Ergonomic Aspects of Product Development and Innovation

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Abstract: Increasing requirements for occupational health and safety emphasize the importance of ergonomics in the development of products and production systems intended directly for human consumption. However, the matter of respecting ergonomic criteria and standards in the product development of mass-produced items is regularly underestimated or even ignored today. A lot of research studies focus on the ergonomic factors of the working environment, but very few researchers deal with product development ergonomics. The aim of this paper is to investigate how seriously ergonomic parameters are considered by designers and industrial innovators developing new products. This study focuses especially on Czech industrial companies, accompanied by several comparisons with other European Union countries. The official statistical data about the actual state of innovation and the aspects of product development most often discussed in the Czech Republic and other European Union countries, as well as the results from the original qualitative investigation within several selected Czech manufacturing companies, are used to gain the required outcomes of the study. The first results proved that ergonomic analysis is not automatically a part of each innovation project for new product development. In view of this fact, respondents were asked to explain why the question of respecting ergonomic criteria is so often underestimated or even ignored during the product design phase. The paper also reflects the most important standards, norms and government regulations in the field of ergonomics that are valid in all the European Union countries.

Keywords: ergonomics, ergonomic factors, innovation, product design, product development

1. Introduction

The increased availability of various technologies and products in the 21st century means that more and more people come into contact with many different product designs every day. On the other hand, each product needs to provide a sufficient fit for many different types of human users. Kutz (1998) found that many engineers concentrated their design efforts on the technology, machine or system alone, forcing the user to adjust to fit to the product. Unfortunately, the situation has not changed very much since that time. This approach can lead not only to discomfort and dissatisfaction with the product design, but also to safety hazards, personal injury or chronic disease.

Kotler & Keller (2011) define a product as any material goods, service or idea used for the satisfaction of people's needs. In this paper, a product is understood as material goods, and more specifically material goods intended directly for human use. Each product has its own life cycle which consists of several phases (Fig. 1). Liang (2013) defines the life cycle through a model depicting various stages of sales, from introduction, through growth and maturity, to decline and withdrawal from the market. Some authors include market research, product design or other potential phases in the product life cycle construction. Product design and development represents one of the earliest phases in all product life cycle concepts.

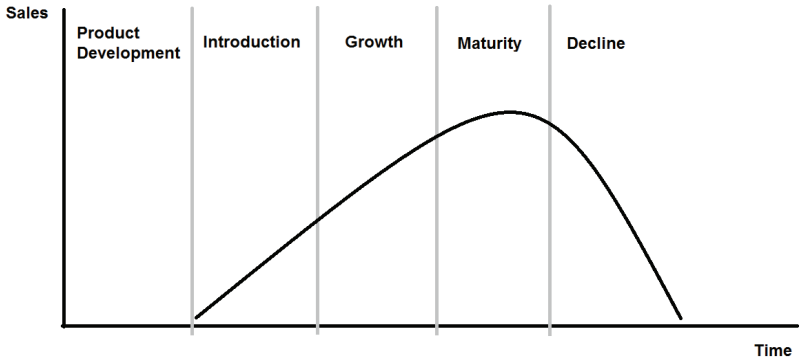

Figure 1: Simple product life cycle modified by Kotler & Keller (2011)

The main role of product design is to solve both function and form of developed product and study the relationship between a product and its future users. The National Academy of Engineering (Pearson and Young, 2002) confirms that despite the fact many products for customer use promise to make their lives easier, healthier or more efficient, they do not really deliver on this promise. The development of consumer products and the application of the principles of human factors, ergonomics and consumer research in industrial design represent one of 20 main subject interests of the Technical Groups of the Human Factors and Ergonomics Society, which deals with human factors in various areas such as the aerospace industry, communications, computer systems, education, and so on (Salvendy, 2006).

The importance of the human and human physical and psychological needs is still growing. In particular, large production companies have to adapt their production processes and factory equipment to the human body's proportions in order to ensure higher productivity and better health for employees. The scientific discipline which makes the user central to design and tries to improve the interaction between the user and his working environment, tools used daily and equipment is called ergonomics. Karmis (2001) discussed the importance of ergonomic design in the mining industry, where work conditions are still among the most hazardous of all occupations. He pointed out that mining equipment very often suffers from poor ergonomic design, which leads to many safety risks. Al-Zuheri, Luong & Xing (2010) presented the same opinion in their analysis of basic problems of poor ergonomic design in manual assembly work.

A lot of researchers (Duffy, 2011; Roth, 2011; Specter, 2012; Gobel and Zschernack, 2012) deal with ergonomics from the viewpoint of the working environment and safety risks in production processes. However, there are a very few authors who deal with the ergonomic aspects of products for daily human use (not just in relation to working area). A very interesting study in the field of ergonomic design was provided by Du, Zhang Yang and Zhuang (2008) who proposed an idea and the implementation of an intelligent design system integrating ergonomic aspects into industrial design. Their proposal includes a detailed procedure of ergonomic design and verification-evaluation based on 3D modelling features. Another model for improving the safety and ergonomics of developed products was introduced by Robert et al. (2012). This model is focused on mechanical products and uses biomechanical simulation to appreciate the impact of the product on users' health. It is a very useful tool which can be transferred to other areas to help improve the quality, safety and ergonomic parameters of newly developed products.

Each company has to observe a number of government regulations, which also include some required ergonomic parameters of their production processes. The most important are briefly discussed in one of the following sections of this paper. These increasing ergonomic requirements for production processes cause increasing requirements with regard to machines and other equipment used in the working process. In this case, the ergonomic requirements for developed products are automatically contracted out to suppliers by customers (production companies). In the case of other products for human use, the inclusion of ergonomic aspects into product design and development activities is still not so obvious, as was found in the results of the qualitative study used in this paper.

2. Methodology

The methodology used for this study is a combination of primary and secondary research methods. In the first part, the author presents some official statistical data about the actual state of innovation and the aspects of product design and development most often discussed in Czech Republic and other European Union countries. Then some basic Czech and European Union regulations in the field of ergonomics are briefly discussed with regard to product design and development. This first part of the study is based especially on the official statistical resources of various government or private statistical organizations and information from several standardization institutions, Czech ministries and EU government sources. Basic overview of the most important regulations in the field of ergonomics that must be respected by all production companies in Czech Republic and other EU countries are discussed in one of the following parts as well.

The second part of this study focuses only on Czech manufacturing companies. It is based on a qualitative investigation that was realized in two ways:

- as an analysis of published case studies and articles; and
- as an in-depth interview with industrial innovators, developers and designers of five selected companies.

All findings are briefly discussed in the concluding section. The main goal is to find out how seriously the ergonomic parameters are considered during the development and design process and explain the main problems that make this question so difficult.

3. The actual state of innovation in Czech Republic and other European countries

The main source of information used for studying innovation drivers, expenditures, objectives and other aspects of innovative enterprises at European level is the Community Innovation Survey which has been conducted every second year since 2004 by Eurostat (Eurostat, 2013). The latest available survey, the data of which were used in this paper, covered three years and ran from the beginning of 2008 to the end of 2010.

The overall turnover from innovation in EU countries (EU27), which is calculated as the ratio of turnover from products new to enterprise and new to the market, varies between 17 and 19% of total turnover every year. The situation in Czech Republic is very similar or a little better in some years (Eurostat, 2013). Table 1 provides a basic overview of expenditures on process or product innovation in Czech and European Union (EU27) innovative enterprises, i.e. enterprises that implemented product or process innovation in 2010. Data are classified by type of expenditure in percentage of the total innovation expenditure.

Table 1: Expenditures on innovation in Czech and European innovative enterprises in 2010 (Eurostat, 2013; CSU, 2013)

	Czech Republic	EU27 (excluding United Kingdom and Greece)
Total innovation expenditure in million EUR	3,243	237,761
Acquisition of machinery, equipment and software (%)	50.9	46.0
Acquisition of external knowledge (%)	4.1	3.8
Purchase of external research & development (%)	20.7	13.1
For in-house research & development (%)	24.4	37.1

In comparison to the majority of European countries, Czech innovative companies' expenditure on the purchase of external research and development services was higher in 2010. On the other hand, Czech companies spent less money on in-house research and development than most European countries. However, more interesting data are included in the following table (Table 2), which shows highly important innovation objectives in Czech and European innovative enterprises that were investigated between 2008 and 2010. The values are given in percentages of the total of innovative enterprises included in the study.

Table 2: The most important innovation objectives in Czech and European innovative enterprises and their share in percentage (Eurostat, 2013; CSU, 2013)

	Czech Republic	**EU27**
Increasing range of goods or services	49.2	50.9
Replacing outdated products or processes	31.9	37.7
Entering new markets	33.0	45.7
Improving quality of goods or services	44.7	54.7
Improving flexibility for producing goods or services	27.7	34.1
Increasing capacity for producing goods or services	24.2	32.6
Improving health and safety	16.1	27.0
Reducing labour costs per unit output	25.0	27.6
Reducing material and energy costs per unit output	19.0	24.3
Reducing environmental impacts	15.1	23.0

It is quite surprising that only 16% of Czech respondent companies mentioned improving health and safety as an important innovation objective. According to the table (Table 2), it is the second least often considered innovation objective in Czech Republic and the third least often considered innovation objective in European Union countries. Despite the fact that these results are not very optimistic, we cannot definitely state that ergonomic parameters are not included in other objectives, such as improving quality of goods or replacing outdated products or processes.

4. The actual state, evolution and valid regulations in the field of ergonomics in EU

In 2005, the European Agency for Safety and Health at Work completed four expert forecasts to anticipate new and emerging risks (physical, chemical, biological and psycho-social risks) related to occupational safety and health (EU-OSHA, 2010) in working process. Their data analysis showed that working conditions with respect to ergonomic aspects are poorer for machine users who are more affected than other workers by various negative factors such as vibration, high noise levels or having to exert high dynamic and static forces. These negative working conditions are often caused by poor ergonomic design of machines and other working equipment, which can also raise some associated problems such as user frustration, poor corporate image, higher financial costs associated with wasted working time, etc. As Dahm (2006) notes, poor ergonomic design of any product that leads to client dissatisfaction very often results in lost sales and damaged company image.

All Czech or European standards and regulations in the field of ergonomics concentrate on machinery, working conditions or safety and work efficiency. European ergonomic standards are defined by the European Standards Committee (CEN TC 122) and include dozens of partial ergonomic and safety standards. The most important families of harmonized standards developed by CEN TC 122 are (CEN):

- EN 1005 – deals with the safety of machinery, human physical performance, force limits for machinery operation, working postures and movements in relation to machinery.
- EN 547 – provides human body measurements and anthropometric data for determining the dimensions required for whole-body access to machinery or for access openings.
- EN 614 – this standard includes and describes basic requirements for safety of machinery as well as the ergonomic design principles for creating new workplaces.
- EN 894 – defines ergonomic requirements for the design of displays and control actuators.
- EN ISO 14738 – includes anthropometric requirements for the design of workstations and machinery; it combines some aspects of families EN 547 and EN 614.
- EN ISO 7731 – deals with danger signals for public and work areas.
- EN ISO 7250 – is the most general standard useful for the product design and development area, as it describes basic human body measurements for technological design.

All European ergonomic standards mentioned above, as well as many others not mentioned in this paper, are generally accepted by individual European Union countries. Czech Republic included these standards into its legislation under the name starting with “ČSN EN” what means “Czech State Norm based on European Norm”. However, Czech legislation includes also some other regulations and government orders focused on safety and ergonomic problems. The most important of them are (Bureš, 2013):

- Government announcement no. 432/2003 Sb., which defines conditions for classifying individual jobs into four risk categories.
- Government order no. 361/2007 Sb., which defines basic requirements for occupational health and safety.
- Government order no. 272/2011 Sb., which describes requirements for reducing adverse effects of high noise and vibrations.
- Government announcement no. 288/2003 Sb., which defines weight limits for special groups of workers, such as pregnant women, young people, seniors, etc.

5. Results from the qualitative investigation within Czech manufacturing companies

As was explained in the previous section, the qualitative investigation was conducted in two steps. Firstly, a basic overview of previously published case studies and official company presentations was undertaken to understand the basic state of ergonomics in the field of product design and development. It was found that the use of ergonomic principles in the phase of product design and development is obvious these days, especially for companies producing medical devices, high-quality furniture or industrial machines and other equipment used in production processes (Figure 2). These organizations have even integrated respect for ergonomic principles into their business strategies and use it as a competitive advantage and a publicity tool.

The sample of this first part of the qualitative study included 70 manufacturing companies that declared somehow including ergonomic principles into their product design and development activities. All these

companies were classified into several groups according to their size and business area in order to better understand the relationship between the consideration of ergonomic design and selected variables defining the company. For the purposes of this study, the general European size classification was used. According to this classification, an enterprise with more than 500 employees is classified as large, one with between 50 and 500 employees is considered medium-sized and a small company has between 10 and 50 employees. Micro enterprises (enterprises employing fewer than 50 people) were not included in this study.

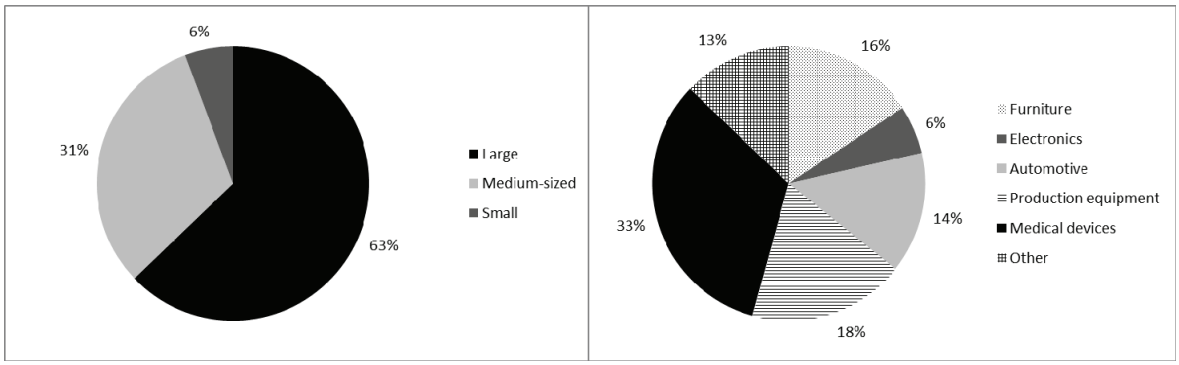

Figure 2: Companies implementing ergonomic principles into product design according to size and business area (author's own)

The basic overview of the actual state of ergonomic design in Czech companies shows (Figure 2) that ergonomic parameters in product design and development are most often considered by large and medium-sized enterprises. Of all investigated companies which declared that they considered ergonomic principles in product design, only 6% came from the small-enterprise segment. The main reasons for these results are more deeply discussed in the second part of the qualitative study.

There are still a lot of other companies producing various items for people's use that do not respect ergonomic requirements during the product development phase. Therefore, in-depth interviews with industrial innovators and designers were conducted in five selected companies in order to find out the reasons of this and to discover their own experiences with ergonomic principles. The sample included manufacturing companies from various areas. With respect to the fact that all respondents wished not to be named, only their business areas can be stated in this paper:

- company A: medium-sized producer of stadium seats
- company B: small producer of safety belts
- company C: medium-sized producer of wooden chairs
- company D: medium-sized producer of power saws
- company E: small producer of musical instruments

Four of the five interviewed companies confirmed that the question of ergonomics is not considered during the product development phase. There are several reasons for this. Unfamiliarity with state regulations and recommended ergonomic properties of products for human use was considered the most serious. Almost the same importance was given to the lack of financial resources for purchasing high-quality research and development services that can solve this problem. Two of the interviewed companies do not even employ a designer; all new designs are done by production managers or workers. The respondents also noted that these two major problems are common for almost all small manufacturing companies and for a lot of medium-sized companies.

Respondents confirmed that their products meet all necessary safety standards (especially in the field of safety belt production, where these standards are very strict) and their designers take care over the aesthetic design of developed products to satisfy high customer needs. However, they also admitted awareness of advanced ergonomic standards is very poor.

The only positive exception is company C – a producer of wooden chairs. During the interview with company representatives it was found that the company respects high ergonomic requirements for final products and the question of ergonomics is taken seriously not only in the product design and development phase, but also

throughout the whole production process. The company confirmed that this strategy has brought them some kind of competitive advantage and their products have been more successful since ergonomic requirements were implemented into the product design.

According to the proven results, respecting ergonomic criteria in product design and development can bring companies some competitive advantage, and this does not have to be expensive. Companies do not need to invest a lot of money into research and development: the knowledge of basic ergonomic standards and regulations (which are usually available free of charge) is sufficient.

6. Conclusion

The paper was focused on ergonomic aspects of product design and development, which were analysed from several viewpoints. It was found out that companies producing products for human use (as opposed to use in production processes) usually do not respect any ergonomic parameters because they often do not have any knowledge about these regulations, as was proven during the conducted interviews. Therefore the main goal of the author's next research activities is to create a simple, understandable and complex methodology which should help to simplify the process of implementation of ergonomic principles into product design and development activities. This methodology should provide also a basic overview of important ergonomic standards and regulations that should be respected by all companies producing product for daily human use.

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