Instead, researchers such as Rice and Trist (1952) began to argue the importance of understanding the whole system, i.e. the socio-technical system, that contained both technical and social dimensions, to explain the kind and direction of change in, for example, labour turnover when either technological or social change occurred.

Since then, much literature has been published in the field and the notions of the socio-technical perspective have been subordinated in different conceptions. Many researchers refer to socio-technical system design and some to the socio-technical theory, but in this thesis, I conform them into one single approach - the socio-technical perspective. They are all coloured by the same principles and values and are all based on the same origin that will now be briefly described.

Pasmore (1995) summarised the socio-technical development, but a description can also be found in Davis (1971), Eijnatten et al. (1993), Trist and Murray (1990) and Weisbord (1987), thus the origin of the socio-technical perspective can be regarded as well described in the literature. Bertlanfy (1950) was the founder of the open system theory, which has played a

big role in the development of the socio-technical perspective. Davis (1971) states that we cannot understand an organisational unit without understanding its environment. In the beginning, the traditional socio-technical paradigm found its roots in biology, cybernetics and neurophysiology (Herbst, 1974), far away from the aero structure industry and its collaborative projects described in this thesis. A group led by Trist at the Tavistock Institute of Technology developed the field through empirical studies based on work done by Lewin in the field of action research and system theory, which had been around for a while.

The Tavistock Institute of Human Relations was founded in London in 1946 with help of a grant from the Rockefeller Foundation (Mumford, 2003). The therapeutic background of the Institute staff led them in the direction of 'action research' (Mumford, 2003). Eijnatten, Hoevenaars et al. (1992) state that the whole socio-technical system design paradigm is based on action research, which strengthens the connection to the research described in this thesis. The studies got their first empirical data from the mining industry and a study from a metal workshop. Part of the mining industry took on a new and, for that time, fairly experimental method of mining. Instead of 'long wall' mining with three shifts conducting a phase, a 'short wall' methodology was used. The new way of working required teamwork and multi-skilled workers. This new type of organising work, consistent of teamwork and self-regulation, made control-oriented managers uncomfortable. The conclusion of the studies showed a breakdown of established social systems, resulting in the formation of maladaptive mechanisms as a defence against the social and psychological consequences of the technological organisation (Trist and Bamforth, 1951). The first step in these studies was to assess the implications of the "long wall" method. A parallel can be drawn to the EU-project studied in this thesis, where the initial step for us in the project was to look at how production was done today to have something to compare to when the new system was in place, and thus assess the implication of the new production systems.

Even though Trist's and Bamforth's studies from 1951 are the most famous, they were followed by Sheppard's more extensive studies from 1951-1953 (Trist, 1973). These extensive experiments became known as the composite method, and showed increased productivity and job satisfaction. To further compare the two approaches to coal mining, an experiment took place between 1954-1958 with two identical coal faces (Trist et al., 1963). This comparison showed that the composite face was superior in all aspects to the conventional method (Trist, 1973), and according to Herbst (1974), the idea that a given work organisation was a necessary consequence of a particular technological system was not discarded until the second series of coal mining started in 1954. Thus, it is interesting to find out if the participating organisations and the EU-project itself worked from the same motto, i.e. there are many ways to organise work around developed technologies and it is important to find the right way.

The next step of the socio-technical perspective evolution came with the studies done by Rice (1953) in the Indian weaving industry. Rice presented a paper describing a preliminary analysis of the socio-technical system of an experimental automatic loom shed that weaves cotton cloth, on the basis of which working methods were reorganised and an increase in productivity was achieved. In the company studied the workers formed multi-skilled teams that were responsible for the entire operation and maintenance of a process. The studies showed that the socio-technical perspective was far more successful than traditional one-person one-job set up. Efficiency increased and cassation decreased. It also showed the importance of the relationships between interdependent workers. The workers who did not

'fit in' had to be relocated to other groups at other places in the organisation, which during the EU-project could be noticed in SWAS and their present production system observed. It became apparent that the difference in status and salary made self-regulation by group members more difficult. During the experimental period the rest of the factory continued with the previous form of organisation. After this, Emery and Trist (1959) pointed out the advantages with a composite system combining a simple formal structure with complex work roles.

When Eric Miller, 16 years later, went back to the same company and studied what had happened during these years, he concluded that the groups without enough support when the socio-technical perspective was implemented had experienced a decline of these values. They went back to a more traditional system of work, where one of the organisations studied was automated and then abandoned the autonomous group system (Miller, 1975). Another organisation was pretty much as it was 16 years earlier.

After these empirical based studies, Fred Emery led the conceptualisation of the theories. Emery based his theories highly on the open system theory. In theory development, Emery differentiated between semi-autonomous groups with the authority to make decisions, but lack the infrastructure, and self-managing groups that have both. Emery continues by stating that the optimal self-managing group consists of 8-10 people with both the skills and the authority to run their work. Emery also constitutes three socio-technical design principles: all groups should be permeated by the goals of the overall system; workers should be able to rearrange their own resources instead of having experts stipulating how a task should be done, participation is advocated; if the workers are multi-skilled, they are more flexible at solving problems and taking advantage of opportunities. All these principles influence the final model obtained at the end of this thesis.

In 1972, the socio-technical movement was formally internationalised by the creation of a Council for the Quality of Working Life (Mumford, 2003). A number of academic groups became actively interested in socio-technical research. Following Emery, Herbst showed in his studies that there were alternatives to hierarchies and he presented the concept of minimal critical specification (Herbst, 1974).

Eijnatten, Hoevenaars et al. (1992) state that a period, called the period of classical Socio-technical System Design (STSD) (1960-75), consisted of more testing of elaborated concepts and expert methods. During the period called the modern STSD (1972-1989), the most prominent nations were the Scandinavian countries, the Netherlands, North America and Australia (Eijnatten et al., 1992).

Based on all this theoretical development in the classical era, a famous nine step analysis was created by Emery in 1967 (Emery, 1993). In 1995 this was still used in the US, while the Participative Design by Fred and Merrelyn Emery (1975) had gained much focus in western Europe and Australia. In *Participative Design*, Emery and Emery state that participation of all organisational levels is important. If the group becomes too big, representatives from all levels of the organisation as a 'deep slice' of the hierarchy should be appointed.

As society changes, so must the socio-technical perspective. At the end of his paper, Scarbrough (1995, pp 28) states that *" any theoretical program is a child of its time"* and that it should be remembered when dealing with the influences of the socio-technical perspective. This is why the socio-technical perspective in this research is adapted to today's prevailing conditions. Herbst (1976) claims that there are many alternatives to hierarchies where each

man has one task. Three of these alternatives are described deeper. First is the autonomous group where each operator is responsible for all tasks. Second is the matrix organisation where there are overlapping competences and a specialised task. The third is the network organisation where there is a just an overlapping of competences and no specialised task. Fred and Merrelyn Emery (1975) agree with this standpoint when they state that in every situation where there is a managerial function to co-ordinate and control the work of numerous people, *" there is always room to involve them in self management of some of the co-ordination and control."* The Emerys continue by stating that the more a group manages itself, the more democratic it is.

In 1976, while working with the democracy at work in Norway, six basic psychological needs were formulated (Thorsrud et al., 1976). Together they represented a minimal set of criteria according to which jobs in concrete technological settings could be designed and evaluated. Two of the criteria are of extra importance to this thesis. The first is the need for the content of a job to be reasonably demanding or challenging, in terms other than sheer endurance, and to provide a minimum of variety. The second one is the need for the individual to be able to relate what he/she does and what he/she produces to his/her social life. In the discussion of replacing the *machine theory of organizing* with a more humanised version, Thorsrud (1976) warns for changing one sort of specialist domination, i.e. the engineers, to a domination of social scientists and psychologists, ergonomics and social workers. They should be combined and not exclusive. The same thing is valid for development projects, as the one described in this thesis.

To end this historical report of the socio-technical perspective, it should be mentioned that Pasmore, Francis et al. (1982), in their formation of the socio-technical perspective history, focused on the great amount of socio-technical experiments described in journals, etc. In 1982, they were at least 100-150 clear cases. However, Pasmore and Francis et al. asked for a more developed and strong theory around the concept. Cherns tried twice (1976, 1987) to summarise the principles of socio-technical systems, but the resulting theory was never very coherent, according to Eijnatten, Hoevenaars et al. (1992).

3.1.2 The essence of the socio-technical perspective

When knowing the history of the socio-technical perspective, it is vital to further explain what the approach comprises. Mumford (2003) states that socio-technical system design has two important components, i.e. to humanise work and support democracy at work. However, it is also important to create possibilities for the technologies together with the operators and the rest of the organisation and to thus create a profit for the company to survive on a competitive market. In the attempts to create this environment, all involved partners need to be aware that every socio-technical system is unique (Das, 1999).

Another thing vital to the socio-technical perspective is, as Chapanis (1979) stresses, that we have to see the consequences for society as a system. We cannot just see how one certain technology would affect the quality of the end product. How other things in the system would be affected has to be considered. A holistic picture is needed (Adler, 1992), even though you cannot consider everything. The importance of studying companies as systems has been shown by, for example Selznick (1953), though a partial way of thinking remains today in many minds of the industry. According to Davis (1966), the piecemeal approach concentrating heavily on the technology component of the system implies less than optimal

total performance. Socio-technical optimisation is directed to the joint optimisation of the utilisation and the development of the employees' qualifications, the implementation of advanced technology, and the design of the work organisation (people– technology–organisation approach) (Strohm, 1999). None of the three should be forgotten and neglected. A typical socio-technical system development process can be seen in Figure 3.

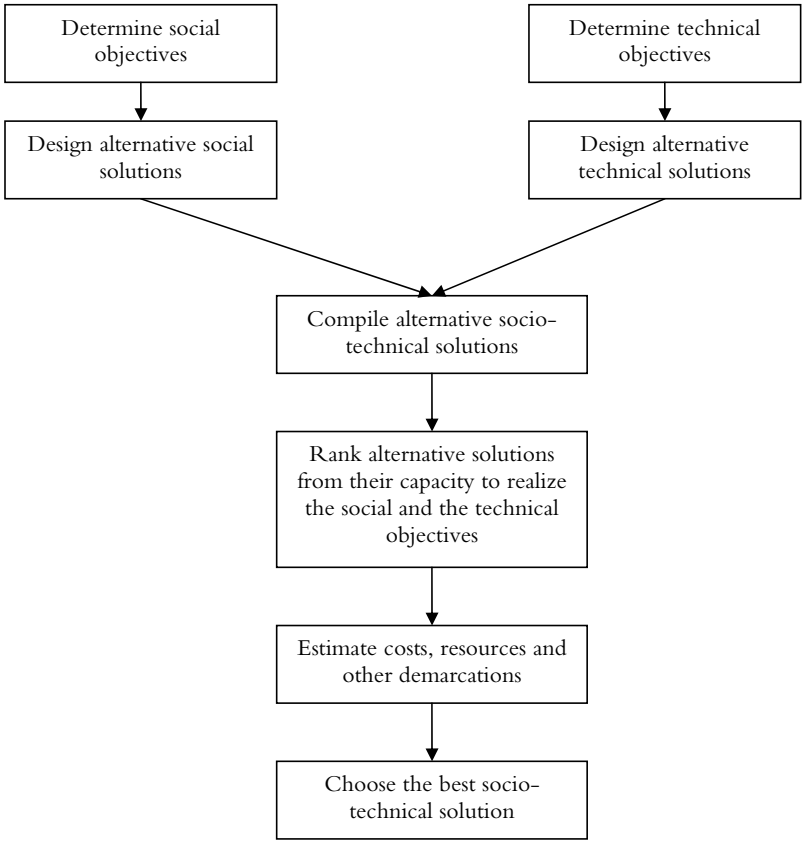

Figure 3 The socio-technical system development adapted from Andersen (1994, pp 450)

In all sorts of literature and in general talk about production systems, a popular word is 'flexibility'. The flexibility of technologies influences variations of both input and output, and in the search for a situation of steady state no such thing can be achieved by any permanent form of input-output rates, internal change mechanisms or environmental contact (Thorsrud et al., 1976). What can be done to maintain steady state, according to Thorsrud, Sorensen et al., is to focus on the basic conditions of leadership and commitment. The leadership's primary task of management is the boundary control of the enterprise and to secure a level of autonomy and selective interdependence that is necessary.

As mentioned, the socio-technical perspective is based on the open system theory. A boundary within the open system theory can be physical, temporal, social, or psychological

(Hanna, 1988), and all four types have to be noticed and discussed. The boundaries of an open system define them as an open system, and to discuss if a socio-technical system approach exists in a company, one has to be certain it is an open system (Pasmore et al., 1982). This is a prerequisite of the production system, which most organisations are today, though to what extent varies. All companies and the EU-project described were all classified as open systems.

It is highlighted within open systems theory how technical tasks and people, etc. interact with each other (Hanna, 1988). The goal of a socio-technical intervention is the principle of joint optimisation, as mentioned before (Pasmore et al., 1982, Emery and Trist, 1959). Many are together with Hanna (1988), who stress and emphasise the importance of applying an open system approach. Katz and Kahn (1966) describe the open system theory, or as they say the approach and the conceptual language. In their description they conclude that all open systems involve a flow of energy from the environment through the system itself and back into the environment. They continue by stating that an open system is defined by its boundaries for the selective reception of inputs (a coding process) and for its typical transmission of outputs.

When discussing company objectives and goals, it can be fruitful how they interrelate with the surrounding environment. Work environment factors influence the correlation between the society and the enterprise or as Thorsrud, Sorensen et al. (1976) put it: *" The goal of an enterprise can be understood as special forms of independence between the enterprise and its environment."*

A commonly used conception when dealing with socio-technical perspective is the autonomous work groups. Emery and Trist (1959) suggest that work group autonomy should not be maximised in all productive settings, but is often a good alternative. Thorsrud (1968) also states the supervision would have to be concentrated on boundary control rather than on internal coordination and control that would be taken over by operators. In the literature this strive for Minimal critical specification was, as mentioned before, developed by Herbst (1974). This can appear to be slightly contradictory compared to the important quality work, but more focus is put on personal quality control, even in the aero structure industry.

As mentioned before, Cherns tried twice to summarise the socio-technical perspective. In 1976, Cherns described nine principles of socio-technical design, viz. *Compatibility, Minimal Critical Specification, The Socio-technical Criterion, The Multifunctional Principle- Organism vs Mechanism, Boundary Location, Information Flow, Support Congruence* (action needed to be in accordance with intentions), *Design and Human Values* (which involves six basic requirements presented by Thorsrud (1968)), and *Incompletion*. One of the most important points made by Cherns (1976) was that problems should be solved at their origin. If operators had the ability and authority to take care of the problems at their own work place, great costs could be avoided. Davis (1966) points out that autonomous job behaviour is a key facet of individual-organisational-technological relationships in productive organisations.

Davis (1977) states 14 attributes of alternative organisation design. All are to some extent weaved together and overlapping, but they are all based on socio-technical values. The attributes are:

- Systemic- all aspects of organisational functioning are interrelated
- Open system
- Joint optimisation
- Organisational Uniqueness- different situations
- Organisational Philosophy- organisational values are congruent with structures and organisational design
- Quality of working life
- Comprehensive Roles of Individuals or Groups
- Self-maintaining Social Systems
- Flat structure
- Participation
- Minimal Status Differentials- there are minimal differences in privileges and status that are unrelated to role and organisational needs
- Make large small
- Organisational Design process
- Minimal Critical Specification

The attributes can be operationalised to various extents, but most of them can be measured in some way. Based on these attributes and what Cherns stated in his second attempt in 1987, the picture becomes clear of what the socio-technical perspective is regarded to comprise. The attributes are used in this study, and further discussed and summarised in the third appended paper of this thesis. What should be remembered, especially regarding the EU-project described in this thesis, of one of the socio-technical principles of design is that the individual is seen as a complement to the machine rather than as an extension to it (Trist, 1981).

In the field of the socio-technical perspective, two frequently used expressions are Quality of Working Life (QWL) and quality of working life. QWL has its origin in the US and gained attention after a big democracy at work conference in New York in 1972. Many of the researchers involved in the socio-technical perspective were also involved in the QWL-movement. In fact, QWL can be said to be a branch of the socio-technical perspective. Throrsrud wrote in 1976 that democratisation of the workplace was part of everyday language, but Quality of Working Life was not. To create a good QWL, a holistic approach to design is essential (Lawler III, 1982). Even though QWL and the socio-technical perspective were very similar they took different directions of development, with QWL becoming a synonym of a working experience, physically and spiritually life enhancing. The socio-technical perspective, however, not only focused on the individual factors, but on the development of the technical measures in the industry. Thus, in this thesis quality of working life is used with respect to the socio-technical perspective, and not QWL. Cherns and Davis (1975) concluded that the disciplines relevant to enhancing the quality of working life are economics, psychology, sociology, industrial relations, and engineering and system theory.

3.1.3 Participation as a part of the socio-technical perspective

The approaches of work environment and other theories can be divided into macro, micro and meso. Most important for the theoretical framework of this thesis is the macro level. Hendrick and Kleiner (2001, pp 7) define macro-ergonomics as *"a top-down socio-technical systems approach to the design of work systems and the application of the overall work systems and the application of the overall work system design to the design of the human-job, human-machine, and human-software interfaces."* They conclude that macro-ergonomics deals with the analysis and design of work systems. One reason for the importance of the macro level is that nowadays, in the post-industrial era, a different perspective is prevalent regarding work. Mankin, Cohen et al. (1997, pp 73) state, regarding the present perspective that *"….the raw material is information, the product is knowledge, the machinery is the computer, and physical labor is replaced by intellectual effort."* However, as shown in this thesis, some problems that have been present for a long time remain, such as the operators often having to perform the tasks leftover from the automation (Hendrick and Kleiner, 2001). One widely spread opinion is that participation can help prevent these problems, implying other positive effects.

Fred and Merrelyn Emery (1975) state that when the involved people work out their own designs it is more likely that the necessary motivation, responsibility and commitment for an effective implementation is present. They are in this case also more effective when it comes to problem solving, since they know their own unique variant of circumstances, history and technology. Participation is necessary if the operators are to take responsibility for the production. The involvement should come at an early state of a project to integrate people into designing and simulating complex networked systems (Brandt et al., 1999). Through participation, users may be able to influence the design of a new system and satisfy their needs (Barki and Hartwick, 1994). They may develop feelings of ownership and a better understanding of the new system and how it can help them in their job.

As Locke and Schweiger (1979, pp 266) state *" No issue in the field of organisational behaviour and industrial relations is more loaded with ideological and moral connotations than that of worker participation in decision making (PDM)."* During the last decade, the necessity of a participatory approach has evolved into a truism in ergonomics (Hägg, 2003). Many have stressed the importance of participation, e.g. Pasmore (1988). However, when speaking about participation, different people mean different things. For some, it is enough to sometimes ask the operators during a change process if they disagree with the planned changes. Ives and Olson (1984) divide the degrees of user involvement into six sets of categories, viz. *No involvement, Symbolic Involvement, Involvement by Advice, Involvement by Weak Control, Involvement by doing,* and *Involvement by Strong Control*. It should be remembered that employee involvement also consists of Information, Knowledge, Rewards, and Power (Lawler et al., 1992).

Locke and Schweiger (1979) state two major categories of benefits derived from PDM. One is the increased morale and job satisfaction and their frequent companions reduced turnover, absenteeism, and conflict. The other one is productive efficiency with higher production, better decision quality, better production quality, and reduced conflict and cost. However, involving ergonomists and operators in early design cycles is still not obvious (Hendrick and Kleiner, 2001).

The reason for this may be that researchers have criticised participation. Davis (1966) harshly criticised worker communication programs, participation techniques directed at providing

workers with 'feeling of importance', and human relations programs dealing with personal relationships and supervision. He says that all too often they do not even reach their own stated objectives. Thorsrud (1976) also states that employees at the lower level of the hierarchy are initially quite sceptical or passive and in some cases negative to participation in change. The reason for this was not because they were not interested, but because they had had bad experience from older change processes. Ives and Olson (1984) state that evidence of a relationship between user involvement and system quality or acceptance is not strong and that the research presented is not that rigorous, at least not in their field of research, i.e. computer based information systems.

The number of people effectively involved in a decision is limited (Mankin et al., 1997). Mankin, Cohen et al. continue by stating that nothing gets accomplished when everyone participates, though the ongoing involvement of key stakeholders is critical. Hence, if everyone cannot be part of the decision-making in a project group, other ways have to be applied to get people involved. Webb and Price (1997) state that the technology to make it all possible is already here. The problem is the cultural hurdles to be surpassed, while the processes need to be regarded as institutionalised. McDonnell Douglas conducted a project demonstrating that three-dimensional master modelling can eliminate two-dimensional drawings and enable physical mock-ups to be replaced by computer generated virtual prototypes (Webb and Price, 1997). Webb and Price state that the introduction of modelling and simulation tools in the virtual manufacturing environment enables proactive involvement by manufacturing engineers early in the design process. By using ergonomic simulation tools and other visualisation tools people can more easily understand and therefore participate in the discussion regarding the new technology. Another solution can be, as Mankin, Cohen et al. (1997) argue, that people with lateral skills should be picked for project teams, since they are able to work effectively with team members of different backgrounds, perspectives, and agendas, and are willing to limit their personal autonomy to achieve the main objectives that link everyone on the team.

3.1.4 The socio-technical perspective- a widespread perspective

Diffusion of the socio-technical perspective took different directions in various nations. The Scandinavian countries, the Netherlands, North America and Australia had leading roles in its development. Mumford (2003) argues that one reason the approach started in Europe was because Europe industry during the 1950s and 1960s was seen as centralised and authoritarian. The socio-technical perspective was a counter force to this.

What happened in the UK and the US can be found in a summary report of the English and US socio-technical field studies (Davis, 1966). What is of greater importance is that in Scandinavia, Fred Emery began some pioneering projects in Norway with Einar Thorsrud of the Norwegian Institute of Industrial Social Research that spread to other parts of Scandinavia (Mumford, 2003).

The developments in Norway were soon followed by developments in Sweden, whose context was similar to that of Norwegian (Davis, 1971). Sweden made its first efforts towards the democratisation of working life through the establishment of joint industrial councils in 1946, followed in 1970s by the Joint Regulation of Working Life Act (Mumford, 2003).

In Sweden, the LOM program (Arbetsmiljöfondens program för Ledning, Organisation och Medbestämmande) was just one example of the changes in working life. The most famous

example, as mentioned in the background, is the creation of the Volvo plant in Kalmar with its autonomous work groups. Increasing efficiency and improving the quality of working life were two simultaneous objectives for the Volvo organisation during the 1970s and 1980s (Jönsson and Lank, 1985). Although it is still discussed today whether the Kalmar plant was a failure or not, Jönsson and Lank (1985) state that Kalmar was a success economically and regarding quality of working life.

When Håkansson (1995) discusses change strategies in working life in Sweden, she concludes many workplaces choose a strategy that is more advanced than they are capable of handling. Even though a broad strategy is chosen that include workers, it is often still management who has the responsibility for change projects. It is the time factor that compensates for the lack of organisational conditions and makes the broad strategy superior than other strategies. There has been a strong tradition of worker participation in Sweden ever since the democratisation of work, described above. Much research in the field of participation regarding work environment design can be found in Sweden today, e.g. Garmer (2002), Sundin (2001), and Lindberg (2000).

3.1.5 The socio-technical perspective in a present context

In 1976, Thorsrud foresaw that the technocratic scenario would not be suitable for the future. If nothing else, the new laws on work environment would put an end to optimising the technical system of work, followed by considering the human and environmental effects. It is questionable if these laws indeed stipulated that end. Still today, exemplified by the project described in this thesis, this approach is still used. Geert Hofstede, a Dutch expert, believed that the humanisation of work could become the third industrial revolution after the move from muscle power into machinery and the information technology (Mumford, 2003). The future will tell if this is the case, but it is hard to find evidence for this evolution of work being a high speed process. What can be said today, in accordance to Mumford (2003), is that the predictions of the 60s and 70s that technology would bring many of us an idyllic life of leisure and wealth in the future appears to have little validity. The new technologies are necessary, but the problems that come with them, e.g. monotonous work tasks, have to be solved.

Pasmore, Francis et al. (1982) state that evidence pointing to the socio-technical systems approach to work restructuring may have moved through introduction, experimentation, and evaluation, into the stage of general acceptance and implementation. Modern STDS interventions can be methodologically treated as theories of practice and the famous 'nine step method' for socio-technical analysis developed by Emery is one example of this (Pasmore, 1995, Emery, 1993). The analysis consists of; *initial scanning; identification of unit operations; identification of key process variances and their interrelationships; analysis of the social system; people's perceptions of their roles; analysis of the maintenance system; analysis of supply and user systems; analysis of the work environment and any proposed development plans;* and *proposals for change*.

Historically, the socio-technical perspective has been a counter force to scientific management and in some part mass production. Today, this struggle has changed guise and is sometimes between a socio-technical perspective and lean production. They can both coexist in an organisation, though they have different directions and stress different things. In essence, lean production is a hybrid of both mass and craft production systems (Genaidy and

Karwowski, 2003). Unfortunately, according to Genaidy and Karwowski, Womack and co-workers, who are said to be the source of the concept, have not presented any data about the demands and resources available to the worker in a lean production environment.

Today, the socio-technical perspective can be found under different names. For example, High performance work system (HPWS) is stated to be a continuation of the socio-technical perspective, where a holistic approach to work, people, technology, and information is part (Nadler and Gerstein, 1992). In recent years, an approach to flexible productive systems in the Netherlands, called AFSP, has been presented as a practical Dutch socio-technical system variant (Eijnatten et al., 1992). What has been understood by some social scientists for decades (Pasmore et al., 1982) is still a challenge for social scientists in the post modern industrialised world, and that is to help create the technologies of the future and not be focused on correcting the problems created by the already outdated technologies in use in most organisations.

Eijnatten, Hoevenaars et al. (1992) state that STSD, socio-technical system design, is becoming less and less popular. The reason for this is discussed, but arguments such as conceptual inadequacies, restrictive emphasis on the work group level, and expert-led application scenarios have been identified as some of the major weaknesses of the original approach. Critique against the socio-technical perspective will be further described in a later section of this thesis.

In Sweden, there is still a strong focus on the socio-technical perspective when developing new production systems, even though it is equally mentioned today. Parts of the socio-technical perspective can be found under new names and belonging to new organisational concepts such as Lean production. One production system development project with a clear socio-technical perspective is found in the study presented by Kihlberg et al (2005). This was a project within COPE (Cooperative for Optimization of industrial production systems regarding Productivity and Ergonomics), whose main objective was to develop methods and action plans for socio-technical optimisation of industrial production systems. Signs of a continuing focus of the socio-technical perspective are found, but e.g. Börnfelt (2006) states that a trend of dehumanisation of industrial work can be noticed in Sweden, foremost in the decrease of influence in the labour market.

3.1.6 Critique against the socio-technical perspective

Because the socio-technical perspective has been around for nearly 60 years, it is no surprise that much critique has been stated against it (Scarbrough, 1995). The major issue has been the discussion of whether the socio-technical perspective is a theory or not, or if it is just an approach or a perspective. Davis (1971, pp 186), states that it can be regarded as a theory, that *"socio-technical systems theory is concerned with any organizational setting in which men combine their efforts in cooperative activity with technology toward the achievement of a goal."* Into the discussion of whether the socio-technical perspective should be regarded as a theory or not, Pasmore, Francis et al.(1982) state that the socio-technical theory has become eclectic. A question is if this is something that should be regarded as negative or positive. Selecting the best parts from other theories can be a good thing, but it is not good if the term eclectic stands for uncritical and not independent. In this thesis the socio-technical perspective is regarded as eclectic in a positive way.

One reason why the socio-technical perspective has not been widely used is because efforts in its direction often become entangled in the politics of the situation. For example, union and top management resistance is often cited as a problem along with economic conditions, turnover among key personnel, rapid changes in technology, and jealously on the part of other groups or units. However, the fact is that it is not thought of as a "power friendly" approach, such as Total Quality Management (TQM) and Business Process Reengineering (BPR). For those supporting the socio-technical perspective, Pasmore (1995) states that the price has been high, as they have been overlooked for promotion or branded as 'soft-hearted' or 'to far out' by their peers, which reflect similarities to them supporting work environment issues. To sum up, the socio-technical system can be seen as too risky, too complex, difficult and politically dangerous. Regarding the socio-technical system, Clark (1975, pp 184), says that it is *"highly relevant, least understood and rarely applied perspectives*."

Criticisms against the socio-technical perspective can be grouped under two headings, i.e. questions about the validity of viewing organisations in terms of systems and subsystems and the challenges to the level of analysis implied by the socio-technical theory. Some say that conventional STSD is not as integral as it claims to be (Eijnatten et al., 1992). Parker and Wall (1998, pp 17), state that Chern's principles of the socio-technical perspective is a *"general, normative and largely content-free approach to organization design."* However, this critique is also directed at, for example work environment legislations. It is more about how the approach is used. Much critique has been stated against the socio-technical perspective, stating it does not involve all steps of a supply chain (Niepce and Molleman, 1996). Although the seventh step in a nine-step analytical model of socio-technical inquiry (Trist, 1981, Emery, 1993) involves a larger part of supply chain management or more exactly how these parts affect the particular production system.

Historically, the approach has only meant job design for some, for which this branch of the approach has been criticised. Parker and Wall (1998) argue that the socio-technical perspective is a general and vague guidance on the nature of job design and the expected consequences for outcomes. However, there has been positive critique. Cordery and Wall (1985) state that the socio-technical system approach offers a much more complete approximation of the complexities inherent in work design than the more restricted job characteristics perspective.

In summary, despite the negative critique, it can be stated for this thesis that the socio-technical perspective can be better understood as what Johansson (1999) calls *"a condition to reach rather than the way to go there"*. The socio-technical perspective can be used to give guidance to analyse how work environment issues are regarded in project development work.

3.2 Work environment design

Technology is a double-edged sword, and according to Chapanis (1979) our mission is to reinforce the good and oppress the bad. When discussing the bad consequences of new technology, an often-referred cause is resistance. Resistance to change may be described as a pyramid with three levels: not knowing, not able and not willing (Galpin, 1996). When one level is satisfied, people move up to the next level. Even if the unwillingness of people to change is one great factor that works as a barrier to success, another one is the low

understanding of the need for change (Bentley, 2003). This thesis will not delve deep in the reasons for change, but deal more with what happens when the decision of change is already taken, because this is where the problems of work environment design in international collaborative projects are prevalent. People are aware that technological changes evoke organisational changes, but not everyone realises that the opposite may occur, i.e. that organisational changes evoke technological changes.

The field of change methodology is a huge field and too big to thoroughly explore in this thesis. Instead, some delimitations have to be made. A difference has to be made between systemic and systematic. Systemic means affecting the whole organisation, whereas systematic is how the change is conducted. This is important in this thesis, since the problems shown are systemic, though one of the causes is regarded as a lack of a systematic method.

In the field of change methodology, several explanation models can be found. According to Cummings and Worley (1997), a model is a simplification of some phenomenon for the purposes of study and understanding, and the concrete embodiment of a theory. To follow a model is to behave in an idealized way so that others might learn or change their behaviour by identifying with and adopting those behaviours displayed.

In this thesis some of the most famous models will be briefly described. Utterback and Abernathy (1975) describe a dynamic model of innovation consisting of both product and process innovation, as well as softer aspects as work organisation. This distinction is interesting, since work environment is affected by all three of them.

One of the most cited models in research literature is the model and taxonomy of organisational change by Porras and Robertsson (1992), where they divide the change in *order of change* and *change category*, see Table 1. The EU-project studied can be said to be planned and of second order, i.e. transformational. However, some of the changes that come as consequences of the planned change can be evolutionary for the companies that will use the developed technologies.

Table 1 The types of organisational change according to Porras and Robertson (1992)

Order of change	Change category	
	Planned	*Unplanned*
First	**Developmental**	**Evolutionary**
Second	**Transformational**	**Revolutionary**

Another famous description of change is Kurt Lewins' three stages of change (Lewin and Cartwright, 1951) see Figure 4. In his formation, the change process can be divided in the stages of unfreeze, change or transformation, and freeze. Lewin meant that the organisational structures have to be initially unfreezed where everybody prepares for a coming change and becomes change ready. In the second stage, the real change or transformation takes place. Finally, the new place of stability is established. The question is whether this perspective is possible to use when working with new production processes in international collaborative projects?

Figure 4 Kurt Lewins three stages of change (Lewin and Cartwright, 1951)

Sadler (1996) describes the organisational change in a four fielder with time on the x-axis and magnitude on the y-axis. In the EU-project in this study, the technology developed makes three fields interesting. If the technology has a great influence on the organisation and if it will be handled on a short-term basis, it is in the field of quick fix. However, if the change has a long-term perspective and a low magnitude of change, it is in the field of incremental or evolutionary change. The last alternative for the project described would be high magnitude and long-term perspective, where a transformation or radical change will take place.

Some researchers, e.g. Klein (1976), state that people are hurt by rapid change, though it may depend on how the change is conducted. Many argue that the rate of technological change increases (Goodman et al., 1990, Adler, 1992). Most of the changes taking place in production sites are in line with an effort to automate the production process as much as possible. There is an ongoing discussion whether automation leads to more or less jobs (Adler, 1992). Advocates of the first opinion state that because automation would lead to higher output, the production cost can be limited when producing more products. Others state that the output will be the same, but with less work opportunities. However, without automation, there may soon be no production jobs left in the western countries. Those who choose to automate will gain work opportunities, but it needs to be done with a human perspective.

Bainbridge (1983) mentions two ironies with automation. The person who often tries to eliminate the operators will still leave them to do the tasks that he cannot think of how to automate, and designers' errors can be a major source of operating problems. Both are of importance in this thesis.

Many models focus on how to change technologies and aspects around this. Checkland (2000, 1990, 1981) developed a model that was easy to teach and understand, and more focused on the soft aspects of management instead of the more common hard, technologically driven. The *soft system model* is based on system thinking and is about managing anything, i.e. overarching issues (Checkland and Scholes, 1990).

As can be seen in these few examples, the models are not specific to work environment design, but are instead interested in either how the change is conducted on a theoretical level or even more in the outcome of the change regarding technologies. Thus, they can be regarded as insufficient when working with work environment design.

3.2.1 Work design theories

Herbst (1954) established the fact that changes to any component part of a social system generally result in complex changes and adjustments in other parts of the system. This was described in the theory section of the socio-technical perspective. It becomes even more

complex when these social systems overarch different national cultures. These issues are not deeply explored and Adler (1992) writes that researchers need to dare to generalise between different countries to benefit from each others' experiences.

Torraco (2005) describes six different theoretical perspectives on work design – *socio-technical systems theory, process improvement, adaptive structuration theory, the job characteristics model, techno structural change models,* and *activity theory*. Beyond the *socio-technical system theory*, which is by far the most commonly used in this study since it forms the basis of the perspective used in the research conducted, all the others have connections to the EU-project studied.

The *process improvement,* which is a part of the quality improvement theory, is based on the understanding of how work is accomplished during various phases of the process being the key to successful efforts to improve or redesign work (Torraco, 2005). In line with these trains of thought, this research study began by getting to know the processes considered affected by the new technology being developed in the EU-project.

According to Farias (2000), in the *Job Characteristics Model*, the internal motivation among employees is based on their feeling of meaningfulness of work, responsibility for the outcomes of the work, and knowledge of the results of the work. To achieve these states the work should be designed with an optimal level of skill variety, task identity, task significance, autonomy, and feedback. Hackman and Lawler III (1971) conceptualise the impact of job characteristics on individual work behaviour and attitudes with the Job Characteristic Model (JCM). A few years later, Hackman and Oldham's (1980) approach to the design and redesign of work in the form of the JCM is something of a hybrid between the behavioural and systems approaches, i.e. to some extent the JCM is derived partly from the socio-technical perspective. JCM and socio-technical systems are very similar, e.g. they are both driven by humanistic values (Farias and Varma, 2000). However, as for the socio-technical perspective, there is also criticism towards the JCM, since studies show only limited support for positive outcomes (Kelly, 1992).

Torraco (2005) describes *Technostructural Change Models* as affecting change by reconfiguring the organisation's technology and structure. These models are used to design or redesign major processes or work units, or to restructure entire organisations. Thus, the models are of broader scope than, for example, JCM. Torraco states that more attention is given to technostructural change as the emphasis on organisational effectiveness and sustained competitive advantage increases. Since the EU-project lay outside the participating organisations, it is not possible to say it was due to a *Technostructural change* in its core. If the technologies developed are instead examined in a larger perspective, they can be a part of the technostructural change within companies that decide to implement them.

The core of *Activity theory*, as Torraco (2005) states, is that the concept of activity as a unit of analysis includes both the individual and his or her culturally defined environment. This theory is psychologically based and even if it was not applicable for the EU-project in this study, it could be another way to analyse the work in the EU-project regarding the work environment, where language, project models, checklists, etc. all can be regarded as tools that make people interrelate with their surroundings. Some of these activity aspects can be found in different discourses described in this thesis, though the specific theory of *Activity theory* lies outside the scope of this thesis.

The last perspective described by Torraco is *Adaptive Structuration Theory*. This theory stresses how the adaptation of new technology can be examined from two sides, i.e. the type of

structures set by advanced technologies and the structures that emerge in human action as people interact with these technologies. Because the EU-project did not reach the implementation stage, neither the empirical material nor the scope of this thesis pointed towards using the theory. Even so, the importance of the theory is understood, since people in different cultures work in different ways with the same type of technology.

The scope of *techno structural change* can be seen as system wide, while *process improvement* and *socio-technical systems theory* can be seen as intermediate (Torraco, 2005). However, the latter two can both be used outside the sub systems, i.e. system wide, as well as for job and task specific applications. The *job characteristics model* is foremost concerned with job or task specific issues and is not intended for scopes in the range of intermediate and system wide. Torraco (2005) states the *job characteristics model* establishes specific task design characteristics and the conditions under which they enhance work motivation and work related outcomes. *Technostructural change models*, however, have emerged to address the need for different types of work structures, including traditional, structural and functional designs.

According to Torraco (2005), all six work design theories discussed in his paper explain work designs of the past better than they explain how to design work for some present and future setting. Still, it is my interpretation they together comprise parts important for future design.

3.2.2 Operational models for work environment evaluation and design

Models for change often soar on a high theoretical level where work environment design questions can be left out and not prioritised. One type of model that somewhat considers these matters is the work design models described above, e.g. JCM. There are four major interdisciplinary theoretical approaches to industrial work design (Das, 1999). They are the *mechanistic approach,* which is based on the concepts of division of labour, specialization, and simplification, and is highly influenced by scientific management and motion economy/methods. The second, the *motivational approach,* is focused on pointing out the drawbacks of too much specialization and over simplified jobs, and is influenced by various psychological theories from organisational psychology. The third, the *perceptual-motor approach*, is based on the ergonomics/human factors discipline and deals specifically with issues such as lighting, displays, workplace layout, information processing and stress. The last one, the *biological approach,* is also based on the ergonomics/human factors discipline, but deals with work physiology, biomechanics, and anthropometry. This approach especially deals with human strength, lifting, seating, work environment and work rest schedule. Das (1999) summarises the four approaches by stating that the important thing is to make an endeavour to design work that will minimize the conflict among approaches. This is because the organisation and design of one's work environment significantly shapes the contribution one makes to the organisation (Torraco, 2005).

When identifying hazards in the manufacturing industry with regards to the four approaches, many different safety analysis methods are available. Willquist and Törner (2003) illuminate several in their literature study, e.g. BeSafe (safety of products), Change analysis (systems of different kinds), Energy analysis (energies are identified), Deviation analysis (deviations from normal production process), Facilities hazard analysis, HAZOP (hazard and operability studies), Job safety analysis, and MORT (management oversight and risk tree). All are assorted with a holistic perspective over the system. A checklist is mentioned as a method that is completely dependent on the quality of the checklists, i.e. whether the right questions

are being asked. The methods are presented with a brief description of method procedure; for some, Harms-Ringdahl (1987) presents a more developed description. Willquist and Törner (2003) diversify the methods in two, one encompassing 'morphological' methods and one encompassing methods for 'forward' or 'backward' event tracking analysis. Examples in the second group are Action error analysis, Cause consequence analysis, Event tree analysis, FMEA (failure mode and effect analysis), and THERP (technique for human error rate prediction). All these methods can be seen as tools to identify hazards, but several questions remain, e.g. Who is responsible for using them? What tools are applicable when you have the future production process only in ideas and drawings?

Hence, why stress the importance of involving work environment factors in change models? About 30 years ago, Welford (1976) saw a lack of cases where ergonomic changes had been proven to confer a substantial benefit. Welford concluded that it was not always clear if the investments made in ergonomics were worth their cost. However, the ergonomic changes Welford talks about are concerned with just the ergonomic factors. This study is about how to take care of these factors while changing substantial technologies in the production system. The main objective is thus to improve the technologies, while improving or at least not deteriorating the work environment. Another fact contradicting Welford is that, as Chapanis (1976) argues, during 1959-1976 ergonomics had widened its boundary and involved more fields than anyone could ever have dreamt about 17 years earlier. This evolution has continued until today and it is hard to dispatch the work environment as a small subject, insignificant to the overall profit.

Already in 1966, Davis had mentioned work models for the physical environment and physiological requirement, but not nearly to the same extent for organisational, social, and personal requirements. In addition, the physical environment has to be acknowledged when developing new technology, since it sets new conditions for the work environment. A typical example that is also relevant for this study is as Schulz and Würz have shown, that in high-speed machining as compared with conventional machining the tools can, due to substantially higher centrifugal forces, be subject to a novel load component resulting in a considerable hazard potential. This means that machines have to be designed for high speed from the beginning or that precautions must be taken when the use of the machines changes (Schulz and Würz, 1998).

Ergonomic programmes are systematic processes to anticipate, identify, analyse, prevent and control hazards that are present. However, current literature reveals that links to company core values, such as quality improvement, are often lacking in ergonomic programmes and are still often seen solely as a matter of health and safety (Hägg, 2003). Hägg states that guidelines of these programmes concerning aspects such as workload, work postures, movements, lifts, equipment, product design, noise levels, vibration, lighting, climate, procedural information, safety and work organisation can be included. However, these guidelines focus on changes when the main objective of a project is to take care of the present work environment and not, as in this case, optimise both production techniques and work environment for a future process. One old example is presented by Umstot, Bell, and Mithell (1976), i.e. an integrated model of job design combining both goal setting theory and job enrichment theory. This will create both satisfied employees and productivity. Still, there is a lack of a holistic approach whose main objective is to improve the production system as a whole system and not as parts of it.

There are more examples of models concerned with the work environment, e.g. Eijnatten, Hoevenaars et al. (1992). Their model shows that the process of redesign is affected by knowledge, environment and methodology in three different levels; micro, meso, and macro. Another model is presented by Das (1999), whose model shows that by manipulating the factors affecting the industrial work design, it may be possible to achieve desirable work design attributes, which in turn influence design outcomes such as production, quality, job satisfaction, worker safety, health and well-being.

Other researchers, e.g. Levi, Slem et al. (1991), have concentrated on the impacts of technological change. Still, the presented models and methods do not concentrate on how to overcome and prevent some of these negative impacts, and a more pragmatic way to tackle the problems is missing.

In addition to these models, there are also methods on how to visualise and describe the work environment. For example, the InStOu (Input-State-Output)- model (Schmidt and Antonsson, 2002) describes where work environment key figures can be set up. Input are contributions made for a better work environment, State describes the status of the work environment and Output describes the effects of the shortcomings in the work environment. This model describes a well-discussed field, i.e. how to translate the work environment into monetary terms, if that is desirable; see earlier remarks in this thesis. One example of this is the well-known method in Sweden, the WEST-method (Work Environment Screening Tool), which is a process method including both physical and psychosocial impact categories. The following impact categories are included:

- Risk of accidents
- Physical work load
- Noise
- Chemical health hazards
- Vibrations
- General physical environment
- Social relations
- Work content
- Freedom to act

(Schmidt and Antonsson, 2002)

In the WEST-method, all the categories are summarised and an estimated cost for defaults is presented. The cost is a summary of societal, company, and individual costs, based on real ill health statistics. A shortage of the model is that it does not separate the costs between the society, company and the individual, but treats it as a whole. So far, this method is only adapted for Swedish related activities, since the cost is based on how much accidents, etc. are estimated to cost in Sweden.

Concerning how to prevent bad work environment, one of the most common solutions is guidelines and checklists. The list of guidelines and checklist is long, each within its specific field, e.g. checklist from the Swedish Standards Institute, checklist described by Pulat (1992), etc. One example of guidelines for function allocation is presented in Sharit (1997). Another

example that can be of a more holistic character is the ergonomic programme at Volvo Car Corporation described by Munck-Ulfsfält et al. (2003). This programme consists of a series of checklists adapted to the design process, which is close to what is presented in this thesis, but not intended for inter-organisational projects. Studies are also done on how to access ergonomic guidelines where visualisation with help of an interactive multimedia system seems to be a good alternative (Blomé et al., 2006). However, general checklists do not involve the operators very much, but are more for the engineers inventing the technologies. Some of the checklists do involve the opinions of operators, but only when a present work environment is available.

As mentioned above, most of the models and methods handling work environment factors only focus on these matters and often only suit projects that have the work environment as a main objective, not inter-organisational projects. The scientific evaluations of these ergonomic programmes are too often insufficient or missing, especially in economical terms, (Hägg, 2003). Only a few companies have reached the state where ergonomics constitutes an integrated part of the overall enterprise strategy. Another problem according to Hägg is that all reports, including the scientifically good ones, are success stories. It is most likely that there are also failed programmes, and maybe even more interestingly, programmes that were never started due to resistance from management. These reports are extremely hard to find or perhaps they were never written. One example of the positive reports is about the car manufacturer Mercedes-Benz, who has developed a system for assembly production planning, which also considers ergonomics (Bullinger et al., 1997). The choice of only presenting successful examples can be seen as a deliberately chosen strategy, to either create good PR for a company or for the reason that other organisations are believed to follow. This strategy can also be found on each EU member state's focal point on the webpage of The European Agency for Safety and Health at Work (European Network- Sweden, 2006), where good practices from each country are presented. This can be criticised, since it describes solutions and seen risks as the only way to do it. It can also be seen as a positive way to handle knowledge transformation between organisations, as long as people realise that each situation is unique and adaptation is necessary.

3.3 Different perspectives regarding work environment design

Each and every one of the theories described in this section can be understood as abrupt and briefly described, but together they create a foundation for a theoretical analysis of the empirical material when analysing different perspectives regarding work environment design.

The perspectives of work environment design were differentiated between the participating partners in the EU-project shortly after the start of the project. How could these differences be explained? After careful consideration, I chose theories that together could help describe and explain many of the differences. As Goodman et al. (1999) state, the added complications inherent in international project teams have been ignored in general. However, Chevrier (2003) describes how different national cultures impact cross-cultural project teams and different strategies for project managers to cope with cultural diversity, and not for specific fields of development.

The difference regarding participation in the EU-project can be traced back to different workforce perspectives. McGregor (1960) came up with the theory of X and Y when

speaking about workers and control, etc. Although the theory can be focused on individuals and based mainly in the field of American organisation theory, it has strong connections to how people perceive participation and the ones who will work in the developed production. It helps to explain why participation has a positive or negative ring to it in different contexts. The theory X says:

- The average human being has an inherent dislike of work and will avoid it if he or she can.
- Because of the human characteristic of disliking work, most people must be coerced, controlled, directed, or threatened with punishment to get them to put forth an adequate effort toward the achievement of organisational objectives.
- The average human being prefers to be directed, wishes to avoid responsibility, has relatively little ambition, and wants security above all.

In contrary, the theory Y states:

- The average human being does not inherently dislike work. Depending on the controllable conditions, work may be a source of satisfaction (and will be voluntarily performed) or a source of punishment (and will be avoided, if possible).
- External control and the threat of punishment are not the only means to bring about an effort towards organisational objectives. Man will exercise self-direction and self-control in the service of objectives to which he is committed.
- Commitment to objectives is a function of rewards associated with their achievement.
- The average human being learns, under proper conditions, not only to accept but to seek responsibility. Avoidance of responsibility, lack of ambition, and emphasis on security are generally consequences of experience, not inherent human characteristics.
- The capacity to exercise a relatively high degree of imagination, ingenuity, and creativity in the solution of organisational problems is widely, not narrowly, distributed in the population.
- Under the conditions of modern industrial life, the intellectual potentialities of the average human being are only partially utilised.

According to McGregor (1960), it is important to leave the thinking of theory X behind us and not fully embrace theory Y. This still applies today, where some parts of theory X can be found in the companies studied and in the project organisation they all participated in, as described in this study. A perspective based on theory Y, both unintentionally and intentionally, permeates this thesis. The underlying reason may be the Swedish origin with a strong participative tradition (Walters and Frick, 2000).

3.3.1 Industrial Relations

Industrial Relations (IR) is an important part of how successful a trans-cultural project can be. Since the scope of Industrial Relations theory has broadened, the issue of how work environment issues are dealt with is part of it. The three contexts of industrial relations, viz. *the technical conditions of the workplace and work community, the market or budgetary constraints,* and *the locus and distribution of power in the larger society*, can all be found in this study, e.g. the

tracks of new developed technologies, the economic resources to accomplish it, and the motive power to develop them. Although Dunlop (1993) separates the three, they affect each other and all three contexts point out the presence of different discourses. What in the past were only issues for the union and the workers is now definitely important to employers to maximise profit, e.g. measures to avoid absence due to illness, etc.

The theory of Industrial Relations deals with explaining variations in the conditions of work, the degree and nature of worker participation in decision-making, the role of labour unions and other forms of worker representation, and patterns of cooperation and conflict resolution among workers and employers (Industrial Relations, 2005). During recent decades, Industrial Relations theory has gone from Karl Marx ideas about questioning the role of workers as commodities in the mid-1800s to involving many more nowadays. Marx argued that the entire value of production came from the worker's input and labour should therefore own the means of production. He continued by stating that in a market economy the means of production are owned and controlled by capitalists, thereby exploiting the workers. In the late 1800s and the beginning of 1900s, Sidney and Beatrice Webb from the UK agreed that workers and employers were separated by class interests. The only way to improve their economical and social conditions was to form strong unions. This would eventually lead to a socialist state. Contrary to Marx, they stated that this could be done without a revolutionary overthrow of the capitalist system.

The American John R Commons also went against the commodity view of labour. He and his associates argued that the traditional view of supply and demand is influenced by the policies, values, structures, and processes used to govern employment relationships. In addition, he stated that the conflicts between workers and employers are a natural and legitimate part of any employment, whether there is a capitalist or socialist system. Mr Commons and his associates, also called the institutional economists, emphasised the importance of legislation protecting the workers. They also participated with ideas when President Franklin D. Roosevelt presented the labour legislation in his program 'The New Deal' in the 1930s.

Unionism in the US increased and reached a level where one-third of all workers were union members by the end of World War II. Several factors led to a large number of strikes breaking out after the war, which implied the creation of several Industrial Relations research and teaching programmes at leading American universities. This was the start of the modern field of Industrial Relations.

"Industrial Relations is more than simply an area of organisational management. Its development reflects changes in the nature of work within society (in both economic and social terms) and differences of view about the regulation of employment". This is how the book "*Industrial Relations- Theory and practice"* by Michael Salomon (2000) starts. The book segments the subject matter into four areas: Perspectives, Participants, Processes and Practices. This thesis will not expand the four areas, but examine the theories behind conception.

Overall, the field of IR-theory is very politically influenced and many researchers in the past have had "left wing leanings and identity with unions" (Whitfield and Strauss, 1998, pp 18). This implies a strong focus on unions instead of management. This study focuses on the middle management level, since they are the ones often participating in EU-projects like the one studied. Whether Industrial Relations can been seen as a separate basic discipline or if it is more like an applied field that draws on the basic disciplines has been debated and

discussed. Specific Industrial Relations theory is one attempt to claim its status as being a discipline. Probably the best known example is Dunlop's (1958) "IR systems", though the critics state that the so-called theory is just a form of typology.

Whitfield and Strauss argue that over the last few years the scope has broadened to include the entire world of work-issues, such as "high-performance" work practices, occupational health and safety, employment discrimination, employee satisfaction, job security, and comparative international industrial relations. Comparative international IR is where questions about the different cultures in the workplace come in. This culture has different layers consistent of basic assumptions, norms and values, and products (Trompenaars, 1994).

Some researchers predicted convergence in the past. For example, it was predicted that production techniques and shop-floor labour relations would be Japanized throughout the world (Womack et al., 1991). This seems overstated in perspective, and other researchers agree (Boyer, 1998, Herrigel and Zeitlin, 2000). Even though some similarities can be found, it is a long way before one emerges. In the mean time within the EU, there are forces striving for more conformability. However, little evidence points towards convergence in workplace relations within the European Union (Strauss, 1998). Strauss states that the differences are less important at the workplace than on a society level. Still, there are distinctive differences between how technologies and work practices are introduced. Kochan (1998) states that even though industrial relations has a long history of international and comparative research, an international perspective and approach are especially needed now to make significant advances in industrial relations theory.

Although the empirical material is shallow in regards to IR, involving the theory is important to explain the differences of perspectives between the EU-project participants. IR-theory is used to illuminate the view on workers, the technical conditions of a workplace, and the influence surrounding factors have on work environment design (as directives and policies of the EU). It is also used in the analyses strictly dealing with physical or psychosocial work environment. Furthermore, it is used to illuminate the differences and similarities and to discuss the convergence regarding aspects of work environment between the participating partners.

3.3.2 Discourse Analysis

Discourse Analysis (DA) can be interpreted as a method, though in this thesis, as a theory to describe different approaches of issues regarding the work environment. Fairclough (1994) separates the discourse analysis into three different dimensions. First is the Text dimension, where the attributes of the text are analysed, Second is the Discourse practice, where the production and consumption processes connected to the text are analysed, and finally is the Socio-cultural practice, of which the text and discourse practice are a part of. Fairclough argues that to study the socio-cultural discourse additional theories have to be used. In this study, DA is combined with the socio-technical perspective and Industrial Relations. It is important not to isolate text analyses from institutional and socio-cultural practices, and when speaking about that connection it is advisable to use the conception of hegemony, since:

"Hegemony is leadership as well as domination across the economic, political, cultural and ideological domains of society. Hegemony is the power over society as a whole and one of the fundamental economically defined classes in alliance (as a bloc) with other social forces,

but is never achieved more than partially and temporarily, as an 'unstable equilibrium'" (Fairclough, 1995, pp 76)

While the discourse is present on a local level, hegemony is seen as a process on a societal level. Hegemony can be used to understand local discourses and the struggle between different discourses. This is used in this thesis, since the companies studied represent different discourses and they are affected by a similar hegemony. To understand this connection, the order of the discourse and how intertextual analysis mediates the relation between text and society/culture has to be comprehended. The critical discourse analysis is focused on how the discourse contributes to the reproduction of macro structures and ideologies that are considered central to understanding the discourse.

Alvesson & Sköldberg (1994) state that there are three levels of results of a discourse analysis. First, there is the descriptive level, where the researcher describes the discourse without making any conclusions beyond the context. At this level the use of language, the way to express oneself, conversation, statements, content of texts and phenomena are described. At the second level, the conceptual level, the researcher expresses him/herself about conceptions, values, myths, fantasies, motives, messages, e.g. an interpretation of the statements and the discourse. At the third and last level, the action and relation level, the researcher expresses him/herself about relations, happenings/events, social patterns and structures. The analysis in this thesis mainly deals with the second and third levels of analysis.

Because the discourse creates us as subjects, we create the discourse through discourse practices, e.g. production and consumption of texts. One example is the managerial discourse explained by Furusten (1999). The production, dissemination and consumption of the managerial discourse can be put in a larger context, where it is part of the institutional environments with laws, regulations and social norms and values, and the overall environment of the organisations, see Figure 5.

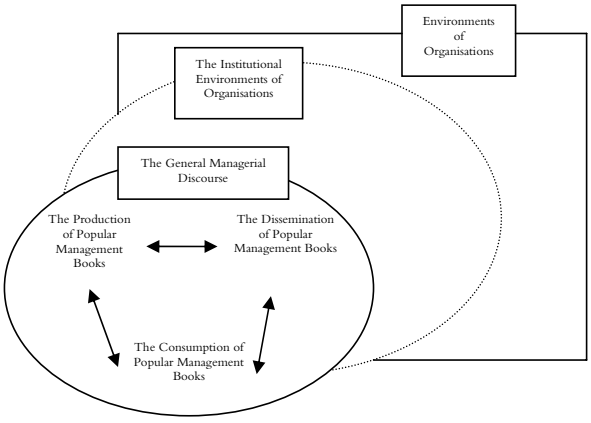

Figure 5 The environments of organisations and the production, dissemination and consumption of managerial manifestations (Furusten, 1999).

In managerial discourses, as in the discourses on work environment, there are different centres of power. People inside the discourse are said to be allies and will support each other

without any major outbreaks from the discourse. Furusten (1999) argues that the behaviour of companies and people are affected by discourses and the institutional environment.

The theory is used to describe and explain if the different discourses regarding work environment design existed in the EU-project, as well as describe the discourses and how they affected the work of work environment design in the EU-project. Parallels are drawn between the management discourse and the prevailing discourses within work environment design.

3.4 Work environment design in project work

The problems of handling work environment issues in the EU-project, which are described in later sections of the thesis, are based on; the project was a form of a temporary organisation (Packendorff, 1993, Lundin, 1998), unique with a start and an end, and that there were no beaten track for handling work environment knowledge transformation in the project. As Neumann and Winkel (2005) state, giving attention to ergonomics last in the design sequence means only very low cost changes may be implemented. Langaa Jensen (2002) argues that the tools to establish this integration are available and that it is often argued to integrate ergonomic considerations into the planning processes, though it is seldom the case in practice. As Andersson et al. (2006) state, one reason may be that the supply of methods within work environment is so rich and almost unforeseeable and impenetrable for the non-specialist. The need for a specialist is also supported by Wulff et al. (1999), who state that it is crucial to ensure a positive outcome for ergonomic criteria in the design negotiation process. To explain this, the theories assumed to have influence over these processes are described.

3.4.1 Knowledge transformation in work environment design

An in-depth explanation of what knowledge is and is not lies outside the scope of this research. Instead, the dimensions of knowledge regarded as important with respect to work environment design in international collaborative projects aimed at developing new production processes is focused upon.

In an EU-project as the one described, two different types of knowledge about work environment factors are present. Some refer to these types as simply *information* and *know-how* (Zander and Kogut, 1995), but a more theoretically used description is exercised. Explicit knowledge is regarded as objective knowledge by many and as knowledge of rationality (Polanyi, 1958, Maula, 2000). In this case, it consisted of knowledge about laws and regulations, along with new research results and recommendations. One part of work package seven, described in section 5, was about illuminating these laws, regulations, and research results and making them more explicit.

Tacit knowledge, however, involves knowledge about how people use to get work environment factors into the final product and the rules of thumbs for possibilities to do this. By definition, tacit knowledge is regarded as subjective knowledge and as knowledge of experience (Polanyi, 1958, Maula, 2000). Takeuchi and Nonaka (2000) state that tacit knowledge is the number one asset with respect to innovation, but since it is not used in a

knowledge spiral concerned with socialisation, externalisation, combination and internalisation, it is not fully taken advantage of.

Tacit and explicit knowledge should not be seen as two definitive alternatives. Knowledge can be seen on a continuum between the two extremes. Although much of the engineers' knowledge can be written on paper, it is more substantial when combined with the commentary of the engineer him or herself, and not even then can all facets be described. It is possible to describe the frames of this sort of knowledge, but not to specify it, since it will become explicit knowledge and no longer be regarded as tacit.

The choice of using Takeuchi and Nonaka's (2000) knowledge spiral and theory can be questioned, since it may be regarded as having too much managerial influence. However, the empirical data and the patterns observed made it applicable for this study, since their theory comprises different ways to transform and transport knowledge between tacit and explicit.

The first process of transformation, i.e. the transformation of explicit knowledge into tacit knowledge, is known as internalisation (Takeuchi and Nonaka, 2000), and should be considered. This is no easy task, but one suggestion can be that the directives are made more easily accessible for those involved in the project. This process is, according to Takeuchi and Nonaka, closely related to learning by doing, since it is about getting the same form of shared mental models or technical know-how. Internalisation is also about spreading the knowledge to other organisations and thereby a form of field building.

The second process of transformation is when tacit knowledge is transformed into explicit, known as externalisation (Takeuchi and Nonaka, 2000). It is not feasible to transform all tacit knowledge into explicit, but demarcations have to be made. According to Takeuchi and Nonaka, it is within the externalisation phase where the key to knowledge creation can be found, since it creates new explicit concepts from tacit knowledge. The use of metaphors, analogies, and models all help in the work of transforming the tacit knowledge into explicit.

The third type of transformation is actually not a transformation, but rather a type of transportation, namely from tacit knowledge to tacit knowledge. This transformation is also referred to as socialisation by Takeuchi and Nonaka (2000) and stipulates the process of sharing experiences and thereby creating tacit knowledge, such as shared mental models and technical skills. The knowledge each individual brings into the project is valuable, even though the different knowledge can sometimes contradict each other. As mentioned above, not all tacit knowledge can be transformed and codified into explicit, but tacit knowledge can be transported anyway. Through social interaction, this type of knowledge can spread throughout the team members. In the EU-project, the limited number of meetings implied that these alternatives were decreased and the importance of having a similar mindset to communicate with each other was increased (Trompenaars, 1994).

The last type of transformation is also a form of transportation, when explicit knowledge is transported into explicit knowledge, refer to as combination by Takeuchi and Nonaka (2000). That is where different bodies of explicit knowledge are combined. Andersson et al. (2006) state that the central mission is to achieve an effective knowledge utilisation within the field of work environment and a better practical work with it, to increase the motivation for individuals who do not professionally work with work environment issues.

Theories about knowledge transformation will be used to explain the problems observed when trying to get all EU-project partners to work towards a common goal, i.e. a 'good' work environment.

3.4.2 Project organisation and project management

It was not until the 1950s when project management was acknowledged as a theoretical field (Engwall, 1999). Engwall states that a greater part of project management literature is in the form of practical oriented handbooks filled with checklists and practical guidelines for professional project leaders. The literature is preferably written by engineers with personal experience of practical project work. Consequently, the practical orientation is a shared mindset by the researchers and the end users. Nothing indicates that successful projects are better planned than less successful projects. However, the normative implication of the symbolic function of planning is not the plans themselves that decide whether or not a project will become successful, but in what purpose the plans are set and how they are used (Blomberg, 2003). This is also the case when integrating work environment design in project work. Even if it is possible to create a project model optimal for integrating work environment factors, it must not be forgotten that every project is unique. Thus, such a model needs to systematise and support the work, but not be too structured.

Engwall's (1999) definition of a project that is adopted in this thesis is translated from Swedish, *"..projects are goal oriented, demand coordinated undertaking of interrelated activities, have a beginning and an end, and are unique.."* Accordingly, the EU-project falls under this definition. As in the EU-project, its aim always changes, sometimes a little and slow and sometimes radically and fast (Blomberg, 2003). Not only does the aim change, but the work in the projects continuously changes over time (Engwall, 1999).

There are always several competitive objectives in a project and what is going to be achieved depends on the participants changing influence and interest, i.e. power structures rather than rational decision-making processes (Blomberg, 2003). The project objectives have three dimensions, viz. costs, time, and quality (Engwall, 1999). Engwall states several researchers claim that optimisation as a combination of the three is impossible, since they are dependent of each other. However, the objectives of the participants can change and evolve during the time of the project work. Often, the objectives are redrafted after the results of the project are observed (Blomberg, 2003).

While there are four basic phases of a project life cycle, according to Engwall (1999), viz. concept, development, implementation, and termination, the research presented in this thesis is also influenced by the next step of the product life cycle, i.e. operation and the corresponding phase of the corporate business life cycle, product in service. Adopting Packendorff's (1995) descriptions of the project as a tool can be useful when looking at the project with the sequences of plan, control and evaluation, or the project as a temporary organisation with expectations, action and learning.

It is of interest to note how knowledge and experiences on work environment aspects are transported to future, similar projects. Björkegren (1999) and Tell and Söderlund (2001) are two of the few dealing with this problem, especially regarding knowledge transfer between projects within an organisation. In the research study presented in this thesis, the project organisations are outside of their own company organisation and therefore additional problems occur, e.g. when no one with previous experience of similar projects participates in

the new project. Antoni (2001) is another advocate of the importance to support both intra- and inter- project learning, and states that the short time perspective of a project, with a start and an end, implies a lack of motivation for project participants and in particular project managers to spend time on transportation of knowledge from one project to the next.

The theory of project organisation and project management will help to explain and describe how the EU-project was run. Cost, time and quality dimensions of the EU-project will be discussed with respect to work environment, and it will also be stressed that changes within the project will affect the work of work environment design. The theory also forms the basic design of the final work model for work environment design presented in this thesis.

4 Methodology

The aim of this research is to describe, explain, and enumerate obstacles and opportunities regarding work environment design when developing new production systems in an international collaborative project. The EU-project studied ran from 2002 until 2005 with the aim to develop new production processes for manufacturing large non-rigid aero structures. Five nationalities participated in the project. The EU-project was divided into eight work packages, of which I with four colleagues from Luleå University of Technology formed a research group that participated actively in one out of the eight work packages. The work package was named "Evaluation of socio-economic effects- WP7". Within the work package our group was to conduct analyses and to design a model for handling work environment design, from early development to industrial implementation. This work was comprised of four different sub-tasks, viz. *Work environment factors, Industrial environment and production context, Milling and automated assembling,* and *Implementation of new production systems in industry*. Since I participated and studied the EU-project, which will be further described later in this section, it was a form of action research. This section of the methodology will focus on the methodology of my own research used when looking for answers to my research questions.

Already from the start of the EU-project, I was aware of the accomplishment of WP7, also served as my 'case' for a future doctoral thesis. This implied that the objective of the research project and the EU-project both affected the choice of methods and how they were used. My context, epistemology, ontology and pre-understanding together with the chosen research questions influenced the choice of strategy, methods and thus results that can be seen in Figure 6. The influence was also in the other direction, i.e. as the results began to show themselves they affected the methods that affected the strategy and to some extent my set of values. This section will deal with how the research was set up and conducted. The methodology used will be further linked to important methodology theories and discussed whether alternative ways were available.

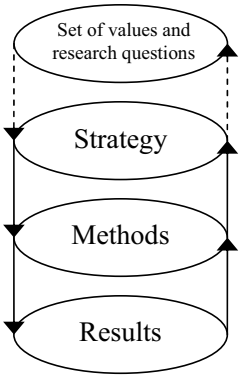

Figure 6 How my set of values and my chosen research questions influenced the choice of strategy which in turn influenced the choice of methods and thus the results. Further, the results influenced the methods, which influenced the strategy and somewhat affected my set of values.

4.1 Data gathering during the time of the EU-project

As mentioned, there was one main case in this study, along with two supporting sub-cases. The EU-project and how its work environment design was handled were the main case, and the two manufacturing companies participating in the project acted as supporting cases. In this research, the main unit of analysis is foremost the processes in the technological development EU-project regarding work environment design, as well as the two sub-units, i.e. the two manufacturing companies participating in the project. Yin (1994) states that the unit of analysis can in fact be an implementation process, meaning that it can also be a design process of work environment. Abstractly, it can be said that the cases can be defined as a phenomenon of any kind that takes place within a demarcated context. The case can then be said to be the unit of analysis (Miles and Huberman, 1994).

4.1.1 Preparations

During the preparation phase, i.e. the phase before the EU-project started, the longing for a chance to start gathering data was apparent, which is often the case according to (Yin, 1994). This longing was not the trigger in this research project, but since the EU-project started, the gathering of data had to start.

Since knowledge about the case had changed over time, so did the prerequisites to answer the different research questions. To be better prepared, a thorough literature study was conducted within the field of aero structure industry. This was a good support when it was time to define the case and its units of analysis. The literature survey unveiled research literature about how to work in aeroplanes regarding pilots and other personnel, and political economy and the history of the aircraft industry, though very little regarding work environment when manufacturing and assembling the aero structures.

As a part of the preparations a theoretical framework was drawn up, where the socio-technical perspective was focused. This version of the framework was not that precise, but as a cross-disciplinary researcher, it can be a good idea to start early to form a mental picture of what sort of theories can be useful. Miles and Huberman (1994) state that this framework can be revised during the field work, which it was in this research project. The preliminary choice of theories before data collection was an important part of the case study strategy, as supported by Yin (1994). The preliminary theoretical framework together with the outline of the research questions helped to put a focus on and set demarcations for the gathering of data, as Miles & Huberman (1994) argue. The theoretical framework, which was of a graphic character, helped to discuss key factors, conceptions, variables, and the assumed connections between the variables.

4.1.2 Data gathering

After the preparations, it was time to start the data collection in the EU-project by conducting our obligations in the project, i.e. work package seven. During the data gathering, it was obvious how the data was going to be handled and treated. Much of this was predestined, since all partners had signed contracts regarding commitments and confidentiality within the EU-project. Even so, it is critical that no partner misunderstands these parts.

Sieber (1992) separates three terms that can be useful to use to explain the data gathering in the EU-project. First, privacy is a control over others' access to oneself and associated information, and is a preservation of boundaries against giving protected information or receiving unwanted information. Privacy was not threatened, since people spoke about their company and not so much about themselves. People chose what to share with us and were never forced to answer questions. Second, confidentiality is the agreements with a person or an organisation about what will be done (and will not be done) with their data, and may include legal constraints. In the EU-project this was set when the companies decided to participate in the project, and then signed the project contract. Finally, anonymity is the lack of identifiers or information that would indicate which individuals or organisations provided which data. In the EU-project, anonymity was not promised, since everyone counted on the signing of the confidentiality agreement to be enough. Due to this contract, no names of companies or persons outside our research group are used in this thesis, as is further explained in section 5 of the EU-project.

Several methods were used to gather data for the research. Sixteen semi-structured interviews of approximately 90 minutes each were carried during the EU-project, i.e. eight interviews with the Swedish company, seven with the Spanish company and one interview with a consultant from the UK participating in the company. Three interviews were video interviews, one was a telephone interview and the remaining twelve interviews were face-to-face. All interviews were recorded and later transcribed verbatim. The respondents were chosen due to their knowledge and experience of new production systems development projects and work environment. Special professions were chosen and then the contact persons of the companies in the EU-project ensured that the respondents were available to us. A list of overarching themes to be discussed were sent over to help the respondents prepare themselves and for the companies to make the right persons available. A general risk with interviews is that the respondent delivers what he or she thinks the interviewer wants. This was prevented as much as possible to assure the respondent that it was their point of view that was interesting. Even so, it cannot be entirely concluded that the respondents were affected in some way by the context.

The direct observations that were used had an advantage, since they gave an insight into real time occurrences and the contextual differences for the events could be noticed. The disadvantages were the time consumption needed, only some objects could be chosen, the observations could affect how the work was done, and it was rather expensive, which is supported by (Yin, 1994). Both the Swedish and the Spanish companies were visited twice for two days each time during the EU-project. During these visits the production was observed and notes were taken. Video cameras and cameras were used to record the studied production processes. The companies then examined these recordings before they gave permission to ensure confidentiality.

Since the EU-project itself serves as my case, it is essential to state that participation in the project was part of the data gathering. I participated in seven official and several informal meetings, described in section 5. I had access to the reports and other documents produced in the EU-project. I wrote some of these reports personally, some involving analyses, e.g. WEST-analyses, light and noise analyses, and chemical analyses. I made some introductory ergonomic analyses of the production processes observed. MSc Carin Stillström later enhanced and further developed these analyses in her Master thesis that I supervised. These

ergonomic analyses were included in the project reports sent in to the coordinators of the project.

During the EU-project I gained knowledge about the production systems where the new technologies developed were supposed to be implemented. This knowledge improved the analyses and together with modern research from the aero structure industry, it formed my perspective.

During the entire EU-project, e-mail served as a good way of communicating. Mail correspondence was a part of the data gathering. People explained and expressed their viewpoints on occurrences within the EU-project.

This section describes the methods of data gathering. If more specific information about the analyses, meetings and observations made are asked for, the reader is directed to section 5 that deals with the EU-project itself.

4.1.3 Action research

As mentioned, the sketched research design revealed a focus on socio-technical theory that has strong connections to action research. The approach to action research and work adopted by, for example, Tavistock was based on Lewin's action research. According to Pasmore (1995), this is one of the reasons why socio-technical theories are so rich of thought and why the methods are as applicable as they are.

Our assignment in the EU-project was to conduct analyses, sometimes together with other partners, and to design a model based on our initial sketched model. This implied that I shared some of the EU-project objectives when I carried out the analyses. It also meant our research group tried to, based on the analyses, create an improved model for handling work environment design that could be used in the future. An additional and not that outspoken aim was to increase the knowledge about work environment design among the participants in the EU-project.

The research started in the project, and from the beginning involved an attempt to actively lead and conduct the project in the areas concerning work environment design, i.e. it is likely to call it participatory action research. This implies additional questions about ethical issues (Whitfield and Strauss, 1998), e.g. regarding confidentiality and anonymity. When asked to join the research group it was not my intention to conduct 'action research' as I comprehended it then. However, as getting more into our research group's proposed work plan and my research questions, it became obvious it could not be done without using action research. Circumstances made the research approach more and more action research in the beginning of the project. Because our research group from the beginning had an aim to lead how the project organisation handled work environment design, it was a form of organisational change. Davis (1977) highlights the importance of the Action Research when it is about organisational change, and as the project proceeded, more focus was put on how organisational factors would be changed by the technologies developed, see also Figure 7. As Herbst (1976) writes in his preface:

"Action research is essentially a long term collaborative learning process of those who are involved in a process of organizational change."

When the project started it became apparent that even though we tried, we lacked the experience, status and the authority to fulfil our initial work plan of the work environment

design, due to, for example, the project structure where we were detached from the rest of the work packages. We participated in the project and tried to create the platforms for change, but in retrospect we were not able to fully adopt the approach during the project and it turned more into observing how work environment design matters were handled in the project.

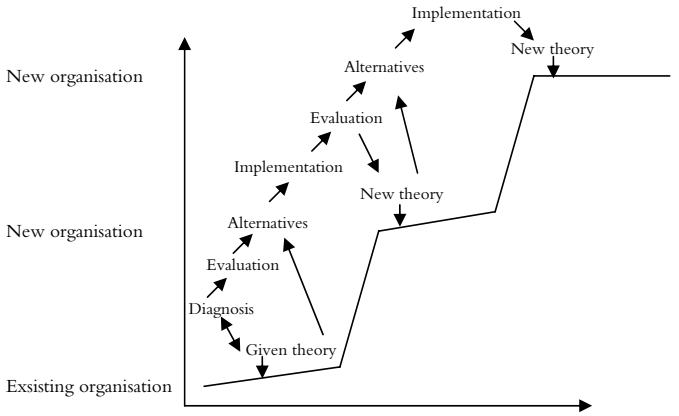

Figure 7 Phases in action research contain basic and applied research as part components in a different form and context (Herbst, 1976).

As can be seen in Figure 8, my different roles in the study can be summarised in two separate, but sometimes coincident roles. In my role as a project member, I conducted interviews and observations to fulfil my obligations and that of my research group in the consortium. The second role as a researcher was about looking at the work in the project I participated in. It is important to maintain objectivity and critically examine my own work. Even though much of the data was collected during the project, the depth in the material was fully understood afterwards. The interviews conducted during the EU-project contained much more issues than were necessary to fulfil our obligations in the project. This material was collected with the aim to succeed research work. Only afterwards could the final results of the project be related to what really happened in the project.

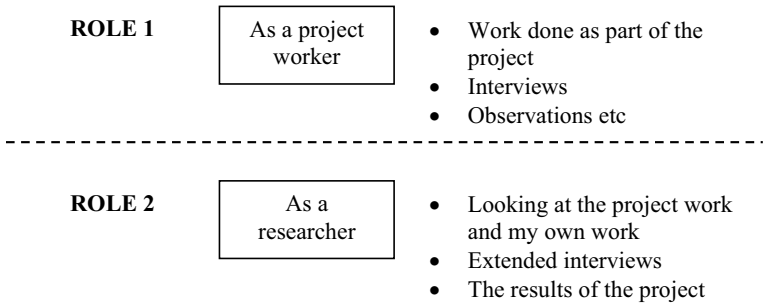

Figure 8 My different roles in the study

Churchman and Emery (1966) draw attention to 22 theses about the classification and comparisons of the ways in which social scientists attempt to study human organisations. In particular, two of these theses are interesting for this research project. The first regards the researcher as both a member of an independent research community and a member pro tem of another organisation that includes the one being observed. The second regards the researcher as a member pro tem of a third organisation, under study to encompass the conflicting interests and yet sufficiently close to it to permit its values to be related to the concrete issues of conflict. These two approaches are the ones the Churchman and Emery themselves state as the most interesting for social science and operational research.

The field of action research has become more and more discussed in literature. The concept has evolved from being referred to as unscientific to being more accepted today in the scientific society. Since the field is big and extensive, it will be sufficient in this thesis to just establish that it has been a form of action research and not elaborate the theories about the concept. The problems people refer to about action research will be noted and discussed under the section about validity and reliability, but not so closely related to the concept of action research.

4.2 Additional data gathering after the project and analysis

After the EU-project a more critical perspective was erected on the data already gathered. With the new perspective the data was coded and analysed again in more depth. In addition to the data already gathered, some data was collected after the end of the project. The presented results from each work package were first studied. These results were presented on the project's own homepage that is not accessible to the public. With these results the different occasions and decisions could be better understood in a new light. In addition, our research group has discussed our own perceptions of what happened in the project and this has also shed additional light on the outcome of the project. Although the research group did not completely share the understanding of the development of events, our discussions lead to a more common comprehension of what really happened in the project.

4.2.1 Analysis

After the data was collected, the interviews were transcribed verbatim and coded with help of standard Microsoft Office programs. Mind maps were drawn as a response to the coding, which was the start of the main analysis (Miles and Huberman, 1994). The codes for this analysis were chosen with respect to the theoretical framework and the research questions. In addition some codes were found when coding, i.e. new codes originated as the analysis went on.

Even though most of the reports written in the EU-project lay somewhat outside the scope of the research, they helped to structure the material and build the foundation for further analyses. Since a summary is the first attempt to derive a logical overarching record of the case (Miles and Huberman, 1994), these reports served as summaries. This approach is also supported by one of Yin's (1994) most important general suggestions, i.e. to write the case study reports as short drafts to be then refined.

Because it was important to maintain a good chain of evidence during the process (Yin, 1994) and to get feedback on the work, both supervisors and external experts gave feedback along the way. They saw things with a different perspective and provided new viewpoints for the analysis of the research.

During the EU-project, meetings that were held with our research group, see section 5, can be called case study analysis meetings, where all in our research group came together and discussed the present situation and exchanged viewpoints. These meetings were steered by questions and every one took notes, which is necessary according to Miles and Huberman (1994).

A discourse analysis in its narrow strict sense was not carried out. Instead, parts of the discourse analysis were used and a discourse analysis perspective was erected. The multi-nationality with several European languages present complicated the analytical approach of the discourse. During the interviews with the Spanish manufacturing company, the questions were raised in Swedish and then translated into English. It was then translated, by the respondent himself or by a translator, into Spanish before being answered, which then was translated back to English and answered. When comparing the answers from the Spanish and Swedish manufacturing companies, the answers were all translated back into Swedish. This process implies that a traditional discourse analysis is hard to accomplish, see Fairclough (1995). It is not possible to analyse the answers word by word, though this was not the intention either. Instead, it was more interesting to look at behaviour regarding work environment design, and how this behaviour and rules of conduct were set by the discourses where they were present.

The transcriptions of the interviews were carefully read through and patterns were detected of how the different respondents comprehended the work environment design process in the EU-project and their specific company.

4.2.2 The design of the relevant outcome

Since five research questions are presented in this thesis including one question about relevant outcome, a part of the analysis and method was also about how to transform the answers of the five research questions into the relevant outcome. The work of relevant outcome, in the form of a work environment design model for future projects, started in the EU-project and continued after it ended. This is described in section 5, but there are still some things worth mentioning even here. Firstly, the basic model evolved during the EU-project, but became more scientific-based afterwards. During the EU-project the model evolved gradually and each version was discussed with project partners and within my research group. All evolutionary steps of the model are not presented in this thesis, but only the initial work model and the final outline. Between them, several models were sketched and discarded.

Secondly, the design of the model required creativity. Our research group's own working model, i.e. designs of models found in literature and their best parts, together with my own creativity formed the basic design of the model. As the analysis of the empirical data became more advanced the model was refined and adjusted to opinions received.

4.3 Discussion of chosen methodology

The choice of research questions limits the number of methods suitable for a study. Still, there are plenty of methods available and much is up to which methods one is familiar with and comfortable in using. Przeworski (1987) presents an interesting view of methods and methodologists, which is shared by me in this thesis. He states:

"Methodologists are the preachers of science. Armed with canons of correct procedure, they have the power to castigate and to exhort. They can instruct us to have clearly defined objectives and explicit frames of reference, to base our studies on good theories, and to follow the examples of Marx, Durkheim or Weber. Moreover, methodologists can inform us that all we have done thus far is wrong and that we must begin again."

Przeworski (1987, pp 31), continues by saying:

" Like preachers, methodologists are at times listened to, always acclaimed, but rarely followed."

This can be regarded as a relaxed view of methodology, but when doing multidisciplinary research, it can be as mentioned in the sections above. Bits of methods are chosen from different strategies. Several things affect the researcher's choice of strategies and methods, e.g. the academic discipline of the researcher, the personal ideology and the problem in the real world, are all important factors to involve in the decision. If one disregards the choice of methods, the long-term objective is to create knowledge and understanding and to some extent change the world. That may seem a slightly over ambitious, but it should be seen in a perspective of labour and work environment. There is no doubt that to achieve it, there are many alternative tracks from where I have chosen to combine several, e.g. interviews, observations, etc. This is something that is stressed by Guba and Lincoln (2000), who state that questions about method are secondary in relation to questions about paradigm, to which I agree.

4.3.1 Views of the research conducted

There are two fundamental alternatives to achieve interdisciplinary research. This study and in the EU-project that formed its empirical base has been a mix of two alternatives. Firstly, our research group belongs to a field called Human Work Sciences, but what should be noted is that this field is itself cross-disciplinary. The field focuses on the science of connections between the human being and her work environment, and tries of find practical results in the form of an improved work environment. However, in the EU-project other researchers and consultants have also participated, of which some shared the same tasks as our research group. It became apparent during the project that we definitely used a different language when discussing work environment, which demonstrated Whitfield and Strauss' (1998) second alternative. First was the track of one researcher or a group of researchers drawing on a variety of disciplines, as in our research group, with experience from both engineering and sociology. The second alternative is several researchers from different disciplines, which can be exemplified by the constellation of the EU-project's organisation. The first alternative has historically been more successful. Using researchers from different disciplines tends to increase the "cross-sterilisation of the social science" because they do not speak the same professional language and thereby have difficulties communicating properly (Whitfield and Strauss, 1998). Disciplines should not be mixed up with methods and it is

thus advisable to borrow methods from other disciplines than your own to create nuances and understanding of the result.

As shown in this thesis, the research described can be found in between the macro and the micro level of organisations and is problem driven, contextual dependent, multidisciplinary, and eclectic, but not uncritical. The main thing to distinguish is that during the time the EU-project was in progress, the empirical data was gathered and partly analysed. After finishing the EU-project the research analysis was taken one step further, denoting it to be classified as a combination of empirical and theoretical perspectives.

4.3.2 The research design

Before entering the EU-project as a participant, an action plan was set up of how the studies were to proceed and with the different steps of data gathering and analysis. This design was precarious, since pre-knowledge about the field and the EU-project was rather low. As this knowledge improved and the knowledge about what possibilities were available, the research design gradually changed, though the pre-knowledge helped to clarify it was necessary to conduct the research as case studies with a qualitative approach. With this primary prerequisite, it became advantageous to set up a research design in the beginning of the work, which Yin (1994, pp 19) agrees with when he states:

"Colloquially, a research design is an action plan for getting from here to there, where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions."

The research design was a form of strategy of how to succeed to bring about the research project. The strategy contained all major events, but not the specific tactics that were developed during the journey. Another way to look at the research design is to regard it as a blueprint concerning at least four problems, viz. what questions to study, what data are relevant, what data to collect, and how to analyse the results (Yin, 1994). Yin states that five components of a research design are especially important, i.e. research questions, propositions if any, units of analysis, the logic connection between data and propositions, and the criteria for interpreting the findings. In retrospect, the embryos of the research questions were already set in the phase of the research design. During the course of the research the questions were fine-tuned and after the end of the EU-project, the final versions of the questions were set. Although the importance of a thorough research design was understood, time and pre-knowledge determined how much effort to put on this matter. The division of the research in the EU-project phase and the after phase implied a difficulty to come up with a valid and reliable research design. The design changed several times as time passed and circumstances altered, which is one of the biggest lessons from this research project. Having the ability to adapt the research work to the situation was essential, considered valid for all project work. Several times during the research project, it was advisable to erect a critical perspective on the design and think about whether alternative ways to go were available.

Already in the research design, both the hermeneutic as well as the positivistic approach could be discerned. Further, as a positivist base, their whole research on raw data in the form of observations produces knowledge about the connection of laws, is objective and anticipates freedom from preconceived opinions, and prefers quantitative methods before qualitative. I have during the last years changed perspective and understood the advantageous sides of the hermeneutic approach. The approach used aims to understanding in which

interpretation constitutes the main method of research. Within the hermeneutic approach, no absolute truths are searched for, since they do not exist. Instead, the researcher looks for new and more fruitful ways to understand phenomena that can be hard to handle in our everyday knowledge. In the process of becoming a researcher, I have concluded that one approach does not excluding another. The empirical data and the aim of the research determine which approach is best. Another factor that influences which approach to use is the context origin of the researcher. In this research project all three factors pointed to a hermeneutical approach and this thesis aims to present hypotheses as a result of the research. The research conducted cannot be said to entirely confirm to the hermeneutical approach, but is more hermeneutical than positivistic. Moreover, a critical perspective has been erected throughout the process, though it should be mentioned that in society as well as in EU-projects, both approaches are vital to move science forward.

4.3.3 A qualitative method based research

Despite choosing to use case studies, the importance was realised not to exclude the quantitative methods in general. This is reinforced by Rossman och Wilson, who state that it can be a good idea to combine qualitative and quantitative data for three reasons (Miles and Huberman, 1994). The reason are because it is then possible to confirm and authenticate each other by triangulation, develop and compile a more detailed analysis, and initiate new ways of thinking by noticing surprises and paradoxes. The possibility to combine the two in a research project was low due to the EU-project, forming the base of empirical data. However, a mixture of qualitative and quantitative methods implies that it is possible to combine precision with depth (Rudestam and Newton, 2001), which the depth has focused upon in this study. In today's society, almost every leading researcher within social sciences and humanities use a methodology combining the features of the two approaches, which are so integrated with each other that the difference has dissolved (Bjerfeld et al., 1999). The discussion about the assumption of a division of the research into the two approaches remains, though most people state it gets more attention than it deserves (Lindén et al., 1999). It is important to acknowledge that this study has a qualitative approach.

A large part of the research described in this thesis is a descriptive study that tries to reveal patterns without emphasising pre-specified hypotheses. Sometimes, as in this research, these types of studies are called hypothesis-generating studies, in contrast to hypothesis testing studies. In philosophy, descriptions often contradict explanations, i.e. the mission of science is not only to describe the world, but also to explain it. Thereby, description is in some cases an opposite of theorisation.

It has been an objective during the entire study to apply a holistic perspective to the research. Klein (1976) argues that there are two dimensions to 'wholeness' when looking at a system. Many are those, as in this thesis, who state that they look at a system in a holistic way. One chooses to look at the relationship between parts of a system, and not as an alternative way of seeing it, comprehensively in all its aspects. Nobody can see a situation as a whole, since everyone perceives it within a particular frame of reference and perceptual set, as argued by Klein. This implies that competition among experts is not so much between their different points, as a struggle for the right to diagnose. The satisfaction of having a high level of abstraction in the concepts dealing with wholes may persuade one to imagine that they have the tools to deal with them in practice. This leads to two possible illusions. The first is when practitioners are led to believe that a problem is being tackled comprehensively, i.e. in all

aspects, when the correct term would be systematically, i.e. relating parts to each other. The second is the risk that the practitioner gets over enthusiastic about quantification and modelling, which may mean that they reject uncertainty when uncertainty is in fact a real part of the situation.

In this thesis, the research conducted can be described in two different parts. First is the theorist part that expresses itself through theoretical based analyses and discussions found in all papers and in the summary. The other part is the role of practitioner, where the end result in the form of a model/guideline presented in this doctoral thesis summary can be something that can have positive effects already in companies today. Society has historically tried to separate the two, but in later years there has been focus on how to transform all theory-based research into useful applications for society. This thesis supports this focus. However, as a reminder, the research that is not possible to transform into useful applications today maybe possible in the future, meaning that both fundamental research and applied research must be seen as equally important. A parallel can be drawn to the area of research handled in this thesis where both short and long perspectives are necessary.

Before this research project started, my objective had been to do a study with a quantitative approach. As an engineer and a believer of the positivism school, discussed before, where the truth was in fact based on statistical proof, this seemed like a good idea. When this research project started, this determination turned into a search for methodologies based on both quantitative and qualitative techniques. However, even though such methods were available the empirical material stated differently. The partners in the EU-project were too few to make any quantitative studies any sense. Another reason was because the research questions developed called for in-depth methods, i.e. a qualitative approach.

Since the research presented in this thesis is mainly based on empirical data, it is a form of induction. Moreover, it is not possible to only use induction. Older explanations and theoretical fields have been used, also guaranteeing that deduction has been used. This thesis shows how the work environment design is handled in the EU-project, while building upon how other researchers stipulate a good work environment, etc.

4.3.4 Case studies

A common misunderstanding is that a case study is a method or a research technique, but as Yin (1994) states, case study is a research strategy containing many methods. Within this research project several data sources described in section 5 were used. Some people state that case studies and, for example, interviews are two different approaches. This may be, but in case studies it is common to use interviews as a source of data, i.e. it is hard to distinguish case studies and interviews from each other. However, interviews can be regarded as a method and not always a strategy.

Although most scholars are at least positive to using case studies, if not overly convinced, it has been seen as a less appropriate form of research than experiments and questionnaires (Yin, 1994). A probable cause for the increased contempt of case studies is the opinion that they supply little or no foundation for generalisation (Yin, 1994). The question has been raised whether it is possible to generalise from one specific case, the EU-project, as in this study. The answer is that case studies like experiment are possible to generalise to theoretical propositions and not to populations or universes (Yin, 1994). In this study the conclusions are based on one case and the generalisation will therefore go no further than to theoretical

propositions. In addition, an interesting quotation can be of interest regarding a generalisation that the American writer Joseph Epstein (b 1937) is supposed to have stated.

"Generalization, especially risky generalization, is one of the chief methods by which knowledge proceeds… Safe generalizations are usually rather boring. Delete that "usually rather." Safe generalizations are quite boring."

It can be interpreted that Epstein possibly would have preferred case studies if he had to choose, since they often lead to less secure generalisations. Another reason for using case studies is due to many of my research questions. How questions, which according to Yin (1994), together with Why questions speak for the use of the strategy that is strengthened when the researcher has little control over the events. In this study the control was present, but insignificant over the studied objects.

Although Yin states it is possible to conduct a rigorous case study of high quality without leaving the library and using the telephone, it is better to support case studies with observations. A substantial characteristic for qualitative data is the focus on naturally occurring events in a natural environment that make it as realistic as possible (Miles and Huberman, 1994). Hence, this is why all interviews in this study have been followed and supported by observations.

In this study, all six different sources of case study data, as described by (Yin, 1994), have been used, viz. documentation, archival records, interviews, direct observations, participant observation and physical artefacts. The focus has been on interviews, participant observations and direct observations. Before explaining these three, the use of the other three will be briefly explained. Documentation was used throughout the whole process, but mainly when the EU-project started in 2002, to strengthen the body of knowledge about the project, EU-projects in general, and the type of industry. Documentation was used to support interviews made. Old surveys conducted in the companies were read through and blueprints of production layouts were collected and analysed. This documentation was old and bordered on to be from an archival record. The use of physical artefacts consisted of the observed machines as well as the technologies developed during the EU-project. One part of the final result was a type of machine prototype that could be observed in real life.

The other three data sources of the case studies are those that have been mostly used. Direct observations were used at the production sites visited and at the project meetings attended. However, during these meetings the observations contained participative observations, since we took part in the meetings and raised questions of our own, described in the section of action research. No participative observations took place outside the project meetings, only direct observations. These observations were conducted in an ordinary form where the observer did not in any way interfere with the process.

In this study mostly face-to-face interviews were used. There were several reasons, but mostly due to language barriers. The use of semi-structured interviews, consistent of some predetermined questions, helped to decrease the language problems. The interviews were not to be too structured, since openness was necessary; Fontana & Frey state that unstructured interviews are more open and thus give more room for probing (Guba and Lincon, 2000). The pros of semi-structured interviews are that they target and focus on the core of the case study, they are knowledgeable and give us noticeable causal conclusions. The disadvantages are the risk of bias and that the respondent delivers what he or she thinks the interviewer wants to hear.

4.3.5 Demarcations

The general aim of research is to always present as overarching results as possible. Since the depth of a study will vanish if the scope of a project is too wide, it is vital to set some demarcations of a study. These demarcations can be chosen, with the attributes of a study occasionally setting the limit. In either case, it is important to present these demarcations for the reader to understand the results in the right perspective. Of note in this research project is that this thesis does not deal very much with ethnographic differences, but with how the EU-project group developed and implemented technology and handled work environment design etc. It is interesting to discuss ethnographic differences, but as Professor Håkan Ylinenpää at Luleå University of Technology once told me, that would be to enter a 'multi cultural swamp', without helping the aim of my thesis. Instead, it is more focused upon how the EU-project organisation dealt with national regulations and available supporting technologies.

The fact that only one EU-project was studied was not a consciously made decision, but a demarcation caused by a lack of availability and time. If it would have been possible, the thesis would without a doubt have gained if several projects could have been studied and observed. Getting access to this type of projects is not that easy and it would have been too time-consuming to finish within an appropriate time scale. However, the most valid reason is that there would be no other chance to study a project in the GROWTH-programme, see section 5, since this programme no longer exists. Hence, even though it could have been good for the quality of the results, additional cases are not possible. A consequence is that the final model presented in this thesis has not been tested in a real project. The model has been tested in its earlier versions, but the final model has due to obvious practical reasons not been fully tested.

Anonymity has implied demarcations. Because we were not allowed to present company names it was difficult, but not impossible to get papers accepted in well-renowned journals. Confidentiality made it difficult to take pictures and in other ways document different production processes.

One important demarcation is the choice of respondents for the interviews. We expressed which functions we wanted to interview, but it was not always possible for the companies to comply with our wishes. This can be understood as a demarcation, but also as a contradiction where the companies were more familiar with those who possessed the right knowledge to answer our questions.

4.3.6 Validity and reliability

It is vital that one reflects upon the quality of the research conducted. This part is of continues improvement of research in general and especially the research conducted by me. It also makes my research as transparent as possible. In all research, quality determines the value of the research. High validity and reliability are desirable, but not always easy to attain. Therefore, the description of validity and reliability is an important tool for those reflecting upon the quality of the research presented here.

Since social reality changes at a higher speed than natural science, this has an implication on the reliability. A researcher would find it difficult to repeat this study later on, which is a prerequisite for good reliability (Yin, 1994). Still, an attempt has been made to describe all

the phases of the study to make it as transparent as possible. As Miles and Huberman (1994) state, it can be worth remembering that a broken thermometer has as high reliability, while its validity is probably rather low. As a consequence, having good reliability is not enough, since it is not worth anything if the validity is not high. Yin (1994) states that case studies are often regarded to increase reliability. In this specific study the language barrier has decreased reliability. This is especially in the interviews with the Spanish manufacturing partners, which were conducted by me as a Swede, without any or limited knowledge of the Spanish language, and often with the help of an interpreter. The interpreter was only used in some of the interviews, but even so, this interpreter was in fact a supervisor for the one interviewed.

Trompenaars (1994) makes an interesting difference between interpreter and translator. While the translator is supposed to be neutral like a black box, the interpreter will usually serve the national group. Translation during the interviews was necessary and the interpretation was something that came into the bargain. According to Trompenaars (1994), communication is only possible between people who share somewhat the same mindset and system of meaning, i.e. the interpretation served a meaning in the interviews. The fact that the translator or interpreter at the Spanish locations held discussions with the respondents during the interviews is something Trompenaars (1994) argues can be due to different cultures.

It is difficult to say whether or not validity is high, since there are different perspectives depending on who will be using the results of these studies. Whitfield & Strauss (1998) state that validity can be divided into internal and external. Since the main focus in the project has been to illuminate the differences and the problems in work environment design in one specific case to come up with something that can help them bridge the gap, the main concern is on internal validity. A pre-understanding is important and my origin as an engineer helps to minimise the effect on the validity. A lack of experience from the aero structure industry and similar EU-projects increases the effect. To increase the validity, the research process have been described, analyses made, and the sample selection has been as detailed as possible without exposing the participating companies. Since some of the results were already presented in the EU-project, participants had the opportunity to question them and sometimes correct them. In hindsight, it is maintained that the chosen methods in this project have been sufficient to achieve the objectives and to obtain a sufficient level of validity and reliability.

During the research process, different sources of data that are affected by different biases and have different strengths so they can complement each other (Yin, 1994) were used. In retrospect, it can be said that triangulation of data sources, methods and data types were used. The use of several sources for the chain of evidence and triangulation is of extreme importance whatever studies one attempts to accomplish, but in case studies it is even more important than, for example, surveys, questionnaires and experiments. This is one of the biggest advantages of case studies (Yin, 1994). Conclusions and results are more convincing if they are based on more sources of information than one. Much has been written about triangulation, in essence it is about strengthening results by showing that other information confirms the findings or at least does not contradict them (Miles and Huberman, 1994).

Some sources of errors have already been mentioned above. However, there can be errors of commission caused by misinterpretation or lack of full understanding on my part, e.g. of literature as well as respondents in the study. These errors are beyond my knowledge and hence, it is not possible to correct them.

"If you want to make enemies, try to change something". Woodrow Wilson

5 Description of the empirical data

The EU-project underlying the analyses is presented here with a special focus on the work package, including work environment design issues.

5.1 The FORWARD-project

Before the start of the project, all partners signed a contract stating that any material considered harmful to the other partners could not be used outside the project. Due to confidentiality, the name of the project is altered and the participating partners are made anonymous, except from the research group of the author, whose anonymity is unnecessary. In this thesis, the project will be entitled "FORWARD-New ways of manufacturing large non-rigid structures through innovative production systems."

The cost of the FORWARD-project was, according to Cordis (Community Reseach & Development Information Service), € 5,661,810. From this amount, the Fifth Framework Programme and the GROWTH programme funded € 3,362,280. Similar projects as the one described in this thesis can be found, for example, at the CORDIS homepage, though in these projects most of the information is classified. The aim and objective and the expected technical outcome can be found, but the actual results are not made public, which is common for EU-projects.

5.1.1 Creation of the project

The Fifth Framework Programme ran between 1998 and 2002 (Fifth Framework Programme, 2002). A major innovation of the Fifth Framework Programme was the concept of "Key actions". These were implemented within each of the four thematic programmes; Quality of Life and management of living resources (Quality of Life), User-friendly information society (IST), Competitive and sustainable growth (GROWTH), and Energy, environment and sustainable development (EESD). The "Key actions" were said to mobilise the wide range of scientific and technological disciplines - both fundamental and applied - required to address a specific problem so as to overcome barriers that may not only exist between disciplines, but also between the programmes and the organisations concerned. Each thematic programme was subdivided into key actions, research activities of a generic nature, and support for research infrastructure. The key actions were actions with a particular emphasis placed on them, targeting specific problems to meet citizens' needs. The idea was to target Europe's research efforts on selected social or economic problems. Each key action encompasses the entire spectrum of activities, from basic research to demonstration projects. The entire Fifth Framework Programme included 23 key actions, accounting for approximately 70 percent of the funding.

As previously mentioned, the GROWTH programme was one of four thematic programmes of the Fifth RTD Framework Programme, see Figure 9. Accordingly, it also ran from 1998 to 2002. The GROWTH programme promoted sustainable industrial growth by stimulating

EU innovation and co-operation in RTD (European Council, 1999). Conceived to help solve problems and to respond to the major socio-economic challenges facing Europe, the GROWTH Programme, with a budget of € 2,705,000,000, had clear targets. They were to increase economic growth and create new jobs in Europe by sustaining the innovation effort of European industry towards improved competitiveness and to support Community policies that enable competitive and sustainable development. The FORWARD-project responded to the call for proposals of GROWTH 2001 and was included in the Key Action 1 of this programme, i.e. 'Innovative products, processes and organisation'.

The objective of the GROWTH programme was to help create competitive European industry and sustainable transport systems and to support efficient, high-quality production. The key action of Innovative products, processes and organisation also had resulting objectives. The overall goal of this key action was to develop new and improved methods of design, advanced equipment and process technologies for production. This should include innovation in and modernisation of traditional industries, which would improve the quality and reduce the costs of processes for products and services. The goals were also to reduce overall life-cycle impacts, to improve the understanding of aspects regarding 'soft technology' (organisation, management, logistics, teleworking, etc.) so as to fully integrate them into relevant industrial processes, and ultimately contribute to employment growth. Implementation of the key action should focus on systemic approaches to production (products, production facilities, processes and organisation) and on clustering and integrating projects into targeted groups, thus making it easier to consider socio-economic, ecological and competition aspects.

Initially, two separate projects were merged into one to be eligible to apply for money from the Fifth Framework Programme. This merge implied that two 'different' projects had to live under the same head project. In the beginning, a major aircraft manufacturer was one of the partners in the project, but as the project approached launch, this company renounced its participation for reasons that are unknown to the author of this thesis.

5.1.2 Aim and objective of the project

The official objective of the FORWARD-project was to produce a new generation of machinery and production equipment for manufacturing, including machining and assembling of large aero structures, achieving multi-functional production systems by integrating the highest number of processes into the same equipment, reducing product development cost and time to market and with more efficient manufacturing by reducing assembly cost and time, and improving machining cost and quality. This would all be achieved through identification, development and integration of critical technologies that fit practical strategies for flexible fixtures, handling automation, and machining and automated assembly of large aero structures that respond to major socio-economic challenges facing the European Union. These objectives were supposed to be achieved through the application of both technical and social research during the project.

The long term objectives of the project were to increase the competitiveness of the machinery builders by opening new market prospects, as well as that of their users by improving their productivity and the quality of the manufactured products through the modernisation of their manufacturing, i.e. achieving new processes more eco-efficiently and the safety and health of the shop floor operators.

The developed technologies would allow the configuration of flexible and scalable integrated production systems using standard modules. The intention was to reduce the cost and implementation time of manufacturing facilities associated with new aircraft models and to increase the opportunities for reconfiguration and reuse. Therefore, not only would this increase automation, improve quality and repeatability, and reduce the potential for accidental damage and shift operators from the most hazardous areas, but it would also increase information integration and make maximum use of off-line simulation tools to simplify and accelerate part programming and reduce costs, errors and manufacturing concessions (using an evolving virtual model of the product and production system that truly reflects the current status - rather than a theoretical model). To sum up, the aim and objectives of the project were high and ambitious.

5.1.3 Partners involved

In the FORWARD-project, 10 partners from 5 European countries participated, viz. England, France, Germany, Spain and Sweden. Consequently, five different languages were present in the project. The language of commerce was set as English. The partners consisted of persons from institutes, consulting companies, universities and manufacturing enterprises. In one case, parts of subsidiary companies participated and in another, two different partners from the same organisation. The organisational headquarters of the partners differed, since there were two industrial users of the manufacturing equipment to be developed, two engineering companies and automation system providers, a tool manufacturer, a consultancy in socio-economic issues, a research centre specialised in robotics, a Material and Manufacturing Engineering department and a Human Work Sciences department of one university, and a Department of Engineering and Applied Science of another university. Most partners had previous experience from EU-projects, with some having significantly more than others.

The dominance of men in the project was striking. Only our department was partially represented by women in the project, i.e. one female senior researcher and one Ph.D.-student. At the final meeting, another partner was represented by, among others, one female, though she was hired temporarily and was not involved in the work of the project. The small representation of women is an interesting fact and is worthy of its own focus, but not in this thesis due to delimitations.

5.1.4 Project working plan

Activities in the FORWARD-project were distributed into work packages that reflected the logical and consecutive phases of the project, namely: Phase 1 - identification, research and development of key enabling technologies and methods; Phase 2 - validation of the previous concepts; Phase 3 - integration and validation of the technology for representative applications.

Two different and interdependent families of processes were considered, since the project was two projects merged into one from the beginning: Machining (milling and drilling) and Automated Handling and Assembly (including handling, holding, fixturing, manipulation etc). To simplify project management and support the focus, these processes were handled in separate work packages during the development phase. The biggest separation of activities occurred during the latter part of Phase 1, but the two groups worked closely again during

Phase 2 validation and when they were merged completely to address Phase 3 - integration of the technological developments in common automating systems or installations.

The work plan was structured and coordinated in six parallel development phases or work packages, formulated as: concept studies, machining development, assembly development, handling and fixturing development, implement, test and validate modules, and integrate, operate, validate and assess. All six work packages described were connected to the overall technical oriented aim of the project.

The two non-technical work packages were said to be as important as the technical in attaining the project objectives and would run throughout the duration of the project. Evaluation of the socio-economic effects work package was said to develop activities that consider the implications at the company and European level to ensure that the technical achievements fulfil the objectives of the partners and the commission in the socio-economic field, and the co-ordination and management work package to ensure that the project successfully achieved its stated objectives on time and within budget.

5.1.5 Components of the project

The FORWARD-project was structured in eight work packages, and based on three entities to get a functional decision making structure within the consortium. These were Board of Directors, a formal steering committee for overall strategic and managerial decisions; project Co-ordinator, executive entity of the Board of Directors responsible for the day-to-day management; and work package leader to co-ordinate the involved activities on each single work package and be responsible for its technical progress and for the availability of its resulting deliverables.

The Co-ordinator, a consultant company from Spain called SPC (Spanish Consultants) in this thesis, chaired the Board of directors, which was the main technical and management organism for the project co-ordination. The board comprised one representative of each company in the project. Professor Jan Johansson represented our organisation. No meetings were held during the execution of the project. This Committee was supposed to decide the overall strategic and managerial decisions related to resolution of conflicts, changes or reviews to the work plan, and on allocation between the Parties of the funding provided by the Commission under the Contract, exploitation and dissemination policy definition. Who took these decisions instead of the Board is unclear, but the Project Co-ordinator seems likely. The Project Co-ordinator, SPC, acted as the executive entity of the Board of directors, since they were responsible for the day-to-day management. They followed-up their decisions as well as the progress relative to the time schedules in the Technical Annex or those set up by common agreement of the Parties. The Co-ordinator was the liaison between the project and the Commission, co-ordinating the preparation and distribution of all reports and deliverables to be submitted to the CEC and maintaining accurate tracking of costs, resources and times of the project. A work package leader, who took the role of co-ordinator of the involved activities in each single work package, chaired each project work package. This leader was supposed to report to the Board of directors, and was responsible for the technical progress of the work package as well as the availability of the work package deliverables. Each work package was then subdivided into several sub-tasks that also had sub-task leaders. Sometimes this subtask leader was an organisation and sometimes both a single name and an organisation.

5.1.6 Course of the project

During the project, some occurrences were of extra importance. Some central features are described below.

Meetings

During the project, seven meetings involved all partners and one with only some of the partners. The first meeting was a kick-off in February 2002 in Spain. This meeting was followed by a general meeting in September 2002 in the UK and one in March 2003 in Sweden. Not all partners attended the third meeting in France. The mid-term review meeting was held in Sweden in September 2003 followed by a fourth general meeting in February 2004 in the UK. The last general meeting was held in France in June 2004 and a final meeting was held in Spain in November 2004. During all meetings, one or two people from each partner attended except from our research group, which sent between 2-5 people to each meeting because the meetings served as empirical groundwork for some of our studies and thus justified our over representation in the meetings. It was possible to follow the steps of the project during these meetings, since every meeting consisted of a status check of each of the eight work packages.

The different partners took dissimilar space and positions at the beginning of the project. Some of the more experienced partners who had participated in similar projects before volunteered and took on the responsibility to informally steer the project and the discussions. This was due to the different levels of experience and closely related knowledge that dictated how much space each partner received in the forum. I apprehended it that these factors formed, together with all personalities, an informal hierarchy in the project organisation that in some cases overtook the role of the Board of directors.

Informal meetings

Some informal meetings also took place in connection to the official meetings. During personal conversations and at the dinner table, for example, people tended to more freely describe their objectives with participating in the FORWARD-project. During these meetings partners showed more of a belief in the automation of production and believed in positive consequences of such an action. They also demonstrated a state of agitation at the risk of loosing job opportunities and of course proclaimed more profit for their companies when using a new type of production system.

Official Reports

During the project, partners from each work package wrote reports on their work. Altogether, over 30 reports were written regarding different subjects. In the official project reports, all partners did their parts, but no conclusion can be found on how they interrelated. They all focus on the technical and quality matters and besides our research group and to some extent the German consultant company, there is very little about work environment factors in the reports written by other partners. It is not possible to understand the development process just from the reports. Instead, the reports focus on showing that something had been done, i.e. to suit the EU- examiners. Some of the partners produced a substantial part of all the written reports, since they had bigger budgets in the projects. When

looking at the reports, it is obvious that the project could be divided into several small sub-projects that together formed the bigger project.

5.1.7 Results of the project

The expected technical achievements derived from the working tasks of the FORWARD-project were mainly the following: reduction of assembly costs by 20 per cent, reduction of assembly times by up to 30 per cent, reduction of production equipment cost by 30 per cent (not accounting for savings through reuse), improve surface integrity and increase the geometrical accuracy of high specification machined parts by 20 per cent, and reduce machining costs by 30 per cent. Moreover, they were expected to dramatically improve working conditions, while fulfilling more environmental friendly processes that would save resources and reduce the use of hazardous substances (reduction of wastes during machining, milling vs. chemical, by 75 per cent was expected).

Two different families of processes considered typical in the manufacturing of large aero structures were tackled in the project, i.e. milling of primary structural components and automated assembly of panels. Regarding the milling of non-rigid monolithic parts, a dynamic cutting condition monitoring and control system, with specific emphasis on vibration control, as well as a cutting process methodology for precision machining of these kinds of structures have been obtained. Regarding the automated assembly of large aero structures, new conceptual designs for the assembly cells of flat and cylindrical structures, including the handling and fixturing of these large parts and the drilling and riveting moving modules, have been obtained. Moreover, new whole assembly processes and methodologies with regards to this new generation of machinery have been developed.

The project ended with the construction of two novel robotic drilling systems to be used in the assembly of aircraft fuselages and wing boxes. One drilling system was displayed during the final meeting in Spain in November 2004. The consortium stated that the objectives established at the beginning of the project were widely attained with these achievements. These results are at the moment not detailed. Perhaps they will be available on the CORDIS homepage, but so far most of the results are confidential to the public. Only those involved in the project have access to the descriptions of the results.

5.1.8 Indirect results

The results presented above are not the only results of the FORWARD-project; some indirect results can be mentioned in reports, as well as often by the partners in the project. They state that one of the biggest advantages of participating in an international collaboration project is the creation of contact networks. People within the same type of industry become familiar with each other and can discuss problems that arise. In some cases the ideas of some essential technologies were already present before entering the project. Participation was a possibility to find a way to finance the development of these ideas into real prototypes.

5.2 Work package 7 (WP7)

One of the eight work packages, i.e. the seventh work package, focused on socio-economic evaluations of the technologies to be developed. Since our research group knew that work

environment design had to be acknowledged to achieve an efficient production system, these socio-economic evaluations turned into socio-technical evaluations. Thus, we chose this interpretation of the socio-economical focus, while the other partners in the project focused only on the socio part of the title though they were aware of our focus of work environment design. The work package will be described further below.

5.2.1 Creation of the work package

Within the Objectives and RTD priorities of the key action, *Innovative products, processes and organisation*, organisation of production and work can be found. The key action states that the goal is to move towards high performance industrial systems, or virtual networks, with a multi-skilled highly motivated labour force that works in efficient, safe and pleasant workplaces and considers the diversity and specificity of European society and manufacturing tradition. Consequently, the RTD priorities were to study human, organisational, socio-economic and regulatory determinants for a smooth transition of enterprises towards efficient and sustainable production and consumption. The priorities were to also come up with new decision-making tools and new approaches to the management of change and human resources covering work organisation, skill needs and worker's protection. Conducting studies on the impact and acceptance of new business ideas, new forms of work and new industrial production patterns compatible with the concept of sustainability including the interface between society and enterprises was also an important priority.

The Fifth Framework Programme describes that competitiveness and sustainability can no longer be considered an exclusive matter for individual organisations or sectors. In the context of an increasingly interlinked and globalising economy, a systems approach is necessary where research activities support the development of coherent, interconnected and eco-efficient industrial and social systems that respond not only to market, but also to societal needs. At the heart of these systems will be efficient and quality-based production systems, embedded in agile organisations and producing high-quality eco-friendly products and services. According to the official description of the Fifth Framework Programme, such a holistic approach is the best way to improve the long-term efficiency and sustainability of Europe's economic system in the face of world-wide evolving market constraints and socio-environmental responsibility.

By stimulating holistic approaches, by strengthening the innovative capacity of the European industrial system and by fostering the creation of businesses and services built upon emerging technologies and new market opportunities, the programme was stated to help face the major challenges of society, in particular employment. In parallel, research into sustainable mobility and environmentally and consumer friendly processes, products and services was supposed to contribute to improving quality of life and working conditions. The description of the Fifth Framework Programme further stated that training and socio-economic research would therefore form an integral part of the programme complemented by appropriate links with the horizontal programme *'Improving the human research potential and the socio-economic knowledge base'*.

In the beginning, this element of socio-economic evaluations was not present in the consortium. Since another department from Luleå University of Technology was already represented, leading persons from this department recommended the department of Human Work Sciences as a partner in the consortium. As described below, a few people from our

research group then wrote a work package description for work package seven, *'Evaluation of socio-economic effects'*.

5.2.2 Aim and objective of the work package

The aim of the seventh work package was to study and assess the socio-economic effects of the new production system concepts and critical technologies (milling and automated assembling) for the manufacturing of large aero structures and their implementation in industry.

The assessment of socio economic aspects for production systems like the ones of the FORWARD-project can be divided into three levels; a study of milling and automated assembling in a laboratory environment, a study of the industrial environment and production context for the new technology, and a study of the external effects of the new technology (e.g. environment, customer relations). The first level is related to health and safety, the second to the industrialisation of the technology and the third to the effects within society. The intention was to emphasise levels one and two.

5.2.3 Partners involved

Our research group worked within WP7, and consisted of three senior researchers, Professor Jan Johansson, Professor Lena Abrahamsson, and Ph.D. Bo Johansson from the Department of Human Work Sciences and Division of Industrial Work Environment of Luleå University of Technology. Two Ph.D.-students, Ms Marie Sandberg and I, were also part of the research group. The three senior researchers laid down the general outline for the work of the research group, with the two Ph.D. students doing most of the work. Since all expertise could not be found in the group some external experts were hired to conduct certain measurements, e.g. sound levels for high-speed milling.

Within WP7 two organisations shared the responsibility of the work package. Late in the project planning, a German consultant company came in and without any appreciable changes in the work package description was given man hours and some of the tasks earlier assigned to Human Work Sciences (HWS) at Luleå University of Technology. This German company became responsible for one of the four sub-tasks and also worked on the rest of the sub-tasks. This seemingly happened because this German company is well-reputed and known all over Europe. Whatever the reason, HWS had to adapt to the new conditions. In the end the project was granted money, which was the main objective of all the work before the project started.

In addition to our research group and the German consultant company, other partners also had, though a small number, man months in the work package. The Spanish consultant company that was also the coordinator of the project, the Spanish aero structure company, the British consultant company, the Swedish aero structure company, and the Swedish Material and Manufacturing Engineering department all had two man months in work package seven.

5.2.4 Work package working plan

The addition of the German consultant company occurred before HWS hired any Ph.D. students, thus the senior researchers did all the preparation work before the project started.

As soon as our research group from Luleå University of Technology, HWS, was accepted as a partner, the group put together a detailed description of what we should do in the project and the prospective outcomes of our work. The plan was based on already conducted research and experiences and was permeated by a socio-technical perspective. At the same time they stated how many man hours were needed in this work and other administrative propositions for the seventh work package in the project, now named Evaluation of socio-economic effects. Due to confidentiality the exact numbers of the budget cannot be stated, though it can be stated that approximately 10% of the overall budget was spent on work package seven, and the German consultant company's budget exceeded ours in this work package.

Work package seven was divided in four different tasks; *Work environment factors, Industrial environment and production context, Milling and automated assembling,* and *Implementation of new production systems in industry*, each with its own subtasks and deliverables. The tasks stated the different partners' task distribution and how many man months they had at their disposal. As the German company became involved they also became task leader of one of the tasks in the seventh work package, task 7.1. Even though we were part of it, they were responsible for it and steered the work in it. Bo Johansson was task leader of two tasks and Lena Abrahamsson for one task. Lena Abrahamsson was work package leader and was thereby responsible for all the four tasks together.

For HWS, it was then time to plan who would do the actual research in the project tasks. The senior researchers were responsible for the tasks, but saw the opportunity to use the project work to appoint two Ph.D. students, which is a common strategy in Swedish post-graduate work. They decided to offer the positions to Marie Sandberg and I, who then were hired and entered our positions at the beginning of 2002.

5.2.5 Components of the work package

The seventh work package was divided into four phases, as described before. The phases *'Criteria for work environment factors'* and *'Evaluation of milling and automated assembling'* belonged to the level of evaluation, measurement and assessment in a laboratory environment. The phases *'Evaluation of the industrial environment and the production context'* and *'Implementation of the new production system concept in industry'* belonged to the level of industrial environment and production context. The phases of production context and implementation of the production system were also intended to include some discussions and analyses belonging to the level of effects of the new technology within society.

The first sub-task, named *'Criteria for work environment factors'*, had the objective to determine the criteria for work environment factors based on modern research and EU- and national legislations of those European countries with considerable aircraft industries. The criteria for work environment factors would enable the assessment of new production concepts and production technologies of the FORWARD-project, to assess their anticipated work environment impact at a later stage. Task leader for this sub-task was the German consultant company and the sub-task started at the same time as the project. The time was set to 12 months.

The second sub-task, named *'Evaluation of the industrial environment and the production context'*, was planned to start at the same time as the first sub-task and continue for 28 months. The objective was to study the environment where the new production technology, flexible

fixturing, handling automation, machining and automated assembly of large aero structures would function. In the sub-task the 'environment' meant work organisation and production system. The aim was to develop a model for evaluation of the manufacturing and production environment where the new technology would be implemented. This model would then be a part of the final work package seven results, i.e. 'a guideline for implementation of the new production system concepts in industry'. The plan was to study actual production sites where the new technology would most likely be implemented as well as similar production environments. However, the focus was on aeronautic applications with their associated requirements and constraints. Task leader for this sub-task was our research group, particularly Professor Lena Abrahamsson.

The third sub-task was called *'Evaluation of milling and automated assembling'* and our research group, foremost Ph.D. Bo Johansson, was the task leader. The task was supposed to start after the first year of the project and last for 13 months. The objective was to study and analyse the particular risks and problems present due to milling and automated assembling processes. Aspects such as chemical emissions of new materials, safety, noise and vibration, vision and lighting, static and dynamic workload, temperature and climate were to be studied. The aim was to identify, describe and, if possible, quantify the most important work environment risks, both short and long-term, associated with the milling and automated assembling processes. The main focus was supposed to be on assembling processes. The aim was to suggest measures for preventive risk management regarding identified major risks.

The last sub-task in work package seven was *'Implementation of new production systems in industry'*, lead by our research group and Ph.D. Bo Johansson. The duration was set to 12 months during the last third year of the FORWARD-project. The aim was to develop a general guideline for the integration of work environment aspects in the development and implementation of new manufacturing and assembly technology. The guideline was to be applicable in the development of automated assembly of wing structures and high speed milling. The guideline should be adopted and addressed to the most influential actors during conceptual design, prototype design, industrialisation, production and maintenance.

5.2.6 Course of the work package

During status checks at the official meetings of other work packages except the seventh, our research group's position was mainly to observe the progress of the work packages and see how the work environment factors were handled. We raised a few questions, though mostly concerning comprehension of the technologies they were about to develop. When it came to the seventh work package, we explained what had been done since the last time along with our future plans. We stressed that we needed an active participation from other partners and all partners promised to give us whatever we needed. Some of the partners also supported our observations of what needed to be done and reinforced them with their own arguments. In retrospect, it seemed as if they had erected a positive rhetoric attitude, while a transfer to tangible work plans failed. Most initiatives came from HWS and rarely from other partners, and not even the German consultant company that was responsible for the same work package as HWS. One initiative raised during one of the meetings was about looking at some of the technologies from a system perspective and analysing them in a future system. However, nowhere was this analysis presented, at least not in work environment factors that a scholar would comprehend as a system analysis. Some simulations were done in the other work packages with computer software, where the typical work in a production cell was

described. The humans in these simulations were represented as solids and no further description was delivered.

The ambition from our research group was to give the partners the means to work with work environment, but because the project group consisted mostly of engineers, the more technical questions were given precedence. Technical questions often led to heated discussions in contrast to the discussions about the work environment and the difference in commitment was striking.

It also became evident during these meetings that the remaining partners thought that our research group was looking for shortcomings regarding the work environment in each organisation instead of, as we tried to, find their views of the work environment and see how they handled work environment factors in development projects. Whether their procedures were good or bad was not focused upon, but rather a more holistic perspective to understand how they did it.

Within the four sub-tasks different strategies were chosen to accomplish the work package goals. Some of the strategies were used in more than one sub-task. These strategies are described below together with some their essential results.

Interviews

During the interviews, a collective picture of the context in the different companies as well as within the FORWARD-project was achieved. It was noticed that the way of handling things regarding the work environment was different within the different organisations and that their views of issues regarding the work environment differed. It was also possible to find different perspectives to technology development projects in general. Together the interviews formed a base for further understanding and interpretation of the context prevailing in the different organisations. Of note was that the organisations all had different ways of regarding the workforce depending on what labour market policies were present in their home countries. Management level in the companies was mostly interviewed, since this was the level that participated in the FORWARD-project.

The intention was to focus on the means at a macro level and thus focus in the extension on the micro level. The interviews were conducted in English. The interviews from the Spanish partners were first translated from Swedish to English, and then the questions were translated into Spanish by either the respondent him or herself or by a translator. The answer in Spanish was translated into English and then Swedish to be compared to answers given by Swedish respondents.

Observations

The observations gave insight into the current work environment in the aero structure industry. Observations took place on several occasions, i.e. in the beginning of 2002 at the Spanish manufacturing company and also in 2002 at the Swedish manufacturing company. The companies were revisited during the project. Risk factors with noise levels, chemical hazards and physical workload could be observed as well as other factors common to the work environment. Other examples were the possibilities to communicate and the noticeable hierarchy present on the shop floor.

Ergonomic analyses

Based on observations, photos and videos, ergonomic analyses were made with the software Jack. This work became time-consuming and an MSc student, Carin Stillström, was appointed to do the work as a part of her Master's thesis. Carin carried out several analyses where strainful working positions were highlighted with, for example, the analysis tools RULA and OWAS. An attempt was also made to evaluate the future production process. The analyses reinforced the concern of many strainful working tasks in the assembly industry today.

WEST analysis

Based on the observations and interviews, WEST analyses were carried out on some processes in the partners' organisations. A WEST analysis is a process method that includes both physical and psychosocial impact categories. The following impact categories are included: risk of accidents, physical work load, noise, chemical health hazards, vibrations, general physical environment, social relations, work content, and freedom to act (Schmidt and Antonsson, 2002). The results from the analyses have been used as a base for further interviews and discussions. The analyses also pointed out the monetary outcome (costs) of some poor working conditions in the processes studied.

Noise and vibration analyses

Since one part of the FORWARD-project was about high-speed milling, conducting analyses of noise and vibrations was essential. This was done by ordering these measurements from experts in the field found at our own HWS department. We planned these analyses and drew the conclusions from them. The analyses showed that high-speed milling could imply significantly higher risks of hearing impairments and disturbances if adapted actions were not made to reduce it. The risks were increased when clear tones were present.

The contribution of the German consultant company

In the first sub-task of WP7, the German consultant company presented a review of legislations and regulations within the European Union and especially from participating countries in the FORWARD-project. They also performed a risk analysis regarding materials and chemical hazards in the third sub-task. The most critical compounds and activities found were in primers and in the extensive use of solvents especially during cleaning activities. As a part of the fourth sub-task, the German consultancy presented a guideline for integration of issues regarding chemical health hazards.

Mail correspondence

E-mail was used when having questions for the partners, both general and specific. This correspondence was essential for our research group, but since we did not have access to correspondence of others, its usage was limited. Before and after each official meeting the correspondence increased and e-mails often were then sent to all partners. These e-mails often concerned PowerPoint presentations and Gant charts of the project's progress.

Pre-understanding

A pre-understanding was essential when working in a project as the one described here. Therefore, as a first step in our work package, we wanted to find out what the state of the art said about work environment factors. With this report, we stated our perspective of the work environment as presumed experts in the field. Prevalent in this report was that a long-term perspective on work environment was stressed. As the project itself was no longer than three years and did not contain all phases of a development process, it was necessary for us to step forward as researchers and be extra pragmatic.

Survey

A survey was sent to all partners regarding the proposed concepts, which had already been examined at the beginning of the project. After a while, it was realised that the given answers were not strongly connected to the end result, and thereby did not form the base of the analysis, though the survey gave valuable information of where to find the different technologies today, but in a different form.

Meetings within Work Package 7

Even in our own work package, problems appeared when trying to cooperate. We were two organisations that made up the work package, both with different bodies of knowledge and experience. As mentioned before, a German consultant company also took part in the package. The two organisations only met once specifically to discuss the work in the work package. The German company came to Luleå in the beginning of the project and spent one day discussing with our research group. Some informal meetings also took place in connection to the official project meetings. Our research group possessed different qualities, but we lacked experience from similar European Union projects. This made the management of our work slightly fussy and ad hoc with both pros and cons.

5.2.7 Results of the Work Package 7

The socio-technical research fulfilled throughout the project has led to obtained guidelines for development of new production system concepts and production technologies in the industrial environment that focus basically on the working conditions and ergonomics of the shop floor workers. This output of the project will, if utilised, positively impact the operators' quality of work on the shop floors of the aeronautic sector, users of the new automated assembly machinery, and users of the machine tool that manufactures non-rigid monolithic parts.

The results of the work package were presented in three different deliveries. The first delivery concerned the first sub-task. The German consultant company delivered a summary of laws and regulations from the concerned countries and the European Union. Our research group contributed with a thorough study of the state of the art in work environment factors. The second and third deliveries were merged together and presented in one final report. A final outline of the guideline model in Microsoft Excel accompanied the final report. The final report contained an Introduction to the final results and the enclosed reports: Remarks and introductory facts about the presented results, General conclusions and remarks and recommended areas of future research, Final model of the guidelines concerning work

environment in new technology development – Description of the final model and introduction to the appended tool, Description of the context in ESPAS and SWAS – Description of organisational issues and present production systems (all written by Ph.D. student Peter Lindelöf). Also included were WEST analyses and other socio economic calculations – Work environment screening of production processes at SWAS and ESPAS by Ph.D. students Peter Lindelöf and Marie Sandberg, Ergonomic simulations and analyses of manual assembly work by MSc Carin Stillström, Noise Exposure during milling by Research engineer Hans Wiklund, Ph.D. Bo Johansson, and Ph.D. student Peter Lindelöf, Risk Analysis Regarding Materials – A guideline for integration of issues regarding Chemical health hazards in production design and production by the German consultant company.

5.2.8 Indirect results

There were also indirect results from the seventh work package in addition to the results presented above. The work in the work package created new contacts for all involved and implied that the involved partners gained experience of working in such a project. The involvement of work environment experts in international collaboration projects is not that common and it was therefore positive for the partners in work package seven to get this experience for the future. Also, other experiences were useful for the partners' future, e.g. project work, international collaboration, etc. As well, the project and the work package served as a source of data for academic research after the project ended. This is also described in the rest of this thesis. Another indirect result may have been the influence of our participation on the rest of the partners. The other partners may have changed their mindset and begun to think in more positive terms when working with work environment factors in development projects, but this was not expressed. However, some might have a more negative mindset about the work environment design due to our interference in the project.

5.2.9 Work of the research group

Even though the senior researchers were appointed as task leaders and work package leaders, the Ph.D. students conducted most of the actual work. Of course, we had support from the senior researchers and when it came to writing the task definitions for the sub-tasks, we were asked for our opinions. The overarching strategies in the form of task definitions were formed together, though we received total freedom to interpret them and form the everyday work. When it came to critical questions, the senior researchers were asked when, e.g. it was time to visit the companies, which should take large part of our budget. In summary, the senior researchers were responsible on paper, but the actual responsibility was delegated to the two Ph.D.-students.

During the project, the Ph.D. students Peter Lindelöf and Marie Sandberg tried to continuously report what was going on in the project and describe the future plans for the rest of the group. This was done through informal meetings with some parts of the research group, meetings with the whole research group, mail correspondence, and by preparing presentations for FORWARD-project meetings, which only the senior researchers participated in.

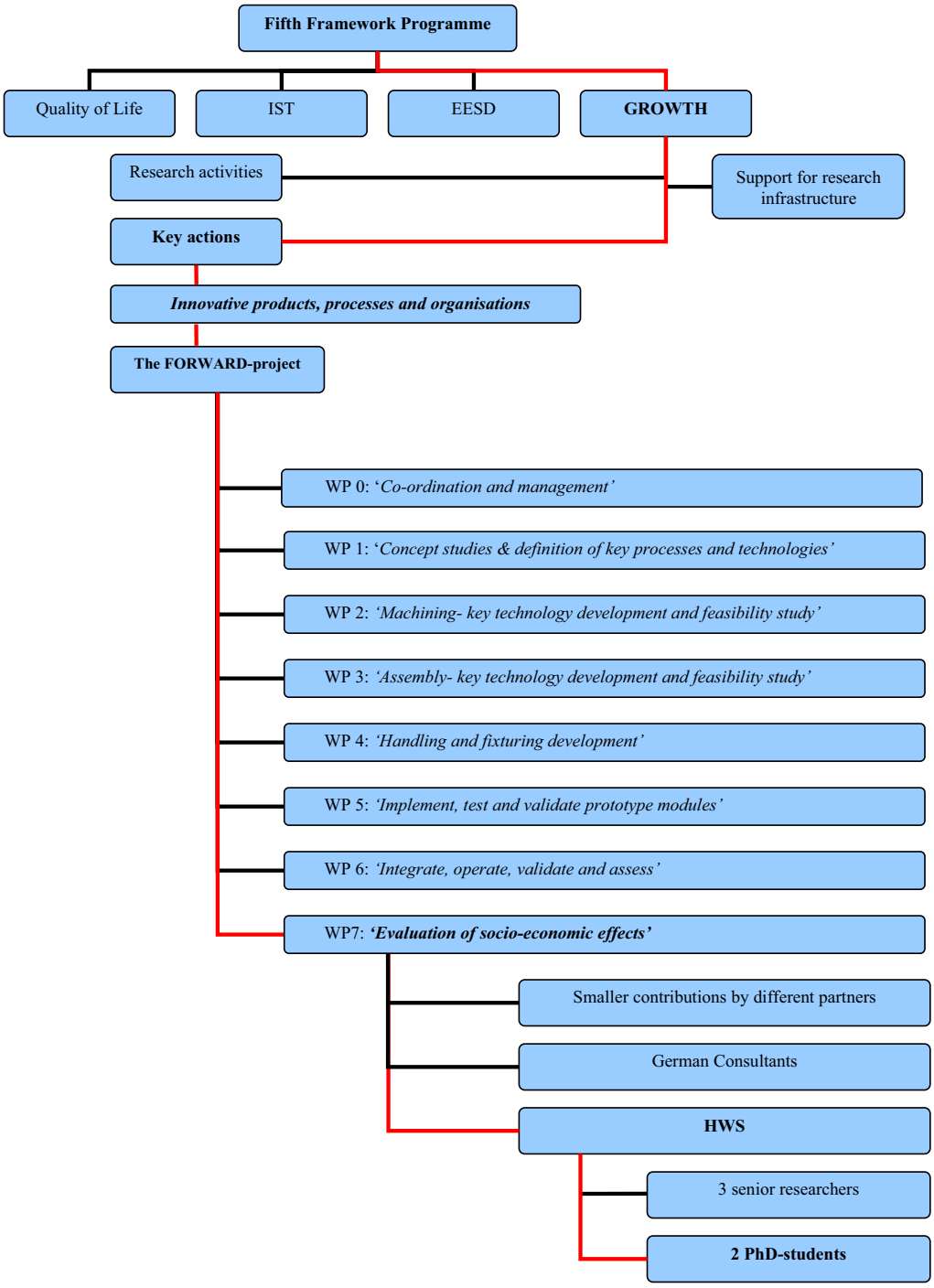

Figure 9 A schematic sketch of how our research group is connected to the Fifth Framework Programme

6 A summarising analysis

This section describes the analysis of the work in the FORWARD-project and its participants referred to the theoretical framework set and the research questions described in the early sections of this thesis. The analysis conducted summarises and further develops the analyses in the appended papers.

Industrial production systems are used on an increasingly global level. A multi-operation machine in Spain does not differ much from that in Sweden, of which the studied FORWARD-project is an example. The differences were primarily found in the organisation of work around the machines, the work tasks, and the design of the work environment, as observed in this research project. However, from the machine manufacturer's perspective, the development of new production technology concerning the work environment and work organisation often occurs within a national context. When new production-related technical components and systems are exported and installed in a different context, national adjustments for work environment demands have to be made, carrying significant costs and losses in time. Even so, most participants in the FORWARD-project, excluding our research group, acted as if work environment design was not that important. This constitutes one of the two basic analyses made in this thesis.

National context not only includes the national legislature regarding the work environment and work organisation, but also the cultural and institutional features that greatly influence the form of work and organisation. This can be found in, for example, the structure of the educational system or trade unions and the position of women in the market place even though this lies outside the scope of this thesis. In the global supply business of today, different factors stressed in different ways in different countries and cultures influence work environment issues. When developing new production technologies, as in the FORWARD-project described, several user cultures are possible. Even though the same legislation may apply for them, at least in Europe in the future, and if work environment issues were acknowledged at all, different norms and values were present to form the second basic analysis made in this thesis, perhaps implying problems if these differences are not considered early on in the development process.

These two basic analyses presented will illuminate factors that made it hard to work with and to speak about work environment within the project organisation. This leads us into if and how work environment design was handled during the FORWARD-project and how systematic this approach was and what could be improved.

6.1 Clashes of approaches and discourses

In this study, comparative research method has been used. Comparison is desirable, since it improves our descriptions and helps us format conceptions, test hypotheses, discover new hypotheses and build new theory (Collier, 1991). It also facilitates an understanding of factors such as technology, economic fluctuations, laws, and culture (Strauss, 1998). In this study, it

has certainly helped to get a holistic picture of the differences between the Spanish and Swedish companies and their somewhat different societies.

The history of work environment development is not consistent in all European Union countries, as described earlier in this thesis. Although it is not possible to generalise the findings from the companies in the FORWARD-project to be valid for entire nations, the observations made in the companies can be compared to the findings of other researchers and thereby strengthened or questioned. During interviews and observations in the FORWARD-project, significant national differences became apparent. However, these differences were hard to distinguish as being caused by nationalities or other affiliations. This thesis focuses on the differences between the participating organisations, from which parallels are drawn to differences in national context. The differences between the two producing companies SWAS and ESPAS were revealed in comments about the work environment, such as *"What do you mean with the psycho-social part?"*, which was stated by one of the respondents in ESPAS. Nowhere in the empirical data collected from SWAS were similar basic questions expressed when asked about the psycho-social work environment. Another example of the different work environment perspective was when asked if there was any preventive service regarding work environment: *"No. There is not this culture here in Spain"*. A final example was when the head of health and safety at ESPAS only saw one incentive that was good enough to take care of work environment factors – to make people afraid of the consequences of neglecting these issues, both operators and management, which seems like an outdated way of managing.

Contrary to ESPAS, SWAS had a tradition to always involve the operators in the developing process. One respondent stated that the operators participated during the whole process. *"We did not just come and say now its time to dig here and move your machine out, but they participated and solved the problem."* The same respondent also wanted to focus on the positive aspects of operators who were critical to some of the changes. According to him it only showed that they were committed; it would have been worse if they did not say anything but just followed. If they participated in a developing process, they tried to fix problems that occurred later on, since they felt somewhat responsible for them. If they had not been involved, they tended to complain about everything.

Respondents in SWAS were highly aware that monotonous tasks and strenuous working positions were present in production. They stated one does not work as an assembler until the age of 65, but often changes jobs to do something less strenuous on the body after a few years. The respondents from ESPAS also acknowledged that they had had problems with strenuous working positions, but that this had decreased substantially compared to previous years. Consequently, they had different comprehensions of what had to be done in the near future.

As an example, the socio-cultural practice of the work environment was different in the two manufacturing companies studied. In addition, both companies had very different views of using the work environment as a tool for public relations. ESPAS could not see any major advantages or incentive to use it. They regarded the work environment in their own company as fairly good, but did not see any connection between this and how they were viewed in the society. Although Schwartz and Gibb (1999) state that a good reputation is an asset that takes years to build up but can be shattered in just a matter of seconds, it seems as though this is not always the case when it comes to the work environment. Companies such as SWAS, which is part of a society that has strategically worked with work environment

issues for a long time, can live on that for a long time as well. Characteristics associated with the national level regarding work environment factors seem to be taken for granted when it comes to specific companies. SWAS and ESPAS showed big differences regarding applying a socio-technical perspective, and when placed in relation to the history of the socio-technical perspective this was no surprise. Because SWAS has been present in a national context whose history has been permeated by socio-technical values, this has also affected the company perspective. The differences implied collaboration problems when they had to be overcome in the FORWARD-project involving more than one perspective.

Differences exist in the field of discourses, but why? One of the causes is due to history, how the national climate has been and where it is headed. It seems ESPAS is going through some issues that SWAS had already dealt with. In Sweden and SWAS, how to handle work environment factors has become normative on a relatively high level. In the past Sweden has been a leading country regarding work environment, at least according to them. In recent years the changing focus to psycho-social factors may be because the physical work environment has been greatly improved, but still present, and that psycho-social factors are causing an increasing portion of sick leaves (SCB, 2006), etc. Focus on the physical part of the work environment in Spain can then be because this is where most of the problems lie today (Eklund et al., 2000), even though the general perception of health and safety protection in the workplace is positive among the safety reps in Spain (García and Rodrigo, 2004). Another example is that SWAS is slightly ahead of ESPAS considering mixing up white and blue-collar workers and the hierarchy is not as strict in SWAS as it is at ESPAS. This influence of history would not be specific for only this study, since every national system is permeated by a history of development and features that define certain critical variables, such as culture, ideology and institutional structures. For a person based in the Swedish discourse, the Spanish manner of viewing the work environment seems a bit like taking a step back and regarding the operators as commodities. Whether this notion is due to the Spanish industry being a few years behind in historical development or whether they are in fact ahead of Sweden is not to be speculated here.

How one speaks about work environment can therefore be a matter of from what context people originate. It is not always obvious that people will handle things in different ways, but they definitely use different words to describe it. Their norms and values reflect what words they use and how they want to address the issues. There are several examples of how they use and do not use different words, such as employee involvement and participation, where the concept of empowerment is not frequently used or at least not as a word. Both companies speak about job rotation, but seldom speak about the other two central parts of empowerment, namely enlargement and enrichment of job tasks. This can be because the rotation is easier and inexpensive, whereas the other two require more resources.

6.2 A lack of a holistic perspective

The discourses affecting the FORWARD-project can be described as a complex net of layers in which the EU, nationality, branch, company, division and the EU-project all represent one layer. This involved the work in the FORWARD-project and the problems observed, such as trying to develop a good future work environment without speaking the same ‘language’, since any method of expression or communication about the matter became problematic. Because our research group had an outspoken socio-technical perspective that

was shared to a varied extent with the other participants in the FORWARD-project, our principle of action was met with resistance. This resistance was not always open, but more of a passive character. Participants declared that they understood our way of looking at work environment factors, but little was done on their part to improve the work environment design. It was our assignment to pay attention to these matters and it seemed as though the other participants were satisfied with this division of focus. If we took care of the social system, they would take care of the technical system. The two were never optimised together. This reveals a lack of a socio-technical understanding and a depreciation of work environment issues in the FORWARD-project.

The boundaries were not considered, for example, where control issues for the prototypes developed were not greatly focused upon. The fact that automation of some tasks sometimes implies several flows being assembled through one machine makes it unlikely that the processes will be more redundant. The jobs of controlling the new machines will be more knowledge demanding for the operators compared to today, but perhaps not more stimulating, since a machine often operates unassisted for extended periods. The loading and unloading of material will be large parts of the operators' future work, something that was not acknowledged as much as needed in the FORWARD-project.

Regarding the immediate physical work setting, orientation towards it was very high. As a starting point the project itself had a low grade of automation, common in this type of industry, and the aim was to increase it. During the project the deliverables were full of sketches, blueprints and simulations. The first deliverable from the project was in fact a description of how the work was done today, with explanations of several parts and jigs. This implied a good starting point for future comparisons of the operators' work tasks, but due to reasons of confidentiality the descriptions were not detailed.

The FORWARD-project described in this study aimed to increase the quality and the general pace of production. Whether this implied that the operators' working pace must also increase is hard to say, since this is a question of if the work organisation is redesigned at the same time as the production process. If an operator's job will be to load and unload machines, the increase of machine process speed will mean that the operator's working pace will also increase. However, if a simultaneous redesign of the work force takes place, perhaps the new techniques developed will decrease the working pace. With new techniques, the operator's slack will become even smaller. The lean production focus in today's industry will counteract the setting of bigger stocks before and after the machine.

New technologies developed in the project will decrease the involvement of manual labour in some processes. The operators will become fewer and the work will be more controlled. The engineers involved in the project were so focused on the detailed technologies that the implications for the system were not discussed. For example, during one of the project meetings, one partner brought up the importance of looking at the developed techniques in a system perspective. What would happen during implementation? Another partner was assigned this task, but when looking for it in the project deliveries, this was nowhere to be found. One reason for this might have been that the end result from the FORWARD-project was in bits and pieces, which an experienced consultant from the UK had warned us about at the beginning of the project.

Whether or not possible new groups formed around the developed technologies will be autonomous, only time will tell. Signs indicate that they most probable will be autonomous,

since the machines are too expensive to stand idle. The operators have to make decisions to get the machine started again, increasing the need for the operators to be well-educated, knowledge intensive and driven to be proactive. At the same time, the fact that the method of production will be stipulated more for the new machines contradicts that the increase in autonomous level.

The clash of perspectives in the FORWARD-project hindered a good work environment design. There is a strong connection between work environment design and the socio-technical perspective that tries to optimise both systems together, though even without a socio-technical perspective the work environment design could have been done better. The total lack of specified work environment factors when evaluating the different concepts in the beginning of the FORWARD-project showed areas for improvement.

The different discourse layers sometimes counteracted each other, for example, when project partners were affected by more than one discourse. Since our research group and our work plan were based on the socio-technical perspective and the fact that we did not fully succeed in making the partners feel like they shared the responsibility for the work environment design, it became interesting to find out why. The question arose as observations and interviews were being conducted, whether or not the two manufacturing companies had socio-technical perspectives in their own companies, outside the FORWARD-project.

6.3 A lack of workers' participation

Concerning the operators' participation in development projects, the studied companies have very different strategies. SWAS is very keen on participating, whereas ESPAS does not greatly use this method. Both companies state that participation in the development processes is very important, but they differ very much when it comes to their application. SWAS has succeeded in creating routines for how to involve operators, etc., in the early stages, which can explain some of the differences, but not all. The divergence in approach is striking. SWAS chooses to give prominence to the positive aspects of the strategy, whereas ESPAS focuses on the fact that it delays development projects, thus implying many extra costs. It is also interesting to note who are allowed to give opinions during the development process. SWAS stressed that they wanted to have the opinion of most people before beginning, but it seems like this was not the case in ESPAS. The positive resistance present in SWAS when implementing new production equipment was either missing in ESPAS or taken for granted. This is connected to the use of participation, where if the operators are not involved at an early stage, their opinions are hard to deal with when the final solution is presented and in particular very expensive to pay attention to. However, some disadvantages with participation have been observed during the FORWARD-project, e.g. operators tend not to complain about things they themselves have developed even if the results are problematic and participation can be very time-consuming. A discourse in Sweden states that participation is good, which very few are willing to contradict. Between 1945-1990, a shortage of labour made Swedish managers listen to workers' demands regarding an improved work environment (Walters and Frick, 2000), and even though a rise in unemployment and in casual work made Swedish workers quieter in their demands (Aronsson, 1999), it was obvious that most people in SWAS were positive to participation. This discourse differs from that in Spanish, where there is much talk of the disadvantages of participation and a stronger outspoken focus of short time profit. However, both companies

agree on attaining a better result when using participation. It seems to be about using a short or long-term perspective. It can also be due to the higher employee turnover in Spain than in Sweden. If involving an operator in Sweden during the early design phases of a new production system, it is common that this person will still work in the company when the process is implemented. That is not always the case in Spain. This highlights two different approaches with different pros and cons.

Even though both companies can be sorted under the same type of industry, i.e. the aero structure industry, the distinctive character of each company's origin filtered through. The company from Sweden illustrated signs of a relatively long history of socio-technical aspects in its participation in the development of production organisations. The company is still affected by how nearby society influences it, of which Swedish society still perceives these issues today as very important. When asked, the respondents at SWAS still proclaim their loyalty for the socio-technical perspective, while it could be understood, between the lines in some cases, that the focus of these issues is being steered away from. Simultaneously, there is a rhetoric influence in ESPAS that they want to erect a more socio-technical perspective than today involving more participation, while keeping in mind the operational management perspective. Whether this is a sincere desire is hard to tell, but because both companies belong to the aircraft manufacturing industry they tend to be influenced by the same international surroundings.

Operators conducting tests on the machines were the only form of worker participation in the FORWARD-project. It may not be possible to involve operators in project meetings, but their thoughts should be noticed during the development process. Even if participation in a project like the one described cannot be higher, it can be compared to the socio-technical perspective and regarded as low.

6.4 Low levels of knowledge and competence in work environment design

Participants in the FORWARD-project group sometimes tried to prove the excellence of the developed techniques by stating they would handle the present manual activities. They did not heed what would happen to the production organisation when reducing the work force need. In addition, it was difficult for any of the project participants to prove it would imply better business efficiency. Although the intention may have been to use system design, the outcome was so focused on the technologies and 'hard' parts of the project; it was difficult to regard it as a typical system design process. For example, there was a strong focus on how much the quality would improve, since the accuracy of the machine would be better than the manual work done today. Because the project was technologically driven, many of the functions allocated in the manufacturing environment ended up leaving leftover tasks for humans to perform, without considering the socio-technical characteristics. This can be illustrated by discussions held with some of the partners, who stated that since not all of the tasks in the process of aircraft manufacturing could be defended economically to automate, they have to take care of those that are. Sometimes, tasks that were obviously badly designed ergonomically would be left out in the middle of the automated process, since the process was too expensive to change. This is common for projects considered to be technologically driven (Kleiner and Shewchuk, 2001) and this sometimes seems like a deliberately chosen

strategy. Reasons for this strategy may be related to cost, the lateness of the guidance relative to the stage of the design cycle and the incompatibility with other organisational or business constraints (Damodaran, 1991). In this project, it seemed as though it was about expensive and high technology inventions placing an extra focus on the technical questions and a decreased will to work with questions about production systems and the related human issues. Damodaran continues by stating that these factors in the long run can cause a rejection of human factors as advised by practitioners and specialists or that they will be inappropriately implemented, or only partially implemented.

The lack of a systematic and a holistic perspective is another reason for the experienced problem of work environment design within the FORWARD-project. This lack can be due to a shortage of knowledge about work environment factors. Many of the participants in the FORWARD-project showed an insight of how the European Machine Directive affected what could and could not be done. The problem was that what our research group regarded as a good work environment required more knowledge of how these machines work in combination with operators and other machines in a production system. As a step in this direction, educating the project participants is necessary. We tried to accomplish this in our first FORWARD-project report focusing on state of the art in the work environment that described what could be regarded as the front edge of work environment research. The problem was that this report, as many of the others in the FORWARD-project, occupied digital space on desktops and was probably never read by other participants. Enhancing knowledge about work environment in future projects requires a different approach and a shared responsibility for work environment design. Each participant should feel a personal responsibility and not entirely rely on the experts to take care of the matter. Work environment experts should assist in setting the demands for a future work environment, and the technical experts should, with assistance from the work environment experts, find appropriate solutions.

Our research group's approach was to use a holistic and systematic approach with a four-step work plan, as described in sections four and five of this thesis. Since we were not able to conduct complete analyses of the proposed technologies, we also focused on three production processes in the two manufacturing companies. The results from these analyses showed several problem areas, e.g. strenuous ergonomic positions, high noise levels due to riveting, etc. These analyses highlighted areas commonly known by both manufacturing companies, but which were stressed further by our analyses. Despite these extra measures the project failed to fully involve these areas for the developed technologies. After studying the Cordis homepage, http://cordis.europa.eu/ and the projects presented, and discussing the matter with experienced EU-project participants, it can be concluded that other similar EU-projects often lack the separate focus and means to deal with work environment design, making it important to find a method to take care of these issues with smaller resources and a smaller supply of experts in the field. As it is unlikely that all future EU-projects will have a comparatively large budget to deal with work environment issues, it is important that knowledge about work environment design is enhanced among the project participants.

6.5 The importance of context was neglected

The two studied companies had their own ways of handling work environment design, which differed from how they handled it in the project. At ESPAS and SWAS, the question

of responsibility for work environment design was clear. SWAS had process flow charts where these issues were brought up and mandatory information duties given to a special group concerned with work environment design. Both companies involved the OSH-department in large parts of their change processes. However, the FORWARD-project described in this paper had no such clear distribution of work environment design factors. There was no obligation to report to anyone about the consequences in the work environment, and no OSH-department was present. Instead, we served as a sort of substitute with no design responsibility and no power to decide. During interviews, respondents from SWAS said that how a project is driven is very much up to the company tradition, which respondents at ESPAS agreed upon. The problem is that a project organisation seldom has a similar tradition, since every constellation is temporary and new.

The importance of the different contexts was ignored by the project organisation. Since the developed production techniques were supposed to be implemented and industrialised, the lack of a discussion regarding the different contexts was noticed. The involved countries were all members of the European Union and thereby had to measure up to the directives stated by the union. The problem is that all countries interpret these directives differently (Vogel, 1994). The differences may not be huge but present. Some countries have additional laws and regulations concerning the work environment that are not present in the European directives. Moreover, the branch conditions are different among countries and the labour market is represented in different forms. The tangible work environment also differs in different nations, companies, contexts, etc. Therefore, it is of importance to initiate a discussion about these different contexts and how they affect the ease of implementation supported by Lovén (1999). In the FORWARD-project this discussion was conspicuous by its absence. Our research group tried to set off this discussion when conducting the second phase, i.e. in the "Evaluation of the industrial environment and the production context". The problem was that no one was really sure how the new technologies would fit in exactly. Instead, it was necessary to focus on typical processes where implementation could have been possible. For future projects, it is then advantageous to find a way that acknowledges future contexts for implementation and thus avoid or at least minimise additional adjustment costs due to context.

In hindsight it can be questioned whether the technologies were supposed to be implemented at all, as the aim and time schedule seemed very optimistic. Even if the stated objective of the FORWARD-project was to involve implementation and industrialisation, the main focus lay on the invention. Irrespective of the project objectives, when asked, the partners brought up things such as networking, benchmarking, idea creating, financing older ideas, etc. An experienced British consultant participating in the FORWARD-project stated during an interview, as mentioned before, that the worst thing that could happen for our human work research group was the project result ending up with technical bits and pieces of several kinds. It had been realised afterwards how right he was and this caused additional problems for the work environment design. Consequently, it was not possible to totally grasp how the developed pieces would affect the future work environment, since the context for implementation was differentiated. Officially, the FORWARD-project was what Engström et al. (1998) and Bellgran and Säfsten (2005) state to be concept-generating when several concepts are developed during the project, some of which are excluded along the way. However, when interviewed, unofficially and to some extent implicitly, some of the organisations knew specifically what they wanted to develop in the project and in some cases

had already started this work. Thus, a hidden agenda and goals were present. Hence, the FORWARD-project was a mixture of both concept-generating and concept-driven approaches. This might have implied a chance to influence the final result of the work environment design. It seems as though it would have been easier to handle the work environment when partners already knew what to develop even though this was not common knowledge within the project organisation.

6.6 The design, disposition and structure of the FORWARD-project implied problems

The engineers in the project were very focused on the detailed technologies; hence, the implications for the system were not discussed. For example, as mentioned, during one of the official meetings, one partner brought up the importance of looking at the developed techniques in a system perspective. What would happen when they were to be implemented? A partner was assigned this task, but when looking for it in the project deliveries these analyses were nowhere to be found. Almost everybody counted on someone else, presumably us, to take care of the work environment design factors. If not us, then engineers responsible for development of the concepts and prototypes of completed solutions. However, some attempts to consider these matters were made, e.g. when presenting the concepts in one report, aspects such as how to fence in the machines and how certain designs may cause a risk for tripping were briefly discussed. When putting the concepts in a matrix to systematically evaluate them no demands regarding the work environment were presented. People in general believed that more and more processes would be automated, thus implicating tasks would remain between the automated tasks, e.g. those with bad working environments like the riveting processes. However, a possible explanation why these matters were not handled properly could be that they were seen as temporary solutions waiting for automation. As well, the supply of workers was high in both SWAS and ESPAS during the FORWARD-project, which meant that low knowledge intensity jobs were not dependent on the workers currently operating the tasks.

Due to different attitudes, perspectives, and the handling of the work environment, collaboration became problematic. The normative way to handle work environment design in their company was set aside when participating in the FORWARD-project. Even though people understood the validity of the new prerequisite in the FORWARD-project, they perhaps saw the opportunity to escape the responsibility even more, instead of adapting their work. As these differences in attitudes, perspectives, and handling of the work environment implied clashes, they were ignored and a lowest common denominator consisting of a shared desire to concentrate on the technical aspect of the end result in the FORWARD-project was instead chosen. Regarding the work environment, confidence in the European Machine Directive (98/37/EC) was the common denominator and each partner was counted upon to solve the rest of the work environment issues if they were going to use the production techniques developed. The same persons in the project were well aware if their organisations handled these issues in a more structured and systematic way. Instead of choosing the lowest common denominator our research group's intention in the FORWARD-project was to choose a higher and better common denominator regarding the work environment. Our research group did not completely succeed with this intention. Both differences and similarities were focused upon, but future work, i.e. to find common ground for the work

environment design, a more systematic approach has to be implemented. This work has to start as early in the project as possible, since it is then the participant seek the common denominator, and when set it is hard to change.

6.6.1 The detachment of work environment design

The lack of a holistic or a system perspective filtered through by the way the project was structured. As can be seen in Figure 10, the work environment design in the work package of *the socio-economic effects* is detached and not integrated in the rest of the project model. In hindsight, convenience might have dictated the look of the project structure. Coordination and management set the framework of the projects and thereby influenced the work packages involved in the two sub-projects. These work packages influenced the one concerned with the evaluation of socio-economic effects, but there was not much influence in the other direction.

When composing a project group working with a new technology in an individual company, several opinions are present. For example, Kleiner and Shewchuk (2001) state that the ideal function allocation design team would be a cross-functional team comprised of six individuals. At least two of the individuals should be operators, with the remaining members representing ergonomics and other functional areas. The operators participating in these groups are advised to get training in ergonomics and function allocation before serving in the teams. Ten partners participated in the studied FORWARD-project. It would be incorrect to compare this project to 'a function allocation design project', since it was really about an international cooperation project between different organisations, though it still seemed like too many persons were involved. Several groups of partners were comprised of numerous persons, totalling approximately 20 in the project group, most of whom were engineers. Operators never attended a meeting. However, the work done in between involved some operators, though mostly to use their skills and not their knowledge. For example, SWAS used operators when testing parts of their techniques in the machines. In line with Broms & Lindahl (2005), the development of new production systems in the future needs to be accompanied by the development of work for the operators. Broms & Lindahl also illuminate nine different areas that need to be focused upon in future investments, two of which are new models for development of production systems and new methods for change processes. This is strengthened by this study.

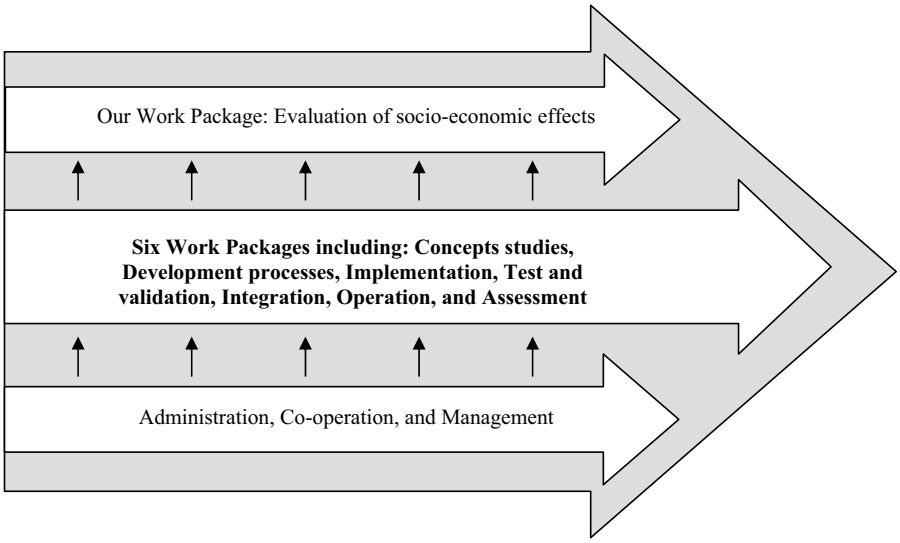

Figure 10 The structure of the FORWARD-project described in this thesis (slightly moderated due to confidentiality). The central arrow symbolises the core processes of the FORWARD-project and the figure visualises the detachment of the work package concerning *Evaluation of socio-economic effects*.

The structure of the FORWARD-project was not optimal concerning work environment design. It could have been a good approach, but according to our research group some vital aspects were missing. The effects of different perspectives and different knowledge levels in work environment design were not evident. The lack of integration amongst work environment issues was significant and implied a detachment of these issues from the project core. However, we did not react until we started the project, since we thought it would be a good idea to organise it in the proposed way. If the work environment issues had been integrated with the rest of the development process, this would never have secured a good work environment design. After all, the detachment meant that we were able to conduct our work plan and analyses in line with our intentions. What we were not able to do was continuously improve the work environment design as hoped. The conditions and objectives we were obliged to follow were set in the beginning, meaning that the project structure needs to be more flexible to adjust to specific circumstances.

6.6.2 The different roles in the project regarding work environment design

The participants in the FORWARD-project were divided into two informal camps concerning the system they were about to develop, viz. the 'hard' and the 'soft' approach. One camp advocated a hard approach on how the work environment factors should be handled in the project and the other tried to use a soft approach. The two camps also differed in how important these factors were considered for a system in operation. Our research group often constituted the soft camp, sometimes with support of other participants, e.g. regarding looking at the whole production system, since Goodman et al. (1999) state that individuals may shift their cultural identity depending on the issue at hand, meaning that they can draw from different mindsets they carry. The general thinking by persons in the hard camp was that the guidelines and legislations on work environment present in the EU were very unclear. There was an urge, for example, among project leaders in the studied

companies for more quantitative data and measures. A good work environment had to be specified with demands on different parameters and in a quantitative way to make the input of the design process result in a good output.

Those with work environment knowledge can be described in different roles. In the observed project and that participated in, three types of participants possessed different levels of knowledge about work environment factors, *administrators/economists, project core participants*, and *experts* in the field of work environment. Of course, these three types are general in nature and one can be situated somewhere between, since they are merely used to describe the typical examples of participants, see Figure 11. The project participant, often an engineer, for example tended to have different work environment knowledge depending from which country, company, etc. they originated. This knowledge was usually in the form of practical knowledge and not theoretical knowledge.

The type of *administrators/economists* consisted mainly of one or two persons from the coordinating company and occasionally people from the European commission who attended the meetings. In the FORWARD-project, the *administrator/economist* took pride in executing the project and their number one priority was to keep the financial budget, while coming up with the desired results. Work environment factors in this group were prioritised as long as it did not risk the budget or the end result in any way. Knowledge about the work environment was limited, but present. Work environment factors seemed to matter if they demonstrably would affect the outcome of the project, for the most part in monetary terms. For the *administrator/economist*, work environment issues and research were also important to be eligible to apply for money for future projects, when higher instances such as the EU so demands. In this group, the state of the research in the field of work environment was not much discussed.

The type of *project core participants,* which in the FORWARD-project consisted of almost everyone and sometimes us as well, can be described as people possessing a great amount of knowledge about different technical dimensions. These individuals were well familiar with different kinds of technology and were used to handling work environment factors in a specific way in their own organisation. They were familiar with basic legislations and some specific regulations, at least in their own specific context. They knew the legislations existed, but not their specific content. Their main focus was to come up with innovative technical solutions, which they were not so strict about how to do as one of the prerequisites of innovation. General knowledge about the overall work environment was fairly good, but fluctuated greatly within the group. It seemed as though they sometimes did not know how to handle these matters themselves, though they tried to when they thought they had time. The *project core participants* often expressed the need to have expert opinions in these matters. They knew the basic legislations, but were not that familiar with what modern research in the field stated, and they seemed to care less, since their focus was on other matters. One got the impression that *project core participants* regarded these matters as privileged things for those who could afford a long-term perspective and who did not need results the following day.

The *expert* type group is involved as a result of several possible factors. All partners were experts in something, but regarding work environment factors, our group together with a German consultant company were officially the experts in the field. The main focus of the *experts* was to look after the work environment in the long-term perspective, while supporting the development of the project's objectives. This was problematic in the project when the *experts* were seen as gatekeepers and to some extent as inbuilt inertia, i.e. only

symbolised negative aspects. The *experts* sometimes became detached during the project and were seen as participants in a secluded project, which should be responsible for that the outcome of the "big" project should fall under the description as work environment friendly. The *experts* occasionally did not conform under the same objectives as the other partners and this could be a problem. The *experts* were naturally most interested in the work environment factors, but needed to embrace the production outcome as well. To be sorted under the label *expert*, one has to be aware of the state of research as well as the production requisites and project objectives. The *experts* should also have an awareness of addressing these problems and ideas of how to overcome them.

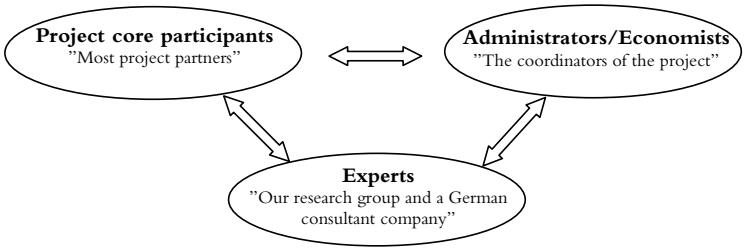

Figure 11 The figure illustrates how the three typical types of participants in the project can be described in respect to work environment design. The arrows symbolise the possibility that a person in one situation can be regarded as an expert and in the next as an engineer etc.

The involvement of the *expert* can be due to the demands of the surrounding society or self-awareness telling the *administrators* and *project core participants* that they themselves will not be able to take care of specific matters in a suitable form. The experts can be consultants working in the field or scholars using the project for higher objectives, as in the case of our research group. There are certainly other alternatives of *experts* present, but the important thing is that they possess a great body of knowledge about work environment factors and work environment design, and for our research group, this was the entrance ticket for the project. If the discussion was instead about, for example, heat cameras then it was the other partners who stepped up as experts. The big difference was that the distance between the rest of the group with all the project participants and the group of experts was then considerably shorter. The project organisation found a common denominator in other technical issues, since all had an interest in these types of questions, but the common denominator was not as clear regarding work environment design.

When illustrating the project organisation in different roles, it should be noted that not all experts were participants in the FORWARD-project. When our research group needed external help, we hired experts. For example, experts in the field of noise and vibrations outside the project organisation were engaged, but they are not included in Figure 11 because they could not move into other roles in the project.

6.6.3 Knowledge creation and transfer

After merging the machining process project and the assembling process project, it was still possible to see the differences in the combined project. Even though an overarching objective was stated, the two sub-projects did not work as smoothly together as was desired. This is probably one reason for the problems experienced with integrating work

environment design factors. The partners were confused for a long time about the actual goal of the project and how they played a part in fulfilling it. This resulted in a lack of determination as to how to proceed. Some work packages were merged in the early stages of the project and confusion about how each partner's interest should be attained was noticeable. If the two sub-projects had been merged to a greater extent, it would probably have increased the possibilities to include work environment design factors in the FORWARD-project. However, the project gradually evolved and partners found ways to cooperate even though they were still in separate sub-projects of the project. Moreover, the partners were also confused about who was the 'receiver' of the new production technology they were supposed to develop. No clear end user was stated. This structure of the FORWARD-project implied a few hindering problems for work environment knowledge creation, transformation and transportation. The transferring of knowledge attained to future similar projects is not ensured, since it is doubtful the same people will participate. Consequently, there is no structured way to use the gained knowledge from the FORWARD-project. This will cause resistance to spend time and money in a collaborative project to enhance the individual knowledge about these matters. Instead, this knowledge creation has to take place in their companies before or after the EU-project. This means that a form of knowledge transfer is needed between different EU-projects instead of counting on luck to get the right participants. Further, the knowledge creation process in the project should be acknowledged. Because knowledge is created in interaction between people, knowledge about work environment design will evolve each time it is used in similar projects. Neither knowledge transfer nor creation is successful if the knowledge cannot be transformed between tacit and explicit forms. Since different individuals in the FORWARD-project all possessed different bodies of work environment knowledge, this knowledge has to be shared and made available to those who lack it. Knowledge and responsibility go hand in hand, and it will then be impossible for participants to rely someone else to take full responsibility for a future work environment.

6.7 A lack and a need of a systematic methodology

Several development models of production technologies in the form of products are available in industry today (Magrab, 1997, Barclay et al., 2000). These models are comprehensive in nature and deal with many issues that are evoked during the process of change, e.g. how to deal with criticism, implementations and industrialisation factors. However, these models tend to lack a holistic perspective of work environment factors, even though some models deal with a few of them (Neumann, 2004). Some models involving work environment factors exist, but only a few can be found on the industry floor. It is commonly a question of meeting legislation limits, etc. Seldom is it a question of excelling in the field of work environment. When development work takes place in project organisations, the models for development of production technologies regarding work environment factors tend to be just a desk product for academics, and development of production systems in general is often lacking a structured methodology and systematics (Bellgran and Säfsten, 2005).

6.7.1 The original 'work package seven' model

Within the FORWARD-project, our research group started out from a proposed model of four steps, described in section 5, whose intention was not to be useful for other

organisations to use, but more a methodological model for the work environment design. This model displayed both pros and cons along the way. The positive things were the reciprocity of both technical and social systems, which illuminated a socio-technical perspective. Both contexts and discourses were analysed along with more 'hard' risk analyses, e.g. noise, chemicals, laws and regulation, ergonomics, etc. Even though we used an approach consisting of both the 'hard' and the 'soft' systems, i.e. a socio-technical approach, paradoxically the work plan was a factor that hindered us from being integrated in the rest of the FORWARD-project. Instead of involving the remaining partners in the work environment design, the model began to focus on utilising the FORWARD-project and the participants as study objects to facilitate my research and to come up with a new design model as an end result, which was the actual aim of WP7. The development of the final outline of a design model can be seen in Figure 12.

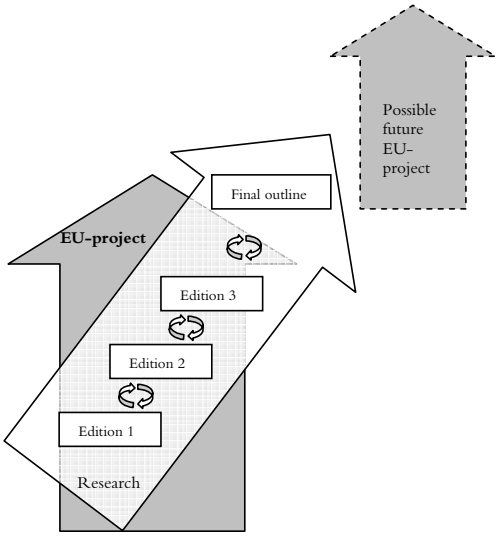

Figure 12 The development of the final work environment design model started when participating in the FORWARD-project studied. The first edition leads to the second etc. As the development went on the work became more influenced by research and the final outline can hopefully be used and further tested in future EU-projects.

This implied that our research group alone was responsible for the work environment design, unlike the shared responsibility in the technical aspects of the project. One reason for this lack of shared responsibility was because our model could not have been regarded as distinct and easy to follow as models other participants were used to. Together with this, our work with the model lacked practical experience, meaning that even though the proposed model was good in theory, it was strictly a method for our research group of how to work in work package seven, and not for other individuals to work from in other projects. Instead, it was about creating a model as an end result for future projects, since this type of work had not been done before, at least not officially. During the work with the model, our research group tended to point out troublesome areas in present and future production, as well as the present state of the art and legislations regarding work environment. Our development work was, as was our intention, more about studying the FORWARD-project instead of helping with real time questions, i.e. we did not give any strong advice, but focused on creating a design model for others to use in future projects. This was somewhat misinterpreted by other

participants in the FORWARD-project, who during the course of the project did not pay much attention to our work, but when approaching the final meeting started to understand us as a resource for securing a future good work environment. The model did not involve any systematic way of spreading work environment knowledge, which needed to be improved in a future design model. Reports written in the FORWARD-project were available for other partners, though not many of them paid any attention. Thus, a systematic way to transport the knowledge could be advisable for a future model.

6.7.2 A proposed work environment design model

Participation in the FORWARD-project called for a more structured way to handle work environment design factors. I found the most important thing was to raise questions and to change the train of thoughts present in the minds of the project team. Not all work environment design factors have to be soft and unstructured, but they are occasionally and we still need to consider them and continue to develop the new production technologies. The guidelines and checklist serve as incentives to think twice and avoid both economical losses and human suffering and achieve a work system that takes care of both machines and personnel properly. Even if some researchers state that productivity and quality of life is strongly connected (Lovén, 1997), certain researchers like Pruijt (2000) state that this statement is only something used by people in the context and discourse of work environment research. Pruijt states instead that the only factors we can refer to are the companies and society's humanitarian beliefs.

The project teams need a structured design tool to work with work environment factors. Models were presented before, but not in a hands-on format. For example, one can easily draw parallels between the needed model and the soft models presented by Checkland (1981, 2000) and Checkland and Scholes (1990), but their methodologies differ greatly. Waterson, Older Gray, & Clegg (2002) have proposed another method to allocate work between and among humans and machines. This method takes a broader scope of the function allocation than before and could be suitable to use as a complement. Function allocation is important, but few deal with these types of questions early on in the development process. Within the FORWARD-project in this research project, allocation was not part of the project phases, at least not in a structured and systemised manner.

The model developed and presented in this study should be seen as a heuristic and iterative model in which nothing is set forever. The model has to be a living 'organism' and will be updated and evolved during use. Its basic design can be consistent, but details, guidelines, and checklists have to change together with development in the field. The model has to be detached to its character from the technology development project model, but follow a similar structure. The model should aim to distribute and give prominence to a socio-technical perspective. In this work an important factor that steers most others is the resources available. Often these resources are already set before the project starts, but despite this, it needs to be acknowledged.

The proposed model is based on how development projects escalate stepwise from one phase to another. The four phases present in the model are *concept, prototype, implementation* and *running process*. Each phase starts with a preparation where authority, tasks and responsibility are distributed. The model does not cover how the overall project is set up, i.e. regarding aim, objective, resources, time plan, organisation, etc. Many of the prerequisites for work

environment design are already set in this phase, as they were in the FORWARD-project, though the evaluation of the project, as shown in the design model, will possibly provide good input for a phase of project definition and planning for a future project.

The guidelines and checklists in the model, see Figure 13, are to date very brief in their nature. As mentioned before, much is formulated as questions that will help to initiate a discussion. Another important detail is how these guidelines and checklists are structured. The first step, i.e. Preparations, contain three sections: Present situation, Organising project, and Changes of the model. In this step the project organisation needs to formulate mutual objectives regarding work environment design, which runs smoothly with the overall project objective. Typical questions in these sections can be found in Table 2.

Table 2 Typical examples what can be found the guidelines for Preparation

Present situation	Tip: Evaluate the present situation in the processes that can be changed.	The work environment screening tool (WEST) can be used for evaluating the present situation
	Q: What work environment is desirable in the future?	Describe goals and demands in quantitative and qualitative terms.
Organising the project	Q: Is the necessary work environment competence available in the project?	If not a discussion must be held and a decision taken, how to make it available.
	Q: How detailed guidelines are desirable during the project?	This can be changed during the project
Changes of the model	Q: Does any company/organisation want to add anything in any phases or levels at this stage?	All companies need to consider company specific factors and discuss these issues with their health and safety department, etc. before entering them in the model of the guideline.
	Q: Is there anything that is wrong or out of date, etc. in the model?	If so, this is the time correct and update.

The model presents alternative ways for companies depending on whether they want to just reach the limits set by the Regulatory level, or if they want to take further steps in the field of work environment and use the Culture/Branch, and Company specific level.

Regulatory

From the work of one partner in the FORWARD-project that studied EU regulations and complementary information, the *regulatory* guidelines were developed. Organisations and engineers need to know where to look for and find regulations and directives, but the information provided does not need to be so detailed, i.e. there is no need to include the limit value of a specific chemical substance, since this would imply a very extensive model. If

the model is to be web-based in the future, there is a possibility to link regulatory information and make it available in an updated form for each project.

Culture/Branch

Globalisation means multiple cultures. Cultures communicate and interact differently (Trompenaars, 1994, Blevins, 2003). Cummings and Worley (1997) state the culture of an organisation can be seen as the peel of an onion. The core consists of some basic assumptions that influence the values, affect the norms, and can be seen as artifacts. There are five key values that describe national cultures and influence organisational outcomes, viz. context orientation, power distance, uncertainty avoidance, masculinity, and individualism (Hofstede, 2001, Hofstede, 1982). Culture is in the model because it is important to be aware of it to succeed with the implementation of new technology (Trompenaars, 1994, Hofstede, 2001). Culture also consists of branch specific guidelines, i.e. the aero structure industry. This branch implies specific conditions in, for example, quality aspects. This level of the model should be filled up by the project organisation with help of trade associations and well-experienced consultants and 'gurus' in the field.

Company specific

The level *company specific criteria* is necessary to seize criteria that differ in the different companies other than direct culture. One company can handle the implementation process one way, whereas another company may do it completely differently. For example, once implementing a new technology, a company will have to write and prepare documentation to be allowed to begin using the new technology. In another example, in one of the production companies, a special form of work environment information must be written and sent to the department of OSH for approval. These OSH resources and capabilities differ vastly from company to company. This level is necessary to make the project team aware of the differences so as to overcome them.

Each guideline for the Regulatory, Culture/Branch, and Company specific levels at each phase of the project contains 10 sections, namely Organising work, Occupational accidents, Noise and Vibrations, Chemical health hazards, Work place design, Ventilation and indoor air quality, Occupational musculoskeletal disorders, Psychosocial work environment, Lighting and visual work environment, and Managements involvement. Each section has the Exceeding level that can be constituted by tips, e.g. to simulate the future lighting in a computer-based dynamic illumination model where the consequences can also be detected, or that one should be aware that the Indoor Air Quality fluctuates over time depending on changes in the emission processes and ventilation, e.g. painting, gluing, sealing, etc.

Regarding Phase Evaluation and feedback, and preparation for the next phase, this guideline comprises three sections; Evaluation, Feedback, and Preparations. These sections ask questions as; Did we achieve minimal levels, desirable levels or both? Is it possible to improve this level later? How can we document the steps conducted in this phase? Who is responsible to ensure the demand and solution specifications are considered in the next phases? These parts are present to carry out continuous improvements that are highly stressed in theory associated with product development (Eppinger et al., 1994, Ranhagen, 2004)

In the last step of the model, Evaluation and feedback of the project, asks questions like; How can we document the steps taken in this project? Can we learn anything from this project? Who might be interested in how we handled work environment factors during this

project? This step is present to enhance the model for future use as well as evoke the idea of what could have been done differently by the different partners, i.e. a form of knowledge transportation. The evolvement of the model is important, along with training of the participants.

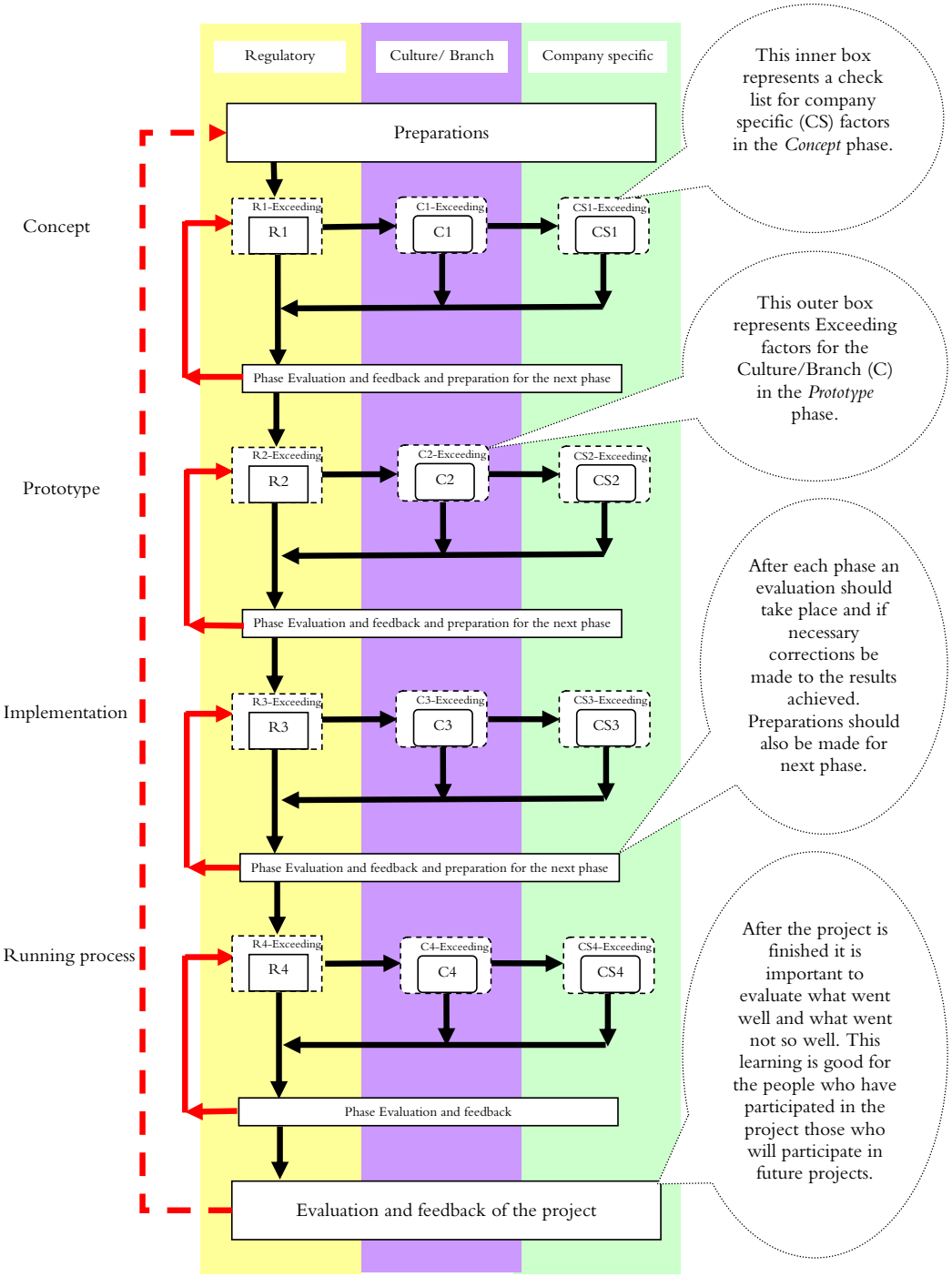

Figure 13 The outline of the proposed model, with some explanations.

The model developed and presented in this thesis should be seen as a heuristic model where nothing is set forever. The model has to be a living organism that will evolve during use. The basic design of the model can be consistent, but the guidelines and checklists have to change with developments in the field. When designing a model like this, it is a good idea to use practices used in other work within the industry. One way to do this is to use what Wu (1994) describes as the $IDEF_0$ system to specify the functional relationships of any manufacturing environment. In this system, the function blocks are linked together through the inputs, the outputs, the mechanism and the controls. Another form of description is the use of State Transition Chart (STC) with different symbols for start/end, text box, conditions, connector, message connections and instance connection. Observations made during the project and experiences all influenced the design of the model.

Besides the descriptions of the model found in this thesis, the final outline is in the form of an Excel document. In this document, every box is coded so that when pressed, the box will redirect you to specific guidelines and checklists. There can be more suitable interfaces, but at this stage the biggest advantages are that most people are used to handling the software, meaning that everyone can participate in the development of the model. It is also possible to make the model web-based, but it can also be a good idea to have it in a printed version to increase its interest and understanding. This can also support training in using the model, since training is identified as an important step in anchoring a new method or tool (Beskow and Ritzén, 2000). The expert in work environment, still needed in the project, will perhaps be the one introducing the model and explaining it to other partners in the project.

As Porras and Robertsson (1992) state, four categories constitute the work setting: organising arrangements, social factors, technology, and physical setting. Organising arrangements consist of goals, strategies, structure, administrative policies and procedures, administrative systems, reward systems, and ownership. The social factors are culture, management style, interaction processes, informal patterns and networks, and individual attributes. The physical setting consists of space configuration, physical ambiance, interior design, and architectural design. Finally, technology consists of tools, equipment and machinery, information technology, job design, technical expertise, technical procedures, and technical systems. All these categories need to be noted during a development project. Moreover, as technological innovations are highly stressed, so are also examples of organisational innovations that play an important role in society (Sanidas, 2004), e.g. Total Quality Management, Lean Production, Just in Time, etc. The model presented in this thesis is not even close to the big organisational innovations, though it can be seen as an organisational innovation that helps the technological innovation proceed.

Work environment factors do not have to be all soft and unstructured, but they are occasionally and then we still need to take note of them and continue to develop new production technologies. Guidelines and checklists serve as incentives to think twice and avoid both economical losses and human suffering and achieve a work system where both machines and personnel will be properly taken care of.

7 Summary of papers

This section presents a summary of the appended papers. The reader is intended to understand the results even though they do not read the appended papers. The results will be divided under the headings of the four papers.

7.1 Paper I

The significance of national contexts regarding work environment functions when developing new production technologies.

When working in a project aimed at developing new production technology, with partners from different nationalities, the work environment design factors for the new solutions are easily forgotten. In this paper the differences and similarities experienced and observed during an EU-project in the Fifth Framework Programme are discussed. The paper describes two companies in the aero structure industry, and points out factors that distinguish them from a discourse analysis perspective.

There is a discursive struggle within EU-projects where the national discourses argue about the right of interpretation. This struggle is also present between company specific discourses, though the same institutional environment present in the European Union influences them all. This case study shows the differences at the company, national and EU-levels. On one side of this specific struggle, the Swedish discourse focuses greatly on work environment factors. During the last decade this focus has shifted from physical environment to psychosocial environment. In the other corner, the Spanish discourse has an outspoken economical focus and a focus of the physical work environment.

The design of the work environment is still not regarded as highly relevant by technology developers. Someday in the future, the design of the work environment might be a natural part of every production development process, even in cross-national projects such as the EU-project described in this study.

The discourses seem to be protecting how things are done today and the positive effects that a membership in the European Union could have do not appear to be or are slowly adopted by the members. Since power and control structures are more dominant on a national level compared to an international level, the national discourse will remain. Likewise, the discourses present on a company level will remain because these structures are more dominant than those at the national level or at least certainly in the case of the companies studied.

A main conclusion from this paper is that different discourses regarding the work environment design do exist. They form a complex net, where the described EU-project reaches over several layers. The problems of cooperation within project organisations regarding the work environment could probably be dramatically reduced with pre-knowledge of the involved discourses. Detailing these discourses of the work environment is not possible, but if focusing on the institutional environment they share, and giving the

opportunity to, if necessary, involve specific discourses, much savings can be made and the positive effects can be a consequence for the operators.

7.2 Paper II

Management of work environment design when developing new technologies of production in international cooperation projects -Learning from an EU-project.

In the international production technology development project described in this paper, the work environment design factors were not prioritised or seen as a natural part in the development process. It seemed as though the partners involved in the project regarded these factors as interfering with the main objective, i.e. developing new production techniques. The authors of this paper describe and analyse some of the experienced problems when trying to integrate work environment factors in the project, problems such as the habit of doing things the way they always have been done, the lack of a holistic picture where short-term perspectives have precedence and the problem of context significance are dealt with. Interestingly enough, while these problems were being observed in the project, none of the partners opposed using improved tools involving work environment factors early in the development process. Thus, there is a future challenge to develop a more holistic model for development of new production technology – a model in which socio-economic criteria can be considered at an early stage and industrialisation in an international context can be rendered more effective.

This paper has been shown a need to develop design models for the management of work environment factors when developing new production technologies in international cooperation projects. A major problem is that the design of work environment becomes detached and sub-organised in projects. This implies a blurred holistic picture and the perspective continues to be short-term instead of the more preferable long-term. Also, the form of the project implies that the prerequisites continuously change, which is something all participants to be aware of. The design of the work environment should not be dependent relative to the changes in the project. Work environment factors should somehow be present in any case. One way to do this is to secure clear main objectives regarding the work environment influenced by the new technologies developed. By doing so, the lack of considering differences in the international context can be somewhat avoided. The company traditions that we have shown to differ must be noted and dealt with in a systematic way. All these issues must be taken care of in a future development model. At the same time, it is important to make the models easy to follow so that they can merge into already existing models for project management and monitoring in this type of project. One way of doing this it to combine the work environment objectives with other objectives such as quality, lean manufacturing and other production key issues. Many of today's models could in fact contain work environment design factors, though they seldom do. If project groups of the future can be supplied with such a design model, both money and personnel can be saved, which may in fact reinforce the positive outcomes of most development projects.

7.3 Paper III

The presence of socio-technical perspectives in the development of future production processes – Experiences from an EU-project within the aero structure industry.

Some fundamental parts of the socio-technical school are still desirable and somewhat present in most manufacturing companies. Because the holistic approaches towards production systems, whose technical and social focus are in line with the socio-technical perspective, involve the technical side of the system, it can be questioned whether the new management concepts also involve the technical side. When technology development projects within a socio-technical sphere include physical and psychological aspects in work environment, it is important to study whether the lack of a socio-technical perspective in a technological development project is the reason why work environment is a side issue in project work. If so, the next question is whether it is due to how much of a socio-technical perspective is found in the organisations of the participating companies.

This paper has shown and described how the socio-technical perspective and thus work environment design filtered through the activities of two manufacturing companies in the aero structure industry as well as in the EU-project they both participated in. Even though neither of the companies showed a full socio-technical perspective, it was stronger in the Swedish company than in the Spanish. At the same time, it seems as though SWAS is steering away from the socio-technical perspective and that ESPAS is steering towards it. A future question is if and where the two will meet. They have already met in the EU-project where it turned out that the socio-technical perspective was not present at a high level. In this EU-project the participation of several partners, mostly engineers, probably influenced the low level of the socio-technical perspective. There is a greater force to create something that is regarded as high-tech than to develop something that is both high-tech and connected to a good work environment. The design of technologies is more important than the design of the work environment, though there is no opposition. The problem is that project partners do not realise the possibility to design both technology and work environment by means of a holistic perspective. The general thinking of the participating partners was that the efforts in the project could be detached from the practical work with the technologies regarding the work environment in their own organisations.

Resistance to the socio-technical perspective in the project was not articulated, but rather about the norms and values the project partners brought from their organisations. These partners, who have a strong position in the project due to their numbers in the project or in status based on knowledge and experience, were able to gain respect for their values and norms. This implied that because they were not frequent advocates of the socio-technical perspective, the project organisation as a whole was not an advocate. This even though our presence as a research group, together with the fact that SWAS had a tradition of the socio-technical perspective, made the project at least lean towards applying a more socio-technical perspective.

The work environment, with all that these words encompass, is certainly an issue for the future. As jobs in the aircraft manufacturing industry go from craftsmanship to semi-automated tasks, this becomes even more important. Companies need to erect a human perspective on the development process, while staying competitive on the global market.

7.4 Paper IV

Knowledge on work environment design in an international collaboration project - Experiences from sharing the concept of work environment design.

This paper reflects and describes the authors' participative experiences of the sharing of work environment knowledge in the technical development process of a collaborative organised project setting. The common platform for this sharing is described, and two main areas are further discussed in this paper. How knowledge about work environment design differentiated between partners in development project is first discussed, followed by how knowledge sharing processes evolved regarding work environment design between different project 'roles' in the development project.

In this paper, theory about knowledge in general and about sharing it were applied on an EU-project involved in the aero structure industry and the work environment design within the project. The paper illuminates a field that has not been sufficiently covered before. An action research approach was used, since we also participated in the project from where we derived our data. An analysis is made on the problems of sharing knowledge within the project. A platform for sharing knowledge about work environment design was present. Instead, the problems detected are, for example, the difference in mindset, experience, and different levels of knowledge, and these are described and discussed. The research presented in this paper has shown the project participants to be divided into the roles of *project core participants*, a*dministrators/economists* and *experts*, all with different characteristics when it comes to knowledge about work environment design. The three roles possess different knowledge, which can be divided into tacit and explicit forms. It is illuminated how important it is to take advantage of the knowledge in the project and it is stated that this was not done in the project studied. However, it is also concluded that knowledge and mindsets do not need to be positive for work environment design. Some mindsets can instead hinder further steps towards a 'good' working environment. Questions need to be raised to achieve something near a common mindset, which is one of the prerequisites for true communication.

"The higher we soar, the smaller we appear to those who cannot fly." Friedrich Wilhelm Nietzsche

8 Discussion

The following sections, whose intentions are to be concise and short, are structured like the theory sections presented earlier in this thesis, i.e. in four fields of theory. It is followed by a section of recommendations for future research. Since the main point in this thesis is of an empirical nature, the empirical analysis requires much space. Some elements presented in this section will add extra weight to the theoretical aspects of the thesis and draw attention to findings expounded on earlier research.

8.1 The socio-technical perspective and work environment

Of the three different approaches to work design (Das, 1999), two could be detected in the FORWARD-project. The *technology-centred approach* was exemplified by the overall project, which strongly emphasised a specific technical design, but not on the whole production system. Parallels can be drawn to the typical organisation of a project, i.e. following a strict linear sequence. The FORWARD-project did not deviate from a typical development project in that aspect. However, our research group had the assignment and a motivation to instead use a *socio-technical perspective*, which we tried to also distribute to the other participants. In retrospect, the other participants likely perceived us as *human-centred*, since we did not succeed entirely with our distribution and because they compared our interests with their own strict *technology-centred*.

Regarding the prevailing connection to Scientific Management, in accordance with Louise E Davis' description in Trist (1973), it can be stated the *technology-centred approach* also comprised mindsets and actions that could be derived from the Scientific Management thinking. Other participants worked in a way in the project that was entirely focused on trying to automate the production process. The remaining task was not of much concern, exemplifying a mindset that man is an extension of the machine, useful only for doing things the machine cannot do. Another characteristic, valid for ESPAS and the production processes studied there, was the presence of supervisors who absorbed the uncertainties and variability that arose in the work situation. Every supervisor had a supervisor, implying a strong hierarchy. Regarding the characteristic of job fractionation, it is two-dimensional with a cost reduction when carrying on the work by reducing the skill contribution of the individual who performs it, i.e. when removing the craftsmanship of the production. The new technologies would increase skills in other areas, e.g. computer programming.

Herbst's (1974) statement about there being more than one way to organise work around a technology was comprehended by the participating organisations and in the FORWARD-project itself as a problem that this knowledge was missing. The problem was that because they did not bother too much about putting on a holistic perspective when developing the new technologies, the organisational questions were not given priority. In our research group's work in WP7, it became obvious that we had a more holistic view of work environment design. For other partners, the European Machine Directive (98/37/EC) was enough. The many similarities of work environment design and the socio-technical

perspective can be one explanation why we had a different approach to these matters. Sweden has been prominent in the history of the socio-technical perspective, though not in its initial devolvement, but in the modern socio-technical perspective as a Scandinavian country (Eijnatten et al., 1992). This supports those who state that Sweden has been a leading country in pursuit of a good working environment, which was also the case in the FORWARD-project.

The piecemeal approach, concentrating on the technology components of the system, implied that the final result lacked a few variables regarding the work environment. This is in line with Davis (1966), who states that it implies less than optimal total performance. The intention was, as described, to find the joint optimisation of the utilisation and the development of the employees' qualifications, the implementation of advanced technology, as well as the design of the work organisation (people–technology–organisation approach), as Strohm (1999) describes. As we ran into problems with this work in the FORWARD-project, the final proposed model for future projects is more adapted to this intention. Although the model does not go into how to improve the technical dimensions, connections can be found with, for example, Andersen's (1994) descriptive model of the socio-technical system. It is not realistic for the social objectives to have the same impact as technical objectives in similar projects, but they need to have more than they had in the presented FORWARD-project. The purpose of the model presented is not to create a new Kalmar plant, even though Jönsson and Lank (1985) state that Kalmar was a success regarding quality of working life and economically, but to help structure work environment issues more than previously. The model will not create the third industrial revolution, i.e. humanisation of work, but increase the importance of these issues in project work aimed at developing new production systems. The model presented can be regarded as present in macro-ergonomics, as reinforced by Hendrick and Kleiner (2001), who state macro-ergonomics set up *"a top-down socio-technical systems approach to the design of work systems and the application of the overall work systems and the application of the overall work system design to the design of the human-job, human-machine, and human-software interfaces."* This is no guarantee that the model will be successful. The initial model in the FORWARD-project, i.e. the WP7-model that structured our work, was of a macro-ergonomic character and as described in this thesis, implied a few problems concerning the integration of work environment design.

The observations made in the FORWARD-project together with the theory about the socio-technical perspective led to effects on the final proposed model. Hendrick and Kleiner (2001) still argue that it is not obvious to involve ergonomists and operators in the early design cycles, and the FORWARD-project can be said to be an exception. The work of integrating work environment design in the future therefore has to include a few strategic tricks to help the project organisation increase the importance of the issues. One example is to use more modelling and simulation tools in the virtual manufacturing environment, which according to Webb and Price (1997), enables proactive involvement by manufacturing engineers early in the design process.

Although the model/method used to integrate work environment design is adapted to its purpose, it is also a question of who is participating in the project organisation. Mankin, Cohen et al. (1997) argue for people being picked for project teams, but this is not realistic for an inter-organisational project like the FORWARD-project. Organisations participate and chose to send whoever they wish, as long as they fulfil the organisations commitments. This means it is not possible to put together a special project team to secure a socio-technical

perspective, thus leaving us with the option of doing the best of the given prerequisites, because it is as Johansson (1999) states *"a condition to reach rather than the way to go there"*.

8.2 Work environment design

The model for work environment design, presented as a consequence of the problems noticed during the FORWARD-project, tries to systematically help future projects and create a systemic change for development projects. The model involves aspects such as looking at how the production process looks today, before the transformation, and if possible involves operators from these processes. This is one way to reach the first step of Lewin's (Lewin and Cartwright, 1951) classical first stage of three, i.e. unfreeze. The important thing is to prepare the organisation for the new technology and make them acknowledge that changes of any component part of a social system generally result in complex changes and adjustments in other parts of the system, as described by Herbst (1954).

In the FORWARD-project, both ironies of automation mentioned by Bainbridge (1983) could be noticed. The project tried to eliminate the operators due to quality and productivity, but also, at least rhetorically, due to the ability to spare people a bad work environment. Still, it left the operators to do the tasks that were not economically justified to automate, resulting in a semi-automated process. The second irony observed was that designers' errors in work environment design could be a major source of operating problems in the future when the technologies are implemented.

Work design is important and all six theoretical perspectives on work design described by Torraco (2005) have been involved in the development of the model. In some cases, they miss the focus of the work environment, i.e. the more technical aspects like chemical hazards, etc. All four of the major interdisciplinary theoretical approaches to industrial work design described by Das (1999), viz. the *mechanistic approach, the motivational approach, the perceptual-motor approach, and the biological approach*, were found in the FORWARD-project. Since most of the other partners founded a *mechanistic approach* to work design, if any, our research group used a mixture of all four with an emphasise on the *motivational approach* when stressing the risk of making jobs to simplified, *a perceptual-motor approach* when stressing lighting and workplace layout, a *biological approach* when conducting ergonomic analyses as RULA and OWAS, and the *mechanistic approach* when appreciating the efficiency aspects of production. Most models and methods used in the project regarding work environment design had their origin in the last three approaches. Examples of methods and models that have contributed to the creation of the model, as well as models used in the WP7 are safety analysis methods described by Willquist and Törner (2003), the integrated model of job design by Umstot, Bell, and Mithell (1976) and the WEST described by Schmidt and Antonsson (2002). It could have been desirable for the presented model, if it had been realistic to as the WEST-model involve the costs of the work environment, but it would also implied negative risks as blind faith on the monetary values.

8.3 Different perspectives regarding work environment

Within the FORWARD-project group, different perspectives of the work environment have been described and interpreted. Partners participating in the FORWARD-project had

different perspectives regarding the work environment as described earlier, even though each team eventually sets up a local frame of reference to counterbalance the lack of shared culture frameworks (Chevrier, 1999). Based on the empirical analysis and theoretical aspects some of the differences can be explained with help of McGregor's (1960) theory of X and Y. It was noticed that some of the participants interviewed had an apprehension similar to the average human being having an inherent dislike of work and would avoid it if he or she could. This opinion was most noticeable in ESPAS and in some discussions in the FORWARD-project. As mentioned in the empirical analysis, it could be detected that a strategy of threatening with punishment was used to get operators to put forth an adequate effort towards the achievement of a good work environment as a part of the organisational objectives. However, the theory Y was applicable to describe some of the opinions noticed at SWAS. For example, most of the interviewed were of the opinion that the average human being does not inherently dislike work, and that work may be a source of satisfaction. In retrospect, the differences might have been due to the way they talked about work and not their actual point of view. A reason can be that they expressed their opinions in a foreign language, as described in the methodology section. The important thing for the final model was to acknowledge that external control and the threat of punishment are not the only means to bring about efforts toward a good work environment. If possible participation is one mean, but information and knowledge transformation are more likely to work in an international collaborative project aiming at developing new production technologies. One thing that indicated most partners had a Y-perspective at heart is that they all in some aspects regarded the intellectual potential of the average human being as only partially utilised. It could have been by sheer convenience, since it made discussions about future work settings less urgent, when it became clear to everyone that it would not be a problem for operators to master the new technology.

Some of the differences can be traced to differences in Industrial Relations. Dunlop (1993) state three contexts of IR, viz. *the technical conditions of the work place and work community, the market or budgetary constraints,* and *the locus and distribution of power in the larger society*. When dealing with work environment design in an EU-context, it must be understood that all three contexts affect the end result. Aspects as time, quality and costs are compared with each other between different actors in the branch, as the same directives from the Union affect companies within the EU. Simultaneously, they have their national characteristics that differ even within the Union. As mentioned, little evidence points to a convergence in work place relations within the European Union (Strauss, 1998). The work in the FORWARD-project studied can be found between the work place level and its differences, which Strauss states to be of less importance, and the society level, which should be of most importance. The position of the FORWARD-project makes the differences on a work place level more important than before, since they have to be combined and adapted to in the same project.

Regarding the theory of IR, it is of interest to note how the work force is regarded. No doubt from the FORWARD-project that some partners in opposition to Marxist ideas about questioning the role of workers as commodities in the mid-1800s, still regarded them as so. This is connected to the more Scientific Management approach described earlier.

Although Marx can be regarded to have political undertones in some of his statements and that Whitfield and Strauss (1998) state that the field of IR is very politically influenced and that many researchers in the past have had "left wing leanings", this is not necessary to see

the advantages of knowing what Industrial Relations look like in each context, and to support a "good" working environment for future workers.

The empirical analysis showed the presence of different discourses regarding work environment design. A deeper analysis of this discussion can also be found in the first appended paper. Interestingly, I as a researcher also belong to different discourses. In this study, the one of most interest must be the Swedish work environment discourse that has similarities to the management discourse presented by Furusten (1999). This Swedish discourse set the framework for what should be equally regarded as a good work environment design and a bad work environment design. However, of note is that other discourses are affected as well, e.g. the production efficiency discourse, and the institutional environment of the organisations, e.g. the European Union. Membership in the EU will probably create a more similar perspective of the work environment in the future when the workforce becomes more and more flexible and moveable. The consequences of this can only be estimated. It might lead to a spreading of the Spanish way of regarding their work force if the unemployment level remains high in the whole Union. At present, the Swedish company stated that the most important thing was to take care of the people already in the workforce, since it is very costly to train them in the beginning.

8.4 Work environment design in project work

Research shows that the studied international collaborative project had problems with handling work environment factors during the technology development process. The major problem for projects like the FORWARD-project is the lack of past experience for how to handle the design of the work environment factors when collaborating outside their company and with international partners. This implies a risk that the preparation steps of a project are rushed through and thus the project stays in the beaten track and the chosen methods are those always used by the project group (Ranhagen, 2004).

In working with work environment design in the FORWARD-project, we did not entirely succeeded with the knowledge transformation and transportation described by Takeuchi and Nonaka (2000). This discussion is deepened in the fourth appended paper, and the model presented in this thesis has been learnt from these problems and aims to facilitate knowledge about work environment design transformation for both inter and intra projects. Since a project can be seen as a temporary organisation (Packendorff, 1993, Packendorff, 1995, Lundin and Söderholm, 1995), the model has to find ways to improve each time it is being used and not force every project to make the same mistakes. Some of the experienced problems in the FORWARD-project could have been avoided if we had had experience from people who tried to achieve the same things before.

How the presented model is structured and specified is important, but it is even more important how the model is used. This is because, as Blomberg (2003) states, nothing points in the direction that successful projects are more well planned than less successful projects, but in what purpose the plans are set and how they are used. Hence, the work in the model should involve partners who are made a party of the work. This will help to adjust to continuous changes in the development project that were common in the FORWARD-project and reinforced by (Engwall, 1999), implying that the model can suit more than one specific project organisation.

The model presented in this thesis with the phases of concept, prototype, implementation, and running process follows the project life cycle described by Engwall (1999), viz. concept, development, implementation, and termination. Instead of development, prototype is used because this was the case in the FORWARD-project. The model has the termination phase in the form of evaluation and preparation phases, but this is just for the collaborative project, i.e. to secure a good knowledge transformation for future projects. It also comprises the phase of running process, which is the next step of the product life cycle, i.e. *operation* and the corresponding phase of the corporate business life cycle, *product in service*. This is to bridge the gap between the project work and the continuous work environment tasks done in each company. Thus, there will still be adaptations to be made by OSH in each organisation.

8.5 Recommendation for future research

This thesis presents a way to work with work environment factors when developing new production technologies in international collaborative projects. The next step must be to make a model like this available for future project organisations. The question is how can we produce a force of change with respect to work environment design? One way is to make these issues more transparent, where the companies' work environment responsibility, or in some cases lack of responsibility, can create a social pressure for change. It is my hope and personal belief that this is doable. The question for future research is what sort of incentives is necessary to create this context.

Because this field of research is explored relatively little, finding interesting fields for future research to explore is rather easy. Close to the research presented in this thesis is to study more deeply what questions are suitable for the guidelines of each step and level of the model. This study demands the collaboration of several different experts in several fields. The checklists and guidelines seem to be a useful memory aide to make sure that the full range of ergonomic issues has been considered. Although the approach may suffer from a problem of situational sensitivity, checklists nevertheless offer a quick and relatively easy method for device evaluation (Stanton and Young, 1998). A holistic picture is needed as stated by Adler (1992), though you cannot consider everything.

"To him who devotes his life to science, nothing can give more happiness than increasing the number of discoveries, but his cup of joy is full when the results of his studies immediately find practical applications. There are not two sciences. There is only one science and the application of science, and these two activities are linked as the fruit is to the tree." Louise Pasteur

9 Conclusions and contributions

This study has resulted in some interesting answers to the introductory research questions, presented at the beginning of this thesis. To begin with, I would like to briefly elucidate the answers to the research questions and refer to the findings presented in this thesis.

A few elements have been presented regarding the first research question, *"What are the problematic elements regarding work environment design when working in an international collaborative project aiming at developing a new production system?"* The problematic elements are to get participants to share the responsibility of work environment design. To avoid the mindset that it is someone else's responsibility, so why care, but to realise that it is a production system and erecting a holistic approach to the development is necessary, which was not done by other participants in the FORWARD-project. Other problematic elements were the clashing of different perspectives and discourses in the project, lack of work environment knowledge by other participants, the context of production was neglected, how the project structured work environment issues, and a lack of a systematic method to deal with work environment design when developing the technologies.

The second question, *"How does the way of looking at work environment design issues, differ between involved partners?"* lead to some interesting conclusions. Some partners regarded certain aspects of work environment design, e.g. participation, as not that important and something that negatively affected the developing work. Others saw an opportunity to take care of these matters, but did not really know how. The different discourses, based on their origins, are involved in a net of discourses which are to some extent fighting each other. The institutional environment simultaneously affected the partners who were part of more than one discourse. Different origins caused problems in integrating work environment design in an international collaboration project that was aimed at developing new production processes. The problems occurred when our research group called attention to the fact that not only the strict technological characteristics of the new machine set the future work environment. Due to these differences many problems occurred in the developing process. There were different perspectives on when work environment design should take place in the process. There were different opinions regarding whom to involve at an early stage. Laws and regulations are mostly followed, but there is no effort to develop technology that implies a good future work environment for the operators.

The third question *"How is work environment design handled when developing new technologies of production in an international collaborative project?"* was answered with the work environment design being handled hesitantly in relation to the more technical aspects of the development process. Partners are used to handling technical aspects of the development project, but do not realise their own influence when dealing with work environment design and hope that someone else will take care of it. Even if it was the EU who demanded the involvement of a

social aspect of the development project, these issues were regarded as a side issue and WP7 was thereby detached from the rest of the project model.

The fourth question was *"How can a socio-technical perspective be said to filter through in the manufacturing companies studied and in the collaborative project they participated in?"* Describing the difference in applying a socio-technical perspective on the development process has been primary. A difference between the Swedish and Spanish companies concerning the criteria stipulating a socio-technical perspective was shown. How the FORWARD-project handled socio-technical questions and how the members of the project group lacked any structure to handle these issues, though they were not reluctant to do so have also been shown.

The socio-technical perspective filtered through both manufacturing companies in different levels and in the FORWARD-project itself. The FORWARD-project's socio-technical perspective lies between the two studied manufacturing companies' perspectives, though the Swedish company SWAS showed more of a socio-technical perspective than the Spanish ESPAS. What was missing in the FORWARD-project was an understanding of the advantages of jointly optimising the technical and the social objectives of a project.

Knowledge about work environment between the participating companies was diversified, which was one of the answers to the fifth research question, "*How is the knowledge of work environment issues and work environment design used in the project?"* Our research group had an overall better understanding that work environment design is more than measuring up to the Machine Directive, even though this is a good start. Our research group tried to transfer our knowledge to other partners, but due to, among other things, the detachment of our work package the transfer was limited, though present. The knowledge of other partners was often restricted to examining if a machine would increase the risk of accidents. Although the partners did not expect much from our work package during the course of the project, they were anxious to see what we could present regarding work environment design as the final meeting approached, since they then realised that it could be a good idea. It was observed in the project that these different roles possess different bodies of knowledge about work environment design. The important thing is to take care of the knowledge present and make sure that the rest of the needed knowledge can be acquired from somewhere else.

An answer to these problems and needs, observed when participating in the FORWARD-project, is the systematic and interactive model for work environment design presented in this thesis. This is a response to the question about the relevant outcome of the study, "*How can the procedures of working with work environment design in international collaborative development projects be improved with regards to stringency, transparency, and the results of the five research questions?"* The model is heuristic when its questions are an important element and iterative, since every step is followed by assessment. The model contains guidelines for each step depending on which level should be obtained, i.e. regulatory, culture/branch, and company specific. Each guideline contains an exceeding level for those who want to achieve more than what is mandatory today.

As research gradually evolves, it is of interest to describe and summarise which steps are taken by the research presented in this thesis. These steps should be seen as my contribution to the branch of science. Regarding theoretical conclusions, the research presented is in a field that is not greatly explored. This required new combinations of theories and perspectives to further develop theories about production system development in EU-projects, and foremost about work environment design in large technology development projects across both

company and national borders. The theoretical framework used is multidisciplinary in its character, considered necessary to answer the research questions and explore the empirical data. The most useable theory to explain the empirical data was the socio-technical perspective, though it had to be combined with others to fully grasp the complexity of the problems observed.

The choice of theoretical framework excluded certain methods, but there were still alternative ways. Regarding the methodological conclusions, action research was used in a new context and in a new way. Action research is commonly used in a socio-technical perspective, but seldom in this specific way. I participated in the project and had assignments in one of the work packages. From the beginning, it contained attempts to actively lead and conduct the project in areas concerning work environment design, and thus I did the best to my ability. Unfortunately, my lack of experience regarding similar EU-projects, how the project was organised, and the lack of earlier presented methodological research in the field made the work troublesome. It can be concluded that the language barriers also implied extra problems for this study.

Empirical data that has not previously been studied is described, and is used to make an important explorative study about how work environment issues are handled or, in some cases, not handled in a large technology development project across both company and national borders. The empirical data is unusual, since development projects with a work environment sub-focus are rather uncommon. Thus, it can be stated the thesis provides a clear empirical contribution.

Areas for improvement are pointed out and the model presented describes how work environment issues should be handled in a large technology development project across both company and national borders. The model is heuristic, iterative, and pragmatic in its nature and can help similar future projects handle work environment design when developing new production systems in international collaborative projects. The model is dynamic, since it can be broadened to be interactive and web based, where guidelines can be changed as the prerequisites change. The model presented has more of a practical character than a theoretical to be applicable and useful even when the theoretical issues are subordinated in projects. This model can be seen as the practical conclusion of this thesis.

As described, the aim of this research was fulfilled, and it can be concluded that the validity and reliability of the research conducted is regarded as sufficient, as was discussed in the methodology section. To sum up and relate to the title of this thesis, it can be stated that what some of the FORWARD-project partners did not understand was that there is much more to work environment design than the Machine Directive. Hence, as an answer to the question heard at one initial FORWARD-project meeting, the Machine Directive is not enough!

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Paper I

The significance of national contexts regarding work environment functions when developing new production technologies.

Lindelöf, P. (forthcoming) Submitted

The significance of national contexts regarding work environment functions when developing new production technologies

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ABSTRACT

Work environment factors for new solutions are easily forgotten in an international project aimed at developing new production technology. If it is on the agenda, cultural or discursive 'clashes' can cause problems. In this article, the author discusses experiences and observations from working with work environment factors in an European Union project in the Fifth Framework Programme. The article describes different discourses around work environment functions in two aero structure companies and how they clashed or interacted in an EU-project. Their differences and similarities are analysed from a discourse analytical perspective and used to explain the experienced problems in the project work. These analyses are of relevance to industry since they can be used to improve the integration of work environment design when developing new production technologies.

Key words: *Aero structure industry, Different perspectives, EU-project, Work environment*

1. Introduction

Work environment questions are often not the most prioritized issues in technology driven development projects. In the project described in this article concerning international production technologies development, the partners' different origins often caused problems in the development of future work places, since the project members were influenced by several different discourses around work environment functions. Ideally, different perspectives will create advantages when people represent different discourses, where a more holistic view of the future work environment can be created. This is vital because the developed technology should work in many countries and organisations. There seems to be a general apprehension, according to the increase in international collaborative projects, that the more countries cooperating, the better the outcome from the project. The reality in fact looks different, for example, when project members seemingly demonstrate a more irrational behaviour and not always choose the best way.

I had the opportunity for three years to participate in a European Union (EU)-project aimed at developing new production technologies for the aero structure industry. Within the project, our research group was responsible for a separate work package that focused on socio-economical evaluations and work environment issues. Very early in the project, it became apparent that partners from northern Europe had different attitudes to work environment functions than

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partners from southern Europe, though both were steered by European directives (Walters, 2002). This made studying the problems different discourses caused for the project as well as our separate work package interesting. It could easily be assumed that cultural[†] borders coincide with national borders, but this is not always the case (Strauss, 1998). Within the project, more complex borders caused by branch, culture, nationality, and status were noticed. This study focuses on two companies from different nations, Spain and Sweden, in the same industrial sector, i.e. aero structures industry. Both companies were large with around 2,000 employees. The article aims to explain the discourse differences regarding work environment functions and address the importance being aware of the problems caused by these differences in international European collaboration projects that aim to develop new production technologies.

1.1. Globalisation in the aero structure industry- more international collaboration projects

Because the aero structure industry has become more global and international, numerous discourses are present in international collaboration projects. Globalization implies that the source of the feedback on how the organization works with human and organizational issues has been enlarged and to some extent moved further away from the companies' geographic locations. This means that a company located in Sweden with a history of socio technical values now has different norms and values to measure up to. With this change, the problems of dealing with new production technology while considering aspects of work environment become apparent, where the standards at an international level sometimes differ from those at a national level.

Even though similarities during the EU-project have been noticed regarding work environment functions, laws, history and culture will still affect the local applications of work environment issues and differences will therefore be present. Locke (1992) argues that the national level will become less important in influencing industrial relations in the future, and thus work environment factors, and the international and workplace levels more so in pace with the internationalisation taking place.

1.2. Work environment- a perspective in the studied multi-cultural collaborative project

In the past, much research has been carried out in the vast field of multi-cultural contexts. For example, Hofstede (1997) conducted well-cited studies in multinational companies such as IBM. However, this research has not greatly involved work environment issues. If so, it has mostly been in the field of psycho-social factors that influence the work environment. In general, people are afraid of fields containing values and norms, since it is easy to trip and fall in the "multi cultural swamp" where conceptions like ethnographic and strict social theory are apparent.

Since the field is unexplored and these types of collaborative projects are more common, especially in the EU where partners from different nations are needed, knowledge about them

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[†] In this article **culture** is defined as the set of ideas, values and norms that characterize a company or another organisation, i.e. the informal, the conceptual framework of a company and the spirit or type of climate that distinguish this. The culture state ideals and policies for interpretation and practices in companies and affect among other things decision making, communication and unity, according to Nationalencyklopedin (2005).

becomes more important to not only create an understanding about the outcome, but to increase profit for the companies involved. When this comes as an additional benefit, it creates a win-win situation. The knowledge base becomes more solid for the scientific community and the companies can pick those "low hanging fruits" and avoid additional costs. According to Johansson, Frick et al (2004), the Swedish government's cost for work-related bad health was approximately 13 billion Euros in 2003, which implies that governments can save come costs as well.

Since participation in the EU-project unveiled problems related to the handling of work environment functions, this article will try to describe these problems with the help of a discourse analytical perspective. Can these problems be due to different discourses? How can these possible discourses be described?

2. Methodology

The research conducted is based on the past EU-project, after which I have analysed the data and my own experiences. Within the EU-project, our research group consisted of three senior researchers, viz. Professor Jan Johansson, Professor Lena Abrahamsson, and PhD Bo Johansson, all from the Department of Human Work Sciences and Division of Industrial Work Environment at Luleå University of Technology. Together with two PhD- students, namely the author of this article and Ms Marie Sandberg, the research group was formed.

The work package included analysing the work environment, which our research group was responsible for, both qualitatively and quantitatively, since socio-technical methods and theory were the base of the work plan. Measures and 16 semi-structured interviews were conducted with people involved in developing new technologies for the EU-project. Interviews were also conducted with persons involved in previous technology development projects carried out at the participating organisations in the project. For example, production managers and the Health and Safety department were interviewed to gather information about production conditions and give insight as to how work environment aspects were handled daily and in the manufacturer's own technology development processes. In most cases, the people involved came from quite different institutional or professional backgrounds (Garrety and Badham, 1999). The interviews were transcribed verbatim and coded before being analysed. As Miles and Huberman (1994) state, the coding was in fact the start of the analysis. Semi-structured interviews were used mostly due to language problems, though the interviews could not be too structured when a certain level of openness was necessary.

To complement and triangulate data from the interviews, many observations were carried out and informal interviews were made on the shop floor of the companies involved. During the observations photos and movies documented the processes and observed tasks. Based on this, Work Environment Screening Tool (WEST) analyses were carried out on some processes in the companies' organisations. A WEST analysis is a process method that includes both physical and psycho-social impact categories. The following impact categories are included: Risk of accidents, Physical work load, Noise, Chemical health hazards, Vibrations, General physical environment, Social relations, Work content, and Freedom to act (Schmidt and Antonsson, 2002). The analyses results formed a base for further interviews and discussions. For example, during the EU-project, observations were made at planning meetings between different partners, and along the way discussions with initiated persons were held to answer specific questions. The interviews and observations took place between spring 2002 and fall 2004.

A major problem in this project was what the language aspect could cause, and should be dealt with extreme caution. English is the international language of commerce, but it is a complex language (Blevins, 2003). The English skills generally varied between Spain and Sweden. Even

though the response rate from the last survey about quality of life conducted in 2004 (2004) was as low as 30 percent in Spain and 54 in Sweden, it showed that 67 percent in Sweden and 19 percent in Spain could read English very or quite well, while 59 percent in Spain and 10 percent could not read English at all. The knowledge level of the English language often decreased further down in the working hierarchy, though regarding the participants in the EU-project, the English skills of the Spanish company seemed better than the Swedish company. This is probably due to the participants not being chosen because of their language skills but rather their professional knowledge. Direct contact with the Swedish partners was held in Swedish, and in English with the Spanish partners. Consequently, there could be problems as to how we perceived the information and vice versa. The information was often second or third hand due to translation steps. The only practical solution is for all participants in a global supply-chain or multi national project to consciously think about the words they use and communicate them in multiple forms: spoken words, written words, pictures, numbers and illustrations (Blevins, 2003).

During interviews with people at the Spanish company, both respondent and interviewer used their second language. This could imply that certain text dimensions disappeared in the process of translation. The companies placed different meanings in the expressions that were very dependent on what discourse they were presented in. Sometimes they said health, but meant safety. This article tries to bridge the gap between the text, in this case speech, and the context. How one speaks about work environment can thus be a matter of what context they originate from. It is not obvious that they handled things differently, but that they used different words to describe it. The norms and values reflected what words were used and how they wanted to address the issues. More examples of how they did and did not use different words are the words employee involvement and participation, which are both important conceptions of the industrial relations theory. What makes it even more interesting is that the concept of empowerment was not so frequently used, at least not as a word. Both companies spoke of job rotation, but seldom spoke of the other two central parts of empowerment: enlargement of job tasks and their enrichment. This can be because rotation is easier and inexpensive, whereas the other two required more resources.

The results and experiences gained from participating and working in the EU-project are interesting. In this article, the results have been seized upon, i.e. the culture clashes, etc., and then further analyzed with a discourse perspective. The transcribed interviews and documents from the EU-project, both official and unofficial, were further studied with a new perspective.

In this study, a comparative research method was used to get a holistic picture of the differences between the Spanish and the Swedish companies and society in general. Strauss (1998) mentions that the expressions “splitters” and “lumpers” express differences and similarities or actually the intention of a study. If there is a “lumping” study, the objective is to focus on similarities and vice versa. The objective of this study covered both similarities and differences, since both are described.

3. Theoretical framework

3.1. Discourse Analysis

When discussing concepts such as discourse and context, it is critical to state the correct definition used in the discussion. In this article, discourse is defined as “an established mode of talking about certain issues in the world… institutionalised forms of conversation” (McCloskey, 1986). Further, it is how to talk about work environment issues. In the concept of context, the definition used in this article refers to the conditions in which something exists or occurs.

The concept ‘Discourse Analysis’ contains many meanings that sometimes differ between researchers. Some state it is as a present flow or trend in society. However, most people state it as general conversation on a macro level in society, or the valid way to speak or write about certain issues in colloquial language, education, media, business and research (Furusten, 1999). This language includes institutionalised codes, rhetoric and forms of conversation. There is also an established opinion that discourse is the valid way to interpret and describe the reality and different events in a specific surrounding and context. This implies that it is within a frame, and that the production, diffusion and consumption of ideas take place.

There are some delimitations of the word discourse. A discourse is always present in a specific context where it has a meaning and a cause, and thereby implies effects and consequences. Discourses are never random or neutral and are often connected to resources, power and control structures. Sometimes, the discourse is a means to reproduce and protect power structures, e.g. social class, gender and ethnical groups. The discourse is used to legitimate a certain way of dealing with issues. In this article, it is interesting to study if the way of handling work environment issues is connected to the discourses. A context does not contain just one discourse. Instead, parallel discourses can be contradictory, disappearing and progressing, stable and passing, on different levels and in different contexts. At the same time, several forces can strive to get the right to steer and define the truth, just as an individual a person can be part of different discourses in different contexts. People in international collaborative projects have to understand the difference in discourses and not allow them to hinder the work in the project, which is in focus in this article. Some discourses become more popular than others and are distributed to an extent that they become referred to as natural and true. These discourses affect all members of a particular context and claim to provide the truth by structuring the world. This implies that knowledge is never clean and strict. It is always politically influenced and constitutes identities and relations between groups of people. The available discourses shape our way of acting. Some discourses can be combined and often support each other. Can the branch affiliation constitute a discourse that withholds several national discourses?

As the discourse creates us as subjects, we create the discourse through discourse practices, e.g. production and consumption of texts. One example of this is the managerial discourse. According to Furusten (1999), the production, dissemination and consumption of the managerial discourse can be put in a larger context where it is part of the institutional environments with laws, regulations and social norms and values, and the overall environment of the organisations. In this specific discourse there are different centres of power. The people inside the discourse are said to be allied and will thereby support each other, without any major outbreaks from the discourse. Furusten (1999) argues that the behaviour of companies and people are affected by both discourses and the institutional environment. Even though this article does not focus on concepts of organisation travelling around, some similarities exist between this discourse and those affecting the work environment more. These discourses are also difficult to steer and are often, in a long term perspective, set by what is happening in the institutional environment.

Carrying out discourse analysis is neither about revealing some kind of objective and underlying truth, nor to search for a deeper or concealed meaning, causes or guilty parties. The main objective of discourse analysis is to focus on the discourse itself, to illuminate its existence, its conditions, how it is constructed, how it works and what the consequences might be. There is also a goal to search for systematic connections between texts, discursive and social practices.

According to Ahl (2004), Foucault’s theory of discourse can be used by looking for practices for writing and publication, rules and rituals for who is allowed to speak, institutional support for economic means for that specific phenomenon, fundamental texts and the extraction of conceptions, content and form (How are the objects positioned, described and compared? Who are perceived as central actors? Which activities are important?), exclusions (What is not

outspoken? What people and activities are seldom discussed?), ontological and epistemological point of departure that guide and restrict, and ideas and conceptions that are taken for granted and natural. The last was most interesting for this specific study. What was taken for granted and considered natural regarding the work environment when working with developing new technology?

3.2. Industrial Relations

Industrial relations, also known as the concept of organizational relations and human management resources, deal with explaining variations in the working conditions, the degree and nature of worker participation in decision making, the role of labour unions and other forms of worker representation, and the patterns of cooperation and conflict resolution that occur among workers and employers (2005).

It is not possible to exclude the political implications when discussing Industrial Relations. Salamon (2000) argues that industrial relations should be seen as integrated and not separated from the political and economic spheres. In regard to this specific article it can be hard to distinguish which political sphere should be referred to, since there is a distinction between 'international or trans-national' and 'comparative' approaches to industrial relations. The first approach is concerned with relations operating across national boundaries, and the latter with relational systems between countries (Salamon, 2000). Salamon continues by stating that a series of societal changes have led to a number of social concerns, such as the potential division between the 'working-rich' and 'working-poor', the need for a better balance between work and personal life, and the effects of an increasing 'retired' population. Hence, one interesting part of Industrial Relations is the field of employee involvement and participation. Three central tasks of this field are job rotation, enlargement and enrichment (Salamon, 2000), all of which increase the workers control of his or her work situation that according to Karasek & Theorell (1990) will lead to a healthier working life. During the 1980s these tasks were formed under the conception of employee empowerment.

Some researchers have predicted convergence in the past, e.g. that production techniques and shop-floor labour relations would be "Japanized" throughout the world (Womack et al., 1991) and Furusten (1999) talks about the North American crusade regarding management and organisation within organisations. In perspective, this seems overstated and some researchers agree with this (Boyer, 1998, Herrigel and Zeitlin, 2000). Even though there are some similarities between production techniques and shop-floor labour relations between different international companies, it is a long way before they merge. Still, within the EU, forces strive for more conformability. The harmonizing work in the EU has been ongoing for several years, but there are still difficulties comparing different nations to each other (Eklund et al., 2000).However, little evidence suggests convergence in work place relations within the European Union (Strauss, 1998). Strauss continues by stating that the differences are less important at the work place than on a societal level, though there are distinctive differences between how technologies and work practices are introduced. This article focuses on how homogenizing and segregating forces affect the attitudes towards work environment functions.

4. Empirical findings

Due to the need for confidentiality, the two companies described in this article will from here on be referred to as Spanish Aero Structures (ESPAS) and Swedish Aero Structures (SWAS).

4.1. Spanish aero structures Ltd (ESPAS)

"*It's no problem to find new workers in Spain, so the company doesn't have to compete for the workers. They just make a job announcement in the newspaper",* stated a respondent in ESPAS. The same respondent continued by saying that the "young guys", who are around 35 years of age, can nowadays choose to stay at home or go to work for the same money. Middle management was of the same opinion that sometimes the "young guys" in fact choose to stay at home or do something else.

By law, workers in Spain have the right to know about accidents that have occurred at their work place, how they occurred, why they happened and the consequences. These facts are given to the workers by their union representative. This was stressed by the respondents in ESPAS. They also stated that the safety and health department is a very important partner in trying to find out what problems to avoid and how to avoid them. They admitted that they chose some devices and machines that are not advisable with respect to ergonomics, and which sometimes tend to generate high sound levels, for example. They then stated that the most important thing is to know the European and Spanish rules or norms and the machine directives. After this, there is a focus on how to learn the conditions considered not healthy for the workers that could cause long-term disorders. They know they have to analyse everything on the shop floor to check all the rules. They continued by stating that it is sometimes advisable to use external health and safety experts, but usually try to use the internal ones. Since ESPAS is a rather large company, they can afford external experts, but if they had been smaller perhaps this would not be an option. The engineers stated that they lack norms of how to calculate with the work environment and are looking for tools to calculate how much they can invest in work environment factors in the new technologies. "*If you are building a house there are systems to calculate, you have norms about this."*

If an operator gets hurt in ESPAS, they will report it to the health service, which will analyse and do statistics, and help them do special rehabilitation exercises. When asked if there is any preventive service the answer was: "*No. There is not this culture here in Spain*".

The opinion of the respondents regarding the level of knowledge about health and safety among workers in general at ESPAS was that it is not so high. When asked why, the head of the health and safety department took the blame, saying that he had not trained them well to see the importance of these matters. According to him, the main reason for his failure was he needed more resources and time. He felt that ESPAS should do more, for example, in ergonomics. He lacked incentive to get these resources from the management. The only good incentive was to make people afraid of the consequences of neglecting these issues, both operators and management.

When several respondents were asked about the psycho-social work environment, they reacted by asking: *"What do you mean with the psycho-social part?*" They admitted that there had been some questions about stress, but that certain things had to be done before the psycho-social parts would be looked into. They had had revised the questions to read like; Do you feel stress by persons from your department?, Does your boss put too much pressure on you?, and Do you feel well? The results of this revision were not well known by the respondents. However, the respondents stated that health service had indicated that much more stress for the middle and upper management levels than at the shop floor. One indicator for this was the use of relaxing drugs, according to respondents.

When it comes to the development of new technologies, the health and safety department was not commonly involved in the early stages. There was no mandatory proceeding that involved them. However, the department would like to be involved in the decision-making process and be

compulsory in the project proceedings for any new change or implementation. According to respondents, there have been occasional conflicts in the past between engineers and the health and safety department when developing new technologies. The engineers were aware that if installing a big machine that can cause risks, it is necessary to have approval from an expert. They did not believe that the involvement of responsible production managers was necessary in the first stage, but later when the machines were to be installed. The machine and jigs/fixtures must function with and complement the workers.

4.2. Swedish aero structures Ltd (SWAS)

SWAS has a tradition of always involving the operators in the developing process. One respondent stated that the operators participated during the whole process. “They did not just come and say, now its time to dig here and move your machine out, but they participated and solved the problem.” The same respondent also wanted to focus on the positive aspects of operators who were critical to some changes. According to him it only showed their commitment, which would be worse if they did not say anything but were just along for the ride. If they participate in a developing process, they also try to fix problems that occur later on, since they feel somewhat responsible. If they have not been involved, they tend to complain about everything.

During recent decades, the hierarchy in SWAS was flattened. Today, only a few levels of hierarchy remain. This has, according to the respondents in SWAS, been positive in many ways. For example, people feel more important at all levels of the company. Regarding organisational concepts, management by objectives or objective groups has re-entered the organisational scene in SWAS. What was noticeable but not surprising was that this focus was stronger higher up in the hierarchy than further down. Sometimes there was not the same definition of the concepts, which were not highly prioritised on the shop floor. The most important factor on the shop floor was to have the product done on time and with the right quality.

The health and safety department did not interfere with a specific machine, since they were often certified by the CE mark. Instead, they were interested in aspects that could slip past the CE mark, e.g. how high the control panels were positioned, etc. However, since the CE mark was implemented, remarks for bad work environment have decreased substantially. Some respondents separated complaints by referring to them as coming from a different group, the so-called “work environment side”.

There was a common idea by the respondents in SWAS that engineers in Sweden tended to think about systems and not a single machine. They thought, both consciously and unconsciously, about how the manual job could fit with the machines. They stated that even though competitors from other nations previously lagged behind when it came to work environment, this was not the case today.

Historically, SWAS has had very low personnel turnover. Those who were committed to their jobs had established themselves, and were offered new challenging jobs. People satisfied with their current positions have not moved on to new technologies as much. There was a swerve towards managing production cells in the future instead of working in production cells as operators do today.

When it comes to ergonomics, respondents at SWAS were aware of the many monotonous tasks and strenuous working positions in production. Few work as an assembler until age 65, and often change jobs to do something less strenuous on the body.

Nowadays, the production teams were responsible for their own production planning. Hence, they tended to avoid job rotation to save time. They found a task they are good at and they stayed there for a long time. There were also discussions within SWAS whether the individual has a responsibility to work the right way or in the right position. People are of different opinions, but they all agree the individual has some responsibility.

One respondent at SWAS, who worked with the technical aspects of the work environment, stated that the big problem today was not the technical work environment, but rather the "crying" management that were not able to fulfil their duties because of too much work. If there was to be a reinforcement of the health and safety department it should be in this area and focus on how management plan and conduct their commitments. The medical department was responsible for analysing the psycho-social work environment and the general opinion among respondents interviewed was that surveys in this field were seldom done on the shop floor.

As preventive services SWAS offered their employees free use of prophylactic establishments, such as gymnasiums. A medical doctor also did personal health assessments every year and physiotherapists were available to the personnel.

5. Analysis and discussion

5.1.1.A complex representation of different discourse layers

When discussing discourses it is advantageous to try to divide their effects into different layers to better describe them. In this case one observed layer was on a division level. The discourse of one division can be different from other divisions in the same department, but are essentially very much alike and can be seen as different sides of the same coin. The next layer observed was the company discourse present in the both companies. The two were different in the aspect of work environment, but shared the same market segment discourse, e.g. within the aero-structure industry. The next layer in this study was the national level discourse that differed between the two nations even though both countries are part of the European Union. Between the national, branch and company layers, regional layers could be observed. These layers were omitted in this study due to a lack of empirical data.

The influence on each other will possibly make the discourses more alike in the future, but there is a long way to go until this happens. Even though the discourses are not the same, they are influenced by some similar outer forces. Both companies were permeated by objectives and visions that lie on a higher level and influence all businesses in the Union. This can be regarded as a force prevalent in the companies' institutional environment that involves striving for better profit, but also political issues such as increasing employment rates, welfare and other economic concerns. The institutional environment acts on all layers and the force, which is a part of the institutional environment, describes the pressure from outside. A common force for both companies will probably never be achieved more than temporarily, i.e. even though some of the discourses will reach conformity in the future there will always be different institutional forces that will result in future discourse struggles. The connections of the different layers can be seen in Figure 1. Since there was a noticeable difference in SWAS hierarchy on the influence of organisational concepts, it is concluded that the management level of the company can be said to be part of all three general management discourse steps described by Furusten (1999), namely Production, Diffusion, and Consumption. Unfortunately, the operators were only involved in the consumption of the ideas and thereby felt less convinced about their excellence. The same thing was valid for approaches to the work environment, where operators behaved in line with management's directives. Most work was done in a top-down manner that implied a differentiation of discourses. The big differences revealed and focused on in this analysis was either on a national or company level.

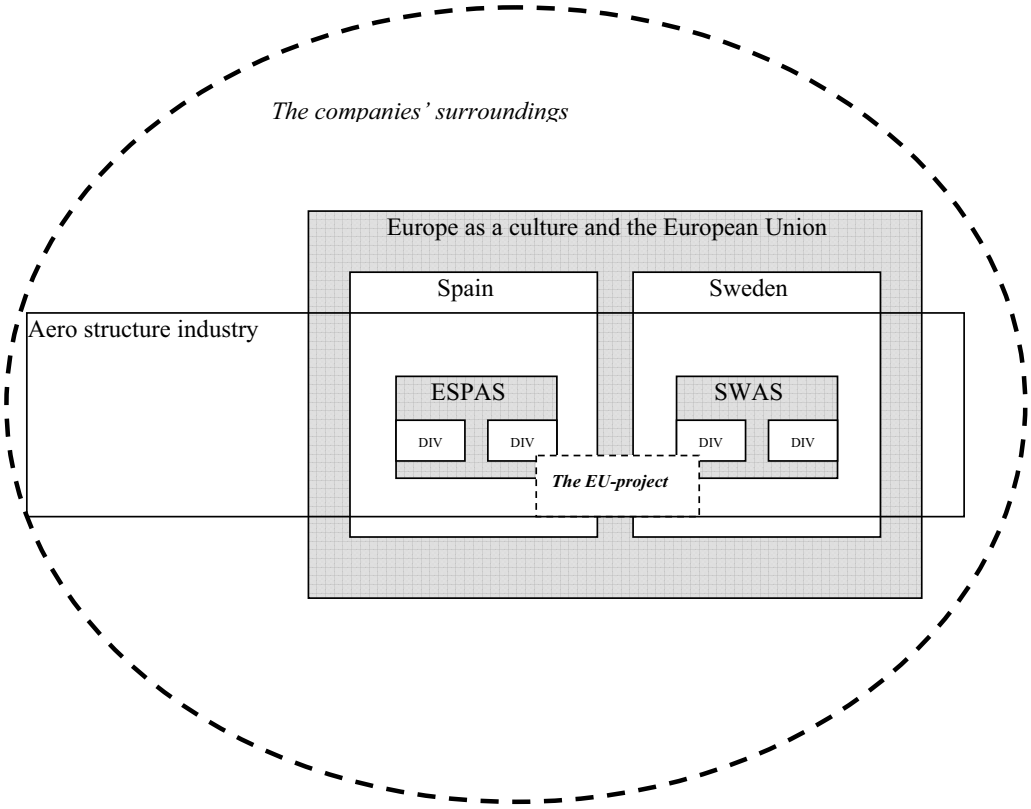

Figure 1 The connection of the discourse layers in the study and how the institutional environment and the world around influence them all.

5.1.2.Project work

There were different perspectives in the EU-project on when in the process the work environment factors should be involved. Opinions differed on whom to involve at an early stage. In ESPAS the operators were involved first during implementation, whereas SWAS involved them already in the purchase process. When working in a cross-national project to develop new production techniques, differences like these can cause mediocre results in aspects of the work environment. The technology developed does not live up to the demands of society. Laws and regulations were followed, but there was not always a pursuit to develop technology that implied a good future work environment for the operators. Engineers in the EU-project were part of different discourses and instead of working with these factors found them easier to ignore, since they were not bound by their own company's proceedings. Instead of taking the opportunity, the project group detached the work environment and made it a side issue, both consciously and unconsciously. The Swedish researcher Kaj Frick (1994) argues that this is one of the reasons Sweden's strategy for work environment factors failed in the end of the 1980s. Although this is stated for the Swedish sector and on a national level, it can be argued that this detachment is even larger in Spain. Within this case study, the work environment seems to have become regarded mostly as a restrain for the production.

5.1.3. Change of course of the discourses

The discourses contribute to the reproduction of how things are today. The way of handling work environment issues will not be dramatically changed in the near future, since it will disturb and contradict the present local discourse, though influences from the EU will be slowly adapted. Because both companies studied were present in the same type of industry, i.e. a multinational sector, is a fact that provides for a faster adoption of ideas than in other types of industries. Since monetary terms are important, the overarching institutional environment that contains making a better profit implies that this can be the fastest way to change the discourses present in both companies. It is impossible to separate industrial relations from economic and political spheres, since they steer the discourses in a certain direction. By directly influencing the institutional environment and the discourses their courses do not change dramatically but noticeably. The politics present in the European Union environment are greatly found on the national level. Political decisions taken in the Union can be reflected in the national economical decisions and together set the standard for industrial relations and influence the described discourses. The EU will influence the discourse practice more in both countries in the future. However, some other positive aspects of collaboration between European nations have also been noticed during the study. The CE mark makes bad work environment caused directly by a single machine less common. Instead, it is more interesting to look at how single machines interact and form a production system.

In summary, this fusion of discourses will ease the problems of different discourses in the future. However, because the aero structure industry is wider than the EU, new clashes will continue to arise when companies inside and outside the EU cooperate. Until the discourses of work environment in the EU approach each other, finding a more effective way to handle them is necessary. Even though the discourses of work environment are different, the companies share parts of the same institutional environment. The structured way of handling work environment issues must focus on a scope set by the institutional environment, while give an opportunity to focus on other layers of discourses.

5.2. Comparisons (cross-case analysis)

Several “splitters” and “lumpers” can be detected in the companies studied. For example, the Spanish company was much younger than the Swedish one, but this should not be the main reason for the differences between how they work with work environment factors. However, ESPAS can benefit from its youth as they can start with a clean slate, without a historical tradition of how to handle these matters. At the same time, they were more influenced by “how things are done in Spain” instead of in their specific company, where the culture was weaker regarding these issues. Although SWAS was influenced by how things were done in Sweden, they also had a tradition of how it was done in their specific company, meaning that the layers of discourses differed in strength. The complex net of layers of discourses are impossible to sketch because they all move in different directions, they never stand still, and it is dependent on which question about the work environment is being discussed.

5.2.1. The socio cultural practice of work environment design

One main finding was that the socio cultural practice of work environment design was different in the two companies, which had very different views of using the prevailing work environment as advertisement. ESPAS could not see any big advantages or incentive to use it. Whether this was because they regarded their work environment in their own company as bad or they did not see any connection to how they are seen in society is unknown. Although Schwartz and Gibb (1999) state that a good reputation is an asset that takes years to build up but can be shattered instantly, it seems as if this is not always the case when it comes to work environment.

Companies that are part of a society that has strategically worked with work environment issues for a long time can live on this for an extensive period as well. Characteristics associated with the national level regarding work environment factors seem to be taken for granted when it comes to specific companies.

The study shows that ESPAS and SWAS workers had different views about their work. The operators in ESPAS seemed to consider work as a means to do what they really wanted to do in their spare time, whereas the operators in SWAS perceived their work as a part of their life. This implies that the management level discourses in the companies have permeated the hierarchy in the Swedish company more than in the Spanish. However, there was a common problem of absenteeism in both companies. The cause of this was disputed, but it was of the opinion that it was not health related but rather to work satisfaction in both companies.

5.2.2.Knowledge about work environment factors

Knowledge held by operators in both ESPAS and SWAS regarding the work environment differed. The level of knowledge could be described as low, but it was even lower in ESPAS than in SWAS. A question for the companies is how can this be enhanced. The use of a method of intimidation was noticed in both companies, though it seems to be outdated. Instead, it was raised as a question of monetary methods in both companies. What is most profitable for the company was highly regarded as most profitable for the operators as well. Even so, it was difficult to make operators and engineers realize the positive effects of taking care of the work environment early in the developing processes of new production techniques. The opinion of "early" was different between discourses. In some it was a question of early in the process of implementation, but in this article it is early in the whole development process, in which the EU-project formed a considerable part.

5.2.3.Status of hierarchy

For a researcher from another discourse it seems as though the Spanish power context in the form of hierarchy can be regarded as what Dunlop (1993) calls dictatorial. The Swedish context was perceived as constitutional or worker participative. However, this may not be the case for either because it can be an effect of expressing oneself. The Swedish hierarchical structure was flattened and later re-erected to some extent. The Spanish hierarchy was much more obvious and it is questioned whether the flattening of their hierarchy is approaching, or if in fact they were ahead, i.e. SWAS will follow and receive a stronger hierarchy. Another possibility is that levels of hierarchy continue to go in different directions.

5.2.4.Access of labour

During the interviews the access of labour was distinguished between both companies. For the Swedish company, the most important thing was to take care of the people already in the work force, since it costs a lot to train them in the beginning. In Spain it was made clear that because there is no lack of labour, the problems could always be solved by hiring new people instead of taking care of those who were already employed. Membership in the EU may influence this opinion in the future when the work force becomes more and more flexible and moveable. The consequences of this can only be estimated. Perhaps it will lead to the spreading of the Spanish way of regarding their work force if the unemployment level remains high throughout the whole Union.

5.2.5. Participation

According to the *Third European survey on working conditions 2000 (Merllié and Paoli, 2001)*, 78 percent of the workers in Sweden and 62 percent in Spain, stated they had the possibility to discuss organisational change and the companies in the EU-project had very different strategies concerning participation by operators in development projects. SWAS was very keen on getting participation, whereas ESPAS did not use this method very much. Both companies stated that participation in the development processes was very important, though they greatly differed when it came to applying it. SWAS had succeeded in creating routines involving operators, etc., in the early stages, and this can explain some of the differences but not all. The divergence in the approaches was striking. SWAS chose to give prominence to the positive aspects of the strategy, but ESPAS focused on the fact that it delayed the development projects and implied high extra costs. It was also interesting to note who were allowed to have opinions during the development process. In Sweden, contrary to Spain, the opinions of almost everyone were desired. The positive resistance when implementing new production equipment in SWAS was either missing or taken for granted in ESPAS. This is connected to the use of participation. If the operators are not involved early on, their opinions are hard to deal with when presented and above all they are very expensive to consider. However, some disadvantages with their participation were observed, e.g. operators tended not to complain about things they themselves had developed even if problematic and their participation can be very time-consuming. A discourse in Sweden states that participation is always good, and few were willing to contradict this. We can call this the Swedish discourse, which differs from the Spanish one. Within the Spanish discourse, there was much talk about the disadvantages of participation as well as a stronger outspoken focus of short time profit. However, both companies agree on reaching a better result when using participation. It is about using a short or long term perspective. It can also be due to the higher employee turnover in Spain than in Sweden. If an operator in Sweden was involved in the early design phases of the new production system, this person usually still worked in the company when the process was implemented. This was not always the case in Spain. These factors highlight two different approaches with both pros and cons.

All respondents in the interviews from both SWAS and ESPAS agreed that collaboration with the health and safety department was really important in a development project. However, it seemed this was only rhetoric, when the respondents in some way perceived collaboration as a burden. Both companies strived in that direction, but in some situations they regarded it as forced collaboration, since their objectives were considered to some extent as contrasting.

5.2.6. Where are the discourses headed?

Although there are differences in the field of discourses, the question is why these arise, with one of the causes due to history, and how the national climate has been and where it is headed. It seems as if ESPAS is going through some issues that SWAS has dealt with already. In Sweden these ways of handling work environment factors have become normative. In the past, Sweden has been a leading country regarding work environment. Although in the last couple of years the switch of focus to psycho-social factors may be since the physical work environment has been greatly improved and psycho-social factors are causing a bigger part of the sick leaves, etc. Spain focuses on the physical part of the work environment due to most of the existing problems there today (Eklund et al., 2000). Another example is that SWAS has come a bit further than ESPAS considering mixing up white and blue-collar workers and the hierarchy is not as strict in SWAS as it was at ESPAS. This influence of history would not be specific for only this study, since every national system is permeated by a history of development and features that define certain critical variables such as culture, ideology and institutional structures. For a person based in the Swedish discourse, it seems as though the Spanish manner of viewing the work environment is a bit like taking a step back regarding the operators as

commodities. Whether this implication is due to the Spanish industry being a few years behind in historical development or whether they are in fact ahead of Sweden, or due to other reasons, is not speculated here. Because the two countries find themselves in different positions of an evolutionary timescale it is more interesting to see how the EU handles the work environment. Should their focus be on physical or psychosocial work environment? Another aspect to consider is that the focus in both countries has shifted somewhat to focus more on white-collar workers than ever before. Could this be connected to who is in charge of the work environment strategies or is it just because the majority of problems occur in the offices nowadays? What in the past were only issues for the union and the workers are now important for the employers to maximise profit.

5.2.7. Monetary implications of a good work environment

It seems as if the money spent on work environment issues had decreased during recent years in both companies. This could be due to fewer problems, employees taking care of these matters themselves and preventing the problems at an early stage, or the fact that it is easy to cut short-term costs in this field. However, in the long run it can backfire and the costs may increase instead of decrease. In the meantime the engineers in ESPAS asked for help to analyse the work environment. They expressed this demand in the day-to-day work with new production systems in their own company. However, it can be assumed that the need for it is even greater in collaborative projects with other companies and nationalities. In the EU-project the WEST-analysis was used, though it is designed for Swedish organisations, written in Swedish, and the reference costs described in the tool are from the Swedish industry and society. Until there is a working tool in English it is difficult to compare and illuminate the costs of bad work environment and how it is affected by technical developments of the production systems. At the same time all focus must not be on costs. In addition, benefits in the form of profits must also be included in such a tool. The total economical effects in individual, corporate and societal levels should be integrated.

The use of preventive service differs a lot. Research on work environment points in the direction of using preventive service, but because its use in ESPAS was not so common it can be questioned whether it presently coincides with the political values of the EU to any extent. SWAS were very proud of the preventive services, but not so clear as to the benefits it has led to for the overall profit of the company.

6. Conclusions

There was a discursive struggle within the EU-project where the national discourses were arguing about the right of interpretation. This struggle was present between company specific discourses, but were all influenced by some similar forces in the institutional environment within the European Union. This case study shows the differences in company, national and EU-layers. On one side in this specific struggle is the Swedish discourse that focuses greatly on work environment factors. During the last decade this focus has shifted from the physical environment to the psychosocial environment. In the other corner is the Spanish discourse with an outspoken economical focus.

The work environment is still not regarded as relevant by most persons involved in international development projects. Perhaps the work environment factors will be a natural part of every production development process some day in the future, even in cross-national projects like the EU-project described in this study.

The discourses seem to protect how work environment functions are handled today and the positive effects that a membership in the European Union could have in form of a common

approach to these issues do not appear or are slowly adopted by the members. Since the power and control structures were more dominant on a national level compared to an international level, the national discourse will remain. Likewise, the discourses present on a company level will remain as these structures are more dominant than the national level discourses or at least in the case of the companies studied.

A main conclusion from this article is that different discourses do exist. They form a complex net, where the described EU-project reaches over several layers. The problems of cooperation within project organisations regarding work environment could be dramatically reduced with pre-knowledge of the involved discourses. It is not possible to detail these discourses of work environment, but if focusing on the institutional environment they share, and give the opportunity to if necessary involve specific discourses, much savings can be made and the positive effects can be a consequence for the operators.

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Paper II

Management of work environment design when developing new technologies of production in international cooperation projects -Learning from an EU-project.

Lindelöf, P., Abrahamsson, L., Johansson, B. (forthcoming) Submitted

Management of Work Environment Design when Developing New Technologies of Production in International Cooperation Projects

Learning from an EU-project

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ABSTRACT

In the international production technology development project described in this article, the work environment factors were not prioritised or seen as a natural part in the development process. It seemed the partners involved in the project regarded these factors as interfering with the main objective, i.e. developing new production techniques. The authors describe and analyse some of the experienced problems when trying to integrate work environment factors in the project. For example, problems such as the habit of doing things the way they always have, the lack of a holistic picture where short term perspectives have precedence and the problem of context significance is dealt with. Interestingly enough, while these problems were observed in the project, the partners did not oppose using improved tools involving work environment factors early in the development process. Thus there is a challenge for the future to develop a more holistic model for development of new production technology – a model in which work environment design can be considered at an early stage as well as industrialisation in an international context can be rendered more effective.

1. INTRODUCTION

The European Union strives for an increase in international collaboration. For example, there are requirements for several nations to participate in the EU-financed projects in order to be qualified to apply for money. There is also an intention by the EU to always have an additional social science perspective, i.e. to handle more 'soft' issues when developing new 'hard' technologies in projects. Neither society, researchers, unions nor managers stop to stress the importance of these factors at any level of organisation, or in these kinds of collaboration projects.

There are approaches present to integration of work environment design in developments projects (Langaa Jensen, 2002; Neumann & Winkel, 2005). They focus on how these matters should be handled inside companies. However, the field of these issues in international collaboration projects is rather unexplored. This is where this article makes its major contribution, since a typical problem is the integration of work environment design criteria into an early stage of production development. There are numerous studies which point out the need to consider work environment and work organisation aspects right in the beginning of the product development process. There are substantial savings in time as well as finances, which can be made if conversions and readjustments of developed technologies are significantly reduced. It is not easy to ingrate these issues in one organisation, and it is even harder when several companies collaborate who derive from different countries. It is not enough to have a classical work environment perspective, one also needs to consider national variations and cultural contexts. The studied EU-project offered a unique opportunity to study and influence the early product/production development

in an industrial project including all the product development phases. In the industrialisation of a new production technology, it is even more important that the particular national characteristics are considered.

From January 2002 until January 2005 we had the opportunity to participate in a production technology development project within the European Fifth Framework Programme, which was a mix of product and production development. The overall objective in this project was to develop new ways of manufacturing large non-rigid structures within the aero-structure industry. From Luleå University of Technology, Department of Human Work Sciences, we were a part of a work package in the project that included work environment analyses with an aim to develop a model for implementation of work environment factors in production technology development processes. There were two partners involved in this work package since the coordinators of the project chose to almost double the cost of this package in the last minute and involve a second partner. Still, they chose to stay with our original plan for the package. This plan was to study firstly *Criteria of work environment factors* and secondly *Evaluation of the industrial environment and the production context*. After this the *Evaluation of the new milling and automated assembly* followed and the plan ended with the forth and last step of *Analyses of the implementation of the new production system concept in industry*. The overall project concerned the whole chain of development, from basic work environment requirements to implementation and assessment of final solutions. All these steps would then make the base for the guidelines that would for example include: restrictions for work environment hazards, safe working procedures and practices, recommendations for work place design, recommendations for work organisation and recommendations for skill requirements and competence development. We were not experts on EU-projects, but we were hired to be the experts on work environment factors. Even though we had, in some aspects, a good initial starting point we ran into several problems along the way.

The aim of this article is to describe and analyse how work environment issues were handled in an international collaboration project and address problems of existing models for development of production technology. As described in this article the uncertainty as to whether the objective of the project was to develop a product or a production technology for a system implied problems. This is one of the reasons for another aim which is to start a discussion on how to develop a more holistic model for development of new production technology, a model which makes it possible to consider work environment design at an early stage, with such a degree of accuracy that practical directives for industrial implementation of new technology in different national environments can be developed.

2. METHODOLOGY

Partners from five European countries: England, France, Germany, Spain and Sweden participated in the EU-project. The partners consisted of persons from institutes, consulting companies, universities and manufacturing enterprises. Our work package, one out of eight, concerned work environment issues, named socio-economic evaluations in the EU-project. Participation in our work package was the initial phase of the research. During this phase, the data collection started which consisted of 16 semi-structured interviews and observations. It was not only a study of work in the EU-project and the decision-making processes between the participants in the project, but also of the production sites inside companies and manufacturing facilities connected to the partners. Due to the need for confidentiality, the two companies mostly described in this paper, one Swedish and one Spanish, will be referred to from here on as Spanish Aero Structures (ESPAS) and Swedish Aero Structures (SWAS).

During the three years of the project (2002-2005) eight official meetings were held, and between these individual and cooperative work took place within eight different work packages. The meetings were interesting to observe and it was fairly easy to do so since our group was a part of the project. The hard

part was to gain information on what took place in between the meetings. This was done primarily by visiting the partners, reading internal documents and listening to discussions between the partners at meetings. We focused on the two manufacturing companies involved since they were the ones who would eventually be the primary users of the technologies developed. The multinational context implied a few communication problems, for example second and third hand information due to steps of translation. Collaboration is well discussed in past literature, but it becomes even more intricate when the collaborators have different nationalities, mother tongues and business cultures. In order, to just communicate with partners from different nations regarding work environment factors, the language becomes a problem.

Five people were involved in our project group at Luleå University of Technology. Though Peter Lindelöf (main author of this paper) was not part of the group when the group's participation was initiated, he was the one most involved in the project since it started in 2002. He took part in all interviews made during the project and carried out most of the analyses presented in the written reports. He also attended most of the meetings, made observations when visiting partners and had discussions with them. This was achieved with support from three senior researchers at the department: Professor Lena Abrahamsson (co-writer of this paper), PhD Bo Johansson (co-writer of this paper) and Professor Jan Johansson. PhD student Marie Sandberg collected parts of data and participated in the first phases of the project. In our work package one additional partner did part of the tasks. This other partner was responsible for mapping of regulations concerning work environment in the countries involved in the project. They were also responsible for a series of measures taken regarding chemical health risks, etc.

Our work followed a model created in relation to the project application, described in the introduction. This model, which was brief in structure, was further developed during the EU-project in order to make it more applicable to similar projects in the future. We did work environment analyses in four steps as described above. During meetings, discussions and in reports we brought the issues of work environment factors up on the agenda. For example the need for integration of the work environment factors in the other packages was stressed a lot. The other partners responded positively to these wishes, at least rhetorically. We were also invited to attend internal work meetings in other work packages. We did not have the authority to steer the other work packages, but we had some possibilities to influence them. Our presence alone may have affected them to focus more on these matters.

In the project proposal writings we had a free hand to structure our own work package as long as we kept it within the frame of the project. During the project the other partners were as supportive as they could, by providing access to premises and to personnel. This made us able to work relatively independently, for better and worse. Despite these seemingly good prerequisites we found the integration of work environment factors to be a tough job. One reason for this may have been the structure of the project organization where our work package was subordinated all the other packages. This discussion will be further developed later on in this paper.

The structure of this research project can be regarded as action research since it tries to build a bridge over theoretical and practical work while studying a phenomenon and trying to change it. This raises an important question to reflect upon: how does the engagement in the project planning and realization phases influence the research result? There are those who are negative about action research, while others state that it in fact influences the researcher to be even more sharp in his/her analyses and thereby more easily find relevant information (Stringer, 1996; Susman & Evered, 1978). We think that without our own participation in the project we would not have had either the knowledge or the possibility to notice all facets of it. We do not doubt there are other ways to conduct studies of phenomenon like the ones presented in this paper, but at the time we found this way the most appropriate for us and for that matter the only way to collect the data needed.

The work done in the project can be seen as one of two parallel and, to some extent, overlapping processes – project work and research. After the EU-project ended, our research has continued. Gradually a new model will be developed that in the figure is called '*the research model'*. In order to make this model as accurate as possible, more studies of similar projects would indeed be good to increase the level of generalisability.

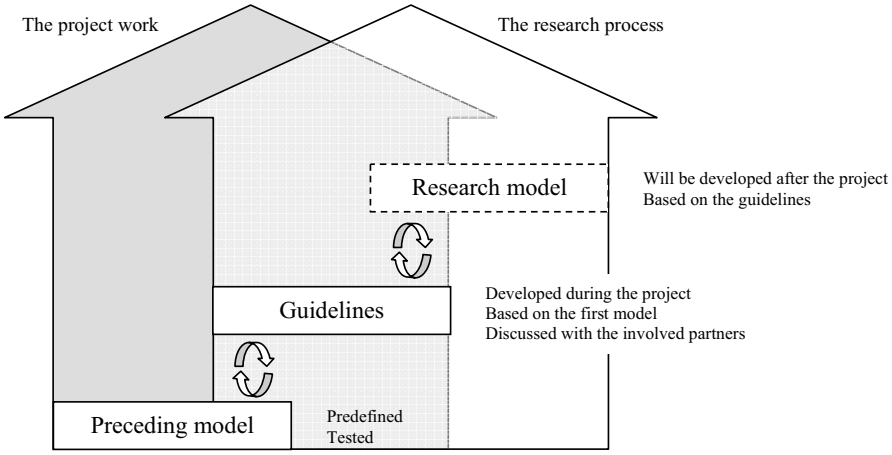

Figure 1. The development scheme of the models of work environment factors in development projects and how the project work and research process overlap each other.

3. ABOUT THE PRODUCTION DEVELOPMENT PROJECT

The project, in which we participated, can be described in many different ways. Below we have focused on some specific aspects of the project that have relevance to the work environment factors.

3.1. A Confusing Background

The decision from the Fifth Framework Programme to support the development of new innovative production systems in the aero-structure industry made an incentive for the project. Within the aero-structure industry a number of multinational actors are present, and in later years the European Union has stressed the importance of excelling in this field. An underlying objective of the studied EU-project has been to secure employment in the European market. This can be understood in the light of Kling's opinion (1981) that there exist trains of thought stating that it is the risk of becoming a losing organisation instead of making transitional profits that stimulate the technological development. He continues by saying that new technologies are most profitable for those who adopt them first.

Even though this specific change was initiated by higher political forces, several other options of change are available. Often a single change in for example the business environment can be due to a series of crises when competitor launches a new superior product, another competitor develops a much more cost-effective manufacturing process and slashes its prices, a new piece of legislation poses a serious threat, a health hazard is discovered which reveals that one of the key activities is seriously dangerous to health, etc. (Sadler, 1996). This specific project can be described as preventive of future crises.

Both production companies studied claimed that they were very inclined to change and often did so. There was a general assumption in the two companies, as one person in ESPAS put it: *"80 percent likes new things and to learn new things."* One question that arises is how to handle the other 20 percent. There was no clear answer to that and there were no stated knowledge as to why these 20 percent (according to the respondent) did not like new things. In SWAS there was evidence that they took advantage of these 20 percent in order to decrease the resistance when it was time for implementation on the shop floor for example by illuminating the negative opinions and discussing them together with the operators. However, there was no such evidence in the project development team.

The objective of the EU-project was to automate some of the production in the aircraft manufacturing industry. Today this type of industry is permeated by a lot of manual work and high quality standards. The intention for the future is to raise the production to even higher quality standards and at the same time automate the processes. Initially, the project was in fact two projects that were eventually merged in order to be eligible to apply for money from the Fifth Framework Programme. One project was about the machining processes and the other about the assembling processes. After the merger it was still possible to see the differences in the combined project. Even though a clear objective was stated, the two sub-projects did not work as smoothly together as was desired. This is probably one explanation for the problems we experienced with our work of integrating work environment factors. Some work packages were merged in early stages of the project and confusion about how each partner's interest should be attained was noticeable. If the two sub-projects had been merged to a greater extent it would have increased the possibilities to include work environment factors in the work. However, the project gradually evolved and partners found ways to cooperate even though they still, to a great extent, were in separate sub-projects of the project. Moreover, the partners were also confused about who was the 'receiver' of the new production technology they were supposed to develop. Nobody really knew in what specific system the technologies should work once ready to implement on the shop floor. The partners in general had ideas about in what type of context but not in what machine etc. This also gave us problems when trying to discuss work environment consequences since we could not really analyse the present situation in a system that we knew for sure was going to be changed. Later on it showed that some of the production phases we had chosen were actually going to be transformed, but this was not clear to us until later on in the project.

3.2. A Changing Project Characteristic

When looking at the project in retrospect, it is hard to distinguish whether it can be regarded as an innovation process, product/production development process, or in fact a production system development process. In the beginning, it seemed to be production system development since there were outspoken objectives about how the technologies should work when implemented and in production. As time went on, the process seemed more like a product development process since the technologies were far from the shop floor and production line. However, in retrospect it was more a part of an innovation process since the technologies developed could not work solely, but needed to be integrated into a larger process. It was about developing ideas about how possible solutions to specific problems could be invented that no one had answers to today. With that said and with the knowledge that the step of making the invention into an innovation was lacking, one can call it a process of invention or the first step of an innovation process. A way to go around this definition problem is as Bennet and Forrester (Bennett & Forrester, 1993) do, to divide the design of a physical production system into Factory, Module and Utility level. With these divisions the project would fall under the Utility level with a possibility to transform into the other levels later on. Regardless of what the project is called, it concerned making inventions that will eventually affect the system they will work in. As the project shifted its identity to us, the focus of work environment design did as well. From the beginning it was about handling and integrating work environment factors in a whole design process all the way until the techniques were implemented on the shop floor. In the end,

the study was more focused on the early design phases of a development project and how to integrate these issues there. The change of the overall structure of the EU-project was merely due to big ambitions from the beginning and to the fact that they needed a lot of time and monetary means to come through. This is one example of the fact that we constantly had to amend our plans due to the fact that partners were late with the realization of prototypes. In fact, our belief that we would have a prototype to do our work environment analyses on turned out to be wrong. This implies that the reasons for running into problems with our planning could be found on many levels.

3.3. The Lack of a Holistic Perspective

The EU-project described in this paper deals mainly with the first one of Sadler's (1996) basic kinds of technological changes, viz. new processes for manufacturing goods or delivering services, but one kind of change may in the end result in several kinds of changes. Sadler continues by stating that when for example organizational changes take place it will involve changes in any or all of the following: structure, systems, procedures, processes, and culture. This may imply that the technologies developed in the project may cause changes in places never deliberately intended, e.g. the social system. This perspective is the basis when stressing the importance of the work environment factors in an early concept study of a new technology and it worked as a starting point for our work. The link also functions in a reverse way: in order to achieve the desired changes to the social system you usually need to make changes in the technology used or at least in the way it is used (Sadler, 1996). This kind of thinking could not be detected among the partners in the EU-project. The engineers involved in the project were so focused on the detailed technologies, so the implications for the system were not discussed. For example, in one of the meetings one of the other partners brought up the importance of looking at the developed techniques in a system perspective. What would happen when they were going to be implemented? One of the other partners was assigned this task, but when we looked for it in the deliveries from the project these were nowhere to be found. Almost everybody counted on someone else, to take care of the work environment design, and if not us 'experts' of work environment in the EU-project, then later engineers responsible for development of the concepts and prototypes of finished solutions. A few attempts to take these matters into account were made though. For example, when presenting the concepts in one of the reports, aspects such as how to fence in the machines and how certain designs may cause a risk for tripping were discussed. But when putting the concepts in a matrix in order to evaluate them nothing regarding the work environment was presented. The cause of this may be complex, since people in general believe more and more processes will be automated which implicates the tasks with bad working environment left over between automated tasks, for example the riveting processes in the aero structure industry, are seen as temporary solutions waiting for automated ones. In addition, the supply of workers is so high at the moment that low knowledge intensity jobs are not dependent on the workers currently operating the tasks.

Wu (1994) states the field of system theory can be separated into two different approaches. One approach is regarded as a 'hard' and one as a 'soft' system. A negative aspect of the 'hard' system is that in many real-life situations, it can be difficult to describe the problem in such a way that it can be tackled by the hard approach and the following methods (Wu, 1994). The hard approach puts more focus on simulations and assumes that one can explain and simulate the output by stating the input. The system is seen as a black box. The hard approach also uses quantitative methods while the soft approach uses a 'conceptual' model for evaluation. Consequently, the hard approach requires a clear picture of the problem.

In working with this specific project, in retrospect it seems people were divided into two camps when it came to the hard or soft approach, concerning the system they were about to develop. One camp advocated a hard approach on how the work environment factors should be handled in the project and the other tried to use a soft one. The two camps also differed in how important these factors were considered for a system in operation. Most times only we, the research group from Luleå, hired to be the 'experts' in

the field of work environment, were apparent in the soft camp, but sometimes other participants switched over and took a stand for the soft issues as well, for example regarding looking at the whole system. A symptom of this difference in approach was a general thinking by persons in the hard camp, that the guidelines and legislations on work environment present in the EU were too fuzzy. There was an urge among for example project leaders in the studied companies, for more numerical values. A good work environment had to be specified with different parameters, to make the input of the process turn out as a good output. One respondent in ESPAS stated *"the problem is that you have no information. You do not know if the ergonomics are good enough etc. I always need to pay somebody to get this information."* Even though this is understandable, it is difficult for anyone to set a limit value of for example psycho-social work environment. It tends to often measure the symptoms and not the cause of the problem.

Within both socio-technical systems and operation management there is a strong credence to the physical design and layout of the production system (Zwaan & Vries, 2000). However, it is the implementation process that to a great extent impacts the way individuals adjust to the new technology (Endsley, 1994). This implies when developing new production technologies, that it is not advisable to only focus on the design phase, but to have a holistic perspective and pay attention to all steps of the development process, including how changes in the design would affect for example the implementation process. No such evidence was found in this project and it is interesting in the light of what Rogers (1995) states, that even when the new idea has obvious advantages, it can be very difficult to get it adopted in a short time. Often it takes several years from the time they become available until the time they are widely adopted. This explains why it is an issue for the partners involved in a project such as the described EU-project to speed up the rate of diffusion of an innovation. One way to do this is to take care of the work environment factors as early as possible in the development process, since it can save money and/or time (Das, 2001; Lovén, 1997; Vingård, Hägg, Jeding, & Thorell, 1999; Winkel et al., 1999).

3.4. A Project Structure with Work Environment on the Side

In the way the project was structured the lack of holistic or system perspective filtered through. As can be seen in Figure 2, the socio-economic effects are detached and not integrated in the rest of the project model. We were not the only ones who were unfamiliar with how to integrate these factors in the other packages. This can be one of the causes which made other partners regard us as a side process. In hindsight, it may have been convenience that made the project structure look the way it did. The coordination and management of the project set the frames of the projects and thereby influenced the work packages involved in the two sub-projects. These work packages influenced the one concerned with the evaluation of socio-economic effects, but there was not much influence in the other direction.

When composing a project group working with the new technology in an individual company there are several opinions present. For example, Kleiner and Shewchuk (2001) state that the ideal function allocation design team would be a cross-functional team comprised of six individuals. At least two of the individuals should be operators and the remaining members should represent ergonomics and other functional areas. It is advisable that the operators participating in these groups should get training in ergonomics and function allocation before serving in the teams. In the studied EU-project ten partners participated. It would not be correct to compare this project to 'a function allocation design project' since it was really about an international cooperation project between different companies aiming at develop new production techniques, but still it seemed like there were too many persons involved. Several partners participated with a number of persons, ending up with a lot of people, approximately 20, in the project group, and then mostly engineers. At no stage were there operators attending a meeting. However, the work that was done in between involved some operators, but mostly to use their skills and not their knowledge. For example, SWAS used operators when testing parts of their techniques in the machines. In line with Broms & Lindahl (2005) the development of new production systems in the future needs to be

accompanied by the development of the work for the operators. Broms & Lindahl also illuminate nine different areas which need to be focused on in future investments. Two of those are new models for development of production systems and new methods for change processes. This is strengthened by this study.

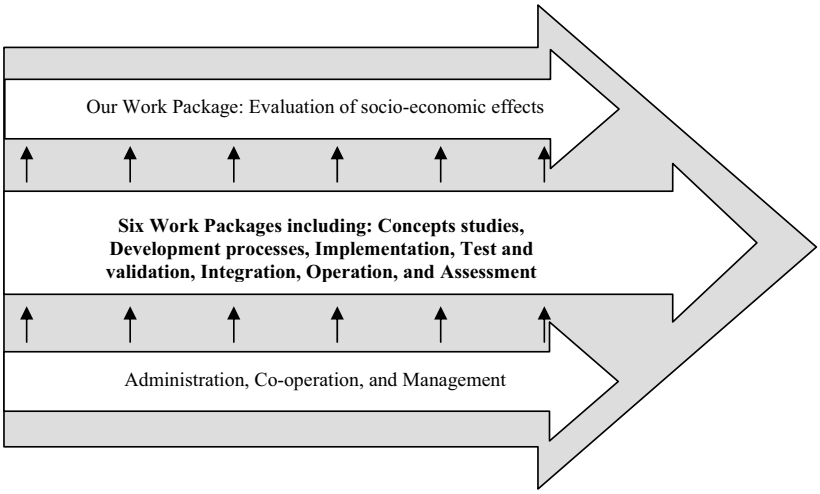

Figure 2. The structure of the EU-project described in this paper (slightly moderated due to confidentiality). The central arrow symbolizes the core processes of the EU-project and the figure visualizes the detachment of the work package concerning *Evaluation of socio-economic effects*.

There are different ways of thinking when developing new technologies that will eventually implicate changes in the production system. Decisions surrounding the specific implementation will affect the multidimensional, nondeterministic occurrence that the change may imply (Endsley, 1994). For example, there are differences between how traditional operations management and the more social-science based paradigm relate to factors in the new technology (Zwaan & Vries, 2000). Accordingly, system design deals with the creation and introduction of new systems which incorporate both technical and organizational components to improve business efficiency and also effectiveness and the quality of working life of the employees who use or are affected by the new components (Mumford, 1991).

When discussing the structure of the studied project, the design approach is interesting. It consisted of an initial problem that had to be solved. This leads to an analysis of the situation, setting of objectives, conceptual modelling, evaluation of concepts, decision, detailed design, evaluation of concepts, decision and in the end a solution (Wu, 1994). This is how most models are structured.

One question is whether the project can be seen as system design when organizational parts of the system were hidden. This can be illustrated by the fact that people in the project group sometimes tried to prove the excellence of the technique by stating it would handle activities that were currently done manually. They did not take notice of what would happen to the production organisation when cutting down the need for work force. In addition, it was difficult for any of the project participants to prove it would imply better business efficiency. Even though the intention may have been to use system design, the outcome was so focused on the technologies and hard parts of the project, that it is difficult for an observer to regard it as a typical system design process. For example, there was a strong focus on how much the quality would improve since the accuracy of the machine could be better than the manual work. Since the

project has been technologically driven, many of the allocations of functions in manufacturing environment ended up leaving leftover tasks for humans to perform, failing to consider socio-technical characteristics. This can be illustrated by discussions held with some of the partners. They stated that since not all of the tasks in the process of air craft manufacturing are economically defendable to automate, they have to take care of those that are. Sometimes it meant that tasks which were obviously badly designed ergonomically, would be left out in the middle of the automated process since it was too expensive to do anything about it. This is common for projects that are considered to be technologically driven (Kleiner & Shewchuk, 2001) and sometimes it seems like a deliberately chosen strategy. One reason for this strategy may be related to cost, another to the lateness of the guidance relative to the stage of the design cycle, but also to incompatibility with other organizational or business constraints (Damodaran, 1991). In this project it seemed as though the fact that it was about expensive and high technology inventions put an extra focus on the technical questions and decreased the will to work with questions about production systems and the related human issues. Damodaran continues by stating these factors can in the long run cause a rejection of human factors practitioners' and specialists' advice or that they will be inappropriately implemented, or only partially implemented. For example, one of the respondents at ESPAS stated: *"but later on we had several experts from different areas e.g. production, maintenance, design etc. involved in the project."* An interesting question is whether it was too late or not. Was the money they saved on involving operators later an imaginary cost saving since involving them earlier may avoid long term costs due to bad work environment? It was no surprise the OSH-departments in each company expressed a will to be involved in the decision-making process and to be obliged to be involved in the project process for any new change or implementation. In reply to that, the engineers, often leading the development projects at the companies, saw some problems with this, even though they in every second sentence stressed the importance of collaborating with the OSH-department. One respondent in ESPAS said for example: *"if you are working in a company where the most important issues are the productivity, it will imply that if you are trying to get all information to the project you lose time."*

In any change process taking place, it is important to evaluate the changes afterwards in order to learn from them and excel before the next change. To be able to do these evaluations, measurements should be taken before and then after, so comparisons can be made over time (Axtell, Pepper, Clegg, Wall, & Gardner, 2001). It is also important to monitor how the organisations implement advanced technologies and to collect data across all of the variables identified and also take measures of individual adjustment (Endsley, 1994). This is important in order to enhance the development process for the future when for example conducting a project similar to the one described in this paper. Regarding evaluation of the technologies developed in this project, it is hard to do measurements since one does not know where the product/production developed will be implemented. One way to do some evaluation is to use computer simulation tools, for process distribution flows, operation sequences, and ergonomic evaluations etc. This is stressed by one respondent in SWAS who says regarding computer simulations that they: *"…increase the trustworthiness and the impact."* The same respondent continues by saying: *"...then you have to put it in relation to the time these analyses consume."* The time consuming aspects of it is one part, but one can also discuss the reliability of such simulations, especially the ergonomic ones. Thus, it can be a supplement to other evaluation forms. The automobile industry has placed itself in the forefront of ergonomic simulations and they have shown that a lot of savings can be made (Sundin, 2001). Although the car industry and the aircraft manufacturing industry differ they are also very similar in some aspects. These positive economical effects ought to be apparent in the aircraft industry as well if they are implemented the right way. Assessment before the production development is implemented is hard and to assess afterwards is not always natural as one of the respondents from SWAS states: *"…regarding assessing afterwards, that has not been done more than only so-so… However, the ambition to do it has always been there."*

3.5. The Lack of Understanding of Context (international) Significance

Industrial production systems are used on an increasingly global level. A multi-operation machine for example in Spain does not differ much from one in Sweden. The differences are primarily found in the organisation of work around the machine and the formulation of the working environment, which has been observed in this research project. However, from the machine manufacturer's perspective, the consideration of working environment and work organisation in relation to the development of new production technology occurs all too often within a national context. When new production-related technical components and systems are exported and installed in a different context, national adjustments to for example work environment demands are made, which carry significant costs and losses in time. National context includes not only the national legislature regarding work environment and work organisation, but the cultural and institutional features which to a large extent influence the form of work and organisation. This can be found in for example the structure of the educational system or trade unions and the position of women in the market place. In the global supply business of today, work environment issues are influenced by different factors which are stressed in different ways in different countries and cultures. When developing new production technologies as in the EU-project described, several possible user cultures are possible. Even though the same legislation may apply for them, at least in Europe in the future, different norms and values are present that can imply problems if they are not taken into account early on in the process. These issues have to be dealt with already from the design phase and someone has to be responsible for them in the project group assigned the technology. Companies developing and exporting new production technology and production systems need knowledge and methods both to improve their product development in order to consider work environment design at an early stage, and to streamline industrialisation in an international context. The conceptual models needed should take into account that particular forms of work organisation should not be considered to fit all, even though the technology is the same (Axtell et al., 2001).

4. MODELS FOR INTEGRATION OF WORK ENVIRONMENT FACTORS

The involved partners in the EU-project described were well experienced in project management etc., but were lacking models with a focus on work environment design in addition to the traditional factors such as technical characteristics, time, economy and quality. In general, there are well known concepts for product development, as for example Design For Manufacturing (DFM) and Design For Assembly (DFA). The problem in the studied EU-project is that the project was, as described before, conducted somewhere between development of production and product and the start of an innovation process. Often the development of production and product coincide, but still the specific models for the production development are missing. Hence, the production development is often unstructured in its nature (Bellgran & Säfsten, 2005).

Several models of development of production technologies as products are available in industry today (Barclay, Holroyd, & Dann, 2000; Magrab, 1997). These models are comprehensive in nature and deal with a lot of issues which are evoked during the process of change, for example how to deal with criticism, implementations and industrialisation factors. However, these models tend to lack a holistic perspective of work environment factors, even though some models deal with a few of them (Neumann, 2004). Some models involving work environment factors exist, but only a few of them can be found in similar projects as the EU-project described. The respondents in the EU-project stated it was mandatory for the companies to ask for and take help of OSH-departments in their organisations. In seeking this help, it is commonly a question of meeting legislation limits etc. Seldom is it a question of excelling in the field of work environment. When the development work took place in the project organisation, the models for development of production technologies regarding work environment factors tended to be just a desk product for academics.

Moreover, there are no details on how the work environment design may or may not be included in the steps in the models for product/production development. It is up to whoever is in charge of the process. One respondent in SWAS stated that a model does not need to be so specific: *"It does not have to be any bigger points but just simple procedures that are so easy that it makes you aware of context of reasoning…."* When using a model it is important to get the work environment factors out in the open in order to make them visible to all partners involved in the project.

The two manufacturing companies studied had their own ways of handling work environment factors which differed from how they were handled in the project. In both ESPAS and SWAS the question of responsibility over work environment factors was clear. In SWAS they had process flow charts where these issues were brought in and mandatory information duties given to a special group concerned with work environment factors. Both companies involved the OSH-department in many change processes. In contrary, the EU-project described in this paper had no such clear distribution of responsibility. There was no obligation to report to anyone about consequences of the work environment, and no OSH-department was present. Instead our research group served as a substitute. Respondents from SWAS said in interviews that how a project is driven is very much up to the company tradition, and respondents at ESPAS agreed upon this description. Since this project had many participating companies there were a lot of traditions to take into account. A question for the future is which tradition has the precedence?

A difference between quality and work environment is the quality aspects are so well known and thereby integrated in the norms and values of the representatives from each company. For example, the quality improvements possible when changing from manual to automated work were taken for granted. In the aero structure industry, quality aspects are even more stressed than in any other industry. This means everyone involved in the project saw the quality of the produced items as the most important subject to discuss. It is therefore functional demands which set the limits and steer the development to a great extent. It is the long term perspective that has to be better illuminated, for example with Life Cost Perspective, which was not used in this project. When engineers usually do for example Failure Mode Effect Analysis (FMEA), or at least list advantages and disadvantages with proposed concepts as in this project, the perspective is usually concerned with how the product ends up and not always with how the operator will function in the new system.

5. CONCLUSIONS

In this paper, we have shown that the work environment design became detached and sub-organized in the EU-project, which is a major problem when developing new production technologies in international cooperation projects. This implies that the holistic picture is blurred and the perspective continues to be short term instead of the more preferable long term. The form of a project implies that the prerequisites continuously change and this is something to be aware of for all participants. The handling of work environment design should not be dependent relative to the changes in the project. These factors should somehow be present anyway. One way to do this is by securing a common objective regarding the work environment influenced by the new technologies developed. By doing so, the lack of considering differences in the international context can be avoided to some extent. The company traditions, that we have shown differ, must be noticed and dealt with in a systematic way. All these issues must be taken care of in a future conceptual model for integrating work environment design in an international collaboration project aiming at developing new production systems. At the same time, it is important to make the models easy to follow so that they can coexist with or merge into the already existing models for project monitoring in this type of project. Many models for product/production development present today could in fact contain the work environment design, however they seldom do. If project groups in the future can be supplied with such a model, both money and personnel can be saved which may in fact reinforce the positive outcomes of most developing projects. Hence, this paper illuminates the need for research to

overcome problems of integrating work environment design in international collaboration projects and to influence future projects to use such conceptual models.

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Paper III

The presence of socio-technical perspectives in the development of future production processes – Experiences from an EU-project within the aero structure industry.

Lindelöf, P. (forthcoming) Submitted

The presence of socio-technical perspectives in the development of future production processes – Experiences from an EU-project within the aero structure industry

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ABSTRACT

Using a socio-technical perspective when developing new production technologies is important to achieve as good work environment as possible. Manufacturing of today and from recent decades has focused on being lean, without sometimes acknowledging technology and organization in an integrated form. Hence, it is interesting to assess how these values appear in industry and in international collaborative development projects, since the socio-technical approach has a strong connection to work environment design. In this paper, 14 characteristics describing the socio-technical perspective from different angles are chosen. Two manufacturing companies in the aero structure industry from two different countries are described on the basis of these characteristics. The comparison shows that the level of socio-technical perspective present is greatly divergent between the two. An EU-project involving the two production companies is analysed in regards of the characteristics. This analysis shows that the socio-technical perspective in the mutual project was present somewhere in between the perspective levels of the two manufacturing companies.

1. Introduction

Emery (2003), Trist (1951) and Rice (1953; 1952) were the first to develop the socio-technical theories; see also Emery and Trist (1959), which has been discussed and used in large industrial projects ever since. Their premier advocates have been the Scandinavian countries, Western Europe and Australia. Nowadays, '*Lean production*', initially developed by Womack, Jones and Roos (1990), is the concept on everybody's lips. The discrepancy between the two approaches can be difficult to single out, but they do focus differently on work environment. Both focus on participation in the process of change but in different ways and extents (Börnfelt, 2006). Some fundamental parts of the socio-technical school are still desirable and somewhat present in most companies in the manufacturing industry. Because the holistic approaches towards production systems, whose technical and social focus are in line with the socio-technical approach, involve the technical side of the system, it can be questioned whether the new management concepts also involve the technical side. When technology development projects within a socio-technical sphere include physical and psychological aspects in work environment, it is of importance to study whether the lack of a socio-technical perspective in a technological development project is the reason why work environment is a side issue in the project work. If so, the next question is whether it is due to how much of a socio-technical perspective is found in the participating companies' organizations. This paper will show how the socio-technical perspective filters through two aero structure companies from Sweden and Spain. How this perspective filtered through an EU-project which the two companies participated in, will also be analysed, with the aim to develop new ways of manufacturing large non-rigid structures through innovative production systems. The EU-project was part of the European Fifth Framework Programme and withheld a general wish that parts of the production could be automated further. The studied project was initially two separate projects that were merged together to be

eligible to apply for money from the fifth framework programme. One project was about the machining processes and the other about the assembling processes.

Several organizational concepts compete to be the most useful and profitable. Historically, work organization has gone from Taylor's Scientific Management, through Human Relations, Socio-technical Systems, Lean Production, Business Process Re-engineering, etc. (Sandkull & Johansson, 2000). As concepts are replaced by new concepts some parts of the old ones will remain (Røvik, 2000). This implies that parts of the Socio-technical theory can be found in Lean Production as well as most other concepts. Since the socio-technical approach has been an important part in the development of work environment, it becomes interesting to see how much of this concept remains in the organizations and how this legacy affects work environment design. This applies especially to international collaborations, when project participants have their own company perspective that sometimes dissolves in the cooperation with other companies having other perspectives.

The objective of this study is to describe and assess the extent of a socio-technical perspective in the two producing companies studied and the EU-project they participated in. Is the level of socio-technical perspective in both companies reflected in the EU-project? Furthermore, the possibilities of the socio-technical perspective to survive in future international collaborative development of production projects will be discussed. These analyses will help explain why work environment became a detached subject during my participation in the EU-project.

2. Methodology

The EU-project ran from January 2002 to January 2005 with 10 partners from 5 different European countries participating: England, France, Germany, Spain and Sweden. The partners consisted of persons from institutes, consulting companies, universities and manufacturing enterprises. The EU-project was divided into eight work packages of which I actively participated in one package together with four colleagues from Luleå University of Technology in a research group. This work package was named "Evaluation of socio-economic effects". Within the work package our group had the obligation to conduct analyses and to design a model to handle work environment design in collaboration projects aimed at developing new production systems from early development to industrial implementation. As a subordinate of the seventh work package in the EU-project, this work constituted four different sub-tasks, viz. *Work environment factors, Industrial environment and production context, Milling and automated assembling,* and *Implementation of new production systems in industry*. These sub-tasks consisted of assignments to analyse and to further develop a proposed model of how to handle work environment design from initial development to industrial implementation of the production processes. Our research group and a German consultant company partnered in work package seven, since the coordinators of the project chose to almost double the cost of this package at the last minute and involve a second partner.

My involvement and influence in the EU-project made me a part of the empirical base and led us into the field of action research, which is very common in socio-technical theory (Davis, 1971; Eijnatten, Hoevenaars, & Rutte, 1992). As described, the structure of this research project can be regarded as action research because it tries to build a bridge over theoretical and practical work, while studying a phenomenon and trying to change it. In this study I consider myself part of the socio-technical perspective that was studied. However, I was not part of the two manufacturing companies and in this case, I refer to my interaction in the EU-project as minor, but still present.

The project team throughout the rest of the paper refers to the whole project, consistent of all eight work packages. I participated in one of the work packages with support from three senior researchers at my department, viz. Professor Lena Abrahamsson, PhD Bo Johansson and Professor Jan Johansson. PhD-

student Marie Sandberg did parts of the data collection and participated in the first phases of the project. None of us were experts on EU-projects, but we were hired as experts on work environment factors, and therefore based our work plan on earlier experiences and work environment theories.

Participation in the EU-project is the empirical base of my research and was the initial phase. During this phase, data collection started by attending an upstart meeting with all partners in January 2002. In this meeting and in the consolidated project description, an insight was achieved as to the starting point of this project. The meeting was followed by an interview with one of the consultants participating in the project to confirm our attained knowledge, and to receive valuable information that could not be found elsewhere. We became aware that to come up with some essential results in the EU-project, we had to focus on the two manufacturing companies involved.

The two companies studied in this project will be here referred to as Spanish Aero Structures (ESPAS) and Swedish Aero Structures (SWAS), due to the need for confidentiality. The fact that the two companies need to be anonymous does not affect the outcome of this study. Since we realised quite early in the project that we would not be able to study the whole production development process in this specific project, from idea to industrialized technique, we decided to study three similar projects that were completed by the two companies and where the implemented results could be observed at the facilities. These projects studied had one significant difference to the EU-project – they were conducted within their own organisation and not within an international collaborative project. Direct observations at the production sites were carried out and a difference in work environment perspectives between different partners was noticed. The observations were followed by 16 semi-structured interviews with involved partners, which were transcribed verbatim and coded with help of standard Microsoft Office programs.

Studying both production companies was one part of the data collection, with the other being the observations made of the work in the project team (see Figure 1). Since our task in the EU-project was to work with work environment factors, this was done during meetings and discussions and in reports, bringing up work environment issues on the agenda. The need to integrate work environment factors in the other work packages and the fact that their results could affect a future work environment was stressed was greatly stressed by our research group. The other partners responded positively to these arguments, at least rhetorically. We were invited to attend meetings between other work packages and may have influenced them to focus more on these matters in the future. We presented our findings throughout the project and observed the other partners, the issues they stressed and how they stressed them. During the entire EU-project, e-mail served as a good way of communicating. Mail correspondence was a part of the data gathering. People explained and expressed their viewpoints on issues in the EU-project.

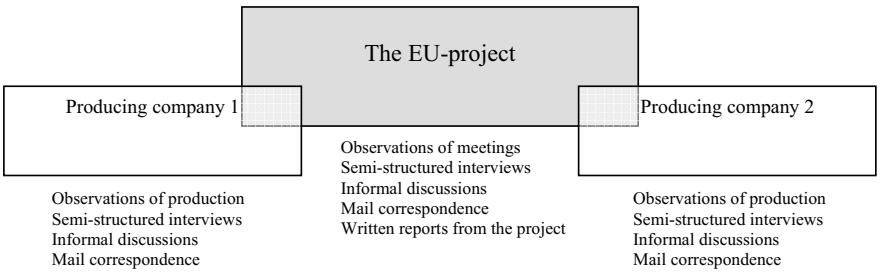

Figure 1 The three studied 'units' and the methods used to collect data from them

After the data was gathered and analysed and our research group had delivered what we were supposed to for the EU-project, a major analysis followed. Patterns were noticed based on the material collected, and when the decision was made to use the socio-technical perspective to analyze the two organizations and the project, these patterns were further examined. When the connection between theory and data material was made the main results of the study were extracted. The analysis presented in this paper should not be interpreted as an attempt to quantify qualitative data traditionally. Instead, it exemplifies another way to relate to the data gathered during the EU-project. The interesting part is the relation between the studied cases and how they use parts of the socio-technical perspective when developing new production processes.

3. What is a socio-technical perspective?

There are many ways to describe a socio-technical perspective. Emery (2003) states that no single body of concepts can claim to be THE theory of socio-technical systems. To somewhat limit the width of the study some delimitations are made. Based on the literature of Dankbaar (1997), de Sitter, den Hertog & Dankbaar (1997), Emery (2003), Niepce & Molleman (1996), Van der zwaan & De vries (2000), Cherns (1987), and (Thorsrud, 1968), 14 different characteristics were selected to determine the presence of a socio-technical perspective. Cherns' 10 principles of a socio-technical design are the main foundation for the 14 characteristics described below. Since most of the empirical material was already collected when the characteristics were set up, it could be understood that to detect the different relationships to the socio-technical perspective of the partners, it was necessary to add and change some of the characteristics in line with other important researchers. Even though other researchers may come up with other and supplementary characteristics, these were chosen on the basis of the type of data collected during the EU-project I participated in and of my own origin as an advocate of the socio-technical perspective.

Participation

Within the socio-technical perspective it is assumed that motivation of workers to work depends very much on their understanding of the logic of production processes and the participation in operational decision making. To do this, they need capacities, credentials, skills, and control capacity (authority).

Minimal critical specification

A task performance should be defined as little as possible to leave enough leeway for employees to perform tasks according to their own expertise, meaning that they can set their own working pace and choose their own working methods. The workers are steered by the expected results, but are free to decide how these are achieved.

Interdependency

In a socio-technical perspective all workers share the responsibility and often work closely together. This is a form of reciprocal interdependency where workers are dependent on one another's co-operation to get their job done. This has occasionally impeded groups becoming rather closed entities and thus a degree of seclusion. Regarding the interdependency activities, the spatiotemporal distribution of machines and operatives tends to influence the ease with which they are coordinated, supplied and maintained. This distribution creates a specific human ecology by throwing some people together and separating others. It is important to have grouping activities where they interrelate and practise communicating with one other.

Boundaries

The principle of boundaries refers to that workers perform closely related tasks should be located in the same autonomous teams. These teams provide the worker an identity in the organisation. The autonomous

teams require production to be organized around parallel product flows (group technology). The work units have to be grouped into phases, and in the new automated industry the controlling of the conditions are grouped to be closely coordinated.

Multifunctionality

Within the principle of multifunctionality it is important to separate job enlargement and job enrichment. Both are important, but job enlargement relates to the integration of tasks inside the boundaries of the work group that will enlarge the cycle time, meaning that the work will not consist of a wide range of narrow tasks. This is in contrast to job rotation/ job alternation between teams and between different departments, since job rotation does not increase the cycle time. Job enrichment, however, is about how to re-design the job to make it more challenging. The socio-technical perspective strives to find an optimal level of multifunctionality, not to maximize it.

Human Values

The socio-technical perspective focuses on work content and job redesign, i.e. job enrichment as mentioned before. When the work becomes more about controlling automated processes, more education is required. In this principle, human values are often in the form of quality of working life, which is an often-quoted term. The quality of work and the quality of the organization are seen as two sides of the same coin.

Leadership style

Leadership style is permeated by low hierarchical levels in a socio-technical perspective, and should be compressed as far as possible. This can help to better resolve local disturbances near the origin.

The immediate physical work setting

A socio-technical perspective has a strong orientation towards the physical structure and layout of the production system. Much of a change process takes its start in how the physical structures of manufacturing facilities look today. There is also an interest in how the natural characteristic of the material being worked upon affects the job, operator and nearby surroundings. The immediate physical work setting also includes the level of mechanization (or automation), since it affects several other factors such as human values. It also involves how flexible the automation is in regard vis-à-vis the operators, production system etc.

Working pace

In the socio-technical perspective, workers have the ability to set their own working pace. This does not imply that they idly sit around at work, but that they are not fully paced by the production process. There is some slack built into the processes in contrast to a fully adopted JIT-system.

Attention to organizational issues

In the socio-technical perspective, an integration of aspects is focused upon instead of the steps. Steps are referred to as the stages in the process, such as purchase, delivery, transport, stocks, operations, and distribution. Aspects refer to the aspects' systems of the production system, e.g. the planning system, the maintenance programme, the quality system, and the personnel qualification policy, the management accounting scheme, and the management development strategy. Another example is when re-designing the work, it should be noted that the maintenance operations needed are to maintain conditions required by the productive process and not to create a social and organizational gap between the groups. As automation continues, the supply operations become more critical to efficient performance.

The balance model

The socio-technical perspective often uses the ’balance’ model to describe the necessity for every control-need to be matched by an ‘equal’ amount of control capacity. By doing so, each task unit can cope with their own disturbances, eventually implying an improved quality of working life. Based on Ashby’s Law (Ashby, 1965) and Karasek’s Job Strain Model (Karasek & Theorell, 1990), the ‘balance’ model was introduced by de Sitter, den Hertog and Dankbaar (1997).

Whole-task groups

In the socio-technical perspective it is important, due to several reasons such as quality of work, job enrichment, etc., that the group/team work with a whole product and not a narrow task that cannot be put in relation to the finished product. The whole-task group is responsible for the execution of whole-tasks and not only perform the production function, but also the functions of preparation, monitoring, control, and external regulation to the highest possible degree. Thus, the gap between performance and control is decreased.

Autonomous task groups

Autonomous groups as the basic unit of organisation are considered in the socio-technical perspective to lead to a better overall performance of the organization. There should be a unity of preparation, execution, and control in the process. The groups are responsible for the results of their work and need the means to realize this responsibility. Self-management is seen as a substitute for leadership. If the groups are autonomous, they can control the pace and the methods they use to do the specific tasks. A group can provide continuity in task performance that is unlikely to be achieved by sole individuals or under supervisory control.

Structures

The socio-technical perspective illustrates a structure propensity and prefers dealing with structures of layout and organization. The structure focus does not involve control issues.

The characteristics are very similar in nature and coincide to some extent. Despite this, all characteristics involve something specific that helps to analyse whether the socio-technical perspective is present or not.

4. How much of the socio-technical perspective filters through in both companies?

The two studied companies will be described and analysed using the 14 characteristics defined above. Each characteristic will be evaluated and put on a five step scale. Of note is the relative position of the two companies. Because a hermeneutical approach is used, the position on each scale is a question of interpretation. All 14 characteristics are interpreted together to come up with the overall scale of whether or not a socio-technical perspective is present. The position on the overall scale is not calculated. Instead, it is a form of interpreting the single factors. The different characteristics are close and overlap each other, and are thereby regarded equally important for the overall scale.

4.1. Swedish Aero Structures (SWAS)

At SWAS, interviews from two different production phases underlay the evaluation. One was a machining cell producing parts for the wing assembly that involved two persons on each shift and was fairly newly developed. The other process was part of the wing assembly process. Eighteen people should work in the set, but only a few were there because it was in ramp up stage. The remaining worked in other places waiting for full production.

The participation level in SWAS was rather high. Production workers participated in the development stages of both processes described above. When it was time to look at possible machines for the milling cell, operators travelled abroad with production engineers and project leaders to visit the machine manufacturers. Cell operators were also part of the task to structure the work, though the machines governed much of the work. The machines are extremely expensive and their work was very self-managing and can be regarded as a "black box". The work outside the machines was more self regulated, though much of the manual work procedures were specified in detail due the extreme quality control and quality systems present in the aircraft manufacturing industry. As more operations were moved to the production cell, boundaries were considered. If a specific operation was needed somewhere in the process, why not move it into the cell? It should be noted that this is not about creating parallel product flows. The redundancy is instead built into the cell with several multi-axel high speed milling machines. The cell itself had no parallel flow except the older machines that were used before the cell, and in some cases were still present on the premises. If the cell broke down and stood still, the work could be done as before the cell was in place. Operators tended to rotate between tasks within the processes. One week they were responsible for planning, another week for quality inspections. As more operations were placed in the cell, the operators were given more training and became more capable of multi-functionality. It seems like SWAS tried to maximise the multi-functionality, compared to when using the socio-technical perspective and trying to find the optimal level.

When it was time to find operators for these fairly new processes, several respondents said they chose the best ones from other internally situated processes. This created a spiral of status where operators worked their way up from rather simple jobs to the jobs with high tech machines. Handpicking those from other processes implied that the remaining operators needed support to not lose their self-esteem, which eventually would lead to a decreased quality of production. This division of labour on a scale of status indeed affected the communication and rivalry between the groups. The different groups were relatively dependent on each other, since they were parts of the same process line. However, this dependency was not so direct because each cell/production process had many products and process flows to support.

Regarding the policy of human values, there was a rhetoric amongst the majority that these matters were taken very seriously. For example, the quality of working life was enhanced through several social gatherings every year when the workers got together and spent time with each other outside of work. There were also company-owned facilities for the workers to use with their families, e.g. recreation centres.

The workers were proud of the low hierarchical leadership style. One respondent said that there were only three levels of management, which made work in production even easier.

Because the products produced at SWAS are very economically intense and the value added to the product is very high, the stock between the different processes must be kept on a low level. Slack in the process was decreased, yet still somewhat present, since the operators could plan the production themselves. Today, aircraft manufacturing is not mass production and it is doubtful whether it will ever be. Even so, it is interesting to see what the urge for a higher level of automation will imply for production, particularly for the working pace of the operators, who will certainly be there somewhere.

There was a tendency in SWAS to start the development processes from the immediate physical setting. During the interviews at SWAS, people often referred to blueprints and how it was before to see the difference, process flow charts were commonly used, and automation was rather low but increasing. This increase seemed to make the job slightly less flexible, since the machines were so advanced and expensive. The machines were flexible regarding what they could do, but were not compared to humans. Due to several factors, e.g. the end usage of the product and environmental issues, the material being

processed in the industry was very important. It seemed like a balancing act, while using the right material concerning environmental issues, both related to the workplace and the surrounding area, and to come up with the right end product features.

In view of the operators' continuous training to enhance their capacity, the control need can be matched. One respondent at SWAS even stated that it was better to have more capacity than control need, which was their starting point when discussing future education plans etc. The problem may occur when operators are not stimulated enough and only see parts of their capacity is being useful. The machines are setting higher demands on the control need in pace with the increased automation.

Automation implied a few problems regarding supply of material, such as in the assembly process that was implemented shortly before the observations took place in the premises. The technical requisites were there and the personnel were standing by, but there was no material to work on. This is an organizational issue that has to be taken care of when implementing new technology. The overall attention to organization issues was reasonable, but not high. Many questions about organisational issues related to the quality assurance system and other systems, leading to the conclusion that the word 'system' was frequently used in the SWAS organization.

Since an advanced and expensive machine requires a high utility level, several products were manufactured in the studied high speed milling cell, making it hard to create whole-task groups. However, even if they did not produce one thing from start to finish in the high speed milling cell, they took care of a whole phase within production from raw material to a finished part that would eventually find its way to assembly operations. The operators within the cell did quality control, and the group in the milling cell seemed fairly autonomous. More tasks and operations were merged into the production cell, where the work was done independently even though a supervisor was nearby. As in every other industry, questions travelled further up the hierarchy if they greatly influenced the business. Because the products were expensive, major decisions were often made after asking management for advice.

The structure factor had a tendency towards control thinking. Structure thinking was present, but rather unobtrusive. People talked about the organisation as a structure of different blocks, though when interviewed further, they tended to look more on specific tasks.

4.2. Spanish Aero Structures (ESPAS)

At ESPAS, interviews and observations connected to the assembling of wing boxes underlay the evaluation. The process involved six persons on each shift, working on a big jig where spars, ribs and panels were drilled, sealed and riveted together with mainly hand-held machines driven by pressurized air.

In ESPAS, participation was not easy detectable. Some respondents stated that only at the end of a change process was it interesting to involve the operators, i.e. in the implementation phases. They stated it was too time consuming and costly compared to its benefits.

Regarding minimal critical specification, many operations in ESPAS and SWAS were set by the quality aspects of the product and the fact that there was only one way to do a job. Numerous tasks consisted of drilling and riveting with the help of hand-held machines. The job was simple but needed and demanded very high accuracy. Six people worked each shift on each jig. Because there were at least three jigs in the production hall, redundancy was present. However, this redundancy was decreased because the parts were so large and the parts assembled in the jigs, i.e. the wing boxes, were so time consuming. At the same time, the work was very task focused and the cycle times were very low, and therefore a low focus on minimal critical specification.

Concerning multi-functionality, a striving for more work rotations could be seen. It was not so much about job enlargement, but about trying to maximize the multi-functionality because the cycle times remained the same. The aim was to teach the operators tasks to make production more flexible. If some process needed reinforcement, management could temporarily move one operator from one task to another. The human values did not seem to be focused and the operators were regarded as a commodity (Davis, 1971), as any other machine. However, all personnel were offered further training of various sorts.

In ESPAS, management chose the operators they regarded as the best for new production processes, but the status hierarchy was more evident in ESPAS than in SWAS. A certain job had a different status and the operators were not that dependent of each other. The operators worked rather individually and had very little interaction with each other. They occasionally worked in pairs when, for example, riveting with one hammer and one counter force.

A strong hierarchy could be noticed in ESPAS. For example, the colour of your clothes was important because it stipulated your status rang. Although this may have been to help find supervisors and so forth, it increased the feeling of the present hierarchy.

In ESPAS, many of the blueprints were used to explain the structure of the process. The level of automation was even lower in ESPAS than in SWAS, making ESPAS more flexible due to the lack of expensive machines. Instead of expensive machines, specially made jigs set the limit of production. In these jigs much of the work was done manually and with help of hand-held machines. The immediate physical work setting can be said to be rather central to ESPAS. Because it was a rather young company less than 15 years old and the premises visited were even newer, production space was not lacking. This gave them an opportunity to get the production flow right from the beginning. In this flow, the working pace can be regarded as high, without almost any detectable slack. The assembly process studied consisted of assembling expensive parts, meaning the process lay rather late in the value adding chain. This made mistakes very costly at this stage, which reflected on how the work was done.

An attention to organisational issues was perhaps present, but not very obvious. ESPAS was more interested in the production steps, though they understood the importance of the organisational issues. This was stressed during the interviews and they stated that these issues took longer than to implement a new production technique. They were also aware that they often had to take care of these issues afterwards. Overall, the lack of system thinking was apparent. Every step of the process was looked upon separately and not considered with respect to all the other processes taking place on the shop floor, such as communication, cooperation and social well-being, etc. No one can look at the “whole” system (Klein, 1976), but one has to be aware that these other parts exist.

It was apparent in ESPAS that there was a need for more control, which was connected to the hierarchy present. If an operator had the capacity to control their own work, the hierarchy in the process would decrease which is not always desirable. As well, education plans for all operators were present but as long as they did not need the education, they would not receive any because there was no need for control. It is possible that the balance model was in state of equilibrium, though there was not as much on each side of the scale as in SWAS.

In ESPAS the operators worked in shifts of six on each jig. Each shift worked as a team, but not by performing a phase of the production together, but rather short and in some cases monotonous individual tasks. Therefore, it cannot be said that a whole-task group could be observed in ESPAS. Although, ESPAS had begun to train its operators to conduct their own quality controls in the process, someone was still looking over their shoulders to control the controller.

The task groups described above did not work very autonomously, since the short tasks were predefined. Some tasks were to be automated in the foreseeable future, and supervisors would be present and the operators would not choose their own method of work until then. The expensive products, in this case the wings, made it rather easy for the operators to see the connection with the finished product. Even though it was only the wings, all operators knew where they were on an aircraft. However, the shift change implied a few setbacks for the jig teams because it became even more important that the different shifts worked in the same way. In other cases, it could imply much wasted time and resources when a new shift begins their work on the same product the previous shift worked upon.

At ESPAS, control thinking was much more apparent than system thinking. There was a desire to think in systems, but it was seldom carried out. Sometimes, the respondents showed glimpses of system thinking that mostly concerned how different machines would interact and not how the operators interrelated with them. Thinking in structures did not include all structures, but only those easiest to include regarding the body of knowledge already possessed.

4.3. The difference between the two

Table 1 In this table the level of the socio-technical perspective that filtered through in the two companies SWAS and ESPAS is described with 14 characteristics. The socio-technical perspective present is graded on a five step scale with; low, moderate, considerable, high, and extreme. Below the 14 characteristics is an overall scale of how much of the socio-technical perspective filtered through. This scale is based both on the separate characteristics and on an overall interpretation of the company. ESPAS is marked with an E and SWAS with a S. The most interesting thing is the distance between the two.

	Low	Moderate	Considerble	High	Extreme
Minima critical specification		ES			
Interdependency		E	S		
Boundaries		E	S		
Production structures		E	S		
Working pacel		E	S		
Attention to organizational issues		E	S		
Multifunctionallity			ES		
Whole task group			ES		
Autonomues work group			ES		
Participation	E			S	
Leadership style		E		S	
Balance model			E	S	
Human values		E			S
The immediate physical work setting					ES
A socio-technical perspective	1E	8E E 1S	4E 8S	 S 3S	1E 2S

Even though both companies can be sorted under the same type of industry, i.e. the aircraft manufacturing, the distinctive character of each company's origin filters through; see Table 1. The company from Sweden showed signs of a relatively long history of socio-technical aspects in the development of production organizations. The company is still affected by how the surrounding society influences it and these issues are still considered very important today in Swedish society. However, to

survive on a global competitive market, companies and society, to some extent, have realized the importance of focusing on the operation management aspect of production as well. When asked, the respondents at SWAS still proclaim their loyalty for the socio-technical perspective, while in some cases, it could be understood indirectly that the focus of these issues is being steered away from. At the same time a rhetoric influence was noticed in ESPAS that they want to erect a more socio-technical perspective than present, though keeping in mind the operational management perspective present in ESPAS today. Whether or not this desire is sincere is hard to tell, but as both companies belong to the aircraft manufacturing industry, they tend to be influenced by the same international surroundings.

There can be positive aspects in the differences of national distinctive character. If disregarding the outcomes for the work environment, each company can compete in the same market without being just one of several companies, since each has its distinctive character. For example, it is important to raise the question of what the operators in ESPAS want. Will more focus on the socio-technical perspective in ESPAS imply better conditions for them? Or is the change of perspective only something to impress the surrounding society with? Upon further examination, many who say they focus a lot of things actually do, just not the things they stated.

5. To what extent was a socio-technical perspective used in the development project?

When it comes to the EU-project involving ESPAS and SWAS, it is interesting to see what impact their own perspectives had on the project. The two companies were not the only ones in the project, and the perspectives of other companies also influenced the overall project perspective. This makes it difficult to say which aspects of the project perspective are due to SWAS' origin and which are due to ESPAS'. However, what can be stated after a project like this is that the two companies may have different distances to go before their developed technologies coincide with their own company perspective. Sometimes these technologies are not that changeable and therefore the company's own perspective has to adjust to the technologies and not only the other way around. The problem is that when a partner fixated on the socio-technical perspective takes part in a project not using the perspective, standing up for their own company perspective becomes difficult because it is more of a train of thought based on norms and values that is hard to express, let along in a foreign language and in an unfamiliar context. All partners participated on a voluntary basis, i.e. they were all prepared to renounce their own demands and find a common aim, at least rhetorically.

The only form of participation in the project, when it came to operators, was to help do tests on the machines. It might not be possible to involve operators in project meetings, but their thoughts should be noted during the development process. Even if the participation in the project cannot be higher, compared to the socio-technical perspective, it can be regarded as low and closer to what it was at ESPAS than SWAS. This is because it is easier to renounce on the demand for participation than it is to convince people of its supremacy in a short time.

It is almost impossible to state whether or not the minimal critical specification was considered, but the manual operations possibly needed between the automated tasks were not at all focused upon. People in the project saw the possibility to fill these gaps with human labour. There was no such thing as thinking about how different operators in a set up with several machines should be able to communicate and interact. Some might say these issues should not be dealt with at this early stage of a development project, but others might say the contrary. Even in the early stages, how the different steps interact and how they become dependent on each other are important. Because the project did not reach the implementation stages as first expected, this question needs to be stressed even more in the later stages when the production techniques will be further developed and adapted for the industry floor.

None of the boundaries were considered, for example, where control issues for the prototypes developed were not greatly focused upon. The fact that automation of some tasks sometimes implies several flows being gathered together through one machine makes more redundancy unlikely in the processes. The jobs of controlling the new machines will be more demanding for the operators compared to the jobs they have today, but perhaps not more stimulating because a machine often runs without any help for a long time. The loading and unloading will be large parts of the operators' future work. Not surprisingly, the factor of boundaries ends up closer to the way it was at ESPAS than SWAS, since it was a common thinking in the project that every task they could not be automated in the machines developed, the operators could do themselves.

Human values were only slightly present in the project, e.g. in the deliverables from the project where some partners noticed the risk of tripping and slipping in the setting of the prototypes. However, the operators were regarded as disposable to the project. What would happen with the work when differentiating it into small tasks in between automated processes was not considered. Again, the project perspective approached that of ESPAS more than to SWAS. The fact that the project group consisted of a majority of engineers affected the minor focus on human values. They were interested in these factors, but when forced to choose between their specialities and things they were not experts in, they chose their own specialities.

Any particular leadership style was not evident in the project. The partners involved did not pay much attention to how the leadership style would affect the new technologies. During meetings, there was a tendency to just regard it as something the management tells the operators to do, even though this opinion was not shared by all.

Orientation towards the immediate physical work setting was very high. The project itself started with a low level of automation common to this type of industry, with the aim to increase this level. During the project, the deliverables were full of sketches, blueprints and simulations. The first deliverable from the project was in fact a description of how the work was done today, with explanations of several parts and jigs.

The project described in this paper aimed to increase the quality and the general working pace. Whether this implied that the operators' working pace must also increase is hard to say, or if it was mainly an effort to decrease the workforce and thereby lower the cost of wages. It is about the organisation of work being redesigned at the same time as the production process. If an operator's job will be to load and unload machines, the increase of machine process speed will also mean an increase in the operator's working pace. However, if the redesign of the workforce occurs simultaneously, perhaps the new techniques developed will decrease the working pace. With the new techniques, the operator's slack will seemingly become even smaller. The focus on lean production in today's industry will counteract the setting of bigger stocks before and after the machine.

Organisational issues were present in the project, but rather detached from the rest of the project. The socio-economical work package worked with these issues. From the beginning, it was about handling and integrating work environment factors in a whole design process until the techniques were implemented on the shop floor. In the end, the study focused more on the early design phases of a development project and how to integrate these issues there. In between, not much focus was paid to organisational issues, but a few examples could be found. Attention was not high, but certainly present as can be seen in Figure 2, where the project perspective ended up closer to SWAS than ESPAS. One reason is because our research group that was responsible for the socio-economical work package in fact were doing this in respect to our own perspective where organisational issues are very important.

Concerning the balance model, these issues were stressed but not considered desirable to call it an integrated perspective. Since the operator's capacities were not focused upon, the control need could not be matched by the control capacities. This implies that with respect to the socio-technical perspective, the project is placed on the lower end of the scale of the balance model, even lower than in ESPAS and SWAS due to the EU-project being more technically driven than the companies' developments projects.

The new technologies developed in the project will decrease the involvement of manual labour in some processes. The operators will become fewer and the work will be more of a controlling type. The engineers involved in the project were so focused on the detailed technologies that the implications for the system were not discussed. For example, during one project meeting, one partner brought up the importance of looking at the developed techniques in a system perspective. What would happen when they were to be implemented? Another partner was assigned this task, but when looking for it in the project deliveries, this was nowhere to be found. Because the number of operators will decrease, it will become even harder to organise them so that they can, for example, communicate with each other. Since the machine will be able to do more and more tasks, the operators will supervise a whole phase that could be put in relation to the finished product, even though it is slightly unclear whether or not to call it a whole-task group when it has less people but more tasks.

Time will tell if the new groups created by the developed technologies will be autonomous. There are signs showing that this is most probable, since the machines are too expensive to stand idle. The operators have to make decisions to get the machine up and running again. This increases the need for the operators to be well educated and knowledge intensive. At the same time, the fact that the method of production will be stipulated more in the new machines contradict that the autonomous level will increase. Quality will be more an issue of the machine's quality. The quality of the products manufactured will probable increase, which in its extension implies that the groups can be more autonomous.

There was a noticeable but not very high propensity for structures in the project, at least for those concerning layout. As mentioned the project was technologically driven and the focus was on innovative solutions of production problems. Based on the participation and observations, the project lacked thorough economical discussions and analyses that were not directly connected to the work environment. Questions regarding what the new automated production systems were allowed to cost, including the increase of quality and decrease of personnel costs, were not up for discussion. The propensity of organisation structures was very low, if at all present.

Table 2 In this table the level of the socio-technical perspective that filtered through SWAS and ESPAS companies, together with how much filtered through in the EU-project are described with 14 characteristics. The socio-technical perspective present is graded on a five step scale; low, moderate, considerable, high, and extreme. Below the 14 characteristics is an overall scale of how much of the socio-technical perspective filtered through. This scale is based on the separate characteristics and the overall interpretations of the companies and the EU-project. ESPAS is marked with an E, SWAS with a S and the position of the EU-project is shaded.

	Low	Moderate	Considerble	High	Extreme
Minima critical specification		ES			
Interdependency		E	S		
Boundaries		E	S		
Production structures		E	S		
Working pace		E	S		
Attention to organizational issues		E	S		
Multifunctionallity			ES		
Whole task group			ES		
Autonomues work group			ES		
Participation	E			S	
Leadership style		E		S	
Balance model			E	S	
Human values		E			S
The immediate physical work setting					ES
A socio-technical perspective	1E	8E E 1S	4E 8S	S 3S	1E 2S

To sum up, the socio-technical perspective seemed more prevalent in the project than in ESPAS, though it was less than in SWAS. This is understandable, since the perspective in the project was reinforced by the fact that our research group was responsible for the seventh work package dealing with work environment, which has strong connections to the socio-technical perspective. Whether this would be the case in a project where this sort of force is missing is doubtful. It is more likely that the socio-technical perspective will be less present if the project had fewer of its advocates.

6. Will the socio-technical perspective gain more respect in future development projects?

Contrary to the increasing focus on Lean Production that has been around for several years, the focus on socio-technical issues has fallen back. Because the operators' tasks around the machines will be more knowledge intensive, the risk of having a lack of human aspects in the process becomes bigger. Management of these companies will conclude that it costs more to loose an operator due to a bad work environment design than to take care of socio-technical aspects already in the design phase of the production processes. The question is why we have not comprehended this already? If we have, why have we not considered it important enough? As the work force decreases for the same scale of production, we will probably come to a level where it is both economically and ethically advantageous to take care of both the soft and hard parts of a production process in the early phases of a development process to prevent future costs due to a bad work environment.

7. Conclusions

In this paper, it has been shown and described how the socio-technical perspective and thus work environment design filtered through the activities of two manufacturing companies in the aero structure industry as well as in the EU-project they both participated in. Even though neither of the companies showed a full socio-technical perspective, it was stronger in the Swedish company than in the Spanish. At the same time, it seems as though SWAS is steering away from the socio-technical perspective and that ESPAS is steering towards it. A future question is if and where the two will meet. They have already met in the EU-project where it turned out that the socio-technical perspective was not present at a high level. In this EU-project the participation of several partners, mostly engineers, probably influenced the low level of the socio-technical perspective. There is a greater force to create something that is regarded as high-tech than to develop something that is both high-tech and connected to a good work environment. The design of technologies is more important than the design of the work environment, though there is no opposition. The problem is that project partners do not realize the possibility to design both by means of a holistic perspective. The general thinking of the participating partners was that the efforts in the project could be detached from the practical work with the technologies regarding the work environment in their own organizations.

The resistance to the socio-technical perspective in the project was not articulated, but more about the norms and values the project partners brought from their organizations. These partners, who have a strong position in the project due to their numbers in the project or in status based on knowledge and experience, were able to gain respect for their values and norms. This implied that because these partners were not frequent advocates of the socio-technical perspective, the project organization as a whole was neither an advocate. Although our presence as a research group, together with the fact that SWAS had a tradition of the socio-technical perspective, made the project at least lean towards applying a more socio-technical perspective.

The work environment, with all that these words encompass, is certainly an issue for the future. As jobs in the aircraft manufacturing industry go from craftsmanship to semi-automated tasks, this becomes even more important. The companies need to erect a human perspective on the development process, while staying competitive on the global market.

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Paper IV

Knowledge on work environment design in an international collaboration project - Experiences from sharing the concept of work environment design.

Lindelöf, P., Sandberg, M. (forthcoming) Submitted

Knowledge on work environment design in an international collaboration project

- Experiences from sharing the concept of work environment design

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ABSTRACT

In this paper, the hindering factors of knowledge sharing processes regarding work environment design in an international collaboration project are described and further explored. The project aimed at developing new production systems for the aero structure industry, and ran between 2002 and 2005. The authors participated and also began their collection of data within the project. With an empirical analysis of the data and of the participatory involvement in the project work, the complexity of knowledge sharing, regarding work environment design was acknowledged. Project participants had different roles in regard to knowledge sharing of work environment design, and they had different levels of knowledge of work environment design. The project seemed to not make use of the higher levels, and rather stuck to the smallest common denominator of knowledge. One of the main conclusions is the importance of building a relationship in the beginning of project collaboration in order to establish knowledge sharing and a joint mind set. Another conclusion is, it is vital to take advantage of the positive tacit knowledge, regarding work environment design, present within the project and make use of it at the same time as making use of the explicit knowledge.

Key words: *work environment design, knowledge sharing*

1. Introduction

In this paper, the hindering factors of knowledge sharing processes regarding work environment design in an international collaboration project are described and further explored. The expansion of what Castells (1996) calls the network society and of 'new' ways of functioning and organising work, have slowly begun to increase the demand for distributed organisational collaboration and integrated work. This is especially a reality in the automotive and aerospace industry where the globalisation trend has increased shared costs and risks by new forms of organising collaborative projects (Larsson, 2005). This trend could also be found at a European level were inter-organisational collaborative work between organisations in the member states is encouraged and financed through different forms of Frame Work Programmes. In addition the public sector, where universities play an important part, is affected by this encouraged and stipulated collaborative research work with other representatives of the society. Both at a local level, and also at an European level.

Traditionally when researchers address work environment design in technology development processes, it has been in relation to the context of 'in-door' activities in a specific company or organisation (Neumann, 2004, Högberg, 2005, Langaa Jensen, 2002, Clausen and Langaa Jensen, 1993, Westgaard and Winkel, 1997). What has not yet been fully described and explained is when the context of interest is a collaborate project, where the participating partners consist of a mix of manufacturing companies, institutions and

universities located in different countries, and in this case European member states. This provides new implications for the research society for trying to fill this gap of research. In this paper a part of this gap is filled when the research area of how to share work environment knowledge in a technology developing project of new technology and production systems is further explored and analysed.

This paper reflects and describes the authors' participative experiences of the sharing of work environment knowledge in the technical development process of a collaborative organised project setting. The common platform for this sharing is described, and two main areas will be discussed further in this paper. First the discussion of how knowledge about work environment design differentiated between partners in the development project and secondly how knowledge sharing processes evolved regarding work environment design between different project 'roles' in the development project.

2. The concept of work environment design

Work environment design can be seen as a continuously ongoing process in companies where physical, psychological and social health promoting aspects are noticed and treated when changes appear in working life. Thus work environment design can be described as the result of joint values on how organizations, formally and informally, can design and change the work situation on the basis of man's different needs and conditions. Despite large stakes made on research, development and legislations in the field of work environment, research results indicate knowledge is still lacking in how structure, procedures and roles in work environment design can be concretely integrated with the work of change and development in an organisation (Neumann, 2004, Högberg, 2005, Westgaard and Winkel, 1997, Hasle and Langaa Jensen, 2006, Hägg, 2003).

The underlying 'ideal' concerning the concept of work environment design lies in the ambition to take a more comprehensive view of working conditions, health and well-being for people at work. This is a complicated task since the work environment could be understood in terms of all circumstances that affect people at work. In reality it has a more practical meaning which is based on a 'fictitious' construction of the work environment into physical, social and psychological work environment factors to be considered during development or change processes at work. To divide work environment design into different areas is a common means of more practically distinguishing and prioritising different factors and processes, although all are strongly linked in complex relations. The physical work environment factors here refer to ergonomic conditions, such as material handling, postures and operator control and to the exposure effects of chemical components, gases, vapours, noise, vibrations, in and outdoor climate etc. The social and psychological factors refer to the social dimensions of work, such as co-workers and superior relations, work content and organisation. Since work environment in this paper springs from a socio-technical perspective, the conception also includes an effort to optimize the efficiency and productivity by optimizing the social system in coordination with the technical system.

The aim of the practical side of work environment design is to handle both the long and short term effects, changes at work have on people's different abilities, health and well-being. The choice not to solely proceed from legislative descriptions of work, originates from the concept that not all development activities at work, which affect peoples abilities, health and well being in a positive manner, have their origin in such legislative demands. Applying the concept of work environment design should be seen as much as a voluntary natural part of a change or development process, as a part of securing good quality end results.

In an international collaboration project developing new production technology, as in this case, it should be noticed that the project participants and leaders actually have a good opportunity to handle work environment design. It is then necessary that the project organization possess the knowledge and

furthermore the right type of knowledge regarding work environment design in order to achieve a 'good' work environment.

In this paper the knowledge of work environment design is divided into eight parts:

1. To know that the work environment affects people's health
2. To know there are directives, laws and regulations about work environment and where to find them, e.g. the EU Directive EEC/89/391.
3. To know how one's own organization works with work environment design and the specific procedures present.
4. To know how to perform and analyse work environment measurements e.g. noise and vibrations, chemical health risks etc., or at least be able to use the results.
5. To know how to conduct work environment procedures and take measures (i.e. solve problems afterwards)
6. To know how to design and analyse workplaces (i.e. prevention)
7. To know how to design and analyse production systems and erect a holistic and contextual perspective

Several of these parts are of equal importance and experts, consultants and researchers can have deep knowledge in one or more. But in relation to integrating work environment design into a collaboration project developing new production technologies these parts can be seen as an escalating scale of seven steps, where we see the preventive, holistic and contextual perspective as important tools for constructing well functioning technologies. The ideal would of course be that the project team has a total knowledge level of the entire scale, but that alone is not enough. It is also important how the knowledge is shared, in order to enhance all project participants' knowledge and thereby influence their practical work both in the present project as well as in future ones.

3. The EU-project as an empirical base

The empirical base for this paper was an EU-project with an overall aim to develop some parts of the new generations of manufacturing technology, machinery, equipment, and production systems, for the aero structure industry. One example was a robot for semi-automation of drilling and riveting on wing-box structures of aeroplanes. The project, in this paper called the FORWARD-project, ran from January 2002 to January 2005. Ten partners, a mix of members from institutes, consulting companies, universities and manufacturing enterprises, from five different European countries: England, France, Germany, Spain, and Sweden, participated in the project.

The FORWARD-project was subdivided into eight different work packages (WP), in which activities were organised. The WP0 covered the aspects of management and control, while WP1 to 6 had a technical orientation and were directly linked to the actual development process of the new production system and machinery. The WP7, which was the part we mostly participated in, ran as a separate detached process named '*Evaluation of socio economic effects'*.

3.1. Decription of WP 7

The aim of the work package was to study and assess the socio-economic effects of the new production system concepts and critical technologies (milling and automated assembling) for manufacturing of large aero structures and their implementation in industry. The work contained a development of guidelines for how to support work environment design in the FORWARD-project as well as for similar production system development projects. Within the course of the research project ergonomic analyses were conducted in order to assess the present state of work environment.

Two partners, the research group from Luleå University of Technology, Department of Human Work Sciences (DHWS) and a German company (GC) that operates within the occupational safety field, had active roles in WP7. The work plan for WP7 was set up by the DHWS-group, in which the two authors of this paper were members, together with three senior researchers. The idea behind this plan was to influence towards and not force knowledge creation within the field of work environment.

WP7 was divided into four activity phases which also constituted a base structure in order to develop guidelines for the integration of work environment design in the development and implementation of manufacturing technology. The phases in chronological order were: *Criteria of work environment factors, Evaluation of the industrial environment and the production context*, E*valuation of the new milling and automated assembly*, and *Analyses of the implementation of the new production system concept in industry*.

The two organizations with active roles in WP7 implied diversity in cultural background. There were also differences in the partners' experiences and backgrounds and while the DHWS group had research experience in the field of industrial work environment, the GC were consultants in the machine working safety certificate area. Since all expertise were not present in the WP7-project group, some external experts were hired to conduct some measurements, e.g. sound level for high speed milling. WP7 also included some of the other partners from the main FORWARD-project, since they were the ones supposed to develop and use the production systems.

4. Methodology

For our research in the FORWARD-project the only option available was to adopt a type of action research approach throughout the course of the project. This implied that our research group by its participation were able to follow the development process in real-time from a position within. In this position we participated in project meetings, had access to and also wrote project reports, visited the manufacturing companies, made work environment analyses in their premises, and conducted interviews with project participants.

As part of our research we wanted to study how the participating manufacturing companies, one from Sweden and one from Spain, worked with work environment design in their 'in house' production development processes and compare with how it was done within the studied collaboration project. Therefore we studied similar projects, from idea to industrialized technique, which had been completed in the two companies. We tried to understand the levels of knowledge in work environment design, both in the two companies, on an individual level of the participants, and in the FORWARD-project. Observations at the production sites were carried out and differences in perspectives could be noticed. These differences were reinforced by the observations made and the following 16 semi-structured interviews.

The sharing of work environment design of the overall FORWARD-project was studied and experienced in three ways *a)* during project meetings by oral presentations, observations, reports, discussions and mail correspondence; *b)* by the 16 semi-structured qualitative interviews; *c)* by the FORWARD-project internal website where project reports and deliverables were distributed. The semi-structured interviews were conducted at the production sites, with project leaders, production leaders, team leaders and shop floor workers. Together it gave us a collective picture of how the context looked like in the two aero structure manufacturing companies, as well as within the FORWARD-project. Thus, the objects of analysis for this study are the overall FORWARD-project and parts of the two manufacturing partners who participated in the project (see Figure 1).

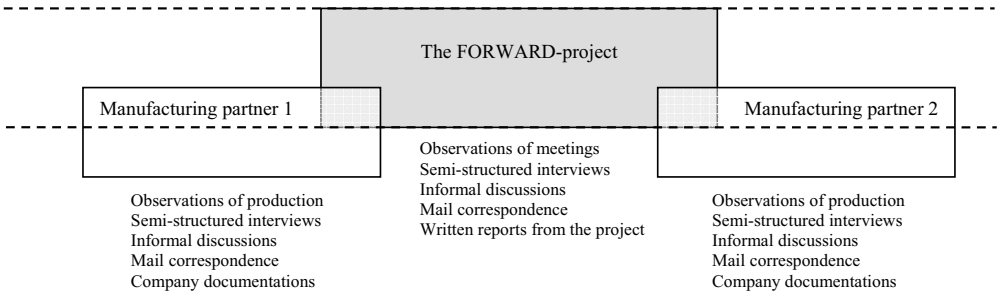

Figure 1 Objects of analysis in this retro perspective study, consistent of two data collecting processes and three studied 'units'.

The different partners took dissimilar space and position in the beginning of the project. Some of the more experienced partners, who had participated in similar projects before, stepped up and took on the responsibility to informally steer the project and the discussions. This was due to different levels of experience and closely-related knowledge which stipulated what space each partner got in the forum. It was obvious that these factors in combination with the individual personalities formed an informal hierarchy in the project organization.

Since we had never been involved in the aero structure industry before a lot of reading up was done in order to better understand this type of production. In order to look at the body of knowledge in the project one has to be aware of what to look for, which implied we had to position our mindset near the context. Since our task in the FORWARD-project was to consider the work environment design, this was done by bringing the issues of work environment design onto the agenda during meetings, discussions and in reports. The need for integration of the work environment design in the other packages was stressed a lot. We were invited to attend meetings between other work packages and did so. We also presented our findings throughout the project, but in most meetings we observed the other partners, what issues they stressed and how they did it.

During participation and analysis of the data different ways of looking at work environment design and the knowledge about it became evident. In our research group the perspective and knowledge were nearly the same, but between nationalities, between experts in the field of work environment as for example between us, experts in the German company and participating engineers from other companies, there were noticeable differences.

5. The platform for knowledge sharing in the FORWARD-project

The structure of the FORWARD-project implied a few hindering problems for work environment knowledge creation and sharing. First of all there is no assurance that the knowledge attained will be transferred to similar future projects since it is doubtful the same people will participate, even though a consultant from the UK seemed to have experience from similar projects and how work environment design had been integrated in those. Consequently, there is no structured way to use the gained knowledge from the FORWARD-project. This will cause inertia, since it is not a high priority for organizations to spend time and money in a collaboration project to enhance the individual knowledge about these matters. Instead this knowledge sharing has to take place in their companies before or after the project in order to

reach higher levels of the scale of knowledge about work environment design. Until all roles and participants reach the higher levels this implies a form for knowledge transfer is needed between different EU-projects in order to end up with a sufficient level in the project organization, instead of counting on luck to get the right participants. At the same time it is of importance to acknowledge the knowledge sharing process in the project in order to do the best with what is available.

In literature on learning in working life, the difficulties in breaking or questioning conceptions which are taken for granted are described (Pfeffer, 1981).The starting point in this study is that the work process itself, the participation in the arena, for example in meetings, face to face or via IT, and the exchange of experiences makes discussions and development of work environment questions possible. This supposedly influences the management of physical, psychological as well as social work environment factors in an overarching project level. Otherwise, work concerning the handling of work environment questions runs the risk of only being temporary. It is important that it is everybody's responsibility, not only the responsibility of the work environment expert in the project, that the sharing of knowledge becomes real and is prioritized.

A well known theory having its base in "Knowledge Management" is Nonaka's "Spiral of Knowledge" about transformation of knowledge, which is based on an understanding of the learning process in terms of transformation from quiet to explicit knowledge. In this paper, Nonika's spiral theory is used in terms of contributing to analytical understanding in various dimensions of knowledge development and learning about work environment design in cohesions of problem solving. It is also used to control the processes of knowledge transmission from a managerial perspective. Nonaka et al. (1995) discuss various forms of knowledge transmission, where silent knowledge is non-verbalised and intuitive while explicit knowledge is more formal and systematically encoded, as in written documents and data files. Silent knowledge is transferred for example by learning by doing, observations or working with someone more experienced. Explicit knowledge can be transferred through written material or knowledge conversation in the form of a meaningful dialog between the participants in the field of interaction. Thus, Nonaka's theory can contribute to the understanding that there is knowledge about work environment design within the individual which is difficult to verbalise, but can become more visible when people interact. By making these transferring processes more visible, the comprehension for the interaction between project participants during the work of development can become greater. Nonaka sees the knowledge conversation as a social process between individuals, and a basic assumption in this theory is that knowledge is created through the interaction between quiet and explicit knowledge, which can be divided into four different processes. These are described below with regard to how they connect to work environment design.

- *Socialization (from tacit knowledge to tacit)*

  Involves a process of sharing experiences and thereby the creation of tacit knowledge as in mental models and technical skills. Individuals can obtain tacit knowledge directly from others without speaking to each other. Examples are when individuals learn from others by observation and imitation i.e. applies what someone else does. This demands good role models when it comes to work environment design so that other partners can imitate the good behaviour in the development project. To create the possibilities for socialization of work environment it is necessary that some of the project participants take the role of 'competent' regarding work environment design. Thus, a typically ensuing problem can be prevented if the right behaviours are shared instead of if an incorrect behaviour regarding work environment design is imitated.

- *Externalization (from tacit to explicit)*

  Is a process which implies tacit knowledge is translated into explicit concepts. This is a process which is expressed by putting words on the unexpressed with help of metaphors, analogies, concepts, and models. It is in externalization different mindsets can be discussed in order to develop a joint conceptual model of what a good

work environment is which can be documented. This can later be used as a complement to directives and laws in order to assess the course and the end result of the project

- *Internalization (from explicit to tacit)*

  Is a process where explicit knowledge is transformed into tacit knowledge. This process can be related to learning by doing. When experiences are gained by socialization and dialog, which then are transformed to something of one's own i.e. a mental model which is hard to put into words. In this way the project participants can develop their own knowledge of how by their actions they can improve the work environment design of the end result. Since there was a distinct work environment content in the FORWARD-project it is possible it has influenced the project participants' mindsets toward work environment design. The problem is whether these mindsets worked against or for a better work environment design.

- *Combination (from explicit to explicit)*

  Combination can be described as a process where explicit concepts and procedures create an explicit knowledge system. This form of knowledge conversation includes a combination of various verbalized sections of knowledge. For example exchange of knowledge occurs through communication in different meetings (face to face, via telephone or virtually) and by spreading information through various documents. Project members can use existing explicit knowledge on work environment design through well-developed models or guidelines in combination with the technological development work within the project. A review of state of the art research in work environment was produced in the FORWARD project and made accessible for the project members. However, it is not likely that they actually used this explicit knowledge. With this report we made a declaration of our perspective of work environment design as presumed experts in the field. It was prevalent in this report that a long term perspective was preferred instead of a short one when dealing with work environment design

The tacit and explicit knowledge of an individual can be summarized referring to Sherehiy and Karwowski's (2006) illustration of explicit and tacit knowledge within the field of ergonomics, brought together with work environment design: explicit knowledge is not enough to provide good working conditions, health and wellbeing for people, whereas tacit knowledge is difficult to capture and transform into explicit knowledge. Thus in an ideal context, the point of learning and knowledge development described in this section is based on continuous dialogue and reflection between project members. In addition, this can contribute to the development work in the project taking a positive direction concerning work environment design. All collected knowledge of every project member will not be expressed during the project, but a characteristic project level of work environment design will grow, in line with what (Chevrier, 1999, Chevrier, 2003) claims happens when various cultures cooperate in projects. After this short description, it is obvious there was a platform of knowledge sharing in the FORWARD-project where learning could occur. The question remains how this happened in the project, and whether it was positive or negative learning?

6. Different roles in the project regarding work environment design

The participants in the FORWARD-project were divided into two informal camps concerning the system they were about to develop, viz. the 'hard' and the 'soft' approach. One camp advocated a hard approach on how the work environment design should be handled in the project and the other tried to use a soft one. Most times our research group constituted the soft camp, sometimes with support of other participants, for example regarding looking at the whole production system, since as Goodman et al. (1999) states that individuals may shift their cultural identity depending on the issue at hand, i.e. they can draw from different mindsets they carry. A symptom of the difference between the hard and soft approach was a general thinking by persons in the hard camp, that the guidelines and legislations on work environment present in the EU were too fuzzy. There was an urge among for example project leaders in the studied companies, for more quantitative data and measures. A good work environment had to be specified with demands on different parameters and in a quantitative way, to make the input of the design process turn

out as a good output. In general the soft camp had a higher level of knowledge about work environment design compared to the scale presented in the beginning of this paper.

When speaking about work environment knowledge in the FORWARD-project, the possessors of it can be described in different roles. In the project three types of participants could be found that all possessed different levels of knowledge about work environment design. The three types are *administrators/economists, project core participants*, and *experts* in the field of work environment design. Of course these three types are general in nature and a person might be situated somewhere between the three types since they are merely used to describe the typical examples of participants, see figure 2. The project participants, often consisting of engineers, tended to have different knowledge about work environment design dependent of from which country, company etc they originated from. This knowledge was for the most part in the form of practical knowledge and not so much in theoretical knowledge.

The type of *administrators/economists,* consisted mainly of one or two persons from the coordinating company and in some occasions people from the European Commission who attended the meetings. In the FORWARD-project, the *administrator/economist* took pride in the execution of the project and their number one priority was to keep the financial budget and at the same time come up with the desired results. Work environment design in this group was prioritised as long as it did not risk the budget or the end result in any way. The knowledge about work environment was limited but present. It seemed as though work environment design mattered if it would demonstrably affect the outcome of the project and then for the most part specifically in monetary terms. For the *administrator/economist*, work environment issues and research were also important in order to be eligible to apply for money for future projects when higher authorities such as EU required it. In this group, the state of the research in the field of work environment was not much discussed. On the scale of level of knowledge about work environment design, the *administrators/economists* could be found between level 2 and 4, most of the times.

The type of *project core participants,* which in the FORWARD-project consisted of almost everyone and sometimes us as well, can be described as a group in which people possess a great amount of knowledge about different technical dimensions. In the project, the *project core participants* were familiar with different kinds of technology and were also used to handle work environment design in a specific way in their own organization. They were familiar with basic legislation and some specific regulations, at least in their own specific contexts. They knew the legislations existed, but not the specific content of them. Their main focus was to come up with innovative technical solutions and they were not so strict about how to do this, which is one of the prerequisites of innovation. The general knowledge about work environment in general was fairly good, but fluctuated a lot within the group. It seemed like they sometimes did not know how to take care of these matters themselves. However, they tried to when they thought they had time to do it. The *project core participants* often expressed the need to have experts' opinions in these matters. They knew the basic legislations, but they were not that familiar with what modern research in the field stated and they seemed to care little since their focus was on other matters. One got the impression that *project core participants* regarded these matters as things that were privileged for those that could afford a long term perspective and not for those that needed results tomorrow. Compared to the scale the *project core participants* could be found most of the times between level 2 and 4, but sometimes some individuals moved closer to the role of experts and reached as high as 7. This only happened occasionally.

The *expert* type is a group that is involved as a result of several possible factors. All partners were experts on something, but regarding work environment design our group together with a German consulting company were officially the experts in the field. The main focus of the *experts* was to look after the work environment in the long term perspective and at the same time support the development of the project's objectives. This was problematic in the project when the *experts* were seen as gate keepers and to some

extent as inbuilt inertia i.e. only symbolized negative aspects. The *experts* sometimes became detached in the project and were seen as participants in a secluded project, who without interference should be responsible for the outcome of the "big" project being described as work environment friendly. Sometimes, the *experts* did not confirm the same objectives as the other partners and this can be a problem. The *experts* were naturally most interested in the work environment design, but needed to embrace the production outcome as well in line with a socio-technical approach. In order to be sorted under the label *expert* one has to be aware of the state of research as well as production requisites and project objectives. The awareness of addressing these problems as well as ideas of how to overcome them should also be possessed by the *expert*. Compared to the scale, the *expert* could be found on level 4 to 7. It can be said that our research group had an approach to share on level 7, but due to adjustments to the other roles where some knowledge was silenced, we mostly shared on a level 5 basis.

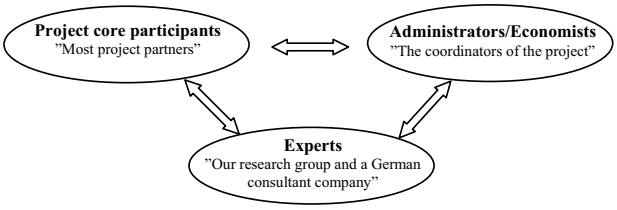

Figure 2 How the three typical types of participants in the project can be described in respect to work environment design. The arrows symbolize the possibility that persons can in one situation be regarded as an expert and in the next as an engineer etc.

The involvement of the *expert* can be due to demands from the surrounding society or due to certain self awareness, the *administrators* and *project core participants* realise they themselves will not be able to take care of specific matters in a suitable form. The experts can be consultants working in the field or scholars using the project for higher objectives as in the case of our research group. There are certainly other alternatives of *experts* present, but the important thing is they possess a great body of knowledge about work environment factors and work environment design. If the discussion concerned for example heat cameras it was then other partners who stepped up as experts. The big difference was that the distance between the rest of the group, with all the project participants and the group of experts was then considerable shorter. The project organization found a common denominator in other technical issues, since all had an interest in these types of questions, but the common denominator was not as clear regarding work environment design.

7. Explicit and tacit knowledge regarding work environment design

The explicit knowledge, which is regarded as objective knowledge by many and as knowledge of rationality (Polanyi, 1958, Maula, 2000), consisted of laws and regulations, but also of new research results and recommendations. In this body of knowledge the European directives played an increasing role in the studied international collaboration project. Several of the other partners, most of them engineers referred to the machine directive when developing new production processes. It seemed as if the limits that the machine directive set were met, everything was alright. Often the engineers were aware that there were directives applicable to a specific situation, but they did not know what the directives really said. This was left for people at their own company to deal with. The explicit knowledge also showed itself in the models observed, used for developing new production processes.

The explicit knowledge also consisted of descriptions of the procedures used in the partners' own companies. The explicit knowledge also contained national regulations that the company had to deal with when it was time to implement the technologies developed in the project.

Tacit knowledge on the other hand can contain anything, but is used here to illuminate that all partners already when entering the project had a mindset of how to tackle work environment design. By definition tacit knowledge is regarded as subjective knowledge and as knowledge of experience (Polanyi, 1958, Maula, 2000). The tacit knowledge about work environment design seemed in most cases to stay in the head of the experienced participant. It should be noticed that tacit knowledge is sometimes what can be regarded as silenced knowledge i.e. knowledge that was not supported for sharing. Takeuchi and Nonaka (2000) state in their work that tacit knowledge is the number one asset in respect to innovation, but as it is not used in a knowledge spiral concerned with socialization as well as externalization, combination and internalization, it is not fully taken advantage of which was the case in the FORWARD-project. The tacit and explicit knowledge should not be seen as two definitive alternatives. The knowledge can be seen on a continuum between the two extremes.

To summarize, one can say the explicit knowledge had precedence over the tacit knowledge in the project. Both the explicit and the tacit knowledge about work environment are important, but when some knowledge was silenced in this specific project a definition of work environment was set that was close to the engineers' way of looking at the matter, but far from and more limited than our research group's definition. It must be stated that tacit knowledge is not more valuable, but only that the two must reinforce each other. For example there was a widespread need for knowledge of what to take into account when developing new production systems. It is not possible to always know, but it was apparent the total lack of knowledge of what effects could be expected when designing a system in a specific way.

8. How can knowledge about work environment design be shared?

Internalization (Takeuchi and Nonaka, 2000) is no easy task, but one suggestion might be that the directives are made more easily accessible for the persons involved in the project. A few of the most important directives should be specially acknowledged in the design phase of the project. When the explicit knowledge is made accessible, the transformation can be done by discussing issues with each other with the same point of departure and mind set. This process is according to Takeuchi and Nonaka closely related to learning by doing since it is about getting the same form of shared mental models or technical know-how. This is also supported by Trompenaars (1994) and Hofstede (1982, 1997, 2001) who state the importance of a similar mind set for project partners to fully communicate with each other. Internalization is also about spreading the knowledge to other organizations and thereby a form of field building.

Externalization (Takeuchi and Nonaka, 2000) is also of importance. The rules of thumb were different between individuals and one person with one mindset was not always aware of others. People agreed that the explicit knowledge was available to all, but not that the tacit knowledge can be used in a project like the FORWARD-project. One way to achieve it is to raise different questions along the way that starts a thinking process and make people aware of the resources. In the beginning of the project, the group has to assess what the resources are and this has to be done throughout the project as it changes phases from idea and design to industrialization. It is important to remember that according to Takeuchi and Nonaka it is within the externalization phase the key to knowledge creation can be found since it creates new explicit concepts from tacit knowledge.

Socialization by (Takeuchi and Nonaka, 2000) stipulates the process of sharing experience and that knowledge which each individual brings into the project, even though they sometimes contradict each

other. Through social interaction with each other as in project meetings, informal meetings etc., the knowledge about work environment design was shared throughout the team members. The language problem, needs to be acknowledged in this process. It is hard to put words to and describe the frame of ones tacit knowledge, but it becomes even harder when it has to be done in a different language than your native one. This is a problem that has to be dealt with, with a lot of respect even though it is possible to acquire tacit knowledge directly from others without using language with e.g. observation, imitation, and practice. In the FORWARD-project the limited number of meetings implied that these alternatives were decreased and thereby the importance of having a similar mind set in order to communicate with each other is increased (Trompenaars, 1994).

Combination (Takeuchi and Nonaka, 2000) is for example when legislations and directives are regarded as important for the technologies developed, it is a problem to make this knowledge available for the team members. The knowledge should be up to date and not all information out there needs to be presented, since it would imply a flood of information that would conceal those aspects that are of extra importance. This explicit knowledge may also have its origin in the companies' organizations i.e. outside the project team. Since for example one of the companies studied has a way of handling work environment design in their own company. This has to be noticed and this explicit knowledge has to be made public to the project members.

9. What are the problems with sharing knowledge about work environment design?

When partners work in a collaborative project like the one described in this paper, they also compete with each other at the same time. The two manufacturing companies in this study were both trying to attract the same customers. This means that a form of confidentiality is needed between the partners, or at least desired by them. This confidentiality mainly regards technical aspects of production, but when trying to merge the work environment design and the technical factors into the same process it becomes problematic. Both companies are reluctant to reveal for the other partners how they take care of these factors.

A problem was that the project organization lacks the organizational conditions; intention, fluctuation/chaos, autonomy, redundancy, and requisite variety that enable the four modes, socialization, externalization, internalization, and combination to be transformed into a knowledge spiral (Takeuchi and Nonaka, 2000). Especially when dealing with international collaboration projects it can be hard to achieve the knowledge spiral since the project organization can be seen as a temporary structure. What will happen to the knowledge created about work environment design when the project is over? Who will be responsible for the internalization of the knowledge into tacit knowledge for other projects organizations dealing with similar issues? These are just some of the questions which need to be answered in the future.

For other projects, without this strong focus on work environment design, partners need help for taking care of these factors in a systematic way. The body of knowledge of work environment design and how to deal with it has to be spread both between projects and organizations as well as inside projects where several organizations collaborate. The knowledge has to be taken up to the surface where it either can be regarded or disregarded, but at least consciously. The project organization present in the FORWARD-project did not know what knowledge it possessed about work environment and the question is if project members did their best to find out? It is important here to find incentives for project organizations to share experiences from other project organizations, which already have used a systematic way of sharing knowledge about work environment design.

Even though a systematic approach may show that a lot of knowledge about work environment design is already available in the project, one must have the presence of mind to understand that in some fields external experts have to be involved at an early stage of the project. Even though they are not members of the project team as the other partners, these experts can support and give an insight of what present research states regarding work environment design and thereby improve the sharing of knowledge and avoid 'bad' knowledge regarding work environment design, i.e. delusions about what creates a 'good' work environment. Though, all partners have a collective responsibility for both the outcome of the projects as well as for the work environment at the shop floor of their own company. Even though an expert is hired it does not imply that other partners can drop their focus on these matters. Instead they can improve their own awareness of what to do in order to achieve a 'good' work environment. The expert help should be seen as assistance, but not substitution.

Some researchers would state that the problems of having tacit and explicit knowledge in a project organization can easily be solved by the correct technical means. Some researchers state distributed concurrent engineering may be one solution to the problems of dealing with tacit knowledge (Larsson, 2005). By using video conferences and chat systems people share their thoughts with each other, although they do not work from the same geographic position.

Another example is to see visualization as an example of turning explicit knowledge into tacit knowledge as well. That can be a good idea when it comes to work environment design when for example ergonomic situations can be visualized by using ergonomic simulation tools, as for example the software Jack, as we did in the project.

In order to achieve a common mindset which is a prerequisite for sharing and creating knowledge across heterogeneous organizational and social communities, it is necessary to invest in the interpersonal interrelationship building (Swan et al., 1999). This would imply those involved can make sense of and envisage the broader goals of the system which they are designing and developing. It is up to the project team to retrieve the knowledge needed and realise this as early as possible. Certainly there are trains of thought which state that as long as the partners get to know each other and get the technological means to cooperate then the knowledge will spread faster than any plague in the world, but that is not completely true since someone has to be the carrier.

10. Conclusions

In this paper the theory about knowledge in general and about sharing it have been applied on an EU-project involved in the aero structure industry and the work environment design within the project. The paper illuminates a field that has not been sufficiently covered before. An action research approach was used since we also participated in the project we derived our data from. First of all it is stated a platform for sharing knowledge about work environment design was present. The problems detected are for example the differences in mindset, experience, and different levels of knowledge and these are described and discussed. The research presented in this paper has shown the project participants can be divided into the roles of *project core participants*, a*dministrators/economists* and *experts*, all with different characteristics when it comes to knowledge about work environment design. The three roles possess different knowledge and this knowledge can be divided into tacit and explicit forms. One can not say that the knowledge present is absolute, but in order to know what you lack you have to know what you have. Since knowledge is created in interaction between people the knowledge about work environment design will evolve each time it is used in similar projects. Neither knowledge transfer nor creation is successful if the knowledge can not be transformed between tacit and explicit forms. Since different individuals in the FORWARD-project all possessed different bodies of knowledge about work environment this knowledge has to be shared and made available for those who lack it. Our study illuminates how important it is to

take advantage of the knowledge in the project and we saw that this was not done in the project studied. However the knowledge and mindsets are not necessarily positive toward the work environment design. Some mindsets can instead hinder further steps towards a 'good' work environment. Questions need to be raised in order to achieve something near a common mindset which is one of the prerequisites for true communication.

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