DEFICIENCIES IN THE INTEGRATION OF ERGONOMICS KNOWLEDGE INTO CONSUMER ELECTRONICS DESIGN

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

OF

MIDDLE EAST TECHNICAL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
INDUSTRIAL DESIGN

DECEMBER 2004

Approval of the Graduate School of Natural and Applied Sciences

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Sultan Kaygýn

ABSTRACT

DEFICIENCIES IN THE INTEGRATION OF
ERGONOMICS KNOWLEDGE INTO CONSUMER
ELECTRONICS DESIGN

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December 2004, 102 pages

Design needs to collaborate with many other disciplines to achieve success. Ergonomics is one of these disciplines that design needs its collaboration. A designed object should be in good relation with the human body and cognitive system to be effectively used by its potential users.

Changes in the competitive market have forced firms to enhance product differentiation for achieving market success. Design is widely used as one of the differentiation tools. As a component of design, ergonomics should also be integrated into the design process to fulfill the user requirements. There are success stories of companies integrating ergonomics into their design process and achieving

differentiation and success on their products through the results of this integration. Even their marketing strategies are based on this integration.

It is observed that there are some missing points in the integration of ergonomics into consumer electronics design which make results in poor interaction with the end users. The background of this problem is investigated by reviewing design processes of four different firms and integration of ergonomics into these processes. The information on the cases is collected by literal information for the former three companies and information based on the participant observation results and company reports for the last company.

Keywords: integration of ergonomics, consumer electronics design, industrial design, design process

ÖZ

ERGONOMİNİN TÜKETİCİ ELEKTRONİĞİ TASARIMINA ENTEGRASYONUNDAKİ SORUNLAR

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Aralık 2004, 102 sayfa

Tasarım, başarıya ulaşmak için diğer birçok disiplinle işbirliğine ihtiyaç duyar. Ergonomi, tasarımın işbirliğine ihtiyaç duyduğu bu disiplinlerden biridir. Tasarlanmış bir obje, potansiyel kullanıcıları tarafından verimli ve efektif bir şekilde kullanılabilmesi için insan vücuduyla ve zihinsel yapısıyla uyumlu bir yapıda olmalıdır.

Rekabetçi pazar koşullarındaki değişiklikler, firmaların pazarda başarılı olabilmeleri için ürün farklılığı yaratmaya zorlamaktadır. Tasarım, bu farklılığı yaratmada yaygın bir araç olarak kullanılmaktadır. Tasarımın bir parçası olarak ergonomi de tasarım sürecine entegre edilmelidir. Ergonomiyi tasarım süreçlerine başarıyla entegre etmiş ve bunun sonucunda farklılık ve başarı elde etmiş firmalarla ilgili başarı

hikayeleri bulunmaktadýr. Bu firmalar içerisinde pazarlama stratejisini bu entegrasyon üzerine kuranlar da vardýr.

Ergonominin tüketici elektroniði tasarýmýna entegrasyonunda sonuç ürünün kullanýcýyla zayýf etkileþim yaþamasýna neden olan bir takým eksiklikler olduðu gözlemlenmiþtir. Bu sorunun temelleri, dört firmanýn tasarým süreçleri ve ergonominin bu süreçlere entegrasyonu ele alýnarak incelenmiþtir. Firmalar hakkýndaki bilgi, ilk üç firma için literatüre, son firma için katýlýmcý gözlem yöntemine ve firma raporlarýna dayalýolarak elde edilmiþtir.

Anahtar Kelimeler: ergonominin entegrasyonu, tüketici elektroniði tasarýmý, endüstriyel tasarým, tasarým süreci

To My Parents…

ACKNOWLEDGEMENTS

I would like to express my thanks to Assoc. Prof. Dr. Çiğdem Erbuğ for her guidance, encouragement and great patience throughout this study. Although being far away from Ankara she always continued her great support.

I also would like to present my deepest appreciation to Sencer Dere for his encouragements, positive contributions to the research, endless support and patience that I would never forget.

Consequently I would like to state my gratefulness to my family for their belief in my success as they always did.

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CHAPTER 1

INTRODUCTION

1.1 Problem Definition

Ergonomics is one of the disciplines that design utilizes its information input. One of the primary aims of designer is to make the objects in good relation with the human body and cognitive system. Accordingly, design has to collaborate with ergonomics to fulfill this aim. There is a huge amount of information in the literature covering the fundamentals of the discipline. However it does not mean that these information sources cover the need of designer.

Industrial companies mostly have an understanding based on the increase of production in a shorter period of time, with lower cost and higher quality. They make their investments to overtake the optimum point of this view. Ergonomics research, which could lead the firm to achieve this aim, requires an investment at the starting period arising from use of tools, models and experts. However, this investment proves its benefits at the end as it is seen in the real life cases. Besides the firms using the term ergonomics as a pseudo adjective there also exist success stories of firms increasing their marketing share with real ergonomic researches they carried and the products based on these researches.

Consumer electronics is one of the industries that would need the information coming from ergonomics during the product cycle. Depending on the information based on the literature, the experiences gained in a consumer electronics company and the samples of competitor companies' products it is visible that the integration of ergonomics knowledge into consumer electronics design has problematic points.

1.2 The Scope of the Study

This study aims to explore the integration of ergonomics into consumer electronics design and to reveal the lacking and problematic points in this integration. To achieve this, a literature survey is carried about design and required ergonomics knowledge for design as represented in Chapter 2. This literature survey aims to lead the former research on the cases assessed. Following this literature survey, ergonomic studies of four manufacturers in different industries are investigated to be able to make comparisons. This investigation was based on the literal information on the design process of each company and the case studies on the products. Additionally a case study about the issue is carried out in a consumer electronics company with the observation method.

Observation as one of the data gathering methods is used in this research to obtain extensive information on the design process of the Company X. As Marcus and Ducklin (1998) state this observation can be either direct which is also called overt or indirect which is called covert. With the participation of the observer to the work group, indirect observation takes the name participant observation. Participant observation besides its advantages of avoiding the influential effects of being observed brings out the criticism of ethical

concerns. The group members being unaware of being observed behave in a more naturalistic pattern and the information required can be gathered realistically. However the information on them is collected and recorded without their permission. To remove the ethical concerns during the representation of the data, the names of the group members and companies can be hidden. Accordingly the consumer electronics company that the observation is carried will be named as company X. The author participated in the design projects being an industrial designer as a member of the design group. Since she has been working in the group for a year of time period the presence of her did not influence the behavior of the other group members.

The research on company X is also dependant on the company reports prepared by industrial designers of the design group (focus group study report, 2004a) and consultant company Millward Brown (focus group study report, 2004b).

1.3 Structure of The Thesis

The structure of the study is formed by following the main questions gathered. These questions are presented below:

- **How is ergonomics supposed to contribute consumer electronics design?** The answer of this question lies under the literature supporting this study and the cases assessed.

- **How manufacturers decide some products are better than the others?** This is the starting point because how much they take ergonomics into consideration or how they use ergonomics knowledge in their design process is a question mark. These

issues will be investigated by reviewing the cases of four different firms:

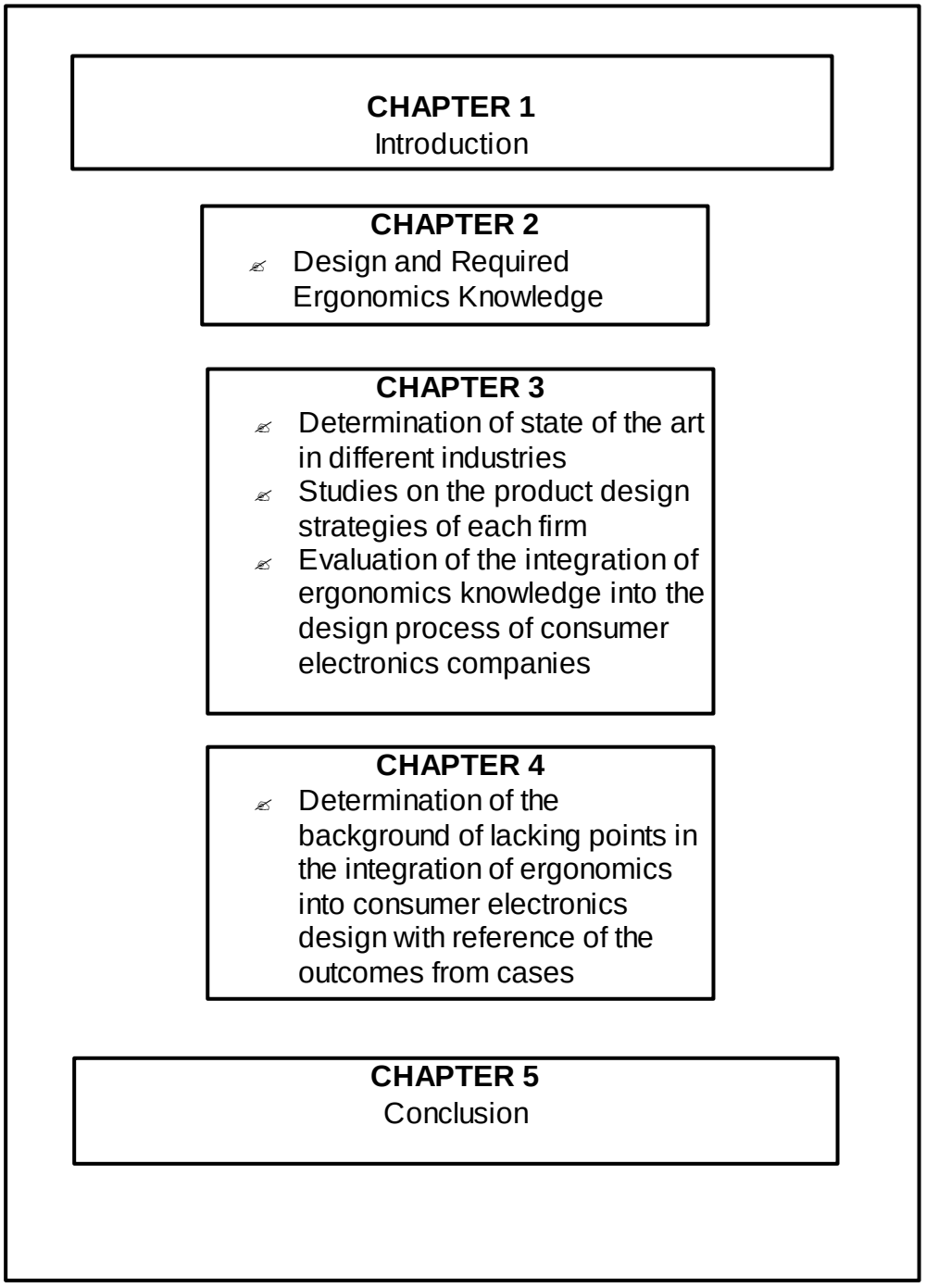
- Hand tools production company
- Automotive company
- Consumer products company
- Consumer Electronics company

Different structures of the companies from different fields and the effects of this diversity will be pointed out.

? **Does ergonomics contribute to a firm's success?** Their strategies on increasing market shares and the role of ergonomics studies carried while designing products based on these strategies will be investigated.

With the reference of these main questions, the structure of the thesis can be represented in a diagrammatic form. (see table 1.1)

Table 1.1 Structure of the thesis



CHAPTER 2

2.1 Design and Required Ergonomics Knowledge

Design needs to collaborate with different disciplines to gather a successful outcome with its functionality, aesthetic appeal and also manufacturing concerns. To prove this success, engineering and social sciences should incorporate their related knowledge for each task (Porter and Porter, 1999). Ergonomics is one of these disciplines that design needs its integration. The lack of this integration leads to mismatch of human, product, task and environment as ergonomics deals with optimization of the effects of the relation in between these four. As Porter et al. (1992) states at best a user/product mismatch may cause only inconvenience or discomfort however in the worst situation it may cause injuries or even deaths (Porter and Porter, 1999).

Baber and Mirza (1998) describe the integration of ergonomics into design process briefly in fourfold:

> ? " Description of potential risk, e.g. using scenario analysis, fault tree analysis, hazard analysis
> ? Descriptions of physical characteristics of user, e.g. using anthropometric / biomechanic analysis
> ? Descriptions of the product, e.g. using checklists or expert appraisals
> ? Descriptions of the use of product e.g. observing people using the product." (p.98)

The integration of ergonomics into design appears in such different forms within each level of the design process. This integration within each level of design is analyzed with the reference of some case studies (Sagot et al., 2003, Porter et al., 1999, Almeida et al., 2000, Hsiao, 2000) and theoretical information (Stanton et al., 1998; Reeder, 2002; Martel, 1998; Kreifeldt, 2000; Sagot et al., 2003; Norris and Wilson, 1999) found in the literature. The diagram prepared by Sagot et al. (2003) describing the integration of ergonomics into design process will be used as a main reference point to have a detailed view about the issue. They define the product development process by putting industrial design to the center and filling the path between ergonomics and design. In this diagram industrial design is used as a core element to describe the integration of ergonomics knowledge in each stage.

Product design is a problem solving activity that aims to develop products fitting consumer's needs. To fulfill this aim systematic methods are used by designers throughout the design process (Hsiao, 2000). Design process is analyzed by many researchers in the literature (Cross, 1984; Jones, 1970; Bayazit, 1994; Roozenburg, 1995; Gregory, 1966). It is commonly defined with a step by step structure. The steps to be followed are mostly resembled with connection diagrams (Gedenryd, 1998).

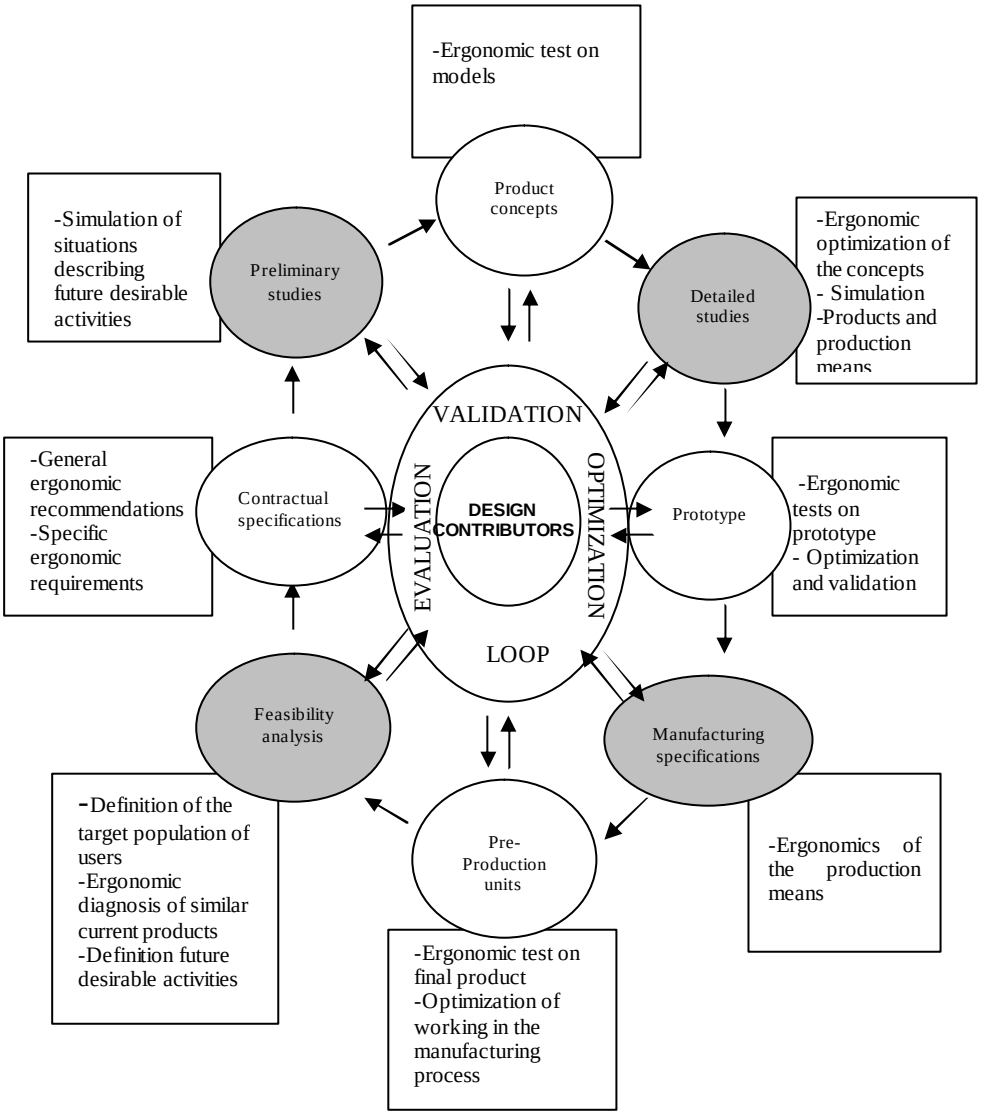


Figure 2.1 Diagram representing the integration of ergonomics into design process (Sagot et al., 2003)

Each step is consisted of defined works to carry, which also has an order to be followed. Coyne et al. (1990) define it with three main stages: *analysis, synthesis and evaluation* whereas Jones (1970) divides it into *divergence*, *transformation* and *convergence* stages. There are many other structure definitions in the literature with different terms associated with each step however; they are mostly similar in their inner structure. Sagot et al. (2003) define the design process in a different manner, which they call 'concurrent engineering based' with its focus on traditional design steps and the relation of coming information from ergonomics in each step. The success of ergonomics lies on the proper integration of the needs and requirements of users to the future product as early as possible. So the integration of ergonomics starts within its first stage.

2.1.1 Research

Some researchers (e.g. Reeder, 2002) call this stage as research and definition or feasibility (e.g. Sagot et al., 2003) and a huge amount of information is compiled about the subject area in this stage. To be able to solve a problem it must be well defined. As the starting point of the design process, proper description of the need, which will also lead to a problem definition, has a great value. A well-defined statement prepares a good path towards the following stages of the design process (Reeder, 2002).

The ergonomics approach to be carried during this starting phase is defined by Sagot et al. (2003) in two forms:

- definition of the target population of the users
- ergonomic diagnosis of similar existing products

This integration is represented in Figure 2.2.a and Figure 2.2.b in detail. Initial integration of ergonomics starts with determining the user population of the design subject. This user population may be investigated in terms of its sociocultural and biometric data (Sagot et al., 2003). Sociocultural data reflects training, lifestyles, cultural models, etc. whereas biometric data covers the information regarding health conditions, psychological conditions and anthropometry.

These information about the potential user of the subject to be designed lead the designer to be aware of the capabilities and limitations of the human body such as physical capability, muscular strength, corporal dimensions, sight, hearing, potential means of receiving information, etc.. The awareness gained in this direction helps the designer to define the framework of the task to be carried by the user while using the subject.

Kahmann (2000) describes this stage as an analysis phase with the purpose of defining the critical users, the critical interactions and the critical circumstances. He claims that " combining critical users and interactions brings us to 'profiles of use'".

As Almeida et al. (2000) state the initial stage of a product development process is strongly influenced by the market/customer relation. In accordance, Feeney et al. (2000) emphasize that the user data collected even at the early stages (analysis of user needs) or at the final prototype testing stages can prove a reliable data source also for marketing purposes. They state that this can reduce the marketing costs and diminish the reliance on standard marketing images, which do not reflect the real product value for the purchaser.

Usually it is not the case, designing completely a new product. Most of the time the object to be designed has similar samples previously produced at that moment in the market. Analyzing the previous experiences on the previously designed versions with human factors point of view is another method of obtaining information, which is recommended by Sagot et al. (2003) and Martel (1998) could be helpful for the designer in this initial research phase.

Analysis of competitor products is also of immense value for gathering initial information on the product (Martel, 1998). The human factors data obtained from the existing products may give two directions; one describing the right integration of ergonomics knowledge to the product, leading the designer benefit from this data; the other assisting in revealing the problems that occur in the communication of product, user and environment, by preventing the designer from doing similar mistakes while integrating ergonomics knowledge into the design. The data required for receiving this information can be gathered with some methods like observation, questionnaires, interviews and task analysis. (Sagot et al., 2003).

These are methods which rely their outcome on subjective evaluations. Martel (1998) depending on his experience at Whirlpool additionally suggests building guidelines reflecting the analysis on previous products both internal and external which has much more objective outcomes.

In this initial stage of the design process the definition of the target population of the user may be obtained by reviewing the potential users of existing products if the new product will also be used by them, however if the user group is defined different than the existing

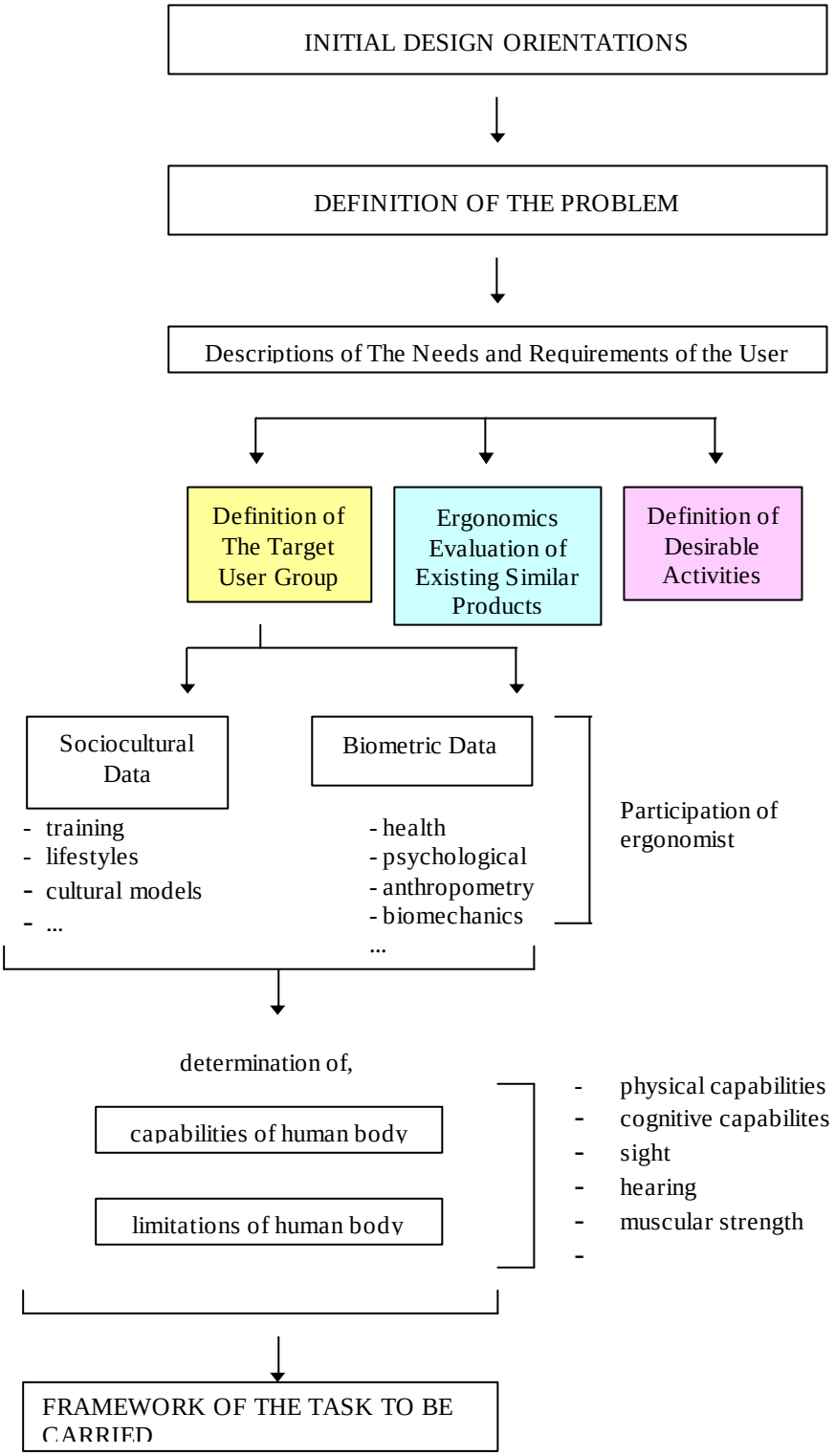


Figure 2.2.a Diagram representing the ergonomics integration in research phase of design process

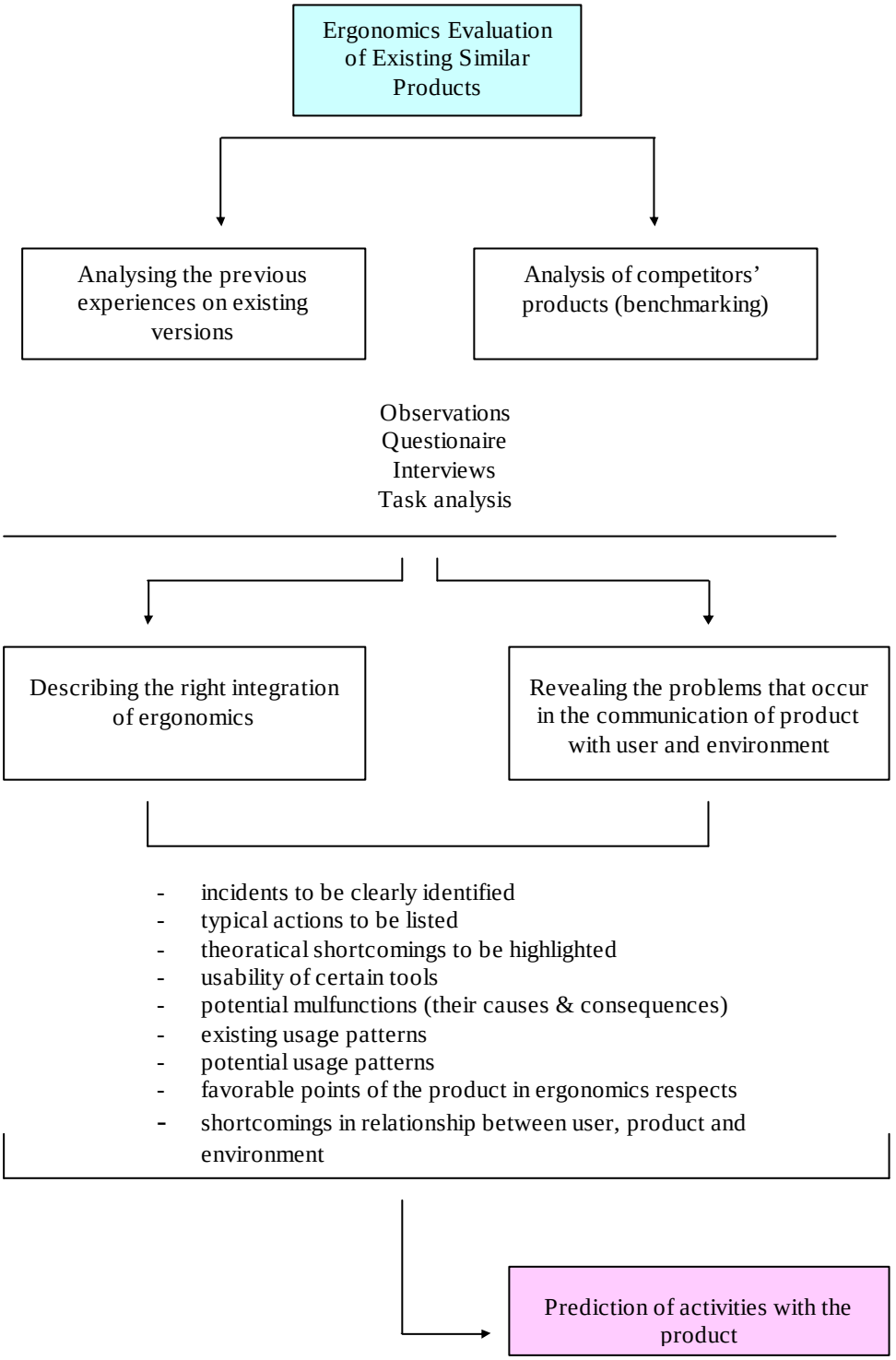


Figure 2.2b Diagram representing the ergonomics integration in research phase of design process

user population the need of an expert may emerge. This expert should be an ergonomist who will make the necessary predictions about the user group by using the existing databases. If the product is being designed for a future user group as it is in Sagot et al. (2003) case (designing an international driving cabin for European population for the years 2000-2030) again ergonomists may take place for making necessary adaptations from the existing information in databases about the intended population.

2.1.2 Concept Generation

Concept generation stage covers the creation of product ideas depending on the information and limitations of the previous study, research. As Reeder (2002) states, the goal of concept generation is to produce new ideas by looking at different ways for solving a problem. By generating a big quantity of ideas the probability of catching the right one increases. In addition, every new idea has a stimulating effect for the next ideas.

After producing as many ideas as possible, each one can be analyzed according to the previously produced criteria, problem definition and also ergonomics principles. These principles can depend on the anthropometric and biomechanical information gathered in the previous stage about the intended user population. For this analysis, additional to the hand sketches, renderings or computer-aided drawings, preparing mock-ups of each concept may be helpful. Preparing mock-ups gives the opportunity of making user tests for taking their initial ideas, expectations and recommendations on the concepts. As Martel (1998) states besides being a user test material, mockups can also be used for the cross-functional

discussions. The fidelity of the mockup depends on the range of the product to be designed and time-cost limitations. However in this phase of the design process preparing as many mock-ups as possible with not a detailed finish may be the best choice within all the limitations since the aim of building it is taking a general view about the idea.

The analysis carried in this stage can be in the form of a focus group study with users required to state their preferences on each concept idea (Martel, 1998). With the light of the results of the analysis, one of the concepts is chosen to make following studies on.

2.1.3 Concept Refinement

After the elimination of the preliminary ideas and choosing the one which best fits the outcomes of research studies (the specifications of the intended user group and future product usage activities) the detailed studies on the final idea takes place. The evaluation of the best idea goes with working on the details (some mechanical or electrical), final dimensions by considering the embedded components and other constraints, materials to be used with the suitable production methods, cost analysis and also ergonomic considerations. While judging the convenience of the concept according to these criteria the need for the support of the related professions may be required.

For the evaluation of product according to the ergonomic criteria, building a prototype of it or specific parts of it can be helpful. This prototype differing from the initial concept mock-ups should be a detailed model with its material, color, surface finish, dimensions, and

structural specifications close to reality. Ergonomic tests can be carried again with the potential users, this time on the final, detailed prototype. These tests aim to assess the product and validate the specifications gathered in the previous stages. Pheasant (1996) mentions the importance of task analysis carried with the users as below:

> " A task analysis is really a formal or semi-formal attempt to define and state what the user/operator is actually going to do with the product/system/environment in question. This is stated in terms of the desired ends of the task, the physical operation the user will perform, the information-processing requirements it entails, the environmental constrains that might pertain and so on. An effective task analysis will clarify the overall goals of the project, establish the criteria that need to be met, point out the most likely areas of mismatch, and so on."

Prototypes play an additional role of making progress on a project when the challenges seem insurmountable (Kelley, 2001). And another outcome of building a good prototype is stated with the persuasive power of it. Tom Kelley (2001) general manager of IDEO explains the issue:

> " It' s easy to reject a dry report or a flat drawing. But models often surprise, making it easier to change your mind and accept new ideas—or make hard choices, such as forgoing costly and complex features. Years of experience have taught us that prototyping is also part performance. If the act isn't well orchestrated and substantial, the audience gets antsy. And executives, understandably, already have enough on their minds. Give your management team a report, and it's likely they won't be able to make a crisp decision.
>
> But a prototype is almost like a spokesperson for a particular point of view, crystallizing the group's feedback, and keeping things moving. We believe in that great old saying: **A picture is worth a thousand words**. Only, at IDEO, we' ve found that a good prototype is worth a thousand pictures. Somehow, you up the data rate." (p.39)

However realistic simulated environments and detailed prototypes representing the product ideas can not be an alternative to the experience with the real product in the real conditions. Still new problems may occur and additional needs of the user may arise.

At the end of this phase, ergonomics and industrial design evaluations come to an increasingly finalized end.

2.1.4 Finalization

In the last phase, the new concept is prepared to be ready for fulfilling the intended need, which was the starting point of the design. Sagot (2003) named this phase as industrialization which covers the production issues of the product however some researchers (e.g. Reeder, 2002) name it as finalization stage which also includes preparing the communication means and methods for the product with the customer or the marketing people. These methods can be 2D or 3D presentation mediums. 2D mediums include sketches, drawings, illustrations and 3D mediums can be 3D computer models, simulations, mock-ups or prototypes. Finalization phase has an immense value since the idea is conveyed to the people who will judge it.

In this phase ergonomics evaluations of the product ends and a new ergonomics approach starts which will cover the safety, health, comfort and efficiency issues in the production and workers who take place in this production process. However, this part of the ongoing study of ergonomics is out of the scope of this study and it won't be dwelled upon.

To summarize, from the ergonomics point of view industrial design process starts with research which, covers the definition of intended user group, ergonomic exploration of existing similar products and prediction of the using activities on the new product. The second phase, concept generation, covers the user tests on the simulations and/or mock-ups of concepts which leads the elimination of them according to the results of these user tests and analysis and choosing the best matching one. Third phase, concept refinement, covers the evaluation of the final idea mostly depending on its prototype. Again, user trials can be carried with the prototype of the final idea.

As it most of the time occurs, ergonomics methods and tools should not only be used for corrective purposes at the end of the design process. At that stage there appears many limitations to the intended changes. Porter and Porter (1999) depending on the experience of designing a car concept at Coventry School of Art and Design support the idea that if the integration of ergonomic information occurs at the appropriate time in the design process it can be assessed at engineering level with aesthetic appeal.

To make the necessary ergonomic assessment efficiently it must start as early as possible. As Olsson (2000) states to carry the necessary assessments from the beginning of the process is crucial for catching both cost and time advantages. So he claims that companies should project their focus on the early project phases where most of the critical decisions are taken. The need for early integration of ergonomics is emphasized by many authors in the literature:

> "The increased rate of technological development of recent decades has created the need to consider human factors early in the design phase, and in a systematic manner (Young Suk Lee, 2000).
>
> To do the right thing from the beginning is crucial for both time and cost, which is a reason for companies to intensify their focus on early project phases where many cost critical decisions are taken (Olsson, and Klingstam, 2000).

For realization of the above activities, ergonomists play a significant role. Sagot et al. (2003) describes the integration of ergonomist into design process in two different manners:

> - " Ergonomist takes place in the design process as an advisor to the designer's activities. This work of ergonomist mostly depends on cognitive and social ergonomics. He defines the user group, its expectations and needs.
> - Ergonomist takes an active role in the design process by helping the designer for assessing the alternative ideas in terms of safety, health, comfort and efficiency."

Porter and Porter (1999) point out the weight of inclusion of ergonomist into design process by reasoning the success of the car design project carried at Coventry School of Art and Design to the inclusion of the ergonomist into the project team and providing the required ergonomics information in the right form at the right time.

In a parallel point of view, Martel (1998) believes that "the most innovative synergy between design and ergonomics is achieved with a close working relationship between the designer and ergonomist throughout the product development process".
However, ergonomists often do not participate in most of the manufacturing firms because of its cost and instead designers have

to carry the human factors issues in reality (Porter and Porter, 1999). Even if there is collaboration with ergonomists, to be able to make an effective one, designer initially should have awareness about ergonomics and its integration into design process. This awareness can be obtained during the design education with a basic ergonomics course. Haslegrave and Holmes (1994) point out the communication problem between ergonomists, engineers and designers and they offer the education of all these professionals to understand each other's methods.

As a second issue, to carry the necessary ergonomics assessments on the new product idea designer should have a basic ergonomics knowledge covering both physical and cognitive issues. The tremendous amount of ergonomics information utilized by designers covers mostly the physical ergonomics (anthropometry, biomechanics, strength-force requirements, etc.) however the information processing activities which is covered by cognitive ergonomics is also an important factor during product design.

The decisions of both the designer and ergonomist on the ergonomic assessment of products depends on different forms of information coming from ergonomic standards (e.g. McCormick and Sanders, 1992) which are composed of recommendations and rules about the capabilities and limitations of human body; ergonomic tests on existing products to find out the problematic points in its relation with the user and on the models of new product idea to make the necessary ergonomic assessments. Sagot et al. (2003) calls them co-operation and design assistance tools. As Stanton et al. (1998) states that there are many methods and tools that represent the ergonomics information. These will be discussed in later chapters.

CHAPTER 3

CASE STUDIES

3.1 First Group of Cases

The methods of integrating ergonomics knowledge into industrial design process is revealed briefly above. Now four companies will be presented to illustrate the route they draw from theory to reality while integrating ergonomics into their design process. This exploration will also lead us to make comparison of the strategy that brings the success to these companies and the strategy that consumer electronics companies constitute.

The first two companies (Bahco and Volvo) are chosen from success stories describing how the firms could raise market share through integrating ergonomics knowledge into product design process. The third and fourth companies (Whirlpool and Company X) are chosen among consumer electronics and appliance manufacturing companies to see how they carry out their design process and how they integrate ergonomics into their design process. The assessment of Bahco, Volvo and Whirlpool cases are based on literal research (Bahco Group AB, 2004; Berkman, 2002; Design Management Institute, 1990; Erbuð, 1996; Svengren, 1994; Mead, 2000; Memmer, S., 2004; Sweden Automotive Transducers, 2004; Volvocars, 2004a;

Volvocars, 2004b) and the assessment of Company X case is based on observational study and information coming from company reports (Focus Group Study Report, 2004a; Focus Group Study Report, 2004b).

3.1.1 BAHCO

One of the cases is built on the success story of Bahco Hand Tools Company. It is chosen from the cases displayed in the exhibition organized by Design Management Institute in 1989 and points out the success story of Bahco, competing in hand tools market which is famous for being resistant to change (Berkman, 2002, Design Management Institute, 1990). The research reflected below is based on the Design Management Institute's TRIAD Design Project (Design Management Institute, 1990) and information presented in their website (Bahco Group AB, 2004). Bahco was an old and at the same time strong Scandinavian hand tools manufacturer until 1970ies. Until that time the company was dominant in its field; hand tools. At 1970ies its competitors which were strong in the price-advantage but poor in quality started to manufacture high quality products with competitive prices. Particularly with the imported products from German manufacturers, quality began to rise with lower prices. Bahco managers estimating the marketing risk decided to take outsource support from a design firm with an intention of catching differentiation. With the integration of the design firm "Ergonomi Design Gruppen" Bahco focused on designing a better screwdriver handle than its competitors. With a focus on ergonomics side of the product, the design team with the integration of Ergonomi Design Gruppen designed a new screwdriver with a textured handle offering a two-handed use.

The design process of the project has followed a parallel way with the theoretical approach in the first chapter. The research has been generally followed on the basis of the information presented about the design process of the company in their website (Bahco Group AB, 2004) and case study analysis carried by Erbuð (1996), Svengren (1994), Berkman (2002) based on the company's strategy.

For the design strategy decisions of this product, product development department, production department and marketing department made a collaborative study. As a result of this collaboration they decided to increase their market share and carried a research on the existing versions of the product in the market. Realizing the problems in the handle of the product, they came to an agreement on making a redesign of it. For this approach, they collaborated with a design firm (EDG).

As it is stated in the first chapter, the research stage aims to determine the target user population and to analyze similar existing products in terms of ergonomics. The ergonomists in the EDG worked on the analysis of existing products, the usage patterns and anthropometric information to fulfill the needs of research phase. Then designers as the team members created new concepts based on the information coming from ergonomists as a result of their initial analysis. These concepts are tested by the ergonomists and one is chosen for surface texture studies. After the development of the final idea, it is transferred to the production department. With some redesign related to the production, material and cost issues, it was produced.

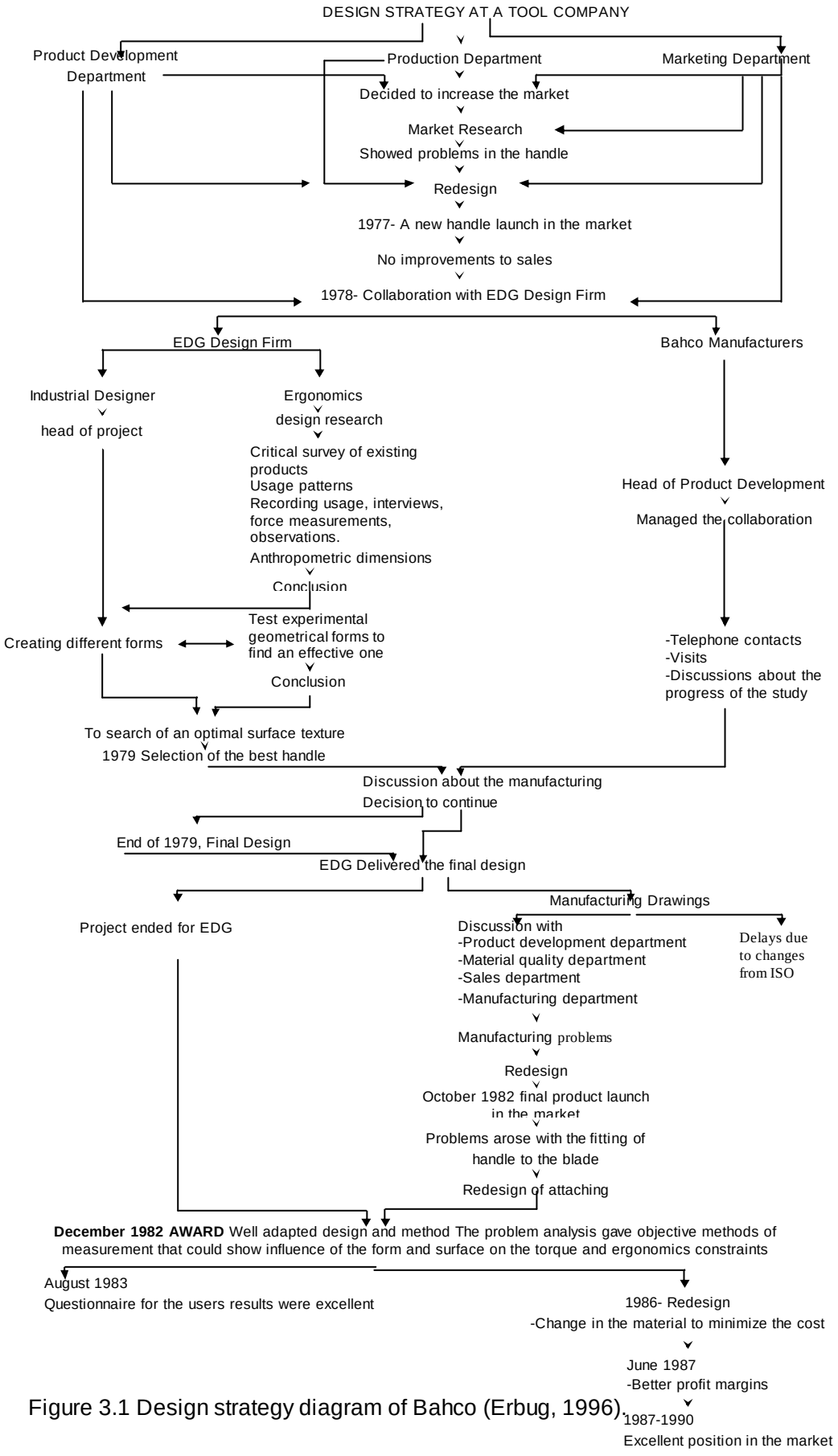


Figure 3.1 Design strategy diagram of Bahco (Erbug, 1996).

In 1982 Bahco introduced the Ergo Screwdriver and gained a design award, which happened by the help of integration of ergonomics into this project. This project ended with a great success that in 1980ies despite the great decline in hand tools market Bahco still increased its profit (Svengren, 1994). Every year Bahco continued designing a new ergonomics based product with the integration of Ergonomi Design Gruppen.

Until 1990ies with the strategy of using ergonomics as a differentiation tool, Bahco attained its peak point in the market share. At 1990ies a big economic crises spread all over the world. It influenced Sweden so severely that in three years time period, the manufacturing industry was cut in half.

In 1991 Bahco was bought by Sandvik AB, a Swedish multinational company which is good at different manufacturing technologies of metal. With this collaboration the product range of the company increased adding the product range of Bahco.

At the beginning, the managers of Bahco had some skepticism on this collaboration because Bahco developed an ergonomics approach with its products for ten years time period of experience and based its activities on relationships with professional users on the other side Sandvik had high quality of production but lack of ergonomics approach and sold its products mainly on dealers.

Bahco managers were worried that the necessary research about ergonomics was not going to be carried as seriously as before. Accordingly, products were not going to be sold as well. This would be the end of ergo products which was a ten years period of

timework. Another threat was the probability that Sandvik would let the sales companies to use the “ Ergo brand” for all the products without considering the existence of scientific studies carried on them.

Bahco managers kept on emphasizing the utmost importance of ergo-products and the managers of Sandvik seemed to listen to their suggestions about marketing strategy but in real, they did not take ergonomics as a basic consideration of the products. In July 1993, a symposium was arranged in Washington, National Ergonomics, Safety and Health in Construction. Sandvik Bahco was also invited to present its ergo-products in the symposium. This presentation resulted with the enthusiasm of Sandvik Managing Director from Canada and Sales Manager from America. They decided to introduce ergo-products to North America. They began with the adjustable wrench and seeing the success of it concluded with all the ergo-product range. Accordingly, the decision of producing a marketing policy depending on ergonomic research emerged which made Bahco Sandvik keep its success.

At 1999 Bahco Group is acquired by Snap-on Inc. that is one of the biggest tool companies in the world which aims to develop tools that make jobs easier, faster and safer for professionals as in a parallel view with Bahco. Following this collaboration, in 2002 Bahco Ergo program has received German "Reddot design award", the Dutch "Erkenningen Goed Industrieel Ontwerp" and "Japanese Good Design Award" (Bahco Group AB, 2004). Recently they define their success on products with the inquiry of quality depending on the inclusion of users, ergonomists, and designers into the design process methodologically as stated below:

> "Why does our saw look the way it does? How long did it take us to develop it? And how could we be absolutely sure that professional user would like it?
>
> The answer is simple: Quality tools are developed in collaboration with professional users, ergonomists and industrial designers, methodical and without rush." (Bahco Group AB, 2004)

Today they have a product range of hand-held tools such as handsaws, adjustable wrenches, combination spanners, socket spanners, screwdrivers, cutters, files, bandsaws blades, holesaws, hacksaw blades, secateurs and pruning tools It is presented in more than 40 countries. (Bahco Group AB, 2004). Starting from adjustable wrench they have reached a huge range of ergo products achieving a number of 400.

These all sign out the increasing quality of Bahco products depending on the extensive ergonomics studies as reflected in their website in detail.

3.1.2 VOLVO

The second success story of integrating ergonomics into design process is about Volvo. Volvo has a reputation of producing world's safest cars. Such that, safety has become its corporate value. Many international awards, reports and tests prove this idea (University Volvo, 2004). Today most of the car manufacturers are using the safety systems developed by Volvo as standard components. The elaborate researches carried in its safety units almost starting from the foundation of the company make this claim fair. Assar Gabrielsson**,** one of the founders of the company has a strong claim:

> " Cars are driven by the miracles we call people - therefore the guiding principle behind everything we do at Volvo is, and must remain, safety." (Volvocars, 2004a)

Gabrielsson and Larson (founders of the company) believed that safety should be the utmost important consideration for good design. This belief carried them to one of the largest car manufacturing companies today.

Before the foundation of Volvo, car manufacturers were following the way of taking separate components from their producers and assembling them. Since they were designed and produced separately, the resultant product was in poor quality. The philosophy of Volvo was different than the former producers: they believed that a quality car could only be built by designing its components with an in-house design group, producing the necessary parts and than assembling them in accordance with the initial design with experienced car makers. This issue is emphasized in the Volvo museum website (Volvo museum, 2004) with the claim that, " Gabrielsson and Larson coined the expression 'building cars the Volvo way'".

After a short warm up period to the market, Volvo started to focus on its major concern safety. The sales manual published in 1936 by the founders of Volvo for the company dealers in Sweden included the words of Gustaf Larson as below:

> "Since a car is made to carry and be driven by people, safety is - and must always be - the guiding principle of our design work. Except for collisions and the like, every single load-bearing part of a car must be designed to withstand every stress to which it may conceivably be

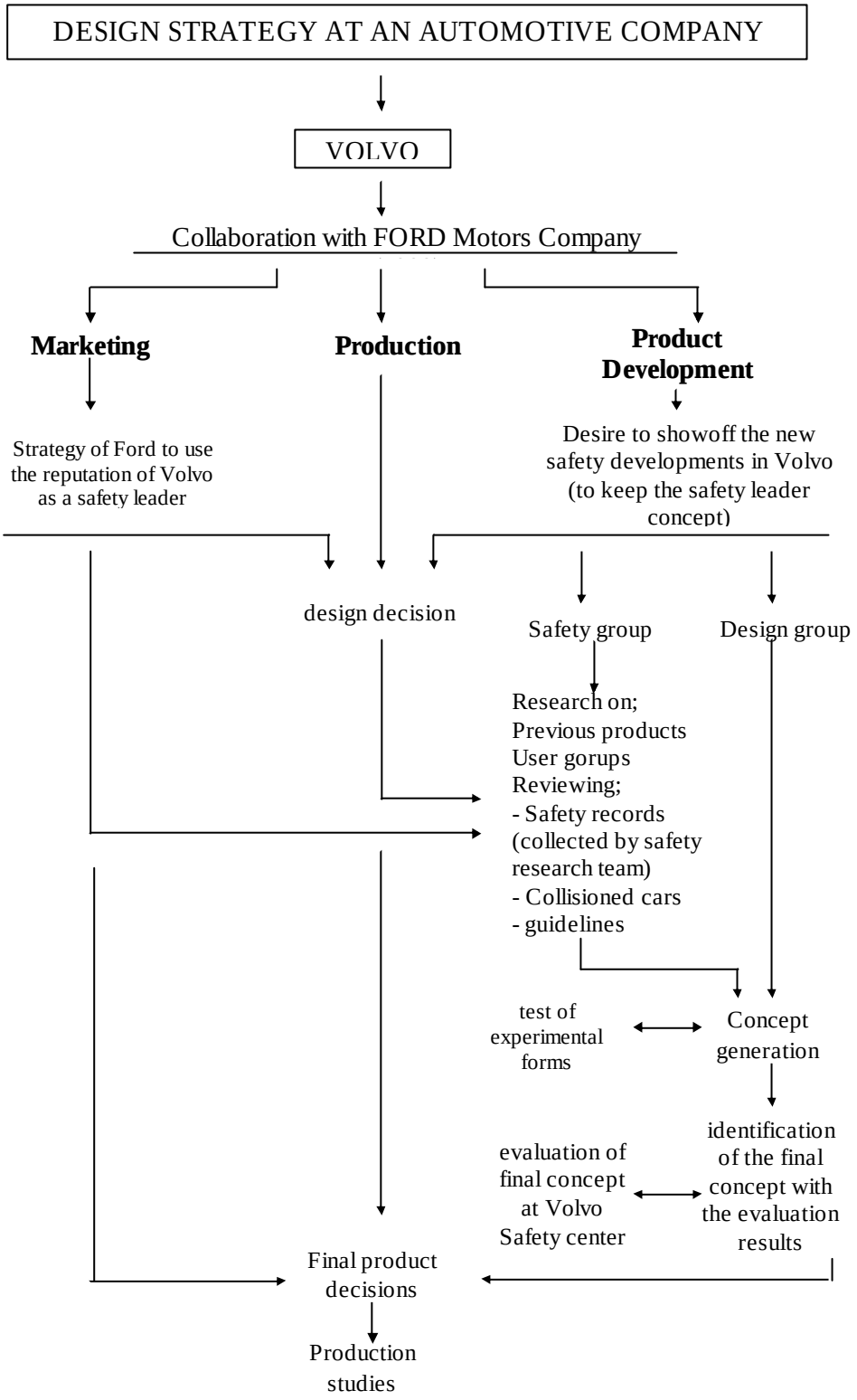


Figure 3.2 Design process of Volvo

> exposed, and every part which is vital to safety must be designed with a high factor of safety. In this respect, we must err on the side of caution. And caution must continue to be our watchword." (Volvocars, 2004b)

This saying signs out the importance given to the safety issue of the Volvo cars starting from the first decade of its foundation. To make the safety evaluations on Volvo cars, they have started collecting data based on real traffic accidents. In accordance, Volvo Accident Investigation Team was founded in 1970 for studying particularly the Volvo accidents. In their website, the foundation of Volvo Accident Investigation Team is explained as below:

> " Volvo realized that by knowing what happens to the car, and its occupants, in an accident can be invaluable to the product development of safer cars. So in 1970, the Traffic Accident Research Team was formed. The unit has been working continuously ever since." (Volvo Traffic Accident Research Team, 2004)

Volvo claims that the team has researched more than 20,000 individual accidents involving more than 42,000 occupants, resulting in significant improvements in automobile safety design. The data included police reports, damage claims, photographs, hospital records etc. They have also carried interviews with the witnesses and the people involved in the accidents. In addition to these, some severely crashed vehicles are transported to the safety laboratories for elaborate investigation. Patrik Settergren one of the test engineers at Volvo's safety center states that " We get requests from all over the world for help in investigating the causes and effects of real-life accidents involving Volvo cars" . (Sweden Automotive Transducers, 2004)

All the materials prepared are analyzed by the safety engineers of the safety group, they are prepared as statistical data (e.g. showing the

most recent type of damages) and all the results are presented to the designers for their use. As it is stated in the website explaining The Volvo Traffic Accident Research Team (Volvo Traffic Accident Research Team, 2004) analysis of the accidents provide the information covering the below issues and with this knowledge, Volvo Cars can determine valuable priorities in new car development.

- the complex mechanisms in different accident types
- how the safeguard systems in the cars function
- and, how the people sitting in the cars receive injuries

The study of accident research team aims to learn more about accidents and their consequences and to reveal the knowledge that can be applied in product development.

Besides collecting data for the improvement of safety issue in their cars, most of these became safety standards and are being used by other car manufacturers. Three point seat belt, safety cage, ABS brakes, airbags, head restraints and the side impact protection system are a few examples to the innovations that Volvo has signed with the light of the researches carried.

In addition to these innovations, Volvo has carried a deep research on child safety for many years. As a result of this research in 1972, they introduced rear-facing child seat that could be fitted easily in the front passenger seat. They continued their safety researches with Bertil Aldman, professor of safety at Chalmers University of Technology, Gothenburg. They appreciated his researches.

Today all these researches are fruiting. The term safety today is one of the basic issues that customers are looking for while buying a car. The

starting point of ergonomics aspects in automotive design was recognized by the car manufacturers with the advent of the term comfortable driving position in 1930ies. Today it is far beyond just comfort of the driver. Consumers are additionally focused on many other factors like safety.

Memmer (2004) in the website explains the state in a different way:

> " It's no secret that many consumers purchase cars as much for their sex appeal, styling and attractiveness as for their functionality. In response to this perceived "need," automotive designers go out of their way — sometimes too far out of their way — to come up with the latest look, to mold sheet metal into sex appeal.
>
> The truth is, we love attractive cars. We love the way they make us feel, the way they make us look, what they say about our own attractiveness. But there's a new maxim in the car business these days: "Safety sells." Believe it or not, safety has become sexy."

He explains the advent of safety with the change of population and people's habits. With the increase in the average age of population, the family understanding developed including the children and also in America, the time spent on the road is increased day by day. These resulted with an advent in the number of people seeking safety in their cars.

Again Norris (2000) supporting this idea states that:

> " Ergonomists have suggested that consumers are becoming increasingly intolerant of poor design, and look for indicators of good design (Bullock, 1994, Wilson and Whittington, 1982). If we assume safety to be a component of good design, this suggests that safety should now be a purchase criterion. This may be true of some markets such as the automotive industry, but perhaps not in market where perceived safety is not such an issue, such as domestic products." (Norris, B., 2000)

According to these advances, car manufacturers started to race for being safety leader and finding a way of improving their image. Memmer (2004) gives the Ford case as an example, which acquired Volvo. Ford being one of the largest car manufacturers in the world by combining its power with the safety reputation of Volvo in 1999 came to an advantageous position in the market.

In the year 2000, Volvo built its safety center with an investment of 80 million dollars. Such an investment is another sign that indicates the importance of safety issue in Volvo. Within the center many different collision tests are possible that are close to reality. By using separate parts of human body models it provides the evaluation of the damage, which occurs during a defined speed of collision. As a result of these tests, engineers and designers look for alternative materials and forms to diminish the effect of collision. This safety center not only provides the safety tests that were impossible or very hard to carry before but also brings the advantage of creating the test environment very precisely in a very short period of time and making the tests with only the related parts of the car and human model avoiding the remaining parts without any damage. This also brings the cost advantage for the tests when compared to the traditional methods. Computerized models are also preferred for faster development of new cars.

It seems that Volvo will always be remembered with its safety studies its successful reflections on its products.

3.1.3 Evaluation of the Bahco and Volvo Cases

After reviewing the integration of ergonomics into design strategies of two different companies from two different field of interest the similarities and differences in between can be listed as below:

Similarities:

- They have integrated ergonomics into their design process successfully
- They have started this integration at the early stages of the design process
- They carry all the research, evaluation and analysis studies defined in the previous chapter
- They have collaborated with ergonomists for their projects
- They have concurrent engineering based design process
- They have an iterative design process
- Ergonomics became a part of their marketing strategy
- They both collaborated with bigger parent companies and carried their reputation of developing ergonomic products to these bigger companies

Differences:

- Bahco started to use ergonomics with the pressure of marketing conditions and the need of catching differentiation among the other companies;
  whereas Volvo defined safety as a core element just from the beginning of its foundation and developed this core element within the years

- Bahco had to persuade the user for the benefits of ergo-products and carried some introductory studies;
  whereas Volvo used the advantage of being focused on safety that is an increasing value in user's mind.

3.1.3.1 Ergonomics and Marketing Strategy

It is seen that they both used ergonomics in a successful manner that even their marketing strategy is now mostly dependent on their ergonomic issues. Bahco names its products ***Ergo products*** and Volvo is known with its reputation for ***world's safest cars***. There is a difference in the growing strategy of the two companies that Bahco introduced its ergo products after the changing market conditions with a need for catching differentiation whereas Volvo started to focus on its safety concept just from the beginning with the starting philosophy developed by its founders Assar Gabrielsson and Gustaf Larson.

3.1.3.2 Evoking the User Awareness

Besides developing ergonomics based products with elaborate researches, Bahco additionally had to deal with the conservative ideas of the users, customers, and the producers. They were used to the hand tools designed about a hundred years ago and they did not believe in the benefits of new designs. To change the minds Bahco had to carry some additional introductory studies to gain the acceptance of users, customers and producers and as a result achieved the success. As Chikak et al. (2000) state although human factors plays an important role in people's daily lives, most of them are not aware of the human factors research, its impacts and its ultimate goal. So the benefits it brings should be made concrete for all the people.

This problem can be solved by building customer awareness. Imac is an example of the success that came with the advent of the awareness of the customer among the ease of use on computers.

> " Although that product's design is critical to its success, it is clear that design was used as just one component of an effective overall strategy. The emphasis of the strategy was simplicity. The message was not that the product was simplistic—it was rather that it would enable the user to do high-tech things in a simple way, without the feeling of the computer getting in the way. Apple builds customer awareness and makes easy for consumers to get the computers. They reinforce the message with packaging and graphics and provide a product that is easy to up and embodies good design. Finally, Apple backs that product with superior customer support. Incidentally, the opening of the new Apple retail stores is meant to further enhance the customer experience by taking more control of the retail experience (addressing location, staff quality, pricing, service, and availability issues)." (Cuffaro et al., 2002)

Another similar example stated by Cuffaro et al. (2002) is OXO hand Tools Company. They state that OXO's Good Grips line is an example of considering the total customer experience and evoking their awareness. Cuffaro et al. (2002) explain how OXO built the awareness of users:

> "The products look good, feel good, and are reasonably priced (considering their high perceived value). To build awareness, OXO didn't rely on a high-profile advertising campaign. Instead, they packaged the products so that the customer could feel the difference. The product line is widely available and very extensive. Also, OXO products are displayed as a group rather than as individual products among other products (that is, OXO peelers are never displayed side by side with Rubbermaid peelers). Visually, this sends a more appealing message and increases the likelihood that the customer will make his or her purchase decision based on comfort rather than price (or perhaps purchase multiple items)."

Volvo on the other side used the advantage of the advent of the term safety in car design which had a rapid spread in society. As Memmer states safety became the most important selection criteria while buying a car.

3.2 Second Group of Cases

Following the assessment of these two cases and other examples, a consumer appliance (Whirlpool) and a consumer electronics company (Company X) will be evaluated in terms of their design process and the integration of ergonomics into the design process.

Whirlpool has an in-house Ergonomics Group and carries the ergonomics studies with this group whereas Company X carries all the ergonomics related studies with the help of industrial design, mechanical design and marketing departments. Whirlpool makes its production with its own brands but Company X carries its production at a big ratio for OEM. The reflections of these variables on the integration of ergonomics into design process of consumer electronics products will be explored. The evaluation of the Whirlpool will be based on literature survey and the evaluation of Company X will be carried out depending on the observational study, and practical participation to the design process. The evaluation of these two companies will lead us to reveal the differences in the structure of ergonomics integration when compared with the two companies evaluated before (hand tools, automotive) which are successful in this integration into their design process. The similarities and differences in this integration and its underlying reasons will be explored. Also the integration of ergonomics in these two companies producing consumer electronics products will be compared.

3.2.1 Whirlpool

The third case is built on a consumer appliance manufacturer, Whirlpool. It is one of the world's leading consumer appliance manufacturers. It is an America originated company and entered the European market at 1992 by taking part in Philips White Goods business. After that it expanded to Asia, South America, and Eastern Europe. (Duarte and Snyder, 1997) The reason behind choosing this company as a case subject was both its being one of the leader consumer appliance producers, which also covers consumer electronics products, and also having an ergonomics evaluation center, Center for Applied Product Ergonomics, which is a part of Central Industrial Design Department. The existence of such a center in the company and the work carried at this center signs out the importance given to ergonomics evaluation of their products. The information about the company and its design strategy is obtained from Martel (1998) and corporate web page of the company (www.whirlpool.com). The following part of the case study will depend on information gathered from these sources.

The company, in the introductory period to the European Market produced only Philips products but now it produces its own brands Baucnecht and Ignis. Martel (1998) claims that " the most innovative synergy between design and ergonomics is achieved through a close relationship between the designer and ergonomist through the product development process" (p. 108). This collaboration can be divided into three phases:

- Collecting information for the design
- Conceptualization

- Development of a single design concept

The evaluation of Whirlpool products in terms of ergonomics is briefly described in Figure 3.3.

3.2.1.1 Initial Information for Design

The initial information for a new design project at Whirlpool is collected with the methods of:

- Focus group studies
- Home observation
- Perception of previous products
- Benchmarking
- Ergonomic guidelines

With these methods they aim to investigate the consumer needs, previous versions of the product, the perceived problems by the users on these products and how they could be improved, the competitor companies' products, their positive and negative points and the suitable ergonomic guidelines.

As Martel (1998) states focus group study is a relatively advantageous method in terms of time and cost for discovering consumer needs about a product. At Whirlpool for each focus group study Center for Applied Product Ergonomics invites six to eight representative consumers to the usability lab. They are asked to talk about their experiences, opinions and expectations on the product that is being developed. Besides the experienced users on the related product, one or two inexperienced users are also included to have their different opinions. In this context the conversation between the moderator and participants of the study starts with the questions about their current products and usage

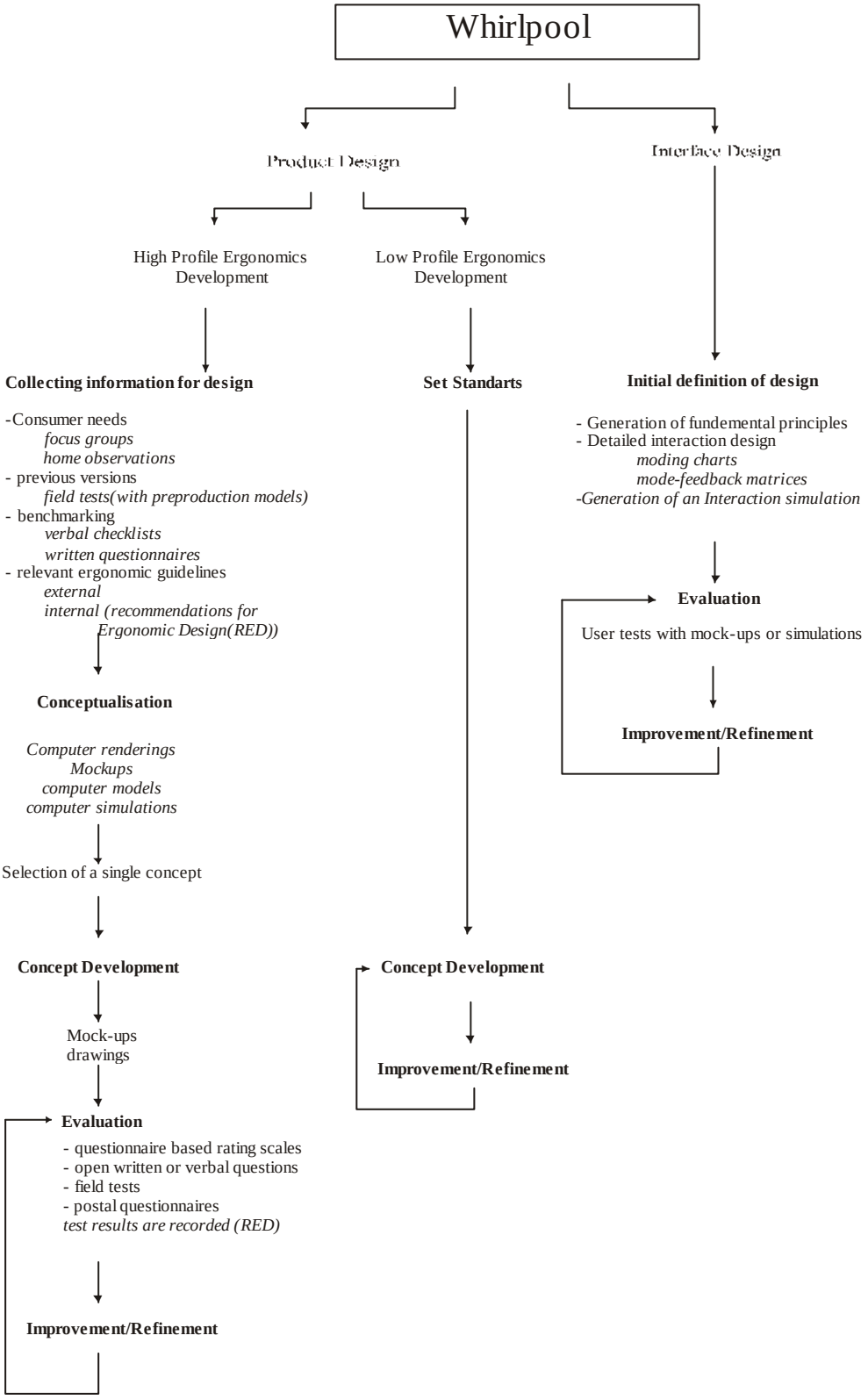


Figure 3.3 Integration of ergonomics into design process of Whirlpool

scenarios. It continues with the discussion between the participants about the related product. At the end of the session an additional part is also carried to evoke the creativity of the participants by letting them draw and discuss their ideas.

Focus group studies can only reveal the consciously known needs. In addition to the focus group study, home observation is also carried out by Applied Ergonomics Group of Whirlpool to point out the unconscious needs of the users. He states that home observation is more time consuming than focus group study but since it is conducted in the real context of use, more intensive information can be gathered. The observational study is carried by observing the user in his/her real working environment and by interviewing. The aim is to capture the needs that are expressed with unconscious behaviors or coping strategies with the problems occurred while using the product.

Evaluation of the previous products is another important source of information since it proves the company to not repeat the same faults in the latter versions of the product. In Whirlpool this data is collected in two forms:

- field tests
- postal questionnaires with purchasers

For the field tests, pre-production versions of the products are used. They are sent to the potential users' houses for a period of time. The users are required to record any difficulty or problem they experienced with the product.

For the second method of evaluating previous products, the required information is collected from the recorded purchasers by posting them questionnaires after a time period of 6 months on purchase.
In both methods the realization of the information about the difficulties and problematic points in use is most of the time too late to be recovered. So this information is used in the latter versions' development.

Evaluating competitor companies' products is another way of obtaining information on existing positive and negative points of the products. At Whirlpool benchmarking study about the user expectations and preferences is carried out by compiling different brands' products and Whirlpool's own products, following this by asking the participants to rate each product's features. This research is carried out in the form of verbal checklists or written questionnaire.

Besides collecting information on consumer needs and preferences Martel (1998) also recommends using ergonomics guidelines both available in the literature and if exists the guidelines that are formed in the company according to the research carried previously on the existing products. Whirlpool has a database (Recommendations for Ergonomic Design (RED)), which is formed with the results of ergonomic researches carried. RED is composed of ergonomic recommendations both in written and visual format. Visual material shows the pictures of design samples.

3.2.1.2 Concept Generation

After collecting the initial information about the related product, as a next step design direction is identified. Within this direction several

concepts are produced by designers. For representing the ideas they use sketches, computer renderings, computer models, foam/wood mock-ups and for relevant projects computer simulations. These representation materials are at the end used for consumer tests and discussions in the group.

In this phase consumer testing is used to define a single solution for further evaluation. For this test, groups including two to four participants are formed. The representations of the concepts are presented to the participants and they are asked to state their opinions on the concepts first on general view and then in detail on each function of each concept. Martel (1998) states that one concept can not be better than the others in every way. The results show a combination of different concepts as the best one.

3.2.1.3 Concept Development

After defining a single solution, it is developed with discussions and refinements, details are resolved. Mock- ups of the different steps in this development are built. Besides their visual purposes these mock-ups are also used for laboratory evaluations. These evaluations consist of questionnaire based rating scales and open written or verbal questions applied to potential users.

As a last step the final design is tested in the laboratory in comparison with the benchmarking samples. The aim of this last test is to see whether they achieved their aim of producing competing products in the market, which was their starting point.

3.2.1.4 Interaction Design

The interface design process of Whirlpool is described as interaction design since it defines the dialogue between the user and the controls/displays of an interface. Interaction design process at Whirlpool is composed of initial design definition, evaluation and improvement stages.

Initial design definition covers:

- Generation of fundamental principles and storyboards
- Detailed design using moding charts and mode-feedback matrices
- Generation of interactive simulation to test the interaction.

As a first step of the initial design definition storyboards of the interface are drawn which define how the interface will appear in each situation. These representations are obtained by both hand sketches and computer drawings. These storyboards are in the next step used to make mode diagrams. Modes are related to each other with arrows and possible actions between them. Accordingly, the visual and audio feedback given for each mode to the user is defined with a mode-feedback matrix. As a final step of the initial definition of the design, interactive simulations of the interface are built. Macromedia-Director is used as a tool for this simulation.

The evaluation of the interface starts with the simulations and their use by the potential users. Martel (1998) states that “the ideal way to test interfaces would be to have a mock-up product with real controls and displays driven from a hidden computer” (p.118). However, this method is both costly and time consuming so at Whirlpool they carry out their usability tests with simulation of the interfaces on a touch screen interface. The users are asked to perform defined tasks, for the

evaluation time taken to finish the tasks and any difficulties and confusions are recorded. Tests are also video recorded to observe the feelings of users while carrying the tasks.

According to the captured confusions and difficulties, moding chart is revised and this revision is reflected to the final design with the collaborative work of designers and ergonomists.

The integration of ergonomics into design process of Whirlpool is divided into two. The part explained above was named as *high-profile ergonomic development*. This part mostly involves ergonomists.

Following this process, there are also two many small parts of products to be designed and ergonomically evaluated. Evaluation of these small parts is carried with a method which lets the ergonomist to have a lighter work when compared to the previous study. For this reason, it is called *low-profile ergonomics development*. In this process, ergonomist defines ergonomic guidelines relevant for each group of products. Designer uses the related guidelines while designing such parts. The structure of high profile ergonomics development and low profile ergonomics development are defined in Figure 3.3.

3.2.2 COMPANY X

Company X is a consumer electronics company, which was founded at 1984 in Turkey. It has a TV production of 6500 in 2002, which makes it the leader TV manufacturer in Europe. In 2003, this number increased to 8000. This rapid development in the production leads to the integration of new technologies into production cycle and reach the numbers intended to fulfill the demand of customers. With the influence

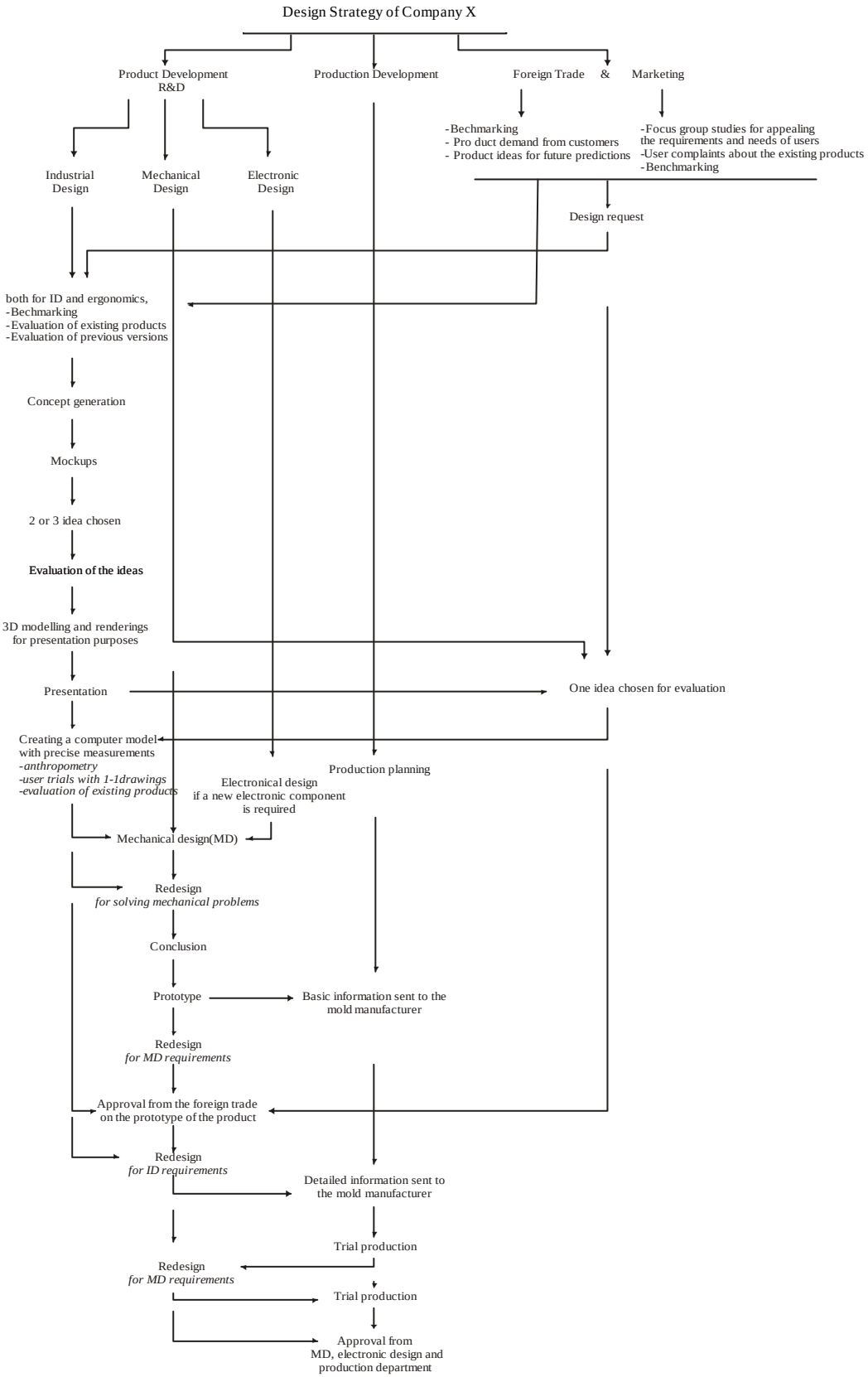


Figure 3.4 Design process of Company X

of economical conditions of Turkey more than 90% of this production occurs under OEM (original equipment manufacture), which means that it serves products to the market with other companies' brands. These brands are all international ones and in the last years strong A brands like Toshiba and Hitachi were also included.

It is a big scale company that has a structured organization with its Research and Development (R&D) Division, Marketing and ForeignTrade Division, Production Division and the sub departments in conjunction with these. The design process of the company is outlined briefly in Figure 3.4. With the reference of this outline, design process at Company X and the integration of ergonomics into the process will be described briefly.Observation method is used in this case study to gather the required information. Monette, Sullivan and DeJong (1998) distinguish the extend of observational methods in three concerns:

- Being qualitative or quantitave
- Naturalistic setting or contrieved setting
- Participation of the observer or merely the observation of him

In the research carried at company X, the required information was intesively qualitative rather than quantitave since the aim was to observe the whole long cycle of design process and integration of ergonomics into this cycle. The observation is carried out in its naturalistic environment in the design office of the company. The author was a member of the design group of the company and participated the design process with the skills of being a designer. According to these extends a participant observation is carried.

Monette, Sullivan and DeJong (1998) assert the stages of carrying participant observation as first defining the research goals, whether participant observation method is consistent with the goals. The goal of research carried at company X was to record the design process of the company and to define its structure with the information coming from ergonomics in each step of the process. Second stage is stated as defining the group of people to make the observation on. Accordingly industrial design group and the groups that are in interaction with the design work are investigated. The third and last stage is stated as getting acceptance from the group as an observer. To fulfill the required investigation the author herself participated the process by taking part in the design work as an industrial designer.

As Marcus and Ducklin (1998) emphasize, there exist the limitation of loosing objectivity while studying with the group that is observed. The author, working as a member of the group being observed, can be influenced from the environmental factors and the colleagues' work methods. This effect on the objectivity of the results should also be considered.

3.2.2.1 Preliminary Studies

The preliminary information about a new product design project comes from the below sources:

- Focus group studies
- Benchmarking studies
- Previous versions of the products

- Company web page with its related link concerning requirements, complaints and opinions of users about their interaction with
- Company X products
- Company X services
- Company X dealers

The design process at Company X starts with research on the user needs and expectations. This research starts in the form of focus group studies carried by a consultant company in conjunction with the marketing division and industrial design department.

Marketing division which is in close relation with the end users deals with national sales. They collect requirements, complaints and opinions of users about their interaction with Company X products. This information in addition to the outcomes of focus group studies is collected by the website of the company with its related link. User tests are another type of information collection method on the pre-production versions of products. These products are sent to the homes of potential users and they are required to record any difficulty they experience. However, the information coming from user tests can be used just for latter versions of products since it is too late to make improvements on the same version. Also, the unofficial information coming from the dealers about the user opinions, the defects and accidents information which are collected from the Company X services on Company X products are other sources of information.

Besides the information related to the Company X products, benchmarking studies are of immense value to be aware of the competitor products. Benchmarking studies are carried by marketing

division foreign trade division and industrial design department. Foreign Trade Division deals with the international sales and customers. In conjunction with OEM production, this interaction takes place on dealers level instead of end users level.

A new product request comes to the R&D division in two ways:

- with the future predictions based on the requirements gathered from the users
- a predefined request coming from a customer

3.2.2.2 Design Process

With the product request coming to the R&D division next phase of the design process starts. The large amount of ergonomics integration into design process occurs during the work of R&D division, which consists of industrial design, mechanical design, electrical hardware and software design departments. Industrial design starts with the information about user groups coming from marketing and foreign trade departments. With this information in hand, industrial designers produce concepts in different forms. To be able to evaluate in real dimensions and in a 3D form they produce mockups of these concepts or the critical parts of them. These mock ups in 2D or 3D form can be hand made or built with the rapid prototype facilities. Following the concept generation phase 2 or 3 of the ideas are chosen by the design team to be presented to the foreign trade and marketing department. With this presentation one idea is chosen (with the integration of mechanical design department also) for the further evaluation. At this phase of the design process

industrial designer has to propose the precise dimensions and form of the final idea to make it ready for mechanical design. Mechanical design continues with redesigns and the approval from industrial designers and marketing people to these redesigns until the product matures for production.

3.2.2.3 Integration of Ergonomics

Integration of ergonomics heavily takes place in the transition period of final design idea (by industrial designer) to a realized product (by mechanical designer). This transition period starts with the preparation of 3D models by industrial designers for communication of the final design idea with mechanical designers. Final ergonomic decisions on the details sometimes which do not appear in the previous stage, presentation, should all be given in this period by the designer. In accordance with the time limitation designers most of the time, base the ergonomics information (e.g. the related body dimensions or force requirements) on themselves or the colleagues in the office as a reference point for their designs. When the design issue is a control button on a TV, the required dimension of the hand can be gathered easily by taking the 95%ile related hand dimension as a reference. It does not need much mental research since the action is only pressing the button. However when the object to be designed is a remote control, ergonomics analysis is needed both in anthropometric issues to prove its good fit with hand and in cognitive issues to make the menu structure of it easy to use, understand, manipulate and remember.

To not disturb the flow of the steps, design process mostly does not have a flexibility letting the process go back to the previous stages

again and again. Every department carries the work that it is responsible for and passes the result to the other department for latter evaluations. As a consequence of this static structure of the process (which is an obligation), when the mechanical design has finished, there is not much to do for industrial design and in accordance for ergonomics. The active role of industrial designer, who also carries the ergonomics evaluations, nearly ends at the beginning of this transfer.

The missing details related to industrial design are integrated to the product by the industrial designer during the MD (e.g. the handle for TVs which comes as a requirement from the customer during the MD) however redesigns are carried for mostly the mechanical necessities. Such a task (designing handle for TVs) has some biomechanical considerations such as cumulative force on the body and acceptable exposure limits that would prevent musculoskeletal problems (Guimaraes and Pereira, 2000) however the decision about its form, place and dimensions should be defined by the designer as soon as possible to not disturb the MD process.

The final prototype is produced at the end of MD, which is synchronous with the receipt of basic model information by the mold manufacturer. Every modification revealed from the evaluation of the prototype lead to disturbance on the mold manufacturer, which is not intended. After the production of the mold and the realization of the trial version modified with the comments of industrial designer and mechanical designer, the possibility of making changes on the form is very limited since each change will be very costly and time consuming even sometimes impossible.

3.2.2.4 Focus Group Study

As stated before, focus group study is carried with the aim of finding out expectations of users from a new product and complaints about the existing products of the company or competitor companies' products and the problems that occur during the interaction with those products. Focus group study in general seems to be one of the most serious approaches in the design process of Company X on the investigation of user needs and expectations. In accordance it will be described and evaluated briefly to weigh the positive effect of it on the integration of ergonomics into design process of the firm.

3.2.2.4.1 Aim of the Study

Figure 3.5 focus group study

The aim of doing this study was to capture user expectations and requirements from a TV, the interaction problems that occur during the use of the products, the reflection of an ideal TV on their mind, information level of different brand's users, priorities of specifications on a TV, preferred and ignored specifications.

3.2.2.4.2 Participants and Methodology

Focus group study is carried out by a consultant company (Millward Brown). It is a regular study carried on May 2004 for Company X Electronics. The study is carried and reported by professional researchers and monitored by people from marketing and industrial design departments. The author herself have not monitored the study but used the research reports prepared by the consultant company (focus group study report, 2004a) and industrial designers (focus group study report, 2004b).

The research is conducted within three levels. The aim of creating these different levels was to obtain groups according to the similar information levels, education levels, similar interests and occupations to avoid dominancy.

First level: It is composed of 4 groups of participants. Participants are chosen among:

- 25-45 years old
- have bought the TV that he/she is using, in the past three years
- watches TV at least 3-4 days a week and 2 hours a day
- owns a 15" or bigger sized TV

The participants chosen according to the listed criteria are divided into four subgroups according to their age and sex. This division is made to prove attendance of people with similar fields of interests, from similar generations to share each other's ideas on the subject and avoid the dominancy of individuals as much as possible.
First Group: 25-35 year old women
Second Group: 36-45 years old women
Third Group: 25-35 years old men
Fourth Group: 36-45 years old men

Second level: It is composed of two groups of participants. Participants are chosen according to the criteria listed:

- 25-35 years old men
- 29" or bigger sized TV owners
- technology followers

Third level: It is composed of six one by one interviews with the participants carrying the specification below:

- plasma TV owners

3.2.2.4.3 Outputs of the Study

Outputs of study are explained under the headings of:

- Purchasing Habits of Users
- Reflection of an Ideal TV on Users' Mind
- Comparison of the price-brand relation by users

3.2.2.4.3.1 Purchasing Habits of Users

Although being participated by industrial designers, since this focus group study is oriented by the marketing division of Company X, most of the research topics are related with purchasing issues. Additionally, to understand the purchasing decisions of users deeply, research is expanded to all factors that would influence this decision. The outcomes of the study reflect that the primary source of information while giving a purchasing decision of a TV comes from the people around. Dealers, advertisements and world wide web pages stand for the second, third and fourth sources of information sources. The factors that would influence the purchase of a TV are listed as:

- brand
- technical service network
- technological capabilities
- aesthetics
- price and promotions
- guarantee periods

These factors change in accordance with the size and specifications of a TV. For instance while buying a Plasma TV, image quality is the utmost important factor whereas for a 14" TV, mobility has a bigger priority than many other factors.

3.2.2.4.3.2 Reflection of an Ideal TV on Users' Mind

Criteria that define the ideal TV image of users can be divided into three subgroups. The first group is composed of the criteria that are

concerned mostly by industrial designers. They are related with the form and function of the product. The users' choices between the below concerns are recorded:

- color (silver, black, combinations)
- form (rounded-sharp, thin-thick)
- size
- stand of TV (if they need it or not)
- materials of stand (glass, plastic, wood)
- function and on/off buttons (their position, form)
- emblem and logo (their position, form, material)
- remote controls (their form, the problems experienced during use)

Second group of specifications are related with the embedded functions into a TV. These embedded functions can be:

- Cinema sound systems
- DVD
- Memory cards…

Third group of criteria are composed of technical specifications of the TV. The participants felt free to tell all the interesting ideas in this group of discussion even the most unusual ones. They felt free mostly in this session and told their expectations of a TV like having a camera or voice recorder as a subsidiary function.

All the studies within three levels are carried not only for TVs (CRT, TFT, plasma) but also for remote controls of the TVs.

3.2.2.4.4 Evaluation of the Focus Group Study

As a result of the focus group study, it is seen that factors that effect purchasing decisions of users differ from criteria defining their ideal TV image. Purchasing decisions reflect technical specifications, cost and maintenance issues, and aesthetic properties of the product. Users' expectations about the successful interaction between the product and themselves do not appear in the purchasing decision level. However, for an ideal TV they are more concentrated on ergonomics issues. For instance, although the criteria related to remote controls in the purchasing decisions level is not considered, for an ideal TV a successful fit of remote control with the hand is strictly expected. They complain about the big, rectangular shaped existing ones, which do not fit their hand. Usability is expected both in physical and cognitive level.

They do not want to see excess number of buttons on the remote control. They think that seeing only the most frequently used buttons and hiding the rest under a cover would be the best solution. Another demand for covering was for the function and on/off buttons on TVs. The reason behind this was keeping children away from the buttons. Both women and men in the groups were focused on the safety issues and accidents related with children. In accordance with this, one of the expectations for ideal TV was front surfaces without any protrusion like buttons or even emblem or logo. The reason behind this expectation was again safety factor as children (1-2 years old) are used to climb up by taking support from TV's protruded parts.

Consequently, it is clearly seen that marketing people are more concentrated on the purchasing decisions than the other factors. Again it is obvious that ergonomics based expectations do not

seriously appear on **purchasing decisions** instead they appear on **the reflection of ideal TV** on the users' mind. As a result of this mismatch, expectations related with the usability of the product don't have a priority from the marketing point of view.

3.2.3 Evaluation of Whirlpool and Company X Cases

The evaluation of Whirlpool and Company X cases brings out the similarities and differences in their design processes and integration of ergonomics as below:

Similarities:

- In both companies' products there does not exist an intensive interaction of the human body with the product.
- The interaction of the user with the menu structures of the products of both companies is of immense value.
- Ergonomics is not the primary concern of both companies.

Differences:

- Whirlpool carries a systematic research on ergonomics whereas Company X carries them partially.
- Both of them start the integration at the early stages of design however at Company X, evaluation of the concepts

and products takes place at later stages than it takes place at Whirlpool.

- Whirlpool collaborates with ergonomists for their projects, whereas at Company X, industrial design, marketing and mechanical design departments organize and carry the research and evaluation studies.
- They have an iterative design process whereas at Company X the loops are so long that some of the errors can not be recovered.

3.2.3.1 The Role of Cognitive Ergonomics

Both of the companies are similarly producing consumer products. In these consumer products (TVs, washing machines, refrigerators, etc.) the most serious physical interaction takes place between the hand and controls of the devices. The interaction of the human with all these products appears at most in " interface level" . For this reason cognitive ergonomics is much more important than physical ergonomics in the evaluation of both companies' products. Hsiao (2000) stresses the need for the satisfaction of consumer's psychological needs as well as physical requirements to achieve a well-designed product. And she attracts attention on the strategy of marketing model which leads the highly consideration of human needs both physical and cognitive. However, with the rapid advent in technology not only the production process but also product specifications and the end products have become more complex. Although its ease of application to consumer electronics products owes to differentiated goods, in users point of view integration of technology leads to cognitive complexity and difficulty in use. Hall et

al. (1999) naming the technology integrated products (which also cover the consumer electronics products) as "walk-up-and-use systems" support the idea and claim that many users experience difficulties when using these systems since it is not always obvious how to use it.

Norman (1988) associates this difficulty in use, with the poor system image. This poor system image results with the below facts:

- users not having an adequate understanding of how the product really works
- users not knowing what actions are possible at any moment
- users not being able to determine what state or mode the product is currently in.
- the mappings between user intentions and the required actions, and between user actions and consequences not being natural or as expected.

Electronic products replaced the mechanical ones with their variability, cost and production advantages (Bonner, 1999). Emergences of them assure the flexibility of creating differentiated products more easily when compared to the traditional methods. Cooper (1999) states that:

> "adding physical controls to devices is still governed by the negative feedback loop of manufacturing, but the process of adding functions and features in software is not. To software makers, it seems virtually free to add features, so any proposed feature is assumed to be a good investment until proven otherwise." (p.28)

In accordance to this, some details on products that were previously solved with mechanical components have now disappeared. The controls and displays even on an ordinary toy are now built with the support of electronic microprocessors. (Wichansky, 2000) describes the shift from pure analog to digital devices with an example as below:

> " The rapid development of interactive television technology has engendered a new class of remote control devices that may have a mixture of analog and digital capabilities, LCD screens, joysticks and other alternatives to pushbutton controls, and software interaction modes. These products require extensive usability testing to provide the correct ergonomic design in hardware and software to meet the needs of a diverse user population."

Cooper (1999) states that interaction with these software-based devices is very high in cognitive friction. He makes its definition as "the resistance encountered by a human intellect when it engages with a complex system of rules that change as the problem permutes" . As he claims, interaction with physical devices is low in cognitive friction since " mechanical devices tend to stay in a narrow range of states when compared to their inputs". With the disappearance of the mechanical controls and displays the basic ergonomic considerations (e.g. good mapping, grouping, function-control coordination…) that should guide the user for an effective, efficient and safe communication with the product also disappeared.

The principles which were easy to integrate into the product with the advantage of 3D are now harder to integrate into the design. It is harder to catch all these clues in an LCD screen. As Sade (1999) states, " the physical product and user interface are disintegrated; the form no longer follows the function" .

Wichansky (2000) points out the complexity of the ergonomics evaluation of such products with challenges listed below:

- "Designs involve evaluation of hardware and software user interfaces.
- Sometimes both aspects are not available for testing simultaneously.
- Designs need to be tested in real world conditions, such as cars or homes.
- The user population is often highly diverse and untrained.
- Observation alone is not sufficient to capture data; some additional automated data logging procedure often needs to be developed to obtain performance data such as button presses or response times.
- Different companies may develop the hardware and software, so achieving agreement on design recommendations can be very challenging."

As Jamison and Hard (2003) state, companies choosing the way of using technology as a competition and differentiation tool start to create new product groups and new markets for these groups as a next step. As a result of this approach composite products which are named as hybrid products by Gültekin (2004) get into form that carry the functions of different products and result in complex systems. New generation mobile phones can be an example of these hybrid products. With the combination of separate products into one, the identity of the end product is lost. It is not a playstation, not a personal computer or either a phone… However, the reflections of all these products should be existing on the interface of the hybrid product which causes a complexity in perception and cognition and the loss of traditional interpretations that exist between the user and each of the products separately.

3.2.3.1.1 Complexity with excess number of features on products

With the advent of microprocessors in terms of cost, size and availability, technology brings out the ease of integration of extra functions in an electronic product. Companies are only dealing with the multifunction side of this issue with its lower costs and have a tendency of using it as a marketing tool (Haubner, 1990). Using this as a tool for creating differentiation, they do not think about the complexity that the end product will cause for the user. As Standaert and Christiaans (2000) states, “although devices may look simple in their system parameters concerning the physical layout, they are difficult to operate as a consequence of the cognitive complexity of the system”.

Asatekin (1997) relates the increasing number of functions of electronic products to the fake perception of human on associating the increase of function quantity with the increase in product quality. As he indicates, the increased numbers of functions don’t sign out the product quality but only the technical complexity. Excess number of functions may even cause the user be unable to find out the main functions of the electronic product and use them properly. This remarks the need for the investigation of user needs and limitations while deciding on the functions that a product will cover.

The background of these drawbacks lies on the formation of design process without considering the human factor. As Norman (1999) states, since consumer market covers billion of users having “ different interests, skills, socioeconomic and educational levels, and concerns” , their needs requirements and limits also change accordingly (p.33). With the alteration in user groups and with the

emergence of technology to everyday life, the context of the use changed totally. With the alterations on user groups and use of context, user requirements and expectations also change accordingly. Rubin (1994) states that:

> "The original users of computer-based products were "hackers" possessing expert knowledge of computers and mechanical devices, a love of technology, the desire to tinker, and pride in their ability to troubleshoot and repair any problem… Whereas before it was very unusual for a nontechnical person to use electronic or computer-based equipment today, it is almost impossible for the average person not to use such a product in either the workplace or in private life." (pp. 5-6)

The needs of consumer electronics products users should be evaluated in terms of the variables in context of use.

New technologies can be used as a differentiation tool in consumer electronics products. The lacking point is the integration of information on user requirements and expectations. Instead of facing the problems at the end of the production cycle, a user centered design approach should be followed. Woodson (1981) defines user centered design as "the practice of designing products so that users can perform required use, operation, service and supportive tasks with a minimum of stress and maximum of efficiency". He stresses the need "to design from the human out" which means that a designer should make the design fit the user as opposed to making user fit the design. Henry (1998) describes the key concepts of user-centered design process as below:

- "*Focus early on users and tasks.* Understand user's cognitive, behavioral, and attitudinal characteristics, the

tasks users perform, how and in what kind of environment

- *First design the user interface.* Separate user interface design from software design. Reverse the traditional process by first designing the user interface.
- *Involve users.* Have users participate in design and design reviews.
- *Insist on iterative prototyping and evaluation.* Evolve user interface design via user testing and iteration." (p.13)

3.2.3.2 Participation of Ergonomists to the Design Process

When the integration of ergonomics into the design of products is evaluated for each firm, it is seen that Whirlpool is more focused on this integration. The company has an ergonomics evaluation center called *Center for Applied Product Ergonomics* which carries out the necessary research, evaluation and improvement studies in the related phases of design. In Company X these studies are carried out by the collaborative work of industrial design, marketing and mechanical design departments in various steps of the design process as expressed in table 3.1 with the comparison table defining the division of ergonomics work between the different work groups of the companies. As it is explained by Martel (1998) for the low profile ergonomics evaluation of products at Whirlpool, the integration of ergonomics into the design of small repetitive parts of products can be carried out by reviewing ergonomic guidelines defined by ergonomists for each group of products.

Table 3.1 comparison table

	BAHCO	VOLVO	WHIRLPOOL	COMPANY X
Research	***EDG Ergonomics Group*** Investigation of; ? user needs ? existing products ? Usage patterns ? Force measurements ? Anthropometric information	***Volvo Safety Group*** ? Investigation of user needs Research on; ? previous products ? Safety records (collected by safety research team) Information on; ? collisioned cars ? User scenarios ? guidelines	***Whirlpool Applied Ergonomics Group*** ? Investigation of user needs ? Evaluation of previous versions ? Benchmarking ? Relevant ergonomic guidelines (external & internal (ex: Recommendations for ergonomic design (RED))	***Company X Design Group*** ? Evaluation of existing products ? Evaluation of existing versions ? Benchmarking ***Company X Foreign Trade & Marketing Divisions*** ? Investigation of consumer preferences
Concept Generation	***EDG Design Group*** ? Creation of different concepts ? ***EDG Ergonomics Group*** ? Test of conceptual forms ***EDG Design Group & Ergonomics Group*** ? identification of the final concept with the evaluation results	***Volvo Design Group*** ? Creation of different concepts ***Volvo Safety Group*** ? Test of conceptual forms ***Volvo Design Group & Safety Group*** ? Defining the final concept	***Whirlpool Design Group*** ? Creation of different concepts ***Whirlpool Applied Ergonomics Group*** ? Test of concepts ***Whirlpool Design Group & Applied Ergonomics Group*** ? Defining the final concept	***Company X Design Group*** ? Creation of different concepts ***Company X Design Group & Mechanical Design Group*** ? Evaluation of concepts ? Defining the final concept
Concept Refinement	***EDG Design Group & Ergonomics Group*** ? Refinement of the final design idea	***Volvo Design Group & Safety Group*** ? Refinement of the final design idea	***Whirlpool design group and Applied Ergonomics Group*** ? Refinement of the final design idea	***Company X Design Group &Mechanical Design Group*** ? Refinement of the final design idea
Finalization	***Production Division*** ? Creating production specifications	***Production Division*** ? Creating production specifications	***Production Division*** ? Creating production specifications	***Production Division*** ? Creating production specifications

However for the development of interfaces or remote controls and their menu structures, participation of ergonomist to the design group is inevitable.

Although Whirlpool carries out all the necessary ergonomics research, evaluation and implementation studies for its products, for both of the companies ergonomics is not the primary concern. They have priorities of :

- reducing the production time
- increasing the production quantity
- increasing the product quality

In consumer electronics, producing within the time and cost constraints brings out the production oriented design process.

3.2.3.3 The Limitations of OEM Production

Company X has a high ratio of OEM production which makes it differ from Whirlpool that makes production for its own brands. OEM is used widespread among consumer products' manufacturers. And as it happens in Company X case OEM brings out the limitation of poor communication with the end user of the product. The information about the end user, their preferences, their satisfaction levels, efficiency and effectiveness of their use of the products becomes harder and harder to attain. Another limitation OEM brings is that the products should be produced not for a specific customer (a group of population) but for a broader market. So the information about the end user even if it is

available can not be used if the production volume is not at such a high level which will tolerate this specialization.

3.3 Comparison of the First Group of Cases with the Second Group of Cases

When the second group of cases (Company X and Whirlpool) is compared with the first group of cases (Bahco and Volvo), it is perceived that the products which are in interaction with the human body are more deeply evaluated in terms of ergonomics. In the Bahco case the products (hand tools) are in close relation with the hand. And in Volvo case the products (automobiles, parts of the automobiles) are in close interaction with whole body. In both cases and similar cases from similar industries, the need to integrate ergonomics into the design process is obvious. The reason behind this inevitable integration is the effect of injuries on the human body depending on the poor integration of ergonomics.

However in consumer electronics design the need of ergonomics knowledge mostly appears in cognitive level. The realization of the vital problems after the actual usage can be obtained with user trials that can be carried with potential users of the products or the real users by getting into contact after a period of time on their purchase.

CHAPTER 4

THE BACKGROUND OF DEFICIENCIES IN THE INTEGRATION OF ERGONOMICS INTO CONSUMER ELECTRONICS DESIGN

Depending on the previous studies both on the literature of the field and the case studies evaluated, factors that lead to the poor integration of ergonomics into consumer electronics design will be stated in below paragraphs.

4.1 The Strategy of The Company

For consumer electronics companies production within the time and cost advantages are so important. These constraints most of the time take the highest priority in companies' strategies or they even replace the other factors that would influence the success. One of these replaced factors is the inclusion of multidisciplinary study into design process. Nowadays it is seen that multidiscipline based design strategy is inevitable for companies, which leads all professionals related with the subject of the company to come together and develop the product in collaboration. In other words a collaborative work should take place. Mesa and Thompson (2000) explain the need of a multidisciplinary work as below:

> " Traditional step-wise processes are becoming increasingly unsuitable since they imply high risks of big loop iterations. In order to carry out the complex multi-objective product design activity companies need multi-disciplinary work-forces with a range of specialized knowledge that work together and consider all criteria simultaneously."

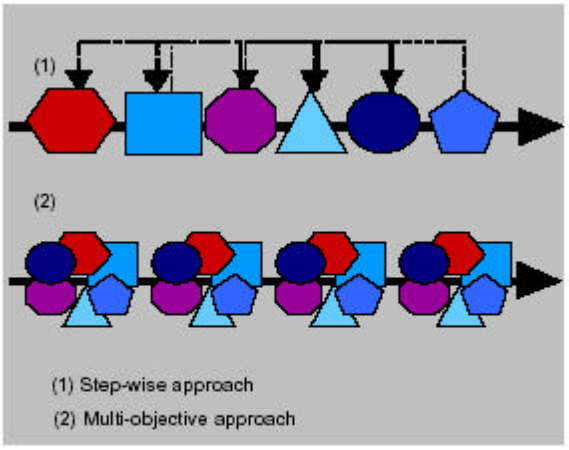


Figure 4.1 Step-wise product development process and multi-objective product development process Mesa and Thompson (2000)

Ergonomics is one of these disciplines to be integrated into the design process for the success of the products for their good communication with their users. Feeney and Bobjer (2000) emphasize that an ergonomics approach to the product design is essentially multi-disciplinary and the involvement of other disciplines can enhance the design process. Depending on his experiences with the design of industrial hand-tools he mentions that:

> "…high quality, high performance tools can only be brought to the market through a combination of disciplines including designers, production engineers, marketing specialists and of course, human factor experts."

The collaboration of the different professionals from different departments also brings iterations to the design process in contrast to the classical, linear flow (Haubner, 1990). Time limitations impede the flow of an iterative design process as it happens in Company X case. The need for this iteration is foreseen and reflected in the previous design theorists' definitions of design and also proved by the researchers in case studies of companies integrating ergonomics successfully. As Mesa and Thompson (2000) stated previously the lack of multidisciplinary approach may bring high risks of big loop iterations. These big loops most often bring losses of time and investment bigger than it would happen with the iteration of the process in a multidisciplinary approach.

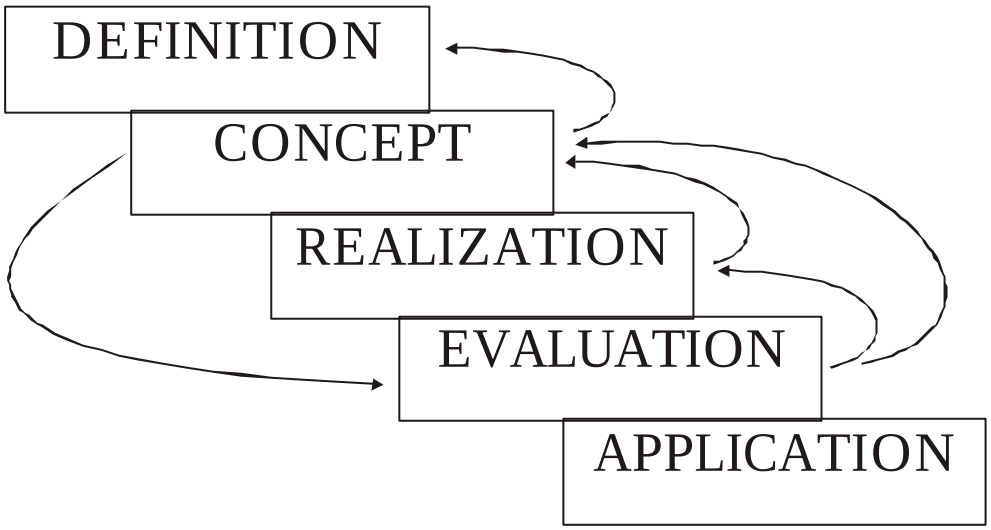


Figure 4.2 iterative structure of design process (Haubner, 1990)

It is reflected in the design strategy table of Company X that there is not enough time period for this iteration and integration of ergonomics at the right time. The late realization of the problems related to the interaction of user with product lead to bigger time losses and

accordingly cost increases occur (Haubner, 1990). Trying to solve the pointed problem in the late stages of the design process leads to costly changes on the production in addition to the unintended cost increases, even it may lead to compensations to be paid because of the delays in deliveries to the customer. Some problems can be realized in such a stage, like finalization, that they can not be recovered. The products produced with these problems may in time damage the prestige of the company over its customers. As Kreifeldt (2000) states there are many important design issues in consumer products however user satisfaction is the utmost important one which distinguishes consumer products from other fields of production such as industrial, medical or military products in which user satisfaction is of secondary or even less importance.

4.2 The Barriers between the Company and End-Users

With the new trends in world economics, most of the big consumer electronics companies are producing their products not in their own production facilities but in OEM companies. This is another way of company strategy, which is based on using the cheap labor power of other countries and catching a marketing advantage of production with lower costs in shorter time periods with large numbers. As a result of this strategy, the OEM company fulfills the requirement of the brands by designing and producing within the intended limitations. However, the OEM company which carries manufacturing or the design+development+manufacturing of the product, although being in close relation with the customer is far from 'the end-user'. The end-user is usually an unknown entity for the designer. Designer carries the ergonomic evaluations of the product to prove the good relation of it with its user by reflecting the specifications of the 'average person',

which is accepted as a big fallacy by the pioneers of the field (e.g. Pheasant, 1986). Popovic (1999) emphasizes this problem as below:

> " Designers still operate in their traditional role (that is in a professional client relationship). The designers receive the client's brief in which needs and wants are specified, and design a product outside its contextual environment by predicting the behavior of a product and its users on the basis of their knowledge as experts, or from personal experience" . (p.27)

4.3 Safety and Perceived Safety on Different Product Groups

The deficiencies pointed above in the integration of ergonomics into consumer electronics products lead to mismatches between the user and product. This occurs sometimes severely. When the integration of ergonomics in three cases is reviewed, there is an obvious point that the severity of the injuries resulting from the poor integration of ergonomics into the development of each company's products differs. The safety expectation level of the users and perceived safety also changes accordingly.

Norris (2000) explains perceived safety in different fields by customers as below:

> If we assume safety to be a component of good design, this suggests that safety should now be a purchase criterion. This may be true of some markets such as the automotive industry, but perhaps not in market where perceived safety is not such an issue, such as domestic products. (Norris, 2000)

The bad communication of the products with its user becomes evident with accidents or injuries (even people still blame themselves for most of these kind of accidents). However users usually are not willing to

express their discomfort on using an electronic product causing confusion in their mind. They usually think that to be unable to use a universal remote control, which has a multi-function of managing TV, DVD and music system is their own fault of being old or unaware of the technology. They never think that the problem is the product itself, which does not have an easy to use, easy to understand and easy to manipulate interface.

4.4 Lack of Awareness on Both Users and Managers

Considerable amount of integration of ergonomics should occur on the usability of the menu structures of the consumer electronics products. The indifference and unawareness of users on the ease of use, efficiency and effectiveness of the use of consumer electronics products leads to the loose of concentration of managers on this issue in consumer electronics companies. Information on these issues can be collected by examining existing products and user trails. These studies although requiring time and effort can be arranged more easily with the help of technology.

To achieve all these, managers stay at the focal point. Since they are the final decision makers, they should be aware of these methods (focus group studies, examination of existing products in ergonomics point of view, user trials, etc.) and their contributions to the design process.

As Norris (2000) states they should be convinced that ergonomics evaluation or inclusion of ergonomics issues in an existing evaluation system is a practicable and cost effective process that can be

accommodated with all other constraints on the product development process.

The awareness problem of both users and marketing people can be solved in different ways. Two methods that are used by Bahco will be mentioned one for persuading the managers and one for convincing the users about the benefits of using ergo products and paying for them.

In the first method Svengren (1994) finds the effort of reaching end-users with information about better tools a costly and time-consuming approach. Since purchasing managers are mostly focused on the price issue, Bahco salesmen developed a strategy on influencing the target users. They have prepared demonstrations of the products that will lead the use of them by the workers in their working environment. Svengren(1994) explains this strategy as below:

> "In September of 1993, a salesperson at Sandvik Bahco explained to me how: " You have to make them try and test the tools. We walk into the factory, and ask the guys to test different products- as well as some from competitors. When they have felt the difference, they do not want to use any other tool."

Another technique was developed for exhibitions and fairs. They have demonstrated their hand tools under the similar environmental conditions with its real context of use. The product manager at Sandvik Bahco mentions this method during an interview that Svengren (1994) carried in September of 1993 with him:

> " At exhibitions and similar events we put a wrench with a rubber handle and one with a metal handle into a small ice box. Then we ask people to 'take one in each hand'. After a few seconds the warmth is back in the

> hand that holds the one with the rubber handle. It is so convincing – they never forget it."

As it is supported by the success of Bahco's marketing techniques a concrete way of representing the benefits of ergo tools among the traditional ones is inevitable. Trying to tell about the advantages of ergo-products to the customers is not enough. An intimate relationship of the product with the end-user should be supplied.

Another way of persuading the managers for the benefits of integrating ergonomics in product design is the concrete demonstration of the costs and benefits it brings. Feeney et al. (2000) in a parallel point of view states that this must be done in a quantifiable manner to show off the tangible reward of the increased investment in time and resources. They suggest that some of these can be quantified depending on the possible increases in the number of target users and hence potential sales. In addition Green and Jordan (1999) recommend that quantification of usability can be advantageous in terms of taking the issue into a concrete domain that can be understood by others such as engineers and product managers who take place in product creation process.

However the integration of ergonomics in the two sectors, hand tools and automotive, is such vital with its close relation to safety that the persuasion of the users and manufacturers is easier. It is not such easy for consumer electronics design in which the outputs of the poor integration of ergonomics is generally ignored.

This is also supported with the results of the focus group study carried in the consumer electronics company, Company X. As it is evaluated in detail in the previous chapter, the marketing people are directly

focused on the purchasing decisions of the users. Since the expectations of users related with the good communication of the products with its user comes at the ideal TV idea, they are not taken into consideration as much as the expectations that come with the purchasing decisions.

4.5 The Role of Ergonomist and Designers

McCelland (1990) states that the effective application of ergonomics depends on the active participation of ergonomists in the design process. They provide the necessary information about the user group (Haubner, 1990), and evaluate the ideas on the good communication of user, product and environment (Porter et al., 1999). Porter et al. (1999) base the success of integration of ergonomics into design process of the lightweight sports car project carried at Coventry School of Art and Design to the inclusion of ergonomist into the design team. As Erbuð (2000) states in these circumstances, for a successful collaboration designer has the role of transforming the ideas and data provided by ergonomics experts into services and products. She defines designers as being moderators and creators of new values and in need of ergonomics experts in order to not get lost in deriving the required information. Nickerson (1999) pointed out that, " ...designers are not full-fledged human factors practitioners. They are team leaders who must consider many additional factors during the design process." (p. 609)

However marketing people are profit oriented and they would not invest on ergonomists until they see the benefits of their work. As it is stated by Mossink (1990) commitment of top management plays an important role on influencing the use of ergonomics in design project.

And in many small sized companies it is the reality that even they would like to integrate ergonomics into their design process they can not effort integrating ergonomists or ergonomics consultant firms in their design process. Instead designer has to carry the required ergonomics evaluations. Porter and Porter (1999) having a parallel view declare that the inclusion of an ergonomist as a permanent team member creates as a major contributing factor to successful ergonomics design. And they add:

> " However for large number of small design consultancies this is not an economic reality and it is designers who are responsible for the ergonomics input to a design." (p. 19)

However as it is widely discussed by the researchers there are some problems that designers face in integrating the ergonomics knowledge into their design process. The main reasons of these problems are stated below:

4.5.1 Lack of Available Information Sources

First one as emphasized by McCelland (1990) is the lack of available information sources usable for designers. Feeney et al. (2000) state that too often human factors data is provided in such a complicated and inappropriate form for designers that it needs extensive improvement to be easily understandable and usable. Many authors and practitioners both from design and ergonomics profession emphasize this belief. As Erbuð (1999) mentions ergonomics is not the fundamental need of product and system design but most of the cases it is the most important issue. In spite of this, the communication problems of ergonomists, who would be the developers of available information sources for designers, with designers is stressed all over

the literature. As Bonner and Porter (2000), two ergonomics experts state that communication between designers and human factors specialists needs to be improved and they declare their investigation about how to do that:

> " Communication between designers and human factors specialists needs to be improved and there is evidence to suggest that human factors specialists need to concentrate on the users of their knowledge and data (John V H Banner a and J. Mark Porter , 2000)"

Feeney et al. (2000) emphasizing the same communication problem states that the problem stems from two main reasons:

1. the form in which human factor data is presented
2. understanding the standpoint and background of the other profession

And Mcdonald (2000) additionally emphasizes the third reason as:

3. limitations of the language each specialism employs

Ergonomists still investigate in the forms of representing the data more clear and appropriate for designers' and other professionals' use.

4.5.2 Unwillingness of Designers to Use Ergonomics Information

Designers are not willing to use ergonomics information. Instead they use their instinctive knowledge. Hasdoðan (1992) states that they take the colleagues as a reference for their anthropometric, biomechanic and cognitive information needs about the user. In accordance Pheasant (1986) gives the five big fallacies of design professionals as below:

> “ (i) This design is satisfactory for me - it will therefore be satisfactory for everybody else
>
> (ii) This design is satisfactory for the average person - it will therefore be satisfactory for everybody else.
>
> (iii) The variability of human beings is so great that it cannot possibly be catered for in any design - but since people are so wonderfully adaptable it doesn't matter anyway.
>
> (iv) Ergonomics is expensive and since products are actually purchased on appearance and styling, ergonomics considerations may be conveniently ignored.
>
> (v) Ergonomics is an excellent idea. I always design with ergonomics in mind - but I do it intuitively and rely on my common sense so I don't need tables of data.”

These fallacies are also relevant for the design process of the consumer electronics company revealed.

4.5.3 Lack of Usable Tools for Industrial Designers

As Porter and Porter (1999) states handbooks are not an answer to the communication problem of ergonomics information with designers. There are some tools developed for easy integration of ergonomics into design. Today with the development of technology as in many fields also in ergonomics field the use of computers got emerged. Computer manikins are now available for people who work on ergonomic analyses. However, this is a rather new area for them working on traditional methods. We have the most common man modeling possibilities from the most traditional one to manikin

softwares as tables with anthropometric data, two-dimensional man models with posturing possibilities, two-dimensional and tree-dimensional computer models with posturing and scaling possibilities and mockup models.

The most recently developed tools among all these are computer programs such as ErgoEaser, ErgoMaster, ErgoIntelligence, PeopleSize (two dimensional) and MannequinPRO, Transom Jack, Ramsis (three dimensional). These programs vary in their capabilities, visual formats and structures. As it is stated by Kaygýn at al. (2003) computers are not thought to be substitutes for ergonomics specialists but on the other hand, there is a need for using computer techniques to retrieve quick and easy information about the specific problems of design. The advantages of the use of these tools by designers are stated as below:

1. "Shorten the time required to retrieve specific information.
2. Shorten the time required for simulations.
3. Motivate designers to apply their ergonomics skills more broadly.
4. Save time during design.
5. Allow time for more sophisticated discussions." (p.500)

However they are mostly designed by engineers and again for engineers. As Porter and James (1994) state designers are essentially visual and not verbal individuals. Since they are used to visual communication more than verbal, they want a clear visualization on the interfaces. As it is also stated as an output of the survey carried by Kaygýn et al. (2003) on these programs, most of them include usability problems on their interaction with the user although being developed to find out and improve ergonomic problems of the products. Another output of the survey points out that there is no

single software covering all the needs during the design process. Erbuð (1999) relates this to the interdisciplinary nature of ergonomics and the complexity of the design process.

As it is stated by Robertson (1997), one of the major problems in ergonomics software tools is that you can carry any kind of analysis with these softwares in theory, but in real you can not, since they are typically designed with specific tasks in mind. They are not flexible enough to fulfill the specific requirements for the research, evaluation and improvement studies of ergonomics at different stages of design. 2D and 3D computer models are being evaluated for some years but they still need further development to be efficiently used by designers.

CHAPTER 5

CONCLUSION

It is obvious that there are lacking and problematic points in the integration of ergonomics knowledge into product design process. This can be derived from the high volume of products that cause usability problems in everyday life. In accordance with the variety of companies, the scope of this integration differs. The underlying reasons of the differentiation in ergonomics integration into different companies' design processes is investigated. Subsequently, being a designer in a consumer electronics company, the study started with practical experience by the observation and evaluation of the design process of consumer electronics products and the literature about the issue is reviewed.

It is realized that there is a different structure in the integration of ergonomics knowledge into consumer electronics design process and there exist inadequacies in ergonomics evaluation and implementation of these products. To find out the underlying reasons of this differentiation in the structure, four companies are assessed in accordance to their design strategy and their integration of ergonomics as it is stated in detail in the third chapter. One of the cases is built on the consumer electronics company (Company X), which the author participated in its design team; the second company (Whirlpool) was

chosen among the companies producing consumer electronics products again and implementing their products with the relevant ergonomics methods in each stage of the design process. They were compared with each other according to this integration. To see the differences in their strategies two other companies (Bahco and Volvo) are chosen from different sectors among the success stories of the integration of ergonomics into their design process. The aim of evaluating these firms from sectors different than consumer electronics was to be able to see the different variables and the effects of these variables on their success.

Since the interaction of the human with consumer electronics products happens mainly via the interfaces, contribution of ergonomics into consumer electronics design occurs at most in cognitive level which deals with mental activities. The interaction of the human with other reviewed companies' (hand tools and automobile) products takes place at most via the human body itself in which physical interaction is the main issue. Consumer electronics products differ from the other companies' products in terms of integration of ergonomics into their design process primarily in this respect. Depending on this primary difference in hand, the underlying reasons of the poor integration of ergonomics knowledge into consumer electronics design is stated in the fourth chapter as below:

Lack of multidisciplinary collaboration in companies.

Multidisciplinary collaboration, which means integration of different professionals from different departments of the company or professionals from outsourced companies, is inevitable for the product development process of information age. Ergonomics is also one of these professions that needs to be integrated into this multidisciplinary structure of design process. This multidisciplinary work also brings

iterations to the whole process in contrast to the traditional flow. As it is observed in Company X case companies, in the competitive nature of production, companies basically concentrated on time and cost constraints do not want to carry out this iterative structure. Carrying out a multidisciplinary work is perceived as a loss of time and money.

Barriers between the company and end-users. Since consumer electronics industry is dominated with OEM manufacturing, there exist a communication problem between the majority of manufacturing companies and end users. This brings out the lack of required information about the end users. In accordance, the interfaces can not be evaluated properly without the required information on them and the prior evaluation tests with the products being developed.

Interaction problems that technology brings. With the advent of technology, developing multifunctional objects became an easy process by integrating simple electronic devices into products. Since manufacturers are more concentrated on the marketing issues they would like to use it as a marketing tool by producing multi-functional products at lower costs. While carrying this task they are not interested in the usability problems that potential users may have, until they get a negative feedback from them. And unfortunately, it is probable to get no feedback from them until their awareness on the issue is evoked.

Variety in the effects of safety on different product groups. The effects of safety problems that would happen due to the poor integration of ergonomics into the product may occur in different severity levels

depending on the product group. If a hammer or a saw is produced by ignoring its interaction with the hand, it may cause serious physical injury on the user. These injuries may bring out bad reputation for the company or the damage of company identity. In consumer electronics products since the interaction of the user with the product mostly occurs in interface level, as a result of the poor interaction, a tangible injury of the user does not happen.

Lack of awareness. Users usually do not prefer to express the problems that they experience while using an electronic product causing confusion in their mind. Due to their low expectation levels for an interaction with products, users experiencing difficulty in using electronic products usually blame themselves instead of the poor interaction design in the interface of the device. Until the awareness on the issue is not maturated on user's mind they will carry on purchasing and using products having poor interaction with them.

Consistency problem on user's and designer's models. The interaction style of an electronic product is built by its designer. The designer codes the interaction elements and to interact with the product user has to decode these elements. Interfaces are mostly designed by software engineers alone who start the development of interaction by coding the information elements according to their mental model. However, the diverse group of consumer electronics products' users have totally different models than the engineer and a mismatch occurs during the process.

The underlying reasons for the poor integration of ergonomics into consumer electronics design is stated above depending on the evaluated cases and author's own implementations. Awareness about

the issue should be evoked at companies. Accordingly a proposal is prepared below for evoking this awareness about ergonomics as stated below.

5.1 A proposal for Evoking Awareness

As it is stated in Chapter 2 the integration of ergonomics into design process brings time, cost and quality advantages. There are many companies experiencing a great amount of losses in terms of time, cost and quality due to the poor integration of ergonomics into their products. However they still carry on their design activities with this poor integration. The fundamental reasons for this deficiency are stated at the fourth chapter. To cope with these deficiencies as a first and main step, companies should be made aware of and convinced about the positive effects of ergonomics in the design of products. This can be achieved in several ways:

Managers should gain awareness. Since last decision maker at a company is the manager, the key point is to evoke awareness on managers about the positive effects of ergonomics. The key principles of taking attention of managers on ergonomics are:

Introduction and promotion of the profession should be made. It is evident that there is an awareness problem on ergonomics that it needs to be introduced and promoted. The people who will introduce and promote it are the authorized people of the subject area, ergonomists. They should possess their profession and to be able to properly execute their profession they should convince the decision makers in the companies about the advantages that integrating ergonomics into the design process brings. To introduce the scope of

their profession publications can be made about the real life success stories of firms using ergonomics as a tool, introductive meetings can be prepared with the managers and also the people taking part in different parts of the design process, pamphlets, promotional booklets or CDs describing the scope of the profession can be sent to the firms.

Additionally, competitions can be prepared by ergonomics organizations for awarding the firms that are integrating ergonomics in a successful manner. This can make the firms eager to use ergonomics as tool and compete with each other in the scope of these competitions with the other competitor companies.

Customer awareness should be evoked. Managers are at most oriented with the success in the sales of the products, which depends on the customer preferences. These preferences vary with the priorities of customers**.** Accordingly, priorities of the customers become a significant factor on the strategy that the manager would draw for the product cycle. By evoking the awareness of the customer on the positive effects of ergonomics in the interaction between man and product, priorities on customer's mind can be influenced in favor of ergonomically evaluated products. As a result this will influence the strategy of the manager in a chain. The information on the consumer preferences can be obtained by research studies carried at the beginning of a project in the form of focus group studies, interviews and user trials of existing products.

Problems arousing as a consequence of poor integration of ergonomics to the design process should be indicated. This can be achieved by referring to the archives of previous projects, results of user tests on the products, accident data, product recall data and

customer complaints compiled from the web site and services about the use of products. To be able to present the problems related with the poor integration of ergonomics in a convincing manner, the resultant deficiencies that they caused should be emphasized. This can even be the corporate identity of the company, which is a great value.

The profits and losses that the integration of ergonomics into the design process brings should be made concrete. Another way of convincing the managers for the benefits of integrating ergonomics into design process is preparing a data sheet, which explains all the inputs and outputs of this integration with definite numbers in terms of costs and time. This method can cause to reveal the return of the investment on cost and time that is spent at the starting period of the design process for this integration. The cost and time savings can be clearly highlighted as a result of the presentation. The success of the products can additionally be emphasized by user trials.

Ergonomics should be emphasized as a tool for creating differentiation. Companies producing within the similar cost and time advantages, with similar production methods and materials are today looking for tools for creating differentiation on their products. Industrial design is in a wide range used for this purpose by the companies. Ergonomics in conjunction with design can be a more powerful attribute for a product to differentiate between its competitors. The positive effects it brings to the product can be used even as a corporate identity as it happens in Bahco case to emphasize the human factor in company strategy. Additionally it can also be used as an advertising theme. This power of ergonomics as explained above should be made visible for the companies. All these emphasis

enhance the customer awareness and enhanced customer awareness forces the companies for a more intensive approach on ergonomics.

5.2 Further Studies

With this research a general view for the integration of ergonomics knowledge into consumer electronics design is formed. Depending on this general view, a detailed analysis on specific product groups can be carried. This study can start with expert analysis continuing with field tests with the products. This study may result in supporting the claims that are formed as a consequence of this thesis defining the underlying reasons in the poor integration of ergonomics into consumer electronics design.

At the end of the study it is recommended that managers should be persuaded for the concrete benefits of integrating ergonomics into design process. As a complementary study for this research, a design project of a consumer product which will be carried with the required information and support (if needed) from ergonomists can be carried by the author and the differing points of the end product from the previously produced products can be presented to the managers and decision makers of the projects. As a result of the study it can be reported how persuasive the method used is (as it is claimed) and what other methods can be created.

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