PRACTICE OF ERGONOMICS

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Introduction

Recurring interest is indicated by the fact that more and more books on ergonomics are available these days. **Ergonomics Check Points 2.0** is a volume issued in a joint effort by IEA and ILO to update a thirty-year old publication, presenting worksite ergonomics in a clear and plain manner.

Major works include the Ergonomics textbook edited by Lajos Izsó and Károly Hercegfi, presenting various areas from the broad palette of ergonomics as an introduction primarily for students involved in technical higher education in accordance with the ergonomics education concept in Hungary at the millennium.

There is a wide range of printed ergonomics textbooks for English speaking students, e.g. *Fitting the Human: Introduction to Ergonomics* by Karl H.E. Kroemer or *Introduction to Human Factors and Ergonomics for Engineers* by Mark R. Lehto and Steven J. Landry.

It is generally accepted that ergonomics can be learned from books as well. However, it is worth mastering in practice, therefore printed and electronic workbooks, sets of tasks or project specifications have been issued for all training courses and are included as compulsory tasks. Completing all the *Ergonomics Laboratory Exercises* required by Timothy Joseph Gallwey and Leonard O'Sullivan is a very good challenge for future ergonomist.


Self-study is assisted by practice tasks and internet sources at the end of each chapter. It is deemed important to support the mastering of knowledge available in the Ergonomic checkpoints, so attention is called to connections therewith at the end of each chapter.

There are several case studies at the end of the textbook. This selection presents an abundance of assignments in ergonomics in Hungary in the past two decades.

Warning: Downloading and possessing the textbook file does not equal to mastering this knowledge. Studies need effort, but the examples and tasks presented are expected to be interesting, sources to be found individually will be interesting, and learning will be a pleasure.

Enjoy!

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Chapter 1. Definitions

Ergonomics (or human factors) is a science involved in the interaction of people with other system components and is a profession to apply theories, principles and methods in design in order to optimize human well-being and overall system performance.¹ In other words, ergonomics is an interdisciplinary science and a practical field engaged in matching the physical, cognitive and social aptitudes of people with the man-made environment.

Joint regulation on musculoskeletal risks is under way in accordance with the EU Community strategy for health and safety at work², expected to give a new impetus to apply ergonomics for work.

The terms ergos (work) and nomos (laws) were contracted by W. Jastrzerbowski in the mid-19th century. Ergonomics is a system-centered science and practice covering all areas of human activities, and taking into consideration physical, cognitive, social, organizational, environmental and other determining factors with a comprehensive approach. Areas of application are not independent from each other: new ones are created and old ones are transformed according to new vistas.

Major areas of ergonomics:

Physical ergonomics deals with the connections between human physique, dimensions, physical and biomechanical properties and physical activities, including posture during work, manual materials handling, repeated movements, work-related musculoskeletal disorders, worksite arrangement, health and safety.

Cognitive ergonomics deals with cognitive processes – sensation, perception, remembrance, thinking, reasoning – as well as the design and execution of motor responses, and the impact of all these on the connection between people and other system components. The latter includes mental stress, decision making, human-computer interconnections, human reliability, stress at work, and the impact thereof on the design of human-machine systems.

Organizational ergonomics deals with the optimization of socio-technical systems consisting of people cooperating with each other and interacting with complex technical equipment, including organizational structure, guidelines and processes. This area comprises corporate communications, human resources management, work planning and scheduling, team work, involvement of employees in development, community ergonomics, collaboration at work, new types of work, virtual organizations, telework, and quality assurance.

• Main focus of ergonomics: it is intended to take human beings into consideration in the design of man-made objects, establishments and the environment, to be “used” by humans in various fields of life.

• The objective of ergonomics is twofold in respect of the design of artificial objects, establishments and the environment: on the one hand, to increase the functional efficiency of human use; and on the other hand, to preserve or develop certain human values (e.g. health, safety and satisfaction) during this process. The latter objective is fundamental for human well-being.

• The central approach of ergonomics involves the consistent application of relevant knowledge with reference to human features and behaviors in the design of objects, establishments and the environment used by people.

Modern ergonomics dates back to World War II. As a result of technical development, the areas of research are expanding; new challenges by technical developments trigger new tendencies in research, while focuses shift in already established areas and they may even be transferred to other fields of science, such as human resources management, marketing, and quality assurance.

In the period of classic ergonomics, safe and efficient cooperation between the machine operator and the machinery (first: fighter planes) had to be achieved, as requirements to manage the technology temporarily surpassed human capabilities, given the level of support determined by the current standards of technology.

By applying a systems approach, a system component called “man” was identified, and it turned out that man was difficult to manage by methods proven in technical practice. The study and modeling of this system
component enabled the investigation and systemization of environmental effects (noise, lighting, climate, air quality) and social factors in the development of systems ergonomics.

As a result of automation, increased market potentials and globalization, the operations of ergonomics – a systematic adjustment of man and the environment – is extended to everyday life including product design.

The spread of informatics (and telecommunications) has brought about life situations – computer use inconceivable earlier on – in which the human-machine connection typically requires cognitive adjustment, giving rise to information ergonomics.

A dominant trend in the 1990s was the risk-based approach: workplace risk management gained ground accordingly. Risk-based ergonomic development programs mainly focused on tackling cumulative motion disorders (including Work Related Musculoskeletal Disorders, hereinafter: WMSD's; Cumulative Trauma Disorder, hereinafter: CTD; Repetitive Strain Injury, hereinafter: RSI), particularly important in assembly works, working with computers and manual materials handling.

After the millennium, easy mastering of ergonomics (only involving linguistic barriers) started to dominate, including the presentation and pursuit of best practices, mastering of knowledge on ergonomics, and familiarization with instant solutions for given problems, for ergonomic guidelines and (standard) assessment sheets, for conducting both individual surveys and complex ergonomic programs. It is essential that various IT applications for ergonomics and the ergonomics modules of design systems make it possible to make immediate use of knowledge and skills.

The Human vs. Machine system is the subject matter of ergonomics in a narrow sense, while the complete Human vs. Machine vs. Environment system is the field of research of ergonomics in a broader sense. Consequently, the area of ergonomics in a broader sense partly overlaps, by nature, with occupational health, labor psychology and certain parts of management science. In spite of this partial overlap of subject matter, however, ergonomics is distinguished from these interdisciplinary sciences by its specific approach even if it applies methods partly identical therewith.

Ergonomic challenges today include an aging society – work at an older age, redefined career path models –, management of vulnerable groups – e.g. rehabilitation to work – and mental well-being.

The system concept is one of the fundamental notions of ergonomics in design and evaluation. It deals with intra-system human interactions between man and other system components. As an example, Figure 1 shows a simple model of the human vs. machine system, presenting man and machine as parts integrated into the system. Through sensory organs, man gets information on the status of the machine and the process controlled; processes this information (considers it in view of objectives and expectations); and changes the system by executive organs (e.g. hands, legs, voice). This model can also be used for illustrating the man vs. man interaction when the machine component is replaced by a second person. It is important to keep in mind, however, that systems are rarely designed for individuals, rather for one or more target groups or populations.

As shown in the figure, there are inputs (e.g. information, energy, material, etc.) coming from sources outside the system and transformed into outputs (e.g. products or information) by the system. Man and machine exist in the same spatial environment as already indicated. Furthermore, the spatial environment exists in a physical and an organizational environment. In addition, social, legal and cultural environments also potentially affect system operation.

![Figure 1. Example of a man-machine-environment system according to ISO 26800](image-url)

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ISO 26800:2011 Ergonomics - General approach, principles and concepts
Today, new research or intervention prospects appear in ergonomics, which are based on the idea of sustainable prevention (mainly of musculoskeletal disorders), of eco-design, of the integration of environmental concerns in the whole life cycle of the product. Ergonomics, which relies on proved concepts allowing the design of safe work systems, is more and more required to contribute to the design of life and work systems allowing a responsible and environmental caring use. In this frame, several questions appear, such as:

How is it possible to pass from an oriented ergonomics prevention to an ergonomics oriented towards the anticipated management of the consequences of work on the human factor?

In which conditions the basic concepts of ergonomics may contribute - directly or due to which adaptations –to the sustainable development?

Is it possible to have as a project the ergonomics of the sustainable development or «eco – ergonomics»?

1. Outlook

In order to master this chapter, solve the following tasks:

• Name a system in a human-related situation, identify its subsystems and outline their interconnections.

• Consider which areas are most in need of planning by taking human properties into consideration.

• Use the Internet to find training locations in Europe where a PhD degree in ergonomics can be attained.

Visit the following homepages:

• http://www.iea.cc/index.html

• http://www.fees-network.org/

• http://www.eurerg.org/

• http://www.iso.org/iso/home/store/catalogue_ics/catalogue_ics_browse.htm?ICS1=13&ICS2=180

• http://www.cen.eu/cen/Sectors/TechnicalCommitteesWorkshops/CENTechnicalCommittees/Pages/Standards.aspx?param=6104&title=CEN/TC%20122

• http://en.wikipedia.org/wiki/Ergonomics
Chapter 2. Ergonomic testing methods of worksites

Methods, many times appearing accidentally, following translation or adaptation, are not necessarily suitable for the quality (and quantity) assessment of ergonomic risks at specific levels as expected, even if potentially in the hands of properly prepared specialists – on the basis of regulatory or professional considerations, as even the selection of a method is a special task.

In an ideal case, experts make their choice of the methods available on the basis of possible applications and the aim of study. It seems that – in respect of costs, capabilities, versatility, generality and accuracy – general, observation-based assessments suit occupational health and safety specialists the most as they need to determine priorities for action plans by using limited resources within a limited timeframe.¹

Numerous methods can be used for assessing physical strain, the rare ones include flow measurements, force measurements or computerized modeling. Methods used for screening attempt to evaluate posture, exertion, and repetition frequency at the same time, supplemented by some environmental and load parameters.

A number of screening / problem identification methods to assess ergonomic risks have spread in Hungary in the course of the past few decades, e.g. the checklist by the International Labour Organization (ILO)², REBA³, RULA⁴, MAC⁵, the NIOSH modified lifting equation⁶, BRIEF⁷, QEC⁸, JSI (JOB Stress Index)⁹, etc.

As regards methodological cases, it is important that there is a consensus based on statements by summary studies of an epidemiological approach that work-related musculoskeletal disorders affect the neck, the shoulders, the elbows, tendons, the hands / the wrists and the back.¹⁰

Similarly, in a generally accepted manner, work-related physical risk factors held responsible are linked to disorder groups according to regions of the body:¹¹

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<td>• manual materials handling</td>
<td>• repetition</td>
</tr>
<tr>
<td>• frequent bending and twisting</td>
<td>• force</td>
</tr>
<tr>
<td>• heavy physical loads</td>
<td>• repetition and force</td>
</tr>
<tr>
<td>• static work</td>
<td>• repetition and cold</td>
</tr>
<tr>
<td>• whole body vibration</td>
<td>• vibration</td>
</tr>
</tbody>
</table>

Figure 2 shows factors to affect the risks of cumulative locomotor disorders in the system set out by manual materials handling regulations of Australian member states\textsuperscript{12}. Fundamentally the same risk factors appear in US and EU regulations as well, including Directive 90/269/EEC - manual handling of loads on the minimum health and safety requirements of manual load moving.\textsuperscript{13}

Figure 2. System of factors to affect the risks of work-related musculoskeletal disorders

1. Conclusions

Hundreds of ergonomics methods are known and classified in the literature based on

- Hundreds of ergonomics methods are known and classified in the literature based on validity (by specifying a level);
- usability;


\textsuperscript{13}\textit{ Directive 90/269/EEC} - manual handling of loads
Ergonomic testing methods of worksites

- benefits / drawbacks,
- popularity (among specialists);
- demand for implements (paper and pencil, web, xls, CAD, etc.);
- practice / training required (up to certification);
- legal / standard history (obligatory or recommended by law or regulatory requirement);
- language availability (in how many languages it is accessible);
- type of result (quality / quantity);
- part of the body (a given part of the body or the entire body);
- area of application (industry);
- developing institution;
- lifetime (how long it is used).

The pattern arising from the analysis of the most frequent ergonomics assessment methods can be interpreted as a development process driven by IT developments.

Former ergonomics analysis tools included paper-and-pencil checklists or evaluation sheets containing simple calculations, tables, and human figures. Standard IT tools were used to translate these methods onto web interfaces, automatic or operable worksheets or documents; this enabled more sophisticated calculations.

With the development of CAD systems, environment and human modeling came to be an integral component of design processes as advanced biomechanical models and detailed anthropometric databases enabled designers and experts to perform detailed ergonomics analyses.

In management research, advanced technologies are applied such as posture analysis based on imaging, 3D imaging, mobile, portable wearable devices, virtual reality or remote presence. These new technologies not only seem to facilitate the application of methods based on our current knowledge but they also open up new vistas, enabling a reconsideration of the methodological bases of work-related musculoskeletal risk assessment.

2. Expert inspection (broken down by worksites)

The analysis is based on an expert walkthrough where checklists (e.g. Ergonomic checkpoints) can be used. This is followed by video recordings of the work activity by involving the ergonomics team and taking a video recording methodology into account. Later analyses will be primarily based on such recordings, but many times it may be necessary to specify data in order to identify recordings and to determine production volumes and mass data. Taking activities as a starting point, several worksites can be analyzed or a number of different activities can be analyzed individually in respect of the same worksite.

3. Employee survey

An employee survey is generally performed by a comprehensive anonymous questionnaire to be filled in by employees individually. Questionnaires returned are processed in respect of each area by statistical and text analysis methods. Answers can be broken down according to demographic (e.g.) or organizational (e.g. unit) variables when relevant statistical tests demonstrate significant differences.

The results of employee surveys are discussed with both the ergonomics team and at management workshops as well. Areas investigated typically include:

- general questions;

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Ergonomic testing methods of worksites

• questions on individual workstations;
• materials handling;
• postures;
• questions on safety;
• questions on tools;
• noise, temperature, air, lighting,
• physical and psychic complaints,
• broader environment,
• aggregated questions.

4. Discomfort assessment sheet
This method is to get to know, to prevent and to forecast work-related physiological deformations. After some initiation, employees can fill it in themselves, but it can also be used by way of questioning them. If recorded at the same worksite with different employees at regular intervals, it yields results suitable for statistical evaluation.
Figure 4. Discomfort and pain assessment sheet of own development
As a first step, employees are to indicate the parts of the body where they feel pain or discomfort on a human figure at the end of the shift. Then they are to evaluate the rate of discomfort on a three-grade scale in respect of each part of the body as follows:

1: no feeling of discomfort
2: a bit inconvenient
3: very inconvenient

By aggregating the parts of the body indicated for each worksite and by the statistical analysis of numerical evaluations, you can get an idea of the impacts of the physical design of the workstation concerned. Symptoms identification is to be followed by exploring the causes and corrections.

As an application example, a survey involving 450 subjects was conducted in 2003 by using this method; the results displayed in the figure also illustrate the benefits of alternating postures during work as opposed to standing or even sitting. The darker is the coloring of a region, the more frequent, the more intensive and the more disturbing is the discomfort or pain ascribed to work in employees’ judgement.

In order to present results figuratively, our "stick" method developed earlier was used for highlighting postures. The method essentially involves the linking of major joints in worksite photos to highlight postures. The lines make postures stand out from the pictures: they help recognize wrong postures and enable specialists to develop their approaches and problem detection skills in the long run.

5. Stick method
Figure 7. Example of wrong posture, "stick"

Figure 8. Bad posture with exertion
6. Ergonomic applications of pressure distribution testers

Various physical loads can be identified during work between employees and the environment, the object of work or the tools used. An external impact (pressure) is produced in a contact area identifiable on the surface of the body, typically on the hands (fingers and palm) and it spreads through the musculoskeletal system towards another impact, body support, typically the soles and the buttock. In addition, anything to contact the surface of the body can act as a source of external physical load, including working clothes, personal protective equipment, tools worn on the body, and the workpiece (on the shoulders, on the head, held against the body).

As a consequence of local pressure, various occupational diseases can develop in line with the formations in contact or exposed to pressure, depending on the personal characteristics of individual employees.

Extremely intensive, short-time impacts of small extension can include stabs or cuts leading to various types of injuries. In the following, only those loads will be discussed which are basically spread over large surfaces, and their impact is considerable precisely because of their permanence.

If joints are permanently exposed to great loads, that is, in case of chronic overload, the cartilage of the load surface will extenuate. As a result of loosening on the one hand and the prolonged deterioration of the joint capsule and the ligament system, on the other hand, inflammation will develop at the stem or insertion of the ligaments. Ossification – “calcification” – occurs in the inflamed section: these osseous deposits at the perimeter of the ligaments are called osteophytes. In a work environment, this can be caused by pinching (tight) working clothes (shoes) or protective equipment, as well as by holding tight transported objects pressed against the body, or by their weighing heavily on the shoulders.

Bad footwear does not help distribute pressure on the sole from hard workspace surfaces; it does not assist in keeping the legs in a physiological position. As a consequence, the ligament system and the joints of the legs can get chronically overloaded, and the arch of the foot can subside and flatfoot can develop. In case of prolonged loads, leg joints can also be afflicted by arthrosis and arthritis and osteophytes can emerge. One of the consequences of transversal arch collapse can be bunion (Hallux valgus) development, when the base phalanx comes to protrude (typically on the opposing side) due to a pathological deflection of the big toe.

Physical risks are specified in accordance with the nature of the work to describe loads. Methods discussed earlier sometimes take load distribution or the way of manual grasp into consideration, but essentially they are insensitive to load (pressure) distribution along the contact surface. Many times, however, load distribution plays a decisive part in causing injuries and disorders: knowledge thereof makes further hazards more understandable.

The simultaneous use of several pressure gauges makes it possible to thoroughly examine the force exerted in the use of tools, machinery operation, and manual materials handling.

Tools, clothes, protective equipment, workpieces, etc. contacting the body exert a complex impact. Occupational safety risk analyses primarily focus on the scale and time of the force impulse. As a local impact, an external force means a load on the given area characterized by the following:

- unidirectional pressure;
- permanence (duration), time;
- friction and shearing stress;
- surface injury;
- temperature (heat);
- moisture;
- other (e.g. presence of chemicals).
Several solutions have been developed for the accurate detection of load and pressure conditions. Initial (e.g., balloon) pressure gauges, performing measurements at a single point (in a relatively small area) have been followed by many generations of pressure distribution testers.

Objectives of pressure distribution testing at worksites:

• to reduce risks arising from body support;
• to describe in more detail and to reduce exertion;
• to find out and reduce the risks of "wearing".

By the use of pressure distribution testers for ergonomics purposes, the pressure distribution impacting the person concerned can be made visible\(^\text{15}\); our objectives within this framework:

• numerical display of the pressure distribution of high-pressure areas, e.g. in Hgmm;
• survey of pressure distribution along the entire area exposed to pressure;
• comparison of various ways of support based on pressure distribution;
• comparison of various strategies to reduce pressure (e.g. leaning forward / fidgeting while sitting);
• evaluation of different mechanical solutions (e.g. slant of seat pan);
• following changes through time.

Features of pressure distribution testers:

• provide posture-dependent and relative data;
• render a graphic display;
• collect a lot of information rapidly;
• can perform individual or continuous measurements;
• only measure the vertical pressure component;
• absolute pressure figures in themselves can be misleading;
• pressure figures can be influenced by the device itself, e.g. a crumpled cushion can cause pressure peaks.

The sensors fixed on the glove can describe exertions by the hand in the tenth of a second breakdown. In special cases, sensors can be fixed on the tool itself. This testing device:

• can specify loads;
• helps identify optimal modes of operation by comparing work performed using various methods by a number of employees;
• enables to select the optimum design, grasp, and arrangement based on the figures;
• enables the monitoring of values to master an optimal working method.

\(^{15}\)Hobson, Douglas A. (1999): Principles of Pressure Management, RERC on Wheeled Mobility, Department of Rehabilitation Science and Technology, University of Pittsburgh, September 1999.
Figure 10. Force distribution measurement on the tool

7. Manual Handling Assessment Chart

Manual Handling Assessment Charts (MAC)\textsuperscript{16} can be used for assessing risks in cases of lifting, transport and lifting in groups, by taking into consideration the modifying factors also included in the NIOSH modified lifting equation.


Figure 11. Example of the xls implementation of the NIOSH modified lifting equation

8. Job Stress Index

The Job Stress Index (JSI) can be applied in case of repeated work activities to survey the risks of work-related musculoskeletal disorders caused by cumulative stress.\textsuperscript{17}

Basic JSI data:

- Intensity of Exertion, IE
- Duration of Exertion, DE
- Efforts / Minute, EM
- Hand / Wrist Posture, HWP
- Speed of Work, SW
- Duration per Day, DD


Basic data are always specified along a five-grade scale; the index is calculated using the following formula:

$$\text{JSI} = \text{IE} \cdot \text{DE} \cdot \text{EM} \cdot \text{HWP} \cdot \text{SW} \cdot \text{DD}$$

JSI is interpreted by the following standard:

- if the score calculated (JSI) is smaller or equal to 3, then work is safe.
- if the JSI score is between 4 and 6, the probability of work-related musculoskeletal disorders of the upper limbs is medium.
- if the JSI score is 7 or over, the probability of work-related musculoskeletal disorders of the upper limbs is high.

Animation 1: Napo
9. Rapid Entire Body Assessment

The Rapid Entire Body Assessment (REBA) method is a problem detection tool to identify the presence of ergonomic hazards at the worksite concerned in the course of repeated physical work.\textsuperscript{18}

In order to present this method, the figures below show the REBA assessment sheet, explanations to help evaluate the position of the trunk, and definitions of level of action.


![Figure 12. Example of REBA assessment: trunk scores](image)

<table>
<thead>
<tr>
<th>Level of action</th>
<th>REBA score</th>
<th>Risk level</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Negligible</td>
<td>Needless</td>
</tr>
<tr>
<td>1</td>
<td>2-3</td>
<td>Low</td>
<td>Can be necessary</td>
</tr>
<tr>
<td>2</td>
<td>4-7</td>
<td>Medium</td>
<td>Necessary</td>
</tr>
<tr>
<td>3</td>
<td>8-10</td>
<td>High</td>
<td>Required in the near future</td>
</tr>
<tr>
<td>4</td>
<td>11-15</td>
<td>Very high</td>
<td>Prompt intervention required</td>
</tr>
</tbody>
</table>

Table 1. REBA levels of action

10. Rapid Upper Limb Assessment

Main features of the Rapid Upper Limb Assessment (RULA)\textsuperscript{19} method:

- A rapid analysis method to investigate worksites from the ergonomics point of view based on MSD reports.
- A filtering tool to analyze biomechanical and posture load impacts on the entire body.
- It focuses on the neck, the trunk and the upper limbs; it is ideal for sitting work, e.g. IT workstations.
- Quick and easy to fill in.

• RULA scores indicate the importance of actions required to reduce the risk of MSD.

• Aligned with other ergonomics systems.

• RULA assesses posture loads at a specific moment of the work cycle. It is essential to assess the posture with the highest hazard. It requires preliminary observation to select the appropriate section of the work cycle.

• The posture with the highest hazard can be selected on the basis of the duration of the posture (e.g. the longest holding) or the level of discomfort of the posture (e.g. work position).

• The left and the right side of the body must be examined independently.

• In case of a long work cycle, the posture needs to be examined at regular intervals.

• If the analysis is performed in several postures during the work cycle, the proportion of the time spent in such position must be taken into consideration.


**11. Outlook**

Study the following Ergonomic checkpoints:

• Materials storage and handling (checkpoints 1–17)

• Workstation design (checkpoints 51–63)

In order to master this chapter, solve the following tasks:

• Find a web-based method on the Internet which is suitable for assessing the appropriateness of pushing or pulling (e.g. a trolley).

• Select physical jobs in your environment and propose a method for their assessment.

• Search the Internet for ergonomics measurement equipment.

Visit the following homepages:

• RULA

• Analysis Tools

• Subjective discomfort survey

• 3/2002. (II. 8.) SzCsM-EüM együttes rendelet

• Noise at work

• the European SLIC inspection and information campaign devoted to manual handling of loads

• MSD Risk Assessment

• Humanics Ergonomics Tools
Chapter 3. Computerized ergonomic evaluation of worksites

Compliance with criteria related to posture, movements, space requirements, exertion, meaning the physical dimensions and capabilities of employees can be assessed, that is, certain ergonomic risks can be evaluated by computer-aided anthropometric investigations in addition to paper-and-pencil methods. General requirements are detailed in ISO 15536-1:2005 Ergonomics -- Computer manikins and body templates -- Part 1: General requirements¹, and the human model applied is detailed in Part 2: Verification of functions and validation of dimensions for computer manikin systems (ISO 15536-2:2007) ².

The design of spaces, furniture, machinery and equipment is essentially determined by the physical properties of the human body. This is supported by increasingly advanced computerized systems, making it possible to model the features and motions of the human body. For instance, anthropometrically accurate models are used to illustrate connections between the human body and the physical environment. Computer Aided Anthropometric Assessment (CAAA) covers a number of assessment methods, so the human model can be used for reach range indication, visual area display, biomechanical calculations of forces required, or motion simulation.

The use of computerized human models was intended to replace real live test subjects in the evaluation of environmental models and prototypes actually built. However, real subjects not only provided the dimensions of their bodies but they also contributed by their functional and perceptive capacities through subjective evaluations of the difficulties of use, comfort, and other product features of the model.

Animation 1: Reach zones

Application of a computerized human model can both eliminate real test subjects and do away with the construction of an environmental model as well; moreover, it accelerates the design process by the rapid detection of dimensional errors, enabling rapid transformations and revaluations of the (modeled) environment.

Obviously, application of computerized human models in itself does not ensure proper design. Errors in design (e.g. acceptance of inconvenient postures and narrow spaces) do not reduce equipment safety because risk analysis requires verification by real test subjects after computerized modeling.

¹ISO 15536-1:2005 Ergonomics -- Computer manikins and body templates -- Part 1: General requirements
Adequate user models – in terms of nationality, gender, age, percentile – are adjusted to the model of the product and its environment.

Collisions, required safety clearances, zones of reach and vision are checked and evaluated in various functional postures set (comfortable – suitable – unsuitable). When a computerized human model is applied, the purpose of evaluation – e.g. animation, biomechanical testing – must be documented together with the limits of ergonomic use. The assessment procedure must also be recorded, for example:

• evaluation using automatic functions or only visual evaluation of the sight;
• animation of motion or only views and images produced;
• types of geometric evaluation, e.g. visual area, reach, access, collisions;
• force requirement checks based on biomechanical calculations.

It is essential that modeling accuracy should be in line with the job task and the importance of dimensions (e.g. access orifice or reach); however, the accuracy of human model tests is affected by several factors. Factors to determine accuracy include the accuracy of the human model itself, on the one hand – meaning to what extent it reflects the dimensions, functioning and mechanics of the human body; and on the other hand, the knowledge and circumspection applied in setting the posture or the degree of sinking the model when placing it on a compressible surface.

Particularly great attention is devoted to the appropriate representation of dimensions and related postures. This is difficult because body dimensions are measured in a standard, possibly upright position, but natural postures are flatter and more collapsed. This way the size can be decreased by as much as 6 cm, so this correction must be taken into consideration for evaluation.

The living organism is made up of hard and rigid tissues (e.g. bones) and soft tissues (e.g. muscles, viscera). As the shape of soft tissues is changed by changes of posture or external pressure, human models should also behave this way, e.g. in the area of the buttock, so that height should remain correct both while standing and sitting. One of the most recent aspects of 3D human body modeling is the consideration – true to nature – of elastic transformations and deformations accompanying posture changes, e.g. sitting down or lying down. One method for this is to measure the relative distances of carefully selected measuring points on the body, to track changes and to model these deformation processes by suitable learning algorithms, e.g. Artificial Neural Networks (ANN).

Joint motion also affects the anthropometric accuracy of a model. So for instance the range of reach is highly affected by the fact that the center point of the shoulder and of shoulder motion are displaced, so the type of reach must also be set for evaluation and even the center of rotation may be displaced.

Main features of CAAA systems:
• Model applied: nearly all postures can be set in case of 3D computerized human models. The level of elaboration of models can range from stick models somewhat like skeletons through wire frame models partly representing the surface of the body to full surface or lifelike models also following the internal structure of the body.

• Number of parts and joints: more natural motions can be displayed with more details and joints, particularly in case of depicting extreme postures. In general, body templates consist of 6-11 relatively easily movable parts. Simpler spatial human models can be moved at 15 points, but more complex systems enable to use as many as 70 points of motion for anatomically and functionally correct individual settings of vertebrae or phalanxes.

• Movability of joints: joint motion varies from uniaxial finger joint motion to complex joint systems resulting in a complexity of movements like the bending, twisting and tilting of the spine, thumb or shoulder motion. The motion range of real joints is limited, so models need to follow this, preventing the configuration of impossible bodily positions. Some systems even indicate the level of comfort of the posture or motion concerned in respect of selected operations and users, e.g. the feasibility of driving, assembly operations, or machinery operation.

• Configuration of postures: Human models can represent a wide range of natural motions due to a variety of parts and options for motion. To be able to manage models, certain motions are simplified or pre-produced by systems (e.g. options for main postures or hand positions) and stored for subsequent usage. Some applications calculate counter-forces to keep balance and the center of gravity of each part of the body, or even simulate continuous motions similar to gait by calculations of typical postures. Systems enable analyses of connections between force and posture, balance and comfort; this is important because exertion and posture must be assessed in interaction in the course of work.

Figure 14. Vehicle dimensioning in the Anthropos system

• Ranges of reach and recommended working zones can be checked by changing postures. The "Reach" function can be used for displaying the accessibility of a given location or the posture required for reaching it; and the display of reach ranges can be adjusted to the various comfort levels associated with the posture concerned. Recommended working zones can be determined by taking into consideration the weight moved, frequency, duration and other factors of influence as well.
The visual area can be checked by displaying the gaze or the area of vision or the area seen beside the model. Such checks can be made necessary in the evaluation of the visibility of displays and controls or the apertures of control cabins.

Motion patterns can be displayed by simulating the lifelike motion of the trunk and the limbs. This assessment can be used to identify obstacles to motion or short-term extreme loads.

Biomechanical assessment enables calculations of loads on various parts of the human body in cases with and without motion. The complexity of the issue is indicated by the fact that the weight and weight distribution of
each part of the body, the momentum of motion, and the interplay of the parts of the body are all displayed. By comparing the calculated scores with the allowable limit values, an ergonomics assessment of the motions and parts of the body can be performed and a more favorable situation can be attained by making changes in the environment.

• User group selection: systems contain a variety of demographic data, wherefrom the appropriate ones can be selected on the basis of different demographic features and percentile figures. Bodily proportions or dimensions can be changed as necessary, or the dimensions and motions of a given person can be specified or input by image processing systems.

![Figure 18. Various users in the Jack system](image)

• Assessment is facilitated for accuracy. For this purpose, body contours and movements appear properly visibly together with the position of joints. Readability is also facilitated by motion and measurement points, should the model’s hair, clothes and shoes be unclear to see. Reference systems can be switched on to assess the situation, e.g. environmental coordinates, the center of gravity of the model, or the reference point of sitting.

![Figure 19. Display modes in the HumanCAD system](image)

Anthropometric alignment is aimed to check or determine optimal product dimensions based on users’ physical features, by taking into consideration any external circumstances to affect product use and any limits to affect product operation. Alignment in the basic model of product ergonomics can be depicted by highlighting physical operation from the product vs. user interaction and displaying characteristics of the interface related to posture, dimensions and exertion.

CAAA softwares make it possible to analyze the critical bodily positions, postures and movements of assembly line operations. By selecting human models of various heights, the adjustment experiment of employees with different anthropometric dimensions with the worksite model can be performed and the results can be evaluated. Incorrect or inconvenient postures – tiring in the long run, moreover, possibly causing temporary or permanent health impairment – can be represented graphically.
Obviously, model production and application are subject to several criteria. The two most important validity criteria are the following: to what extent the human model represents the anthropometric features of employees working on the assembly line and what the rate of accuracy is for setting functional postures. As regards settings for bodily positions, the angle ranges of displacement allowed by the softwares are authoritative, simulating average human capacities. In the event of any changes in workplace conditions or planned changes, these situations can be reproduced, to be repeated by an assumed or actual employee model.

In Figure 20, the service of conveyor belts was checked by using human models of various sizes. Human models were generated using a CAAA software titled JACK. The 102 cm strap height of the belt and the 107 cm height of the baffle fails to enable male employees to put workpieces on the belt and to remove them therefrom in a comfortable posture – with vertical upper arm and nearly horizontal forearm. According to Figure 20, the position of the upper arm / the angle included between the upper arm and the vertical is within the range 58-37/40-24/24-0 degrees in case of a 5/50/95 percentile male. This functional bodily position can be deemed as acceptable only in the case of employees near 95 percentiles of body height. Comfortable hand positions are expected by the use of foot grids, at least 8-10 cm high in case of males, and 20-25 cm in case of females.

Figure 20. P₅ and P₉₅ male models beside conveyor belt HI-1 in side view
1. Outlook

Study the following Ergonomic checkpoints:

• Materials storage and handling (checkpoints 1–17)
• Workstation design (checkpoints 51–63)
• Lighting (checkpoints 64–72)

In order to master this chapter, solve the following tasks:

• Take a cube of 40 cm long edges (simplified model of a chair), a cube of 72 cm long edges (simplified model of a desk), and a European male model of 95 percentile height.
• Arrange the chair, the desk and the man into the best sitting position for work. Evaluate the resulting posture.
• Consider what the man can see on the desk and what he can reach.
• How big is the lumbar (L4-L5) intervertebral compressive force if the man lies forward on his stomach on the desk?

Visit the following homepages:

• http://www.simsol.co.uk/ergonomic_analysis_jack.php
• http://www.nexgenergo.com/ergonomics/mqpro.html
Chapter 4. Evaluation of ergonomic risks at workplaces

An important application of ergonomics is to design worksites to meet workers’ features. Workers feel uncomfortable both physically and mentally at badly designed worksites. At inadequate workplaces, the costs of selection and training are higher due to the high rates of sick leave and employees quitting. However, ergonomic developments result in safety, higher productivity and higher quality coupled with employee satisfaction.

Disregard of ergonomic factors may lead to cumulative diseases consequent upon repeated body moves, exertion, bad posture and vibrations, the same way as a bad move may lead to injury. Ergonomics problems are frequently brought to light by low productivity, bad quality or employee satisfaction.

1. Regulatory background

The Act on health and safety (Health and Safety Act)\(^1\) discusses occupational diseases or ergonomic origin and prevention measures, while Decree 33/1998. (VI. 24.) NM\(^2\) discusses aptitude tests.

Ergonomics appears in the criteria for establishment set out in the Health and Safety Act: "ergonomic aspects shall also be taken into consideration in the design and installation of worksites and working tools as well as in work organization. The employer shall be responsible for ensuring the prevalence of ergonomics and ergonomic aspects in the development of the system of connections between the working tool, the worksite (work environment) and the employee."

Pursuant to Decree 3/2002. (II. 8.) SzCsM-EüM on minimum worksite requirements, "as regards the occupational health interpretation of ergonomics and ergonomic aspects in the development of the system of connections between the working tool, the worksite (work environment) and the employee, measures shall be taken by taking into consideration the provisions set out in the applicable regulation."

The Health and Safety Act requires the employer to assess the quality – and if necessary, the quantity – of risks to employees’ health and safety and to take measures to eliminate hazards or to reduce risks to an acceptable level.

In accordance with standardized EU legislation, ergonomics principles appear among requirements for machinery – Decree 16/2008. (VIII. 30.) NFGM\(^5\) and personal protective equipment – Decree 18/2008. (XII. 3.) SZMM\(^6\) as well.

In order to preserve physical capabilities and to prevent occupational injuries and diseases, conditions shall be provided for safe work not posing a health hazard. This includes, pursuant to the Health and Safety Act, the employer’s obligation to

- take the human factor into consideration in worksite design as well as in the selection of working tools and work processes, with particular regard to reducing the duration of monotonous work of a fixed rhythm and mitigating its harmful effects, work schedules, and avoiding stress caused by psycho-social risks concomitant with work;

- develop a standardized and comprehensive prevention strategy to cover work processes, technologies, work organization, working conditions, social relationships and the impact of work environment factors;

- take all measures as required for the health and safety of employees, also taking changing circumstances into consideration, and making attempts for the continuous improvement of working conditions.

\(^{1}\) Act XCIII of 1993 on health and safety  
\(^{2}\) Decree 33/1998. (VI. 24.) NM on fitness for work in terms of job, profession and personal hygiene  
\(^{3}\) Act XCIII of 1993 on health and safety  
\(^{4}\) Joint decree 3/2002. (II. 8.) SzCsM-EüM on the minimal levels of health and safety requirements at workplaces  
\(^{6}\) Decree 18/2008. (XII. 3.) SZMM on the requirements for and compliance certification of personal protective equipment
Establishments, structures, technologies and worksites may be put into operation if they meet the requirements for planned use as well as health and safety regulations, and they have records of the completion of a preliminary health and safety inspection with adequate results as well as the required documentation of operation. In the course of such inspection, the committee examines the suitability of structures, technologies, working tools, war implements, and security equipment built in or installed in terms of the entire functionality. A preliminary health and safety inspection must be conducted simultaneously with such investigations in accordance with the Health and Safety Act.

Pursuant to the Health and Safety Act, the party assessing risks shall be obligated to evaluate the quality – and if necessary, the quantity – of risks to employees’ health and safety, with particular regard to the tools applied, hazardous substances and preparations, employee loads and worksite design. Based on such evaluation, preventive measures should be introduced to improve working conditions and built in operations at all management levels of the employer. Risk assessment is qualified as a special activity of work safety and occupational health.

2. Ergonomic risks

Workplace risks include repeated, exertive, and prolonged efforts, frequent or heavyweight lifting, pushing, pulling, or the transport of heavy objects, static or discomforting postures, vibration locally or of the entire body, cold environment, and poor lighting. Workplace risks may be aggravated by work organization specificities such as improper selection of the schedule of work and rest, excessive frequency and / or working hours, unusual work, monotony of tasks, mechanized work, and piece wages.

Risks of occupational locomotor disorders may include the following: static or unnatural posture, restrictive worksite (insufficient workspace), unsuitable chair / support, high frequency and / or high-speed work, repeated use of the same muscle group, repeated use of smaller and weaker muscles, exertion – particularly in an unnatural posture, tool design, vibration, machine operation, nearly maximum frequency of repetition, work performed in a cold or damp environment, weather extremities, lifting of heavy weights, wrong working height.

Initial symptoms of musculoskeletal diseases include narrowed motion range, deformations, reduced gripping force or muscular dysfunction. Symptoms of a developing disease include pain, numbness, tingling, burning, spasm, and stiffness.

Disregard of ergonomic factors may lead to cumulative diseases consequent upon repeated body moves, exertion, bad posture and vibrations, the same way as a bad move may lead to injury. Ergonomics problems are frequently brought to light by low productivity, bad quality or employee dissatisfaction.

Typical work-related musculoskeletal disorders:

- Back injuries primarily include injuries of the spine and adjoining soft parts (strain, rupture, haemorrhage), and the development of diseases causing permanent pathological states ranging from a simple sprain to discopathy.

- Tendosynovitis: a disease particularly frequent on the forearms, the hands, the legs and the feet, caused by prolonged overexertion. It can also develop as a consequence of numerous repetitions of identical movements with low exertion; on the legs, it is triggered by excessive standing or walking. In an acute state, the afflicted part of the body is highly sensitive to pressure and very painful to move. Treatment involves total rest (plastered up), and medication, possibly supplemented by hot physical therapy such as bath or mud treatment.

- "Carpal tunnel syndrome": In the so-called carpal tunnel along the inside of the wrist, one nerve and nine tendons run from the forearm to the hand. Overexertion of the hand caused by repeated movements, as well as prolonged overstretching of or pressure on the wrist play a dominant role in its development. Symptoms generally include numbness, pain, tingling or a combination of the three in one or both hands, in the thumb, the index finger, the middle finger and more rarely in the ring finger, reduction in the gripping power of the hand and insensibility at fingertips. It is generally cured by relieving the hands and medical treatment, but it may take months for the gripping force to recur and for the original activity of the hands to be restored.

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1 Decree 5/1993. (XII. 26.) MüM on the implementation of certain provisions of Act XCIII of 1993 on health and safety
• Bursitis: bursae cover osseous protrusions and assist the displacement of muscles and tendons over the bones. Bursitis can develop as a consequence of prolonged elbowing, kneeling or sitting in the course of welding, most frequently in the bursae over the shoulder, the elbow or the knee. It generally starts with sudden and intense pain which will abate later on. Many times, patients recover in a couple of weeks by repose, immobilization and ice packing of the limb and medication, but sometimes a surgical intervention is required.

• Shoulder pain – pain in the upper parts of the shoulder caused by the compression of blood vessels and nerves, consequent upon prolonged work performed overhead.

• Genicular disorders caused by prolonged kneeling.

In the course of work, various musculoskeletal injuries such as bone fractures, cuts, muscle ruptures can occur, the same way as slowly developing cumulative diseases caused by the repeated performance of work tasks. What they have in common is that they develop slowly as a consequence of increased loads on the organism, rather than occurring suddenly caused by a single powerful impact. Pressures and forces on the organism have an impact on muscles, nerves, tendons, intervertebral disks, the skin and the formations beneath, blood vessels and bones. The diseases above are also similar in that they cause pain, recovery needs a long time and the part of the body afflicted needs to be at rest – that is, absence from work is required.

The working environment and the way of performing work play a significant role in the emergence of work-related musculoskeletal diseases: working conditions can accelerate or curb their development. Obviously, individual characteristics are also of importance, such as existing health problems, physical condition, gender, age, working method, etc.

Factors to determine ergonomic risks:

• **Frequency**: how often the impact is exerted, e.g. how many times the given move needs to be performed.

• **Duration**: how long the given task is required to be performed, e.g. length of shift, duration of uninterrupted welding.

• **Force**: how strong the impact is, e.g. what force must be exerted to grip the retainer, what force is required to displace the welding apparatus.

• **Posture**: how natural the bodily position is during work, with particular regard to the position of the back and the upper limbs.

• **Vibration**: vibrations affecting the entire body or the hand, coming from vibrations of the structure or the hand tool.

If repeated movements must be performed for a long time in a bad posture, and they involve exertion, musculoskeletal disorders can be expected.

Factors affecting ergonomic risks:

• **Immobility**: the uninterrupted tension of muscles impedes metabolism.

• **Part of the body used for exertion or exposed to pressure**: in respect of welding, the exposure of hands is obviously coupled with the pressure of the mask on the head or the knees being loaded when kneeling.

• **Temperature of the environment or of the object handled**: risks are higher in case of too hot or too cold objects.

When establishing the conditions of safe work not constituting a health hazard, the aim is that the potential impact of risks on each employee should not exceed an acceptable level, also taking the severity of health impairment into consideration. This means that all hazards occurring during work must be tackled and the time devoted to the activity concerned must also be taken into consideration when deciding on measures to take.
Typical ergonomic risks:12

- Mechanical hazards, including numerous repetitions of the same movement, motionless exertion, unnatural bodily positions, physical loads, vibrations, or extreme temperature conditions.

- Physical and mental hazards can arise from information processing, social relationships, psychic factors, control, visual environment or noise.

- Organizational hazards include too intensive pace of work, long working hours, work rhythm specified from outside, improper schedule of intervals, monotonous work or the risk of being laid off.

For the sake of completeness of the ergonomic assessment of welding, positive inputs of this operation should also be mentioned besides potential negative consequences in line with safety risks. Actually, employees develop by practice, learning, and problem solving.

Gymnastics contributes to the prevention of musculoskeletal disorders. Some minutes of exercise can be used for

- warming up exposed muscle groups before starting work;

- moving muscles not loaded by the work task in the meantime to balance physical loads on the body and to maintain consistent physical fitness;

- reconditioning your body with stretching exercises to cool down after work.

Some of the most important means of solving ergonomic problems are prevention and early identification. This can be made possible by systematic ergonomic analyses of worksites, workplace development programs with employee involvement, as well as by the exploration and elimination of the root causes of incipient diseases usually accompanied by complaints in addition to their treatment.

In the course of ergonomic development, a complex solution to integrate safety, efficiency and comfort aspects is arrived at after exploring all factors; at the same time, typical solutions can be identified to reduce certain risk types.

The number of identical movements to be performed by a given employee in a single shift can be reduced to an acceptable level by any of the following, for example:

- simple tools;

- enrichment of work operations;

- mechanization of tasks;

- work exchange;

11ISO 26800:2011 Ergonomics -- General approach, principles and concepts
• longer breaks;
• even spread of tasks over all shifts; or
• job redesign.

Hazards by physical loads can be reduced by any of the following:
• reducing the weight of tools, workpieces, and crates;
• higher adhesion of the hand and the grip;
• improvements in the dimensions and form of grasps;
• employing power assistance;
• balancing or suspending hand tools and containers;
• torque limiters;
• rounding off corners and edges; and
• using supports and cushions.

The risk of bad postures can be reduced, for instance, by
• selecting working positions requiring natural postures;
• tools accessible and usable without bending the wrist;
• placing workpieces near the worker;
• selecting a worker location to result in a natural posture;
• applying tools to fit to the worksite.

Vibration impact can be reduced, for instance, by
• applying vibration-free tools or tools with the lowest vibration levels;
• technologies with little rubbing of surfaces;
• machine-assisted applications;
• insulation of tools operated over their resonance point;
• damping of tools operated at their resonance point;
• selecting tool speeds not creating resonance.

Psycho-social hazards can be mitigated by the following, for instance:
• enriching work tasks;
• providing more freedom of work;
• inserting micro-breaks;
• eliminating work at machine beat.

3. Manual materials handling
Materials and equipment are moved by hand many times. Manual materials handling can cause disorders both in a cumulative manner and by sudden injuries, therefore it is highly important to use appropriate means and techniques. Risk factors of materials handling:

- weight of the object moved, or the weight per person when the object is moved by several people: the heavier is the weight, the higher is the risk;
- the greater is the level difference of lifting, the higher is the risk;
- the longer is the transport distance, the higher is the risk;
- movement of objects held close to the body involves lower risks than the movement of objects held away from the body;
- the farther away lifting is from elbow height, the higher is the risk, so it is higher when lifting an object from the ground and lifting it overhead;
- the better is the grip / hold / form of the load, the lower is the risk;
- the more frequently and the more times lifting is required to be performed, the higher is the risk;
- breaks reduce risks;
- the situation is deteriorated by certain circumstances, e.g. vibration, handling of hot objects, slippery floor;
- movement by two hands with the trunk upright is more favorable than doing it unilaterally;
- effects also depend on individual characteristics.

The risks of work-related manual materials handling can be reduced by mechanization, as well as by the reduction of materials handling demands through shortening distances or forwarding by gravitation. Hazards can be decreased by the use of proper materials handling equipment, by the appropriate selection or modification of the features of loads to be moved, and by the right lifting methods.

- Use materials handling equipment if available.
- Use an easily transportable welding machine. It should be lightweight, easy to grab, with a design to facilitate transport.
- Don’t walk if unnecessary. Don’t excessively morsel the quantity handled to avoid overexertion because too much walking leads to loss of time and increased strain.
- Convert your accessories into unit packages. Packages easy to pile up, good to grasp, subject to weight limits, and with their content easy to identify from the outside make deployment easier and more efficient.
- Don’t carry things: send them rolling. Use trolleys and similar tools to transport equipment, materials and other packages. This solution can also be used to ease the transport of work platforms of variable height to the field.
- Clasp loads closely. If the object must and can be carried by hand, hold it with two hands and bring it close to your trunk.
- Observe the rules of lifting.
  - Legs apart
  - Small steps forward
  - Bend your knees
  - Lift the weight in several steps
  - Keep your back straight
Evaluation of ergonomic risks at workplaces

- Load near the body
- Bend a bit forward for a better grip
- Shoulders flush
- Firm grip
- First to put down, then to adjust
- Produce sub-units. It is more comfortable to move sub-units produced at ease in a well-designed worksite than to transport many-many small components.
- Alternate activities. Continuous lifting and transport can be followed by welding operations and vice versa; it is expedient to change in every one or two hours.
- Let it be carried by someone who is strong enough. As the risks of lifting weights are also affected by the momentary physical status of the individual, think this over before going for it. Employees who are much too young and those who have just recovered from an illness should carry lighter packages and let the strong ones carry the really heavy pieces.
- Push rather than pull. It is less of a burden to push trolleys rather than to pull them; besides, a grip at elbow height which is easy to grasp is the most appropriate.
- Watch out when moving gas cylinders. If the cap is properly fixed, use materials handling equipment for longer distances and roll it a bit tilted at a short distance. If you still need to lift the cylinder, hold the cap with one hand and the side of the cylinder with the other hand.
- Keep to weight limits. The figure below shows the heaviest weights allowed to be lifted by males and females in different ranges if lifting is performed by using an otherwise regular solution.

![Figure 22. Acceptable weight limits](image)

4. Outlook

Study the following Ergonomic checkpoints:

- Materials storage and handling (checkpoints 1–17)
- Machine safety (checkpoints 32–50)
- Lighting (checkpoints 64–72)
- Hazardous substances and agents (checkpoints 85–94)

In order to master this chapter, solve the following tasks:
• Select a worksite from your environment and identify at least five ergonomic hazards. Consider who the parties affected are, for how long the hazard subsists and what consequences it can entail.

• There is a pallet of 20kg sacks on the platform of a truck. List five options for the sacks to get into a garage, then arrange your solutions according to ergonomic risks.

• Select an occupation, identify the main ergonomic problems and present suggestions to mitigate risks.

Visit the following homepages:


• http://www.hse.gov.uk/pubns/indg270.pdf


• Quality of work

• United Electrical


Animation 4: Static Strength Prediction
Chapter 5. Composite ergonomic risk assessment

An ergonomics risk assessment method has been developed at Donát Bánki Faculty of Mechanical and Safety Engineering of Óbuda University which is in Hungarian, easy to manage, and can be used reliably in health and safety practice to explore ergonomic hazards and to specify situations of acceptable and unacceptable risks, as well as to select situations of questionable hazards.

In accordance with professional traditions, the abbreviation for "Composite Ergonomic Risk Assessment” is CERA according to the English denomination. CERA assessments enable the quality and quantity assessment of physical load risks arising from posture, exertion, manual materials handling, and repeated movements.

Composite ergonomic risk assessment is a method to be used for assessing the quality and quantity of risks of physical loads arising from posture, exertion, manual materials handling, and repeated movements during physical work.

1. CERA assessment

In accordance with professional traditions, the abbreviation for "Composite Ergonomic Risk Assessment” is CERA according to the English denomination.

1.1. Simplicity

CERA is an easy-to-use method aligned to the circumstances of application. Assessment sheets can be filled in by health and safety experts, members of the ergonomics team, or other participants of workstation design with several hours of practice. In order to fill in the assessment sheets, textual answers must be provided, parts of the body must be indicated in figures, and yes/no questions must be answered.

1.2. Standard background

The methodological reliability of CERA assessment is based on its standard background. Standard EN 1005 sets out methods to take into consideration the factors affecting people’s physical performance and to assess the risks arising therefrom. This standard integrates methods accumulated in this area and widely recognized by the profession.1

Although the application of EN 1005 as a standard is only compulsory in machinery risk assessment, it is expedient to use for existing machinery and activities. In reality, not all machines are checked for compliance with the standard above; this particularly applies to situations when machines produced on site or used machinery are put into operation. Factors assessed in the standard primarily cover human productivity and motions, so assessments can be performed not only for machine operation but for other activities as well, such as assembly or manual materials handling.

1.3. Areas of assessment

CERA assessment is suitable for assessments corresponding to the components of the standard series EN 1005, namely:

EN 1005-5:2007 Safety of machinery - Human physical performance - Part 5: Risk assessment for repetitive handling at high frequency
• posture;
• manual materials handling;
• exertion;
• repeated movements.

CERA also includes a pain and discomfort assessment, encouraging both employee involvement and recordings of worksite precedents and development ideas.

The primary objective of CERA assessment sheets is to verify risk-free status and to filter high-risk situations. The application is particularly recommended in the following situations:

• as part of health and safety risk assessment;
• in the course of commissioning;
• for ergonomics reviews;
• to clarify the ergonomic reasons of events (e.g. occupational accidents);
• to supplement occupational health surveys.

2. Assessment sheet design

Assessment sheet design reflects a combination of beneficial solutions of existing methods, practical needs and methodologies set out by the standard.

2.1. Marking of assessment areas

CERA includes a total of eight assessment areas in three assessment sheets. Each assessment area is enclosed by a frame and the description of the assessment area can be found in the upper part of the frame.

2.2. Graphic and explanatory elements

CERA assessment is assisted by large-sized human sketches suitable for indicating the parts of the body affected.

2.3. Indication of risk levels

Risk levels must be indicated clearly on the assessment sheet as instructed.

CERA assessments provide one or two outputs with risk assessment color codes per assessment area, rather than aggregate ergonomic risk levels:

• Green indicates acceptable risk;
• Red indicates unacceptably high risk;
• Yellow indicates an uncertain situation where a more detailed investigation can verify even an acceptable risk level, but many times it is expedient to introduce measures to mitigate hazards.

2.4. Conditions of filling in

The standard includes a number of factors affecting risks which are not examined in detail, and which, theoretically, are a pre-condition for filling in the particular assessment areas. Data can be recorded in such cases as well with considerable experience and circumspection, but the impact of distortion must be taken into consideration when specifying risk levels. If any of the control criteria are not met in the assessment area concerned, risk will be higher than the value resulting on the assessment sheet.
2.5. Requirements of recording data

Assessment sheets must be filled in to be readable and understandable for others as well. Efforts should be made for completeness and for recording situations true to the facts.

In the course of data recordings, the identifiability of each assessment sheet should be ensured, e.g. by clipping sheets pertaining to a given assessment and by filling in the identification field in the top right corner of the sheets.

Assessments should be supplemented by photos and video recordings, with allowance for corporate regulations and rights relating to personality.

2.6. Multiple framework selection

Multiple framework selection is required in the areas of manual materials handling and repeated movements after inspection criteria are met. This means that a risk is acceptable if all the criteria in one of the individually enframed short checklists here are met.

3. Structure of assessment sheet

3.1. Administration and summary area

This area includes the main data and identifiers of the worksite and the employee. Investigation circumstances must be indicated here.

More than the typical posture can be indicated, since in an ideal case employees can alternate between sitting and standing positions at their own discretion.

Results of other assessment areas must be copied into this summary area at the end of the inspection.

![Figure 23. Assessment sheet I of Composite Ergonomic Risk Assessment](image-url)
Figure 24. Assessment sheets II-III of Composite Ergonomic Risk Assessment

Figure 25. Assessment sheets IV-V of Composite Ergonomic Risk Assessment
This assessment area must be filled in at each occasion.

3.2. Worker discomfort and pain survey area
Employees’ opinions and proposals are important for development. Their answers should be a basis for indicating the parts of the body with work-related complaints. Both the text area and the figure can include textual supplementation on complaint intensity, frequency or inconvenience. Complaints which cannot be indicated in the drawing – e.g. smarting of the eyes or head noises, or workplace violence. These observations must be forwarded to the appropriate area of worksite development without employee identification.

This assessment area should be filled in at each occasion.

### 3.3. Worksite precedents (accidents, diseases, etc.) area

Records of worksite precedents (accidents, diseases, etc.,) supplement the assessment and assist in the interpretation of data. Such data can be available from other sources as well (it is sufficient to enclose them in such cases), but they can be surfaced at the workplace as well.

This assessment area should be filled in at each occasion.

### 3.4. Remarks / ideas for solution area

Although risk assessment is not intended to solve the problem, specialists performing the assessment and other participants inevitably reflect on improving the situation. This area serves for recording such ideas. Thoughts written here can be useful for development; however, prudent design and implementation with interconnections understood will be the real solution.

This assessment area can be freely used.

### 3.5. Posture assessment area

Postures are assessed by parts of the body. If assessment results are acceptable or unacceptable for each part of the body, no further assessment is required. Assessment is based on the fact whether the positions indicated occur while performing the work examined, meaning what is the largest joint angle to appear.

Assessment must be performed in two steps in three cases: there is a yellow area in the drawing for medium elevation of the upper arm forward or to the sides, and for the trunk leaning backward. Two green postures can be selected in the supplementary boxes indicated by arrows; otherwise the result will be red.

Other static or inconvenient postures observed in addition to the positions of the head, the arms and the trunk – analyzed in detail – must be indicated in the large human drawing, with explanations to be provided in the box enclosed. This drawing is the specialist assessment area, meaning that employee complaints must be recorded on the standing figure, and the posture problems observed on the sitting figure.

The parts of the body with red and green results are to be counted up to summarize the assessment. If the assessment result is red in any area, action is needed.

### 3.6. Exertion assessment area

Activities should be observed to identify operations accompanied by exertion and to determine their periods of occurrence. Exertion primarily involves the operation of equipment controls and altering workpieces by force. Movement of workpieces or tools should not be taken into consideration here but in the assessment area for manual materials handling. Depending on operational arrangements and task complexity, exertion can characterize the entire shift (machine operator) or can be limited to some uninterrupted periods of the shift (machine operator to change pallets each hour), or can be repeated (machine operator with tasks including the insertion and removal of workpieces as well).

This assessment area must be filled in if exertion is required for processing operations or for operating controls.

Interpretation of inspection criteria:

- It can be stated that the duration of work does not exceed 8 hours if the total time of work involving exertion, including periods of exertion and related rest periods, does not exceed 8 hours within the shift.
• It can be stated that the duration of exertion does not exceed three seconds if there is no exertion any longer three seconds after the commencement of such exertion, regardless of the intensity of exertion in the meantime or whether several consecutive short exertions are involved. The journey of the legs or the arms to the place of exertion is not included in the duration.

• It can be stated that there are no more than two exertions per minute if exertions, perhaps of various types, occur no more than twice per minute in a more or less uniform pace during the period taken into consideration for exertion.

• A pre-condition for examining exertion is that the part of the body concerned should not be considerably displaced and any motion should be slow and without jerking.

If the criteria above are collectively met, the assessment can be continued; otherwise, risks must be identified by some other methods.

Further on, figures corresponding to the exertions occurring during work must be selected, and the highest force figures must be indicated per figure in the areas below the figures.

Green represents acceptable risks, and red represents unacceptable risks; the area in between is the yellow range. The parts of the body with red and green results are to be counted up to summarize the assessment. If the assessment result is red in any area, action is needed; in cases of yellow coloring, action must be taken to reduce the force required or the risk level should perhaps be determined by further investigations.

The force figures on the assessment sheet are based on the average productive capacity of industrial workers; employees with outstanding capabilities may exert greater forces and physically weaker employees may exert smaller forces than that, subject to acceptable risks.

If the value of the exertion required is not known in respect of any exertion (e.g. there are no measurement results), assessment must be performed on the basis of surveying all employees performing the operation concerned. In such a case, evaluation will be green if employees uniformly state that the exertion is not a toil; it will be yellow if up to half of the employees state that some exertion is required and up to one out of ten employees states that considerable exertion is required. If a larger proportion of employees indicate exertion or deem it to be more intensive, the result of the assessment will be red.

3.7. Manual materials handling assessment area

By observing activities, operations involving movements of objects of at least 3 kg of weight (e.g. tools, workpieces) must be identified to determine periods when they occur. Exertion concomitant on working operations must be taken into consideration in the exertion assessment area, while the movement of workpieces or objects lighter than 3 kg should be included in the assessment area of repeated movements, not here. Manual materials handling can fill the entire shift (insertion of workpiece for processing, followed by removal thereof); or it can be limited to some uninterrupted periods within the shift (insertion of workpiece for processing, followed by removal thereof, but the machine must be periodically adjusted); or it can be repeated (machine operator with tasks including the insertion and removal of workpieces as well).

This assessment area must be filled in if objects of 3 kg (e.g. tools, workpieces) are moved in the course of work.

Risks are not acceptable without further assessment in any of the cases below:

• any weight lifted manually by a single person reaches 25 kg (or 50 kg lifted by two people);

• a person lifts up another person without any aids;

• lifting is performed above shoulder height.

Interpretation of inspection criteria:

• Horizontal weight displacement may not exceed two metres.
• Manual materials handling is performed while standing (e.g. not sitting or kneeling), and the employee is not hindered by external obstacles in executing the correct lifting method and in following the shortest movement route; no level differences need to be overcome during movement (e.g. slopes, stairs).

• Lifting is performed by only one person, using only muscular power.

• There are no rapid movements, jerks, or jams during lifting.

• The object moved can be grasped properly, meaning that it has a grasp or grip to be grabbed properly by both hands.

• The object moved can be held against the body, meaning that it is not too cold or not too hot and not polluted.

• Legs do not slip, so the floor is not oily, icy or wet, for instance.

• No other operation is required to be performed in the course of the operation in addition to lifting the object concerned.

• There are no extreme environmental factors such as too hot, too cold, vibration, darkness.

• The manner of lifting is correct, meaning that the worker performs lifting with two hands, by grasping the object symmetrically, and this is made possible by the shape of the weight.

• The manner of lifting is correct, meaning that the trunk is upright, it does not lean sideways, there is no need of tilting.

• The manner of lifting is correct, meaning that the worker holds the weight close to the body.

If all the criteria for all the situations of materials handling are met, the assessment can be continued; otherwise another method should be used for risk assessment.

In order to determine risks, further assessments need to be performed using the short checklists here, enframed individually as well.

The lifting characteristics appearing in the frames must be compared to various limit values:

• The weight lifted means the figure of the heaviest load lifted during the assessment period. If the shift includes well-defined periods consisting of homogeneous acts of lifting (e.g. unloading 20 kg sacks of cement from pallets in the first half of the shift and bricklaying using 4 kg bricks in the second half of the shift), the appropriate frame must be selected and risks must be checked. If the activity is characterized by inhomogeneous handling (e.g. transferring suitcases to a conveyor belt), then the evaluation should be performed by calculating with the heaviest weight.

• The vertical position of the weight means its starting height relative to the worker’s sole, while vertical displacement means the level difference between its top and bottom position while being moved.

• Lifting frequency must be determined for the periods assessed in respect of manual materials handling; such periods result from the average time elapsed between lifting movements, possibly at a steady pace, including the time devoted to taking a rest after lifting.

Selection of the appropriate frames is assisted by their names:

• In case of moving objects heavier than 9 kg, the “critical weight” case should be examined;

• If the weight gets below elbow height, the case of “critical vertical weight displacement_1” should be examined. This can typically involve the loading of shelves, by moving loads close to the body within the range of knee and shoulder height.

• If lifting is performed from a pallet to a desk or from a desk to a pallet, the case of “critical weight displacement_2” should be examined. It is important here that holding the load against the body is not a pre-condition as load grasping can be as much as 60 cm, so loads can be placed onto pallets. The largest acceptable range of motion can be between 10 cm and 110 cm, or between 60 cm and shoulder height, which
corresponds to placing the weight from a pallet to a desk or from a desk to a pallet. (However, lifting the weight from 10 cm to shoulder height is not included here.)

- If lifting is performed more frequently than five minutes, use “critical frequency 1”.
- If heavy weights are lifted frequently, use “critical frequency 2”.

Risk is acceptable if all the criteria in one of the individually enframed short checklists here are met. Otherwise a measure can be taken to reduce loads or to specify the risk by another method.

3.8. Repeated movements assessment area

Periods characterized by operational cycles – including movements repeated highly frequently – must be identified by observing the activity.

The activity consists of operations, such as reaching, grasping, movement, adjustment, release, pushing in, pulling out, and carrying. This assessment area needs to be filled in very thoroughly to identify operational components as it is difficult to break down activities into operational components: e.g. putting an object from one hand into the other is considered as two separate operational components, one of them is grasping, the other one is release.

The operational component of movement may involve the movement of objects of up to 3 kg of weight (e.g. tools, workpieces); the manual movement of objects heavier than 3 kg must be taken into consideration in the manual materials handling assessment area. The operational component of pushing in and pulling out indicates the exertions taking place; these must be taken into consideration in the exertion assessment area. Work characterized by repeated movements can fill the entire shift (selecting apples), or it can be limited to some uninterrupted periods within the shift (selecting apples and packing them in boxes, and placing full boxes onto pallets).

This assessment area must be filled in if repeated movements / periods characterized by operational cycles occur during work.

Interpretation of inspection criteria:

- The work can be characterized by operational cycles if a given series of operations is repeated. Such series of operations can even be the repetition of a few actions, e.g. peeling apples using a knife. Cycle time is determined from the net working time based on shift performance or by measuring the time required for at least 10 cycles and recorded on the assessment sheet.

- If the work is primarily intellectual, or it does not entail the visible movement of the upper limb, this assessment is not required.

- Activities characterized by operational cycles make up 4-8 hours in the course of the shift.

- There are at least three 10-minute breaks, so the maximum number of working hours not interrupted by rest may be up to 4 hours.

If control criteria are not met, risks must be estimated by another method; otherwise the assessment can be performed.

Risk must be identified and evaluated first for the left hand and then for the right hand separately. To this end, further assessments need to be performed separately for the two hands, using the individually enframed short checklists here.

The first frame contains a basic case, and the rest of the frames show in bold in the absence of which criteria included in the basic case they should be filled in. Factors evaluated:

- Frequency: the number of operations do not exceed twenty per cycle, and the cycle time is at least thirty seconds. If this is not complied with, it is expedient to examine the case of “critical repetition” where operational frequency may increase, subject to other – more stringent – requirements. (In the case of “critical repetition”, the limit value refers to the number of operations per minute.)
There are no extreme postures: according to explanatory figures, movements do not quit the green range during the activity. If so, the "critical posture" should be examined where yellow postures may also appear subject to other – more stringent – requirements.

There are no operational components to fill at least half of the cycle time – meaning the time spent with the activity concerned. There are no static loads, so there are no operational components involving a static position of the upper limbs. Repetition is not excessive, either, because the cycle time is longer than 15 seconds. If this is not complied with, it is again expedient to examine the case of "critical circumstances" where operational frequency may increase, subject to other – more stringent – requirements. (In the case of "critical repetition", the limit value refers to the number of operations per minute.

Factors to affect work only appear in up to 25% of cycle time (e.g. use of vibrating tools, precision operations for integration, local pressure, cold environment, gloves to hinder task performance, handling objects on slippery surfaces, sudden tearing or twisting or quick movements, hitting operations). If there is a longer time passing while a factor to affect work is present, it is expedient to examine the case of "critical circumstances" where the impact of affecting factors is accepted, subject to other – more stringent – requirements during the entire cycle.

It can be stated that work does not require exertion or it entails negligible exertion if the risk of pushing in and pulling out as an operational component – forming a part of the series of operations – is acceptable on the basis of the result of the exertion assessment area. If the result is yellow there, the case titled "critical exertion" may be complied with, potentially subject to other restrictions.

Risk is determined separately for each hand, and it will be acceptable if all the criteria in any one of the individually enframed short checklists here are met. It is not a pre-condition to determine risks for both hands on the basis of identical cases. If the result is yellow for either hand, a measure can be taken to reduce loads or to specify the risk by another method.

4. Terms of use of CERA assessment sheets

4.1. Ideal application

As CERA assessment sheets are based on the EN 1005 standard series, it is the easiest to use them for cases of machine tending. Further application areas include homogeneous activities, that is, situations where workers spend their entire working day by identical activities or at least the same type of activities, e.g. by manual materials handling, assembly, machine operation, etc.

CERA assessment sheets are also easy to apply at low-risk – that is, properly designed and properly used worksites because control criteria are definitely met in such cases and favorable situations can be verified rapidly in the course of further analysis. Assessment can also be easy in case of high-risk – that is, badly designed and organized – worksites as red figures are quickly yielded in the areas of posture, exertion and manual materials handling and a decision should be made on intervention.

Based on the values included in CERA sheets, they can be applied for homogeneous 8-hour work interrupted by breaks three times, for favorable environmental conditions and industrial workers of average capabilities.

4.2. Reliability

Similarly to other ergonomics risk assessment methods, assessment results are influenced by a number of factors, e.g. the level of expertise of the person performing the assessment, the personal characteristics of the employee actually observed, circumstances at the very moment, etc. In the course of risk assessment it must be taken into consideration that the evaluation and management of workplace risks is the employer’s responsibility, and there may be regulatory restrictions in respect of those involved in risk assessment. The CERA assessment sheet is a possible means of risk management made available by the developers free of charge; however, developers may not be held liable for the results of assessments.

For the sake of easy manageability, the circumstances of application had to be restricted many times in the design of assessment sheets. In such cases, safety was the highest priority, resulting in the fact that the method would yield risks higher than the actual risk levels.
5. Course of evaluation

Surveys with CERA assessment sheets should be conducted according to the following steps.

- Preparations
- Worksite analysis
- Evaluation
- Summary of results
- Identification of measures
- Execution of interventions

Obviously, CERA can be integrated into more complex procedures similarly to other ergonomics methods; in such cases the provisions set out in Chapters 3-5 should be followed.

5.1. Preparations

In preparation of the assessment, the tasks usual in worksite assessment should be performed, including the following:

- specify the scope of the survey (e.g. worksites, employees);
- inform employees on the objective and circumstances of the survey;
- prepare the staff to conduct the survey for the survey itself and local health and safety requirements (e.g. health and safety training and personal protective equipment supply);
- print assessment sheets, prepare technical equipment;
- collect technological and production data;
- collect occupational health and work safety precedents;
- collect earlier assessment and development documentation;
- collect worksite measurement results;
- draw up inspection plan based on the activity, the technology, and employee data.

5.2. Worksite analysis

The first step of the analysis is to determine which CERA assessment area needs to be filled in. It frequently happens that some assessment areas are left blank. Several, obviously uniform activities may be pursued at the same worksite, in respect of which the CERA assessment area concerned must be filled in several copies.

No repeated assessments need to be performed in case of several identical workstations, or if the activity has been surveyed at other locations, or if the same work is done by many employees. However, when making decisions to mitigate hazards, these reductions, quantities and staff data must be taken into consideration.

It should be determined which employees should be involved in assessments. Attempts should be made to involve a number of employees different in terms of build, working method, etc. from various shifts.

Assessment should be performed by disturbing the work as little as possible, and by observing workplace rules. Results must be recorded on the assessment sheet.

5.3. Summary of results
CERA sheets show results in the summary area, with the rest of the sheets annexed. The results in the sheets must be arranged and summarized in a breakdown according to the inspection plan, in a manner to show at how many employees, at which worksites, in the course of which activities, and on the basis of which assessment area red, yellow, and green figures were found.

It occurs that the resultant numerical assessment of the given workstation is attempted to be determined by some sort of weighing from the proportions of red, yellow and green figures, to be followed by setting up an order of priority. Actually, a red assessment result in itself represents an unacceptable risk, so a workstation with “one red score” is no better than a workstation with “triple red score.

However, it is expedient to specify typical problems, where they occur and which employee groups are affected.

5.4. Identification of measures

Parties involved in evaluation and development decide on further investigations on the basis of raw data; further support is provided by summaries.

Being aware of the overall picture, the management of yellow figures should be decided on by preferring measures to mitigate hazards over further investigations.

Measures are typically intended to transform worksites or the working environment, to develop processes and methods, organizational solutions or employees.

It is expedient to set up a list of ergonomics tasks, to include new tasks therein, to schedule future tasks, and to follow developments in progress. It is expedient to have the list reviewed with management involvement every six months, to allocate resources for resolving tasks, and to designate staff in charge.

5.5. Execution of interventions

A joint objective of health and safety and ergonomics is to ensure conditions for sustainable work. Completion of CERA or any other investigation will not improve the situation; only follow-up measures can do so. Therefore it is essential that surveys should be followed by actual developments.

The implementation of measures should be followed by a repeated inspection of the area to verify that risk is already acceptable in the new situation.

5.6. Methodological limits

- There is no fully-fledged, specific, detailed assessment method for a number of work situations appearing in practice, such as alpine technology, car driving or several components of military service; in respect of these, risk assessment methods presumably indicate risks higher than in reality.

- Several basic motion elements are not integrated in risk assessment methods, such as gait or various ways of sitting. These are taken into consideration for specifying risk levels through the selection of testing tools, but many times the evaluation results in the diagnosis of an inappropriate posture.

- Although the standard contains many influencing factors, the combined effects of loads and the summation of complex loads are incomplete. Although there is great interest today in the impact of psycho-social factors on the development of wMSD, the role of even traditional environmental and influencing factors such as noise or vibrations is not yet clarified and quantified.

- This assessment is typically based on the summation of loads on various parts of the body and the risks of expected impacts. This way, risks are determined on the basis of postures and movements which do not even occur in reality.

- It is difficult to assess the resultant strain from complex activities, in spite of the fact that there are methods for summarizing certain load types. Risks cannot really be aggregated in case of miscellaneous activities, e.g. maintenance or repeated fixing works diversified by manual materials handling.

- Current methods are not really suitable for taking individual differences into consideration in an industrial environment, nor for calibrating load limits to individuals.
• Ergonomics methods included in design systems and those serving to assess existing worksites are both easy to access, and as the way of utilization is uncontrolled, competencies to effect analyses – actually analysis results – are questionable.

Even in spite of the difficulties stated above, it can be stated that the professional use of ergonomics risk assessment methods enables the identification of hazards and risk levels of different rates of accuracy. The strength of multi-level reinforcement is to ensure the most expedient approach in the situation concerned.

6. Outlook

Study the following Ergonomic checkpoints:

• Materials storage and handling (checkpoints 1–17)
• Workstation design (checkpoints 51–63)
• Lighting (checkpoints 64–72)

In order to master this chapter, solve the following tasks:

• Select a work activity and conduct a CERA analysis with a paper-and-pencil method.
• Assess a materials handling activity with the CERA xls version.
• Complete a CERA analysis of the worksite assessed in Chapter 4, and compare the results of the two analyses. What can be the reasons for discrepancies?

Visit the following homepage:

• http://cera.munkavedelmitovabbkepzes.hu/
Chapter 6. Ergonomics of office workstations

The design of a really well-operating and comfortable office is more than selecting the appropriate furniture: it is preceded by planning work based on the activity, architectural features and user properties.

A workstation operates most effectively if its physical design corresponds to work expectations, meaning that it provides space for both individual and collective work in a healthy environment, it takes into consideration and reflects organizational relations, provides opportunities to spend rest periods in a decent manner and to have meals, and has a positive impact on workplace atmosphere. In order to implement the above, the first step is to analyze and plan the activities pursued at a workstation. It is expedient to choose a sample as a starting point of work activity planning where similar work activities are pursued. The former workstation can serve as a sample when the existing office is renovated or relocated, or it can be a tried and tested domestic or foreign example as well. The sample can be analyzed to identify and classify partial activities in the future office (e.g. receiving clients, discussions in a group of some people, individual IT data recording, word processing, faxing, phone and computer based work, multiplication, etc. It is important to survey the average time required for each type of activity, as well as their daily and weekly time requirement. These tasks are placed in space and time when designing the office, and the individual workstation is designed by taking this into consideration. Reasons for local changes effected in the course of on-going work in an existing office can be reconsidered from the point of view of the entire office at the time of physical reconstruction, and any harmful consequences can be eliminated.

It is expedient to use reconstruction for changing the image, to reconsider the activity, to reorganize and rationalize administration, and to re-distribute tasks. These functional changes may even result in organizational transformations as well, since the distribution of the main tasks must be visible in the organizational structure as well. Organizational units are placed according to their external and internal contacts derived from their tasks; e.g. units to handle frequent and short-time client traffic are to be placed near the entrance to the office to separate most of the traffic from other parts of the office. Organizational units differ e.g. in their main work activities, in the frequency of various forms of activities, or in the composition of employees, etc. These features will determine the nature of the office: a landscape office can be designed in case of activities requiring intensive teamwork or routine work, while offices for only few people are expedient to be provided in case of work requiring great attention and immersion or entailing the handling of confidential documents. The entire office designed is considerably influenced by the information technologies applied.

1. Traditional office design

State-of-the-art telecommunications devices (phone, voice mail, fax, etc.) and computers are considered as default office equipment; paper-based administration is replaced by electronic archiving at several points; secretarial activities are transformed by the use of text editors and other user applications; the way of keeping contacts is changing by electronic correspondence; the type of work is changing by employment of network-based shared resources, with potential emphasis on working at home. The use of office automation should also be defined as part of activities design, as completely different layouts result from the placement of a central power printer than from a number of individual printers.

Familiarization with the system of activities is followed by an estimation of the space demanded by organizational units, dimensioning additional premises and division of the architectural space on the basis thereof. It is essential to infer the total surface area of the office from the activities, the number of staff and the space demand, rather than to have the required staff number seated within a given area because this would probably lead to crowdedness.

Certain solutions are offered by building properties: spaces of large span are more suitable for offices, while more narrow spaces are fit for individual offices; load-bearing columns indicate traffic routes or walls or furniture can be built around them; protruding spaces suggest opportunities for divisions. From the ergonomics point of view, the environmental features of the building are highly important, including natural and artificial lighting, noise, air quality and climatic conditions. These parameters can be basically checked by instrumental measurements, but subjective evaluation should never be omitted (that is, a specialist survey of opinions by the staff concerned). Favorable and still acceptable values in respect of various types of work are set out by standard. Natural light highly affects people’s general condition. Offices in windowless premises are unacceptable; workstations used more frequently (continuously) should be placed beside the window; surfaces
to screen sunlight from workstations more to the inside should be avoided. Controllability of natural lighting should also be ensured, e.g. by applying curtains or blinds. Sunlight should be supplemented by general and local lighting to be switched in several stages. Lighting design is a special problem if there are many workstations at the office where computer work is done in most of the working hours. In such cases, workstations must be arranged properly and natural and artificial lighting must be suitably combined to ensure the light intensity required for work without any reflections, glare or dazzling to irritate the eyes.

Workplace noise at the office is a frequent source of complaints; it is usually aggregated from infiltrating outside noise, conversations, and the noise produced by office equipment. Several ways of noise protection can be applied at offices, e.g. to eliminate noise sources (to apply flashing lights or earphones instead of ringers in phones); to isolate noise sources (to remove noisy printers from the work area); to absorb noise (sound absorbing wall covers, folding screens). In landscape offices, the so-called masking noise – not too trenchant and of appropriate “composition” – plays a positive role as well, preventing audibility at neighboring workstations.

Climatic conditions of a workplace primarily include temperature, humidity and air flow (ventilation), but air quality is also closely associated. In general, temperature and humidity can be properly controlled by air conditioning, but then windows cannot be opened, it is difficult to designate a smoking area, and draught occurs at inlet holes. Air conditioning equipment is often an unpleasant source of noise at the office as well. Air quality is considerably deteriorated by office machinery, which is also a reason for removing laser printers and copiers from the work area. The smell of food is also disturbing in the work area, but if there is no kitchenette or canteen, employees are compelled to have their snack (lunch) at their workstation. In case of landscape offices, high-standard conditions for meals and recreation are only ensured by a detached and properly equipped dining area. Changing rooms may also be necessary to start and finish work. In landscape offices, the convenient placement and safe storage of personal belongings not used for work (e.g. clothing, bags, etc.) are usually a problem.

In addition to rationality, office design should be transparent to be able to find organizational units and employees easily and to provide easy access to them.

Furthermore, security requirements must also be taken into consideration in planning internal traffic (escape routes in case of an emergency or power failure). Directions and ease of orientation can be ensured e.g. by applying information signs showing the layout plan and with different colors corresponding to each organizational unit. It is difficult to designate traffic routes to access individual workstations due to the cramming of furniture because the adjacent employee may need to be disturbed. Needs of the disabled must also be taken into consideration when designing traffic routes.

As a general rule, a number of individual workstations are established within an office. They are not necessarily used as the workstation of a single person, but as the location of a certain activity as well: for instance, a copier used collectively at the office can also be an individual workstation. As a rule, the tools associated with the workstation and the quantity of materials stored there determine the space demand of the workstation concerned; however, the size and location of such space suggests status as well: the surface area of individual rooms for management personnel is usually determined by the organizational hierarchy rather than by the space demand of the activity.

Workstation dimensions should be adjusted to the body measurements and characteristics or needs of users (e.g. being right or left handed, etc.), so setting possibilities and accessories for customization should be provided for workstations. Workstation comfort can also be increased by the practical rearrangement of furnishings, so tools used more frequently should be closer to employees and those used more rarely should be farther. Similarly, documents and materials rarely used should be placed in a less easily accessible part of the storage cabinet. In line with the company image, opportunities should be provided to personalize workstations, e.g. by placing plants, pen trays, mascots, photos or other decorative elements individually, but without ruining office aesthetics. Opportunities to decorate and personalize individual workstations can bring about higher satisfaction and lead to improved individual work performance.

Offices today are typically made up of computerized workstations. The following is a list of the most general requirements for the correct ergonomic design of computerized workstations:

- chair height is set to have the elbow point in the plane of the desk
- the top edge of the monitor is precisely at eye level
• no lighting surface is reflected in the monitor
• the arrangement is symmetrical from above, the trunk is not twisted
• the wrists rest on a wrist support, they are not stretched out
• the back support of the chair follows trunk motion, the return force is set to the user
• the chair is a roller chair of at least five legs
• feet should rest comfortably on the footrest
• connectors are fixed, cabling is hidden in the furniture
• the edges of the flat of the desk are rounded

So far, the criteria applied by us as external experts for ergonomics audits of offices have been described. Furthermore, it is essential to involve employees in design, in the ergonomic qualification of the office, because this way their experience accumulated can be effectively used in design. Moreover, employees will perceive new offices so designed to be more of their own, and will exploit positive opportunities inherent in tools, furniture, and in the environment more extensively.

The three key concepts of ergonomics are safety, efficiency and comfort. These requirements must be enforced together in the design and establishment of office workstations and the work environment. Understandably, this leads to compromises most of the time. However, one should never lose sight of the fact that it is only workstations designed by taking ergonomic aspects into consideration (that is, designed in a user-centered manner) result in the realization of the interests of both employers and employees, at least in the long run. Our experience shows that ergonomics aspects must always be started to be enforced in advance, in the very first phases of design, when there is still enough scope for action to consider various solutions, and when it is still reasonable to initiate the real involvement of future users (or their representatives) in preparations before decision making.

2. Telework

Telework – the issue of working at home – also deserves attention because the home is also a worksite where information, materials, tools, etc. can all be found and where one shows up each day to work. It has always been taken for granted that work is performed at a worksite: a blacksmith would not take the iron home even if he is in arrears; however, in some special cases the outworker system has functioned, particularly in areas with large living labor demand (domestic industry, assembly).

In our information society, however, constraints leading to the establishment of workplaces can be released. The value, the design and size of office tools enables them to be made available at home as well. Some decades ago, typewriters were hard to find at home; soon it will only be a matter of liking to take your laptop everywhere or have a desktop computer at home as well.

Similar is the case with access from home to information required for office work. Telecommunications devices for data and voice transmission can be used for accessing all the required office information easily and without time limits, for transmitting work parts already completed, and for contacting colleagues and clients.

Ergonomic workspace design must be started at home as well by activity analysis. If you take notes of shorter paper-based documents only occasionally, you can do so in an armchair, under a reading lamp. If there are only few times a year when you work intensively at home, you can declare a state of emergency and rearrange your home for the period required, and after the work is finished the computer can even be hidden in the wardrobe. In case of regular work at home for short periods, you are faced with a more serious decision making situation: you either undertake to set things in order all the time (preparations, e.g. on the dining table beforehand, to be followed by restoring the original arrangement) or you devote and individual space or at least a corner for work. For those who work at home full time, it is expedient to designate a separate room for work as the materials to be stored will accumulate sooner or later and other activities concomitant with work (e.g. face-to-face work-related discussions) require further space. Additional extensions of home offices may lead to a change in the approach, with the office adjacent to one’s home.
It varies from person to person to what extent you require order in your environment; however, there is a general demand to be able to put things in order, meaning that everything should have its proper place and the environment should look according to its name and function. It is a first priority when furnishing a study corner to fit with existing furniture, the style and atmosphere of your home. However, furniture trends developed for centuries focus on traditional office activities, so they contain the combo of a desk, a chair and a container. Monitors and printers placed on Colonial-style tables are becoming a regular sight in management offices, but you may consider them as a violation of style at home: an office chair and a printer will be foreign bodies in your home as extensive, hardly concealable pieces.

Certain wall units have a folding / pullout desk where the table flap covers the content of the cabinet in the storage position. When selecting such type of furniture, you should make sure that the computer devices required fit in the cabinet part (e.g., monitor and cabinet depth) and that an appropriate workspace is created by opening it both in terms of orientation and dimensions.

Many people decide to procure a compact computer desk. These solutions, intended to be all-purpose, are sometimes difficult to handle as they realize too many functions within the smallest space possible. The pullout keyboard tray, the printer placed in the footwell or over the monitor, rollers for easy handling, the convertible mousepad holder, and a variety of height settings may finally result in a solution where there is no room, for the legs or the wrist is not supported.

If required by the frequency and duration of work at home and made possible by the size of the home, it is definitely expedient to make arrangements for an individual workspace. Its location is determined by the layout of the home and family schedules. Work requires immersion, and incessant interruptions just prolong the time spent on tuning in, therefore the place selected should be tranquil and avoided by family members during work. This place can be the solitary spot in the home, but if visitors are often received (e.g. the home is also used as an accounting office) a room close to the entrance should be selected.

If you establish a permanent study room or corner or if you decide to set up a workspace only occasionally, an environment suitable for the activity and in compliance with general ergonomics principles should be provided during working time: these are the requirements for computer workstations.

You should pay attention to the correct posture: a work chair to support the body by following its motion is recommended in addition to settings of the height of the desk, the chair, and other supports. Sufficient work surfaces and storage space is also required for work at home; they should be allocated according to the volume and access frequency of materials so that things that are used more rarely should be put to places that are more difficult to access. Tools (e.g. phone, notepad) should be at hand at your home office as well.

It is important to select high-quality IT devices and to adjust their settings correctly, both in terms of physical arrangement (e.g. the top edge of the screen displayed should be at eye level) and software functions (e.g. to select a high refresh rate).

It is a frequent mistake that others are intended to be less disturbed by lighting only a small part of the work surface (or only the monitor gives light by night). It is more convenient, however to have the visual area more uniformly lighted without spots that are much darker and brighter than one another. Similarly to TV sets, the monitor should be oriented in a way that no illuminators or window surfaces should be reflected in it while watching it and that such light sources should not be within the visual area, either.

3. Accessible office

There are natural things, like when you start the day, switching off the alarm clock with a habitual move of the hand and walking out to the bathroom. You can hardly wait for the lights to turn green, and rush to the bus being aware that you will obviously not be able to sit down. You are immersed in a conversation while treading up the impressive stairs of the office building, and slide in through the revolving door.

There are natural things. For instance, that we are not all alike (fortunately). There are people who are woken up by the alarm of their wrist watch, others by an alarm clock. Many people wait for the bus at the bus stop, there are some who can jump up, some others miss it. There are people who hightail the stairs in twos and there are others who hold on to the banisters and gasp for breath.

There are things that are only becoming natural; natural in the sense that the vast majority of people know enough about something, accept it and act being aware of it. Such ideas becoming natural include the one that
natural things should be made accessible to everyone; for instance, the environment should be designed in a way to provide access and services to everyone.

Accessibility in the strictest sense of the word is the design of structures to enable wheelchair access to premises. In a narrow sense, accessibility means the design of structures for usability by everyone, including various disability groups. In a broader sense, accessibility means the accessibility of services and the availability of conditions for leading a self-sustained life. Accordingly, accessibility involves both the physical transformation of structures and the shaping of opinions and services related to disability.

There are more and more connections with accessibility. The end of this year is the deadline of providing accessibility to public buildings, actually seen as a distant future when the Equal Opportunities Act¹ and the National Disability Program were adopted. Theoretically, only accessible public buildings would be allowed to be built for years. As a matter of fact, buildings not meeting the criteria are still being built today when attempts should be made to eliminate the very last obstacles.

If you sit in a wheelchair (or imagine to do so), you can assess whether a building meets the minimum criteria of accessibility, meaning that you can get to all parts of the building without being assisted or without being subjected to circumstances unbecoming for human dignity. Although there are some examples, it is not an acceptable way of getting upstairs when a person in a wheelchair is lifted by four strapping fellows, nor that access to a marriage hall is provided through a dark freight elevator from the rear entrance.

Accessibility ends at the first stair, narrow door or confined premises. The building itself may not be accessible as there is a flight of stairs leading to the entrance. A lower berm can be surmounted by a wheelchair, but two stairs cannot. Only more spacious elevators can be used, to be able to turn the wheelchair inside. Steep or curved ramps are not a solution, either.

An accessible design does not entail high costs when thinking in advance, but it does so subsequently. It is actually a matter of paying attention to design doors and passage ways to be wide enough for a wheelchair and to redesign traffic routes in this approach. On the contrary, it is much more problematic to install wheelchair lifts (perhaps along an arched stairway), to make space for ramps, to buy platform lifts or to enlarge existing elevators subsequently.

Another great challenge in the accessibility of buildings is the design of sanitary rooms because the surface area must be spacious enough to move, handholds must be installed, fixture specifications must depart from wheelchair height, and wider (sometimes sliding) doors must be applied.

An accessible environment also includes an appropriate selection and arrangement of furnishings. In case of people in wheelchairs, it is sufficient (and necessary) to leave out seats at an easily accessible part of an auditorium. Traffic routes must be broad enough within the auditorium as well (without level differences). Tables should be a bit higher as wheelchairs must get under the table. In storage design, it should be kept in mind that motion ranges are smaller when sitting in a wheelchair, so things placed higher up cannot be reached.

Even in a narrow sense, accessibility involves taking the specificities of disability groups into consideration. In order to facilitate orientation, notices and signs should be supplemented by tangible or audible signage, e.g. elevator controls. In order to avoid accidents, the contour of objects protruding into the traffic route (e.g. glass cases) must be indicated on floor level to be detectable by a white cane. Acoustic signs (e.g. fire alarms) should be repeated visually in the interest of hearing-impaired people.

The next level of accessibility is making services accessible, meaning that everyone should be able to reach the functions offered by the institution in their own way. A library should provide audibly recorded books for those who cannot read and there should be telecommunications services for hearing-impaired people. Anyone should be able to withdraw money from ATMs, and anyone should be able to get into stores, sports facilities or to the doctor’s. Opportunities should be provided for participating in training courses and for using qualifications at work.

Accessibility in a broader sense is creating the conditions for a self-sustained lifestyle, meaning that the injury to express physical condition should not represent a disability. Actually, disability expresses that someone cannot use appliances and the environment.

¹Act XXVI of 1998 on provision of the the rights of persons living with disability and their equality of opportunity
Labor regulations also provide for the employment of people with disabilities. At present, there are no special requirements for workplaces designed for them, only accessibility (in the architectural sense) is expected. In addition, general ergonomics solutions can be taken into account which are applied anyway to make work quicker, more effective and less of a burden, e.g. position adjusters, fixers, signage.

In office design, the accessibility of computerized workstations should be specially considered. There are special input devices who cannot or can hardly use traditional keyboards. Speech synthesizer programs to represent textual information acoustically and Braille printers to feel out graphic information (pictures, tables). A challenge of our days in the world of the Internet is to process and display increasingly graphic information to make browsing a pleasure for visually challenged people as well.

Accessibility seemingly involves special user groups. A complete picture also involves that the special requirements mentioned above are attempted to be met to result in solutions suitable for everyone. Many times, novel design for accessibility may be simpler for everyone.

4. IT tools

The rapid and large-scale expansion of information technologies has brought about consequences which have not been duly surveyed by developers or producers, particularly not by distributors.

The size of the impact of a given case may range from some inconvenience caused by individual software use to worldwide IT difficulties. However, loss statements are only produced in the most important cases: perhaps it was the millennium problem that the high costs of problems related to computer use came to be widely known.

In general, no statements are made about minor individual user difficulties and annoyances which are much more frequent; nevertheless, control problems occurring in large numbers, suffered by many-many users have a larger overall impact than the small number of isolated but notorious software errors.

These minor difficulties are all but unavoidable: inevitably, we are faced with information technologies just as with the administration of pharmaceuticals. Both these achievements of mankind have fundamentally changed the quality of life. As users, we can raise the question with good reason: if pharmaceuticals are tested for years, sometimes for decades before introduction, how can softwares get to users practically subject to no control?

To put it simply, good softwares and the indispensable hardware configuration to ensure their operation are efficient, safe, and easy to use, facilitating our lives as systems to follow good sense (user expectations).

Therefore, software product use should be clear, easy to learn (and re-learn), fail safe and capable of error corrections and customization.

4.1. Good softwares

Appropriate to the targeted task: To the point, follows task changes, data are entered and results are displayed in a form required by the task, default values are known and offered, operates using the original data.

Easy to understand: It continuously indicates what is happening, its feedback is understandable, follows the user’s wording, and adjusts its messages to the user’s knowledge.

Controllable: Calculable (short) response time, adjustable to the situation, interruptible use, work can be left unfinished, the user is to control inputs and the display of results, working with various input tools adjusted to the tasks concerned.

Coinciding with user expectations: Built on a task model, consistent in terms of operation and wording, contrivable (similar task – similar dialogue).

Fail safe: Detects errors and explains corrections, prevents user errors (or makes them "undone"), indicates the error location, provides more detailed explanations on request, its error messages are understandable.

Custom: Saves user properties, texts (explanations) are adjustable in quantity, object names can be specified, users can handle it at their own pace and by their own method, and it takes cultural specificities (e.g. language) into consideration. The question arises in this respect under what terms and conditions software developers and distributors are entitled to enforce users to use the language with the largest vocabulary in the world. Putting it
in another way, are Hungarian users obligated to accept a software for several hundred thousand HUF without a single line of user’s instructions or manual in Hungarian and to buy it separately for 500-1000 HUF.

Supports familiarization: Allows various modes of operation for users of different levels of expertise, explains correlations, takes the user’s memory load into consideration, includes task-dependent help functions, and assists users in getting used to the system.

Standards can be observed if software developers’ operations are prudential, systematic, and properly documented. In addition, a user-centered approach is also required: representatives of the targeted user group should be increasingly involved in the development process.

5. Work chair

Research has shown the detriments of sitting postures with little motion in a number of areas. There is an increased load on intervertebral disks as the spine deviates from the natural double "S" shape, on the one hand, and on the other hand, ascending muscles do not operate in accordance with an upright position. The edge of the seat pan makes the thighs numb, thus impeding circulation in the legs. Implementation of a sitting posture poses increased stress on practically the entire body. As most of our time is spent by sitting, though, it is essential to use chairs of high quality.

There are many types of furniture to sit on, including piano stools, dentist’s chairs, high chairs to feed babies, armchairs and office work chairs, etc. Each of them are intended for different activities, therefore they must satisfy different expectations. It might be surprising, but chairs need not be comfortable in any case: for instance, meeting room chairs are specially designed to make users depart after one or one and a half hours…

In respect of work chair design, the most important thing is anthropometric compliance (in accordance with body dimensions), practically for the entire adult population. A proper solution for this is the adjustability of chair dimensions; in such cases, however, the design of controls is yet another task. It is essential to be able to adjust seat height, as this is the way to control and coordinate the position of the user and the work surface. It is equally important to be able to adjust the back support because it really serves to support the waist, that is, the lumbar section of the spine, to buttress the upper body, rather than the back.

Supplements to office chairs include elbow-rests, application of which should be decided on by the user concerned, similarly to other options of adjustment. Combined workstations – desk and computer rack – result in large work surfaces. Frequent employee displacement should be assisted by chairs, e.g. by applying rollers.

Various levels of attention are accompanied by different postures. Changes in attention levels can be demonstrated even during simple intellectual work, accompanied by upper body motion. Employees performing sitting work with little motion involved connect their health complaints to working at many instances, and this is also well-grounded because static loads deteriorate metabolism in e.g. intervertebral disks. Some part of complaints attributed to chairs can be eliminated by applying chairs enabling to assume various postures or which continuously adapt to upper body motion, thus enabling dynamic sitting. In an ideal design, the return force of the back support is adjusted to the user’s properties.

Products must be accompanied by documentation in line with users’ current knowledge, and training should be provided to master their handling. This also applies to office chairs, as these chairs may have as many as three or four controls, and users cannot be expected to have the required technical knowledge. The importance of correct chair adjustment should be recognized and options of adjustment should be used to make work more comfortable and to reduce health-related complaints, and finally to improve the quality of work on the one hand, and on the other hand, the lifetime of chairs is also expected to increase by their proper use.

Most general requirements of adjusting a chair in front of a desk:

• to set chair height so that the elbow point should coincide with the surface of the desk;
• the arrangement should be symmetrical from above, so the trunk should not be twisted;
• the wrists should rest on a wrist support, they should not be stretched out;
• the back support of the chair should follow trunk motion, the return force should be set to the user;
• the chair should be a roller chair of at least five legs;
• feet should rest comfortably on the footrest;
• the edges of the flat of the table should be rounded.

5.1. Local pressure impacts

Prolonged pressure also plays a dominant role in the development of surface and deep decubitus. In most severe cases, this involves extensive destruction, necrosis, or muscle, bone or skeletal injuries with partial excoriation. This lesion can develop in a work environment as well in the course of rehabilitation, e.g. at the buttock if wheelchair employees are seated for a long time or at the support of the ankles and the elbows.

In addition to the examples above, the effects of local external pressure include further lesions ranging from hindrances of circulation and lymph flow to pains because of the irritation of the nervous system: any parts of the human organism may react pathologically in an unfavorable case.

Loads can be described in more detail to identify progress in the course of time and salient figures as well as to relate the entire exposure to specific tissue areas, enabling a more accurate estimation of musculoskeletal risks and further risk reduction.

Figure 27 shows pressure distribution values in one of the display modes of the mFLEX pressure distribution tester device. Data are displayed in mmHg (optional), colors change from white to red according to the color scale. The right side of the image shows the aggregated statistical indices of the 16 · 16 sensor points of the cushion.

The image shows a really bad sitting posture. The subject is slipped down in the chair, with the thighs supported in only a small area and tilting to the left can also be observed on the basis of the outstanding pressure figure (200 mmHg) at the left-side sciatic tuberosity.

Figure 27. Pressure distribution on sitting surface (mFLEX system)

Chairs and correct sitting postures are kept in the focus of ergonomics attempts by reason of selecting the correct posture, the issue of sitting or standing workstations, and the problems of office work in front of a display.

Attempts for equal opportunities and occupational rehabilitation in the area of rehabilitation ergonomics highlight again the importance of sitting correctly in case of employing disabled people. For paraplegic employees, sitting hazards are increased by wheelchair use as it is much longer compared to healthy people, uninterrupted, and does not involve body weight relocation or fidgeting because there is no sense of discomfort or pain by pressure.

It is also important for healthy employees but it is essential for people in wheelchairs to be employed to be able to sit in devices with no diseases to develop even in the course of prolonged use.
The Rolling project (Social Renewal Operational Program - TÁMOP 1.4.2) implemented in the Rehabilitation Center for Handicapped People (MEREK) is intended to assist the social and labor market integration of disabled people by the development and adaptation of devices to assist an individual life. In order to support professional work, it was decided to acquire a pressure distribution testing system (mFLEX).

Animation 5: mFLEX system

Device parts (Figure 28):
- two cushion sensors to be able to examine the seat pan and the back support simultaneously while sitting;
- data logger unit;
- video camera,
- interface;
- computer for data processing.

Pressure distribution testers are used for the following:
- single measurements to detect pressure distribution, to estimate the risk of ulcer by pressure.
- as the system stores test figures associated with individuals, documentation is assisted this way, and after implements are transformed, the previous and the new situation can be compared.
• measurement series can be used for comparing various product versions, e.g. antidecubitus (anti-ulcer) air cushions or different settings.

• analysis of temporal processes. Data collection runs for about an hour even without power supply, so pressure figures can be recorded in use while going through the practice track in the yard of MEREK.

• searching for the optimum: the appropriacy of each posture can be checked through objective data as well by immediately detecting pressure values after placing the pressure distribution measurement cushion in the posture finding and measurement frame.

• sitting conduct, feedback: by using the cushion, clients can see the pressure values their sitting results in. The impact of movements, body weight relocations and posture changes can be promptly viewed graphically, so clients can get to know more favorable postures either individually or by professional support and can master pressure reduction techniques.

• objective identification of peak values: peak values play a dominant role in the development of decubitus ulcer. The device identifies the location and value of pressure peaks.

5.2. Chair selection criteria

• targeted use
• load bearing capacity, stability
• durability
• angle of back support, length and width of seat pan, adjustability of waist support
• size, height adjustment range
• ease of handling
• elbow rest, rollers
• cover quality (e.g. whether it is sweat-free) and color
• aesthetics
• comfortable design
• number of comfortable positions
• price

In office building design, the question arises which the best chair is. Surveys show that there is no absolutely best chair (to be rated as the best by everyone) by reason of individual specificities (e.g. shape and mass distribution of seat pan). However, there are very good chairs which can compensate the majority of disadvantages arising from sitting by their dimensions, options for adjustment, material and form.

6. Outlook

Study the following Ergonomic checkpoints:

• Workstation design (checkpoints 51–63)
• Lighting (checkpoints 64–72)
• Premises (checkpoints 73–84)
• Welfare facilities (checkpoints 95–105)

In order to master this chapter, solve the following tasks:
• Go to a furniture store and try out chairs in terms of sitting and adjustment.

• Measure out a computer workstation.

• Review recent input tools and accessories in a store or on the Internet. Identify ergonomics problems and solutions.

• Check your workplace and home with an ergonomics approach.

Visit the following homepages:


• iarchitect.com

• http://ergonomics.ucla.edu/homepage/office-ergonomics.html

• http://www.osha.gov/SLTC/etools/computerworkstations/index.html
Chapter 7. Ergonomic development of worksites

Worksite development is a complex process implemented by management support, expert contribution, and employee involvement; results include decreased workplace hazards, less fatigue, less absences, less bottlenecks and improved efficiency.

Areas to be developed should be designated by exploring ergonomic hazards and upon identifying risks and importance. There are many ergonomic assessment tools; they are generally used by physicians involved in occupational health, by health and safety experts and ergonomists. These methods do not work without employee involvement, either, as many changes can be best devised by those who perform the work and afterwards they will be in charge of maintaining the advantageous situation and applying the appropriate methods.

It is impossible to solve everything at one go. The sequence of measures is determined by the number of people afflicted, the chance of occurrence of the given impact, the severity of the output, the time and resources available, the level of elaboration of the solution, and the difficulties of implementing interventions.

Interventions are required to develop a worksite rather than surveys and analyses. The objective is to harmonize employees’ capabilities and work requirements, primarily by improving working conditions. Employee proposals and solutions applied in similar situations elsewhere can be utilized in this development. There are ergonomists in Hungary as well who meet international requirements based on their knowledge, experience and working norms.

The impact of developments must be verified to make sure that they have met the respective expectations. A modified state is acceptable when risks, disorders and injuries have decreased in numbers and the rates of discomfort and fatigue are lower. Beneficial developments are actually followed by the use of appropriate solutions which have not generated further problems and / or loss of quality and / or productivity.

Ergonomics programs are conducted as part of occupational health and safety programs at many places. Such programs are aimed to:  

- prevent occupational injuries;
- reduce the medical and other associated costs of occupational locomotor disorders;
- preserve the combat value of military forces.

Early diagnosis and prevention of work-related locomotor disorders makes it possible to protect and preserve military and civil manpower besides reductions in associated costs because:

- work-related locomotor disorders and injuries are prevented or controlled by eliminating or reducing exposure;
- tasks and worksites are adjusted to employees’ capabilities and limitations, therefore the probability of fatigue, errors, and dangerous interventions is diminished;
- the resulting productivity of employees increases;
- employee compensation claims and associated costs are reduced;
- the combat value of units is enhanced.

A workplace ergonomics program aims to work out solutions and methods to reduce the risk of work-related musculoskeletal injuries, including the following:

Ergonomic development of worksites

- identify practical intervention points and solutions (define a methodology for analysis and explore worksites);
- summarize results, proposals for prevention;
- develop prevention tools, produce prototypes.

It is clear from the wording of tasks that each element of the worksite design and development process is tackled in the course of the development program. This is really a valuable feature as it is well-known that it is much easier and cheaper to apply ergonomics principles during the planning process than subsequently, should designs prove to be defective, to be in need of correction.

In a development realized, the ergonomics program was implemented according to Figure 29. The first step was to set up an ergonomics team; an introductory ergonomics training course was provided for them.³

Ergonomic screening tests of worksites can be conducted by the parallel application of several methods:

- inspections to be conducted by the research team using checklists and evaluation sheets, as well as video recordings and photos taken on site;
- questionnaire-based surveys among employees.

Data are discussed by the ergonomics team; results are evaluated jointly with the management, to determine developments to be realized in the development program.

Proposals for development are summarized in a prioritized list; then conceptual proposals for solution are worked out for the tasks specified; and the developments to be realized are selected from them, again with employees involved.

1. **Full-scale ergonomics**

Before 2001, it was prescribed by law as a general obligation in the USA to conduct ergonomics development programs. Accordingly – e.g. pursuant to the command in effect for military forces (DoD Safety and Occupational Health Program) – occupational health and safety operations must be conducted in each organizational unit, the main components of which are as follows:

- occupational health and safety program requirements and processes, including obligations of risk management operations besides information, records, occurrence investigations, and staffing conditions;
- personal protective equipment program requirements and processes;
- rules on supply staff and operations;
- ergonomics program requirements and processes;
- risk level identification;
- performance evaluation.

An ergonomics program must contain at least the six basic elements of ergonomics intervention, namely:

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Ergonomic development of worksites

- workplace analysis,
- risk prevention and mitigation,
- health management,
- training,
- evaluation and
- procurement.

According to this approach, the objective of ergonomics operations is to intervene in working conditions so that they should not bring about or give rise to work-related locomotor disorders.

As per the ergonomics working group beside the Department of Defense, operating with the involvement of competent bodies of various services, an ergonomics program is intended to prevent and mitigate diseases and injuries by eliminating or reducing the risks of factors leading to work-related musculoskeletal disorders and injuries of employees. Such factors include unnatural postures, repetition, manual materials handling, exertion, mechanical pressure, vibration, extreme temperature conditions, dazzle, insufficient lighting, and duration of work. An ergonomics program results in:

- reduced chances of fatigue, errors or hazardous acts by worksite design aligned to the physical capabilities and limits of employees;
- reduced absenteeism and fluctuation;
- increased overall productivity and quality;
- less claims for compensation by employees and reduced costs associated therewith.

The following parties are involved in the implementation of an ergonomics program: heads of safety at development sites and commandants of ergonomics units by producing and implementing plans of ergonomics; local leaders within their own area by enforcing an ergonomics approach; and stakeholders by executing instructions.

An ergonomics program is developed and implemented by an ergonomics team. Main tools include:

- a process to enable an ergonomics survey simultaneously with worksite risk assessment;
- worksite analysis;
- problem and risk identification;
- detailed analysis of hazardous worksites;
- prevention or mitigation of ergonomic risks.

Information sources for identifying problems and hazards:

- on-site observations;
- medical service reports;
- reports on cases of accidents and diseases;
- presence of certain risk factors, for example:
  - repeated movements;
  - static or unnatural postures;

• extreme tilting or bending of the trunk;
• extreme tilting or bending of the wrist;
• strain on the arms and the shoulders in case of continued lifting, e.g. overhead works, excessive exertion;
• certain muscle groups overloaded;
• confined workspace;
• bad seat pan;
• any combination of the above.

Prevention of ergonomic risks is regulated in detail by the instructions. The following solutions must be applied (in a priority order):

• eliminate hazardous process;
• adequately transform engineering solutions, that is, tools;
• replace hazardous tools and processes by harmless ones;
• change work process, e.g. by more frequent maintenance;
• change the way of work: master new grasps / the correct posture;
• prescribe administrative measures e.g. to limit duration, frequency or loads; order more breaks and activity swaps;
• post those injured to light duty;
• report injuries early to avoid aggravation.

Regulations on ergonomics programs\textsuperscript{6} specify the main processes required, namely those of:

• issuing an ergonomics policy and developing an ergonomics plan;
• designating a person in charge of ergonomics;
• working out a process for the early recognition of disorders;
• mastering the required ergonomics skills by training;
• enforcing ergonomics requirements in supplier contracts and procurements;
• setting up an ergonomics committee within the health and safety committee.

Tasks of the ergonomics committee:

• identify work-related musculoskeletal risk factors based on active and passive observation;
• prioritize the risk factors explored;
• design and implement interventions;
• provide employee and management training courses;
• cooperate with the medical corps;
• record interventions and evaluate results.

As set out in the detailed regulations of ergonomics programs,

- success of an ergonomics program requires management commitment;
- it is essential for an ergonomics program to involve those affected and their representative bodies;
- ergonomic risks must be explored both in process development and work activity analysis;
- there are various intervention approaches ranging from hazard prevention to administrative solutions: they should be tried in a specific order;
- program implementation requires expertise to be acquired by the parties in charge though specific training courses;
- the medical corps are also required to take part in program implementation, and various positions are associated with different responsibilities in the ergonomics program.

In order to implement an ergonomics program, the following are required:

- Physical Risk Factor Ergonomic Checklist;
- IT workstation checklist;
- ergonomics resources;
- recommended training courses in ergonomics;
- ergonomics issues of shift work.

The Physical Risk Factor Ergonomic Checklist (OPNAV 5100/20)\(^7\) is intended for detecting ergonomic risks and identifying risk levels of warning and intervention, respectively, in the following areas:

- bad posture;
- vibrations affecting the hands;
- frequently repeated movements;
- considerable force at grasping or during manual work;
- lifting heavy loads, doing it frequently or in a bad posture.

### 2. Ergonomics in the United Kingdom

In the United Kingdom, the issue of occupational health and safety is treated uniformly based on a manual issued by the Ministry of Defence (Health & Safety Handbook JSP375). This continuously updated online publication provides both comprehensive and detailed specifications on documentation ranging from policy making through responsibilities to special forms, as required for ensuring occupational health and safety.\(^8\)

The first and the second chapters in Volume 3 set out general regulations, specifying the components to be implemented by each unit under any circumstances:

- organization, responsibility;
- cooperation and liaison;
- provision of expertise;
- design and implementation;

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\(^7\) OPNAV 5100/20 Physical Risk Factor Ergonomic Checklist

\(^8\) MoD 375-2 Health & Safety Handbook JSP 375 Vol 2 Leaflet HEALTH AND SAFETY RISK ASSESSMENT
• performance measurement;
• evaluation of results;
• compliance review (audit).

The ensuing chapters in Volume 3 set out safety requirements for hazardous works – performed e.g. in closed spaces, aloft, or under pressure.

The first component of design and implementation is risk assessment, which is required to be performed by all employers in respect of their employees and those affected in the course of their operations. Risk assessment details are included in the guidelines for 23. Site Risk Assessment\(^9\) and 39. Health and Safety Risk Assessment\(^{10}\), setting out requirements, risk assessment procedures, responsibilities, and the five stages of risk assessment. These guidelines also include references to areas of risk assessment with further guidelines attached, such as manual materials handling or upper limb disorders.\(^{11}\)

**3. Outlook**

Study the following Ergonomic checkpoints:

• Workstation design (checkpoints 51–63)
• Lighting (checkpoints 64–72)
• Premises (checkpoints 73–84)
• Hazardous substances and agents (checkpoints 85–94)
• Welfare facilities (checkpoints 95–105)
• Work organization (checkpoints 106–132)

In order to master this chapter, solve the following tasks:

• Recall a situation when you were involved in the design of your environment. What benefits and drawbacks did you experience?
• What can be the causes or objectives of launching an (ergonomic) worksite development?
• What is the importance of ergonomics training for employees in worksite design?
• What special areas (specialists) need to cooperate in worksite design?

Visit the following homepages:

• PeopleSize
• Anthropometry
• NASA database
• Dine - TU Delft adatbázis

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\(^9\)Health & Safety Handbook JSP 375 Vol 2 Leaflet 23 October 2001 SITE RISK ASSESSMENT  
\(^{10}\)MoD 375-2 Health & Safety Handbook JSP 375 Vol 2 Leaflet HEALTH AND SAFETY RISK ASSESSMENT  
\(^{11}\)MoD 375-52 Health & Safety Handbook JSP 375 Vol 2 Leaflet Work Related Upper Limb Disorder
Chapter 8. Products and users

In respect of product ergonomics, products are things in an objective form which are created by conforming to a previously determined process (technology) in a suitably established working environment and which serve for a definite purpose of a specific group of people (target population).

This product definition includes cars, cereal bars, yum-burgers, emergency plans, ready-to-wear suits, glasses, braces, and office chairs in product ergonomics. Obviously, these products have not been designed in their entirety by ergonomists, but our methods can be applied properly in the development of certain features of the products listed; moreover, their current form is partly due to the (instinctive) application of an ergonomics approach.

1. Main areas of product ergonomics

Product ergonomics is intended to familiarize with user characteristics as thoroughly as possible and to vindicate them in the course of product design. The main areas of product ergonomics are summarized in Figure 30 on the basis of the model of product ergonomics and an extended process tree.

User profile

User characteristics and opinions cannot be taken into consideration without identifying the group of users. There are several methods of description and many aspects for characterizing users; you should opt for the one which answers design-related questions as best as possible.

Product safety

Full product safety is a basic product expectation; it should apply in extreme situations of use as well. Due to their material, design, operation, ways of utilization, and communication, products can involve numberless hazards to be detected and eliminated as part of the design task.

Product parameters

Users naturally expect product dimensions and physical parameters to correspond to their own physical features (e.g. body measurements). In order to meet this requirement, various anthropometric features must be known (e.g. body measurements related to length, reach and exertion), and procedures must be applied in which product and user dimensions are concerted in spite of the considerable variety of the body measurements above.

![Figure 30. Main areas of product ergonomics](image-url)
Usability

Product usability analysis is gaining ground today within the scope of product ergonomics. Tests, studies and inspection methods applied in various phases of product development help improve product ergonomics by directly analyzing product use.

Fixing and maintenance

The process tree makes it clear how important it is to design fixing and maintenance features: *users include not only those who use (buy) the product, but manufacturing and maintenance personnel as well. These users make design for maintenance to be a significant area of product ergonomics, including documentation on assembly, maintenance, internal signs, connectors, joints, and methods of access.*

Documentation and packaging

Documentation and packaging as carriers of value-adding functions directly appear in a physical form in the product, thus the usability of the product is extended, it is easier to handle, and use and maintenance thereof are made safer. Similarly to basic products, ergonomics methods need to be applied in working up documentation to accompany and upgrade the product.

Special users

Formerly, industrial products were produced primarily for average users, but later on the importance of special user groups became manifest. Now it is clear that no user groups can be excluded from product use, so particular attention should be devoted to the specificities of elderly people, children, disabled, hearing and vision impaired people.

Applications of ergonomics

Product development is an endless process; it can start in the formulation of a product idea and although its completion may be indicated by the market evaluation of the product, it is intertwined with the development of the next product version. It will be discussed as a separate topic where and how ergonomics methods and knowledge can be used in development, and what roles are played by product developers and ergonomics specialists.

Ergonomic quality of products

Ergonomic quality is determined by meeting user expectations and satisfaction. This expresses all previously discussed areas of product ergonomics. Products can be improved on the basis of quality assessments and data can be supplied to partner areas (e.g. marketing, production engineering, etc.).

2. Identification of users

It is fully accepted in modern production and economics that the successful market performance of a product is inconceivable without thoroughly familiarizing with user needs and the consistent use of knowledge. When the secret of a successful product is attempted to be revealed – with the user in focus –, marketing, technical developer and ergonomics experts need to cooperate and it is indispensable to know each other’s way of thinking to this end.

The following will be a discussion of the ways of describing and characterizing users based on various approaches.

The roll-out of a new product is practically preceded by market research generally performed by the marketing department. In addition to descriptions of function, the planned price and sales incentive plans, a new product concept includes a definition of the target market as well, which has a significant impact on product features in design. In the following it is intended to find out how target group features specified in marketing research can be converted into product development terms and how they can be integrated in the product development process.
The separation of the sales target group – the market segment – from the design target group – can also be deduced on the basis of the roles present in the purchase process: originator - influencer – decision maker – purchaser – user.

A purchase decision is based, inter alia, on a belief resulting from product information and earlier experience, and in general the product intended to be purchased cannot be tried and tested thoroughly. Detailed knowledge from use finally influences the sales prospects of further products. In order to improve sales prospects, it is a widespread method to follow the afterlife of products sold through familiarization with user roles (e.g. used for a long time or discarded the next day). It is also customary to study existing own and competitive products and product opinions in searching for market opportunities.

After the purchase decision, that is, after buying the product, the user is left alone with the product purchased; and this is the point where it is decided to what extent earlier product beliefs corresponded to actual product properties. This is the moment of truth when the technological features, functionality, formal and aesthetic solutions of the product must demonstrate what was claimed before the act of sale, even in extreme conditions of use. From the moment of putting into use, the product is required to meet the expectations of the user only, but to meet them completely.

Similarly to the roles taken into account for market segment specification, various roles can be determined in respect of user groups. Therefore a number of human vs. product connections can be identified in the course of the production, transport, sale, commissioning, use, maintenance, and disassembly of the product, the human side of which can also be considered as users.

3. Description of users

One of the first stages in product design is to specify the group of users, and the design team already plays a substantial part in this.

The user profile is a detailed description of planned product users to which the technical and form design of the product can be adjusted.

In certain cases, the user profile can be specified by a typical person (the group sample) or by itemization as well.

In practice it is more expedient to apply rules, that is, to specify the members of the user group by several characteristic features. The group of users should also be specified along several dimensions in order to mean the same for each party involved in design. The following will be a description of typical dimensions to use for specifying the group of users relevant for a given product. Users are classified by these features in various ways, so there are frequent overlaps, but target group descriptions can still be improved by naming typical persons belonging (or excluded from) here.

User characteristics are classified into four groups, starting with self-evident everyday factors and progressing towards increasingly hidden factors more difficult to explore – and more difficult to manage by market means. These four groups are as follows:

- group characteristics
- individual differences
- physiological and anthropometric features
- psychological features

Group characteristics can describe the targeted user group, while the rest of the features basically describe expected users, although market segmentation can be found in there, too.

4. Designer’s approaches

Developers use designated user profile specifications (e.g. age: 20-40 years; gender: female, etc.) in a primary and secondary fashion as well. In this case, primary use means the selection of data collection samples, both required for measuring data not yet included in databases and for development testing.\(^2\)

The secondary method is more widespread, meaning the collection of data required for planning from existing data stores and guidelines. At this time, data are selected from the data store available in various breakdowns as appropriate to the group of users. Typical examples include the use of anthropometric data (e.g. body height, shoulder joint angles, pedaling force) as these are also available in various breakdowns e.g. according to nationality, age, generation, and gender. User characteristics can be converted into product properties by various approaches during design.

Within a user group, design criteria are usually in normal distribution (user characteristics include e.g. body measurements, favored color shades, experience with similar products, and age).

The "Procrustean bed" approach (Figure 31a) – can be used to arbitrarily exclude some part of users from use and to satisfy the needs of a given user. In the worst case, this is a value yielded, meaning that product features are specified by the technology or any other external factor and user characteristics are completely disregarded (the product is black because black paint was at hand).\(^2\)

\(^1\)Antalovits, Miklós – Peczöli, Irén: A termék ergonómiai minősége /Ergonomic quality of products/, teaching aid, BUTE Department of Ergonomics and Psychology, 1996.
It frequently occurs that designers - in their best intention – work out a version which is ideal for them (Figure 31b). In this case as well, they commit the error of failing to ask or watch real users, so a product usable by only few people is produced again (software developers rarely do accounting work with accounting softwares of their own development).

**Design for the average** is the most self-evident manner of keeping user characteristics in mind (Figure 31c). In this case, a product feature is created which is convenient for a considerable part of users – that is, ”average users” (e.g. fountain pens, chairs for catering).

The name **smaller and taller** (Figures 31d-e) is derived from taking body height figures into consideration. It essentially means that a product property is suitable for every user starting from a certain value. Appropriate examples are doors (where those smaller than its headroom can get through without bowing their heads), or even a given intensity of lighting or equipment output.

An adjustable product (Figure 31f) has discrete or continuous setting options making it suitable for a broader range of users (e.g. adjustable chairs). The figure shows the range of adjustment and some specific settings within.

**Variations** (Figure 31g) mean that different user needs are satisfied by supplying various product versions (e.g. shoes, ready-to-wear clothes). In the figure, user characteristics are divided into several ranges, each of them served by a product version.

The approaches of controllable products and variations both cover a broad range of users; nevertheless, in the former case, each piece is convenient for nearly each user and in the latter case a selection should be made before use (purchase).

The approach of the user with **special needs** (Figure 31h) means that special users are found for each user feature. There are 210 cm tall people, disabled, those with extreme likings, elderly, and people with excessive spendings. It is a real challenge to meet these demands, requiring a more thorough familiarization with user characteristics. In the knowledge of the user’s personality, full compliance can be ensured, but in such a case the product will probably be difficult for other users to use. (Examples for customization include chamber costumes produced by dressmakers, racing car seats or removable braces.)

## 5. Outlook

Study the following Ergonomic checkpoints:

- Hand tools (checkpoints 18–31)
- Workstation design (checkpoints 51–63)

In order to master this chapter, solve the following tasks:

- Look for characteristic products for each designer’s approach.
- What is your favorite product? Specify the user group(s) of the product.
- How should this product be transformed so that more people can use it? Is there a version of "universal design"?

Visit the following homepages:

- DesignCouncil
- MFT
- useit.com: Jakob Nielsen
- iarchitect.com
Chapter 9. Place of ergonomic methods in product development

Traditionally, ergonomics methods have been based on the cognition and systematization of human characteristics and on the elaboration of procedures and recommendations in respect of shaping the objective world. As time goes by, users can be acquainted with more and more thoroughly and from more and more aspects, but it should be noticed that the limits of our knowledge are always reached by definition and knowledge not yet available in a processed and systematized form is required for design.\(^1\)

Basic measurements on the human body were performed early as static anthropometric data are well-defined; height or head perimeter can be measured reliably. In spite of the fact that biomechanical measurements are still not comprehensive, or that the data of certain populations (e.g. the elderly) are not processed, and being aware of the fact that anthropometric features change in the course of time, it can be stated that dimension-related information is mostly available and easy to use, e.g. by computerized modeling systems.

The physiological cognition of man is a task more difficult than anthropometric measurements; still, there are significant results in this area as well. For instance, perception or thermoregulation functions can be measured easily; there are integrated measurement instruments for the measurement and prompt processing of physiological characteristics.

The psychological features required for designing thinking-related product properties are the least measurable. Based on general correlations recognized in psychology, cognitive ergonomics endeavors to take thinking-related specificities into consideration in product design. However, individual specificities, the characteristic features of particular groups – e.g. opinions on rounded forms – are not available in a tabular format like the anthropometric features of groups.

While the required anthropometric data are most probably available in ergonomics-based product development (and measurements need to be performed in extreme cases only), independent testing is most probably required in case of cognitive adjustment.

Initially, knowledge of ergonomics was used to increase the performance of a selected, highly qualified, highly improvable group of users. The successful execution of tactical missions required a perfect match between tools and users, in the framework of which the most suitable individuals were selected and trained for completing the mission, and tools were optimized to match their characteristic features. The use of military equipment is also specific because regular product use is under maximum control, so product deficiencies can be compensated by the human factor and this can be made compulsory as well.

As a next stage, knowledge of ergonomics was used systematically for designing production tools. This environment also provides opportunities for selecting users (admission tests), training (initiation), and work supervision, but the control of product use is definitely more restricted than in case of the army.

As regards the development of retail products, knowledge of ergonomics must be applied at a complete loss of control of product use. Anyone can buy the product regardless of qualifications and practice, and even worse, they can do with it whatever they want. Experience shows that it is against all odds for product developers to hit upon the right point within the broad spectrum of product use demonstrated by a variegated and creative mass of users, diverse in terms of age, nationality, knowledge and interest. The solution is to involve users and systematically use their feedback.

Obviously, user characteristics were used to be taken into consideration even before the evolution of ergonomics. When consumers bought products directly from producers at the market, they gave really quick feedback on the goods (whether to buy or not, or at least an exchange of ideas). In such an environment, producers change products step by step, attempting to effect changes in a "trial and error" fashion, with successful versions to survive by way of gradual development. This mode of development is suitable for perfecting a product; however, it is slow and thus inappropriate for a rapidly changing environment.

\(^1\)Green, William S.: Usability: Concepts, Methods and Practice, Lecture notes, BUTE Department of Ergonomics and Psychology, March 1998
Increases in production volume (large-scale industry production) have alienated manufacturers from users: feedback has become more complex and slower with the increase of intermediary loops. In such an environment, developers need to anticipate user demands because designs prove to be unviable on the market only after a long time and at a great loss. In such an environment, technical specialists well-versed in solving problems design user interfaces based on their own notions, and as these reflect their own demands, the product will not be adjusted to the specificities of the given group of users. This intuitive problem solving appears in the approach of the "designer himself".

By the systematic application of ergonomics in product development, products conforming to the characteristics and needs of a real and large potential group of users are generated; feedback from users to developers is shortened; and innovation is accelerated.

1. Linear product development model

It depends on the attitude of the manufacturer (the organization creating the product) what is considered to be an initial and final limit by researchers in the product development or innovation process. By analyzing the product development processes of products already on the market – e.g. on the basis of participants, tasks or partial results --, the endeavor and convergence of development can be identified as a common feature. Between the commencement of development and market rollout, there is a creative process in which an increasingly specific, tangible and complete product is generated, originating in the product idea and evolving as a chain of analysis, design and other steps.

Figure 32 shows this characteristic feature of development, indicating typical partial results at the top and a typical breakdown into development phases at the bottom.

1.1. Stages of product development

As shown in the breakdown of the figure below\(^2\), product design begins with preliminary planning. This is essentially a period of analysis, including market research (exploring opportunities, analyzing similar products, identifying market requirements and user target group), gathering product expectations (appearance, functionality, production technology, development team), and working out the general direction and concept of design. According to this model, it takes shape as early as by the end of preliminary planning who the product is intended for, for what purpose and how it will be used.

The concept is shaped in the design phase, mostly involving traditional engineering work. This is when functions and the user interface are specified and the technical description is completed. Detailed preliminary design is coupled with engineering analyses, product risk assessment and packaging design. Specimens and engineering models are produced and comparative tests are conducted in order to check technical solutions.

In the testing and review phase, the first version of the user’s instructions is produced in addition to an analysis of the subsystems of the product generated. It can be stated in general that difficulties in writing the product

accompanying documentation can be traced back to complicated product operation. Simple operation is easy to document, but if some operating tasks are complicated, consisting of several steps, if the place of operation is difficult to illustrate, then it will be difficult to understand and learn how to use the product properly. Both the product and the instructions can be revised in view of experiences with the product accompanying documentation.

After the product design phase is closed, **series production** can follow; in preparation, equipment and tools are required to be procured or produced. Product documentation to accompany the product is also copied in production.

**Sales** finally take place after the products manufactured are forwarded to distributors. After this, the process returns to the area of product development as developers can get acquainted with real users and can study product behavior on the market.

This process of product development is always cascaded to the next phase, presuming that the conscientious completion of one stage can be safely followed by starting the next one, finally to result in high quality.

Marketing and development professionals frequently happen to pertain to different organizational units, but product development can only be successful by their close cooperation. The basis for cooperation is effective communication, awareness of each other’s system of criteria and a correct distribution of tasks. "Marketing experts must inform developers about the product feature preferences of users and on what basis they decide whether they have really got them", Kotler says, but it is not unraveled what the role of developers is, how contacts should be kept, and what the recommended division of tasks is. This approach suggests that products really meeting users’ needs can be generated by industrial product development if the needs revealed can be converted into particular – specifiable, measurable, controllable, assessable, etc. – product features; these aggregated features can be handed over for development to the developers; and further information can be acquired as deemed to be important in the design process (steps of technical and form design).

### 1.2. Designer's role

In the process described above, the role of the designer is to solve technical tasks; it starts by information collection and analysis as customary in engineering activities, followed by creation and simulation and finished by product evaluation.

Designers may think that they have the necessary information. Then it can be stated that they make good use of their personal knowledge and experience. Manuals can provide a lot of information with data charts and by presenting procedures and solutions. Consultations during design are intended to profit from the knowledge of other experts in solving special problems. Experimentation or observation, that is, individual data collection remains in the absence of other sources of information. However, reading the sources of information available or a user survey does not constitute design per se: design requires identification of the data required, to be followed by the interpretation of the set of information collected. In the course of interpreting data, designers either extend them (e.g. they use Hungarian anthropometric data for planning to the Dutch market) or violate them (by incorrect value selection) in determining the physical appearance of the product. In such cases, information is screened through designers’ experience and is probably represented in a distorted format within the product.

So, designers’ experience affects the success of development; this can be dangerous when designers are not open to remarks on their work, believing themselves to be infallible. Designers’ experience includes images of human behavior as well based on personal knowledge and experiences. At best, this experience is accurate, aligned with the design task and is therefore very valuable, but at worst, it can be completely misleading or simply wrong. The role of designers’ experience must always be counted on for sure, and when it comes into play, it can either help or set back.

The five root fallacies typical of designers according to Pheasant (his statement is extremely edifying because he summarized his observations in connection with easily obtainable and usable anthropometric data, rather than in a quest for more cumbersome cognitive features):

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No. 1. This design is satisfactory for me, so it will be satisfactory for everyone else.

No. 2. This design is satisfactory for average people, so it will be satisfactory for everyone else.

No. 3. Human features are so different that they are impossible to be satisfied with a single design; but as people’s adaptability is amazing, this is not of importance at all.

No. 4. Ergonomics is expensive, and as products are purchased on the basis of appearance and style, ergonomics considerations can be comfortably disregarded.

No. 5. Ergonomics is an excellent idea. I always do my design work by keeping ergonomic aspects in mind – but I do so intuitively, relying on my general knowledge, so I don’t need tables.

2. User-centered approach – feedback model

In the course of design, the way of using information (that is, the role of experience) is a risk factor to be reduced by feedback. Design is prone to be all the more a success the earlier user expectations can be taken into consideration, moreover, the earlier feedback can be obtained. Figure 33 shows the progress of the development process, but here the freedom of decision is also displayed in addition to the time and investment accumulated. "Anything goes" in the initial period: little energy has been devoted to development, it can even be started all over again if there is a dead end. The product is outlined as a result of decisions made in the course of time parallelly with constrictions of the scope for development. Development work results in more and more detailed plans, total investment is increasing, but step by step it also gets more expensive to continue the development process. Initially, if there is a need to return to an earlier, highly different concept, only a couple of working hours are lost; however, after the manufacturing tool is produced, a change in only a single detail of form will cost an enormous amount. In the final stage of development, only few details can be corrected because e.g. the elimination of design errors surfaced after the pilot lot is produced entails considerable costs (to be justified).

It is revealed in use whether a product is easy or difficult to handle, therefore designers also need to know the method of product use. On the other hand, product use depends on e.g. external circumstances or user behavior, but this latter cannot be predicted from repositories or experimentation with other products.

A solution is provided by feedback from users, in which the linear model is set aside and several subsequent versions are considered during product development: each version is subjected to user testing to improve user image and the product itself. This mode of development represents a chain of producing and assessing.

Figure 33. Reduction of designer’s freedom

A solution is provided by feedback from users, in which the linear model is set aside and several subsequent versions are considered during product development: each version is subjected to user testing to improve user image and the product itself. This mode of development represents a chain of producing and assessing.

Prof. Dr. Rudy den Buurman: User-centered design of smart products; a case study, Teaching aid, Budapest, October 1996.
prototypes, in the course of which the system of design criteria – also mapping user properties – changes as well.

## 2.1. User-centered development process of intelligent products

The figure below shows a product development model built on intensive user involvement. The figure shows the stages discussed earlier with a marked display of feedback and user tests.

Figure 34. shows the stages of the development process together with partial results by documentation: the main working documents of development are shaded, ranging from specifications (list of criteria) to the product realized and launched on the market.

In an ideal case, designer and marketing professionals closely cooperate all throughout the development process. However, it also seems to be an appropriate distribution of tasks if information derived from the market behavior of the product is supplied by marketing in the form of a (preliminary) list of criteria and data collection during development is coordinated by development, with marketing to resume control at the end of the development process. Development can progress depending on the evaluation of partial results, or it is required to return to an earlier phase or to modify the list of criteria as shown by the arrows on the left.

![Figure 34. Process of user-centered development of intelligent products](image)

This rigorous separation of development work and assessment stages enables us to study design itself much more critically. This way backtrack is formalized: it is not considered to be an error if, for instance, models derived from a concept do not stand the trial of assessment; it is rather deemed as a deviation from the ideal direction of development. The fact that the assessment of working documents is so much in focus, the scope of the methods applied can be extended and the identity of parties performing the assessment may change. In a linear model assessment was performed by the designer using some classification or comparison (e.g. date) methods. Assessment can be performed by designer in case of this feedback model as well, but here they can also form a jury with partner areas (e.g. production, sales, logistics), internal or external clients.

In a user-centered development model, assessment can be performed by users as well. User feedback can be obtained during the entire development process by applying methods corresponding to the level of elaboration of the product, the type of working documents, and the weight of decision making (perhaps the confidentiality

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1Prof. Dr. Rudy den Buurman: User-centered design of smart products; a case study, Teaching aid, Budapest, October 1996.
of development). The methods on the right side of the figure show examples of user assessment based on working materials.

### 2.2. Intensity of user involvement

In the feedback model presented, focus is on user involvement to be achieved during development work; the figure does not even analyze preliminary market research or market behavior after roll-out. Development analysis shows that users are much less involved in this phase of design than in stages closer to the market. As shown in Figure 35 below, user involvement is more intensive in development preparations and conceptual design than in the classic phase of engineering design. Again there is increased user involvement before market rollout and in respect of product in commercial circulation. This fluctuation can be explained by the fact that it is more complicated to perform the tests in the course of design on the one hand; on the other hand, designers perceive it to be less within the scope of a designer’s work to deal with users: they rely on the specifications received rather than initiate independent tests.

![Figure 35. Place of user involvement in product development](image)

### 2.3. Levels of user involvement

Manufacturers can be grouped according to the intensity and manner of taking user characteristics into account. In the examples below, users are increasingly placed in the focus of development:

- **No user involvement**: developers do their development work fully relying on their former experiences, without taking user needs into consideration. Development success is uncertain.

- **Intuitive**: developers envisage / try to invent user needs, perhaps they ask their close acquaintances and shape products to conform to this image. Although success continues to be accidental, this approach already recognizes that products are produced for users.

- **Indirect**: developers use data, data tables, guidelines and checklists referring to users. In this approach, developers rely on the user image formed by others but they do not make attempts to verify it.

- **Inquiries**: there is feedback from users in the course of development, received by developers in the form of jury participation and expression of opinions. User data reliability is distorted by errors of inquiry methods.

- **Testing**: data are collected in actual situations of product use; developers draw conclusions from primary data using testing methods in line with the level of elaboration.

Within the scope of development stages, tests are applied for three characteristic purposes:

- **Comparison tests**: Tests performed among potential users in the first stage of development, intended to survey reactions to product ideas, to get to know user preferences, to select promising product ideas, and to identify possible ergonomics problems.

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Place of ergonomic methods in product development

- Iterative testing of product model (prototype): Survey and evaluation of the performance (objective data), opinions and attitudes (subjective data) of the group to represent future users in the framework of a simulated experiment with an (operative) model or (one or more) prototype(s) of the product. It is intended to meet ergonomics criteria as fully as possible.

- Verification tests of new products: Verification of the full realization of objectives related to ergonomics requirements in the framework of real product use.

Verification tests can be divided into in-house and external versions. ”Alpha tests” are user experiments with the prototype intended to be final (before series production), performed in laboratory conditions at the development location (“in-house verification”). ”Beta tests” are performed already at the location of use, with samples of the product (pilot series) before commercial roll-out, and with the purpose of comprehensive testing in situation(s) of actual use (“evaluation at customer sites”).

A number of factors must be taken into consideration in testing (Figure 36). Environmental, user and product characteristics and test assignments to determine interaction are independent variables that can be influenced in the course of experiment design. This influence practically involves either the provision of a constant value to eliminate the variable (constant set of tasks, identical environment), or the deliberate provocation of different situations by carefully selecting values (several product versions, different user groups).

![Figure 36. Independent testing variables](image)

The values of dependent variables are yielded in the course of testing; they cannot be influenced directly by the arrangement. Researchers have experimented really creatively to develop numberless dependent variables for evaluations, including:

- direct indices to indicate user performance (time for completing task, learning time, average time for decision making, response time, error rate, frequency of occurrence of specific errors, frequency of assistance required, injuries, number of accidents, etc.)

- indirect (physiological, psychological) indices associated with user performance (pulse, eye movements, pupillary dilatation, EMG, subjective fatigue, etc.).

In the analysis of user vs. product interaction, objective data have both benefits and drawbacks compared to subjective data. Objective data result from a detailed elaboration of the test arrangement (compilation of the set of tasks, selection of critical tasks), execution of measurements and an analysis of the data obtained. Here you need to make sure (evidence required) that the data actually measure the feature examined and that measurements have not been influenced by any circumstances left out of consideration. Tests must produce the same results when performed by different tools or at different places, or if repeated after some time. In respect of objective data, the impact of regular and random errors of arrangement must be taken into account.

The use of subjective data requires attention by reason of uncontrolled psychological processes. It should be ensured that interviewees fit in the target user group and are willing to cooperate. It should be taken into account that their opinions, attitudes and preferences are affected by recent experiences (e.g. meals are less important after having lunch). It frequently happens that one or more things are required to be evaluated from several aspects. In reality, some features are more important for subjects, so their evaluation of other aspects is also shifted towards their opinion on the former. This phenomenon is termed the “halo effect” in psychology.

Test planning is similar to experiment planning in research. Steps include the following:

- Define objective

- Specify results expected (the information intended to be obtained), raise (measurable and answerable) questions
• Develop tool - tasks, equipment, staff
• Collect, process, and evaluate data
• Present results and their uses.

The critical task is to select subjects from the target group. The number of subjects is affected by the purpose of the test, the procedures selected, and the required statistical reliability. In general, participants are selected in an equal gender division, but there may be deviations according to the nature of the product (e.g. razors). The sample is to include participants according to the age composition of the target group; earlier experience (e.g. have you ever used an electric razor?), or certain possessions (e.g. do you have an electric razor?) may be considered.

Records are drawn up of test results. The main content parts of the document are the following:10

• test objective
• description of subjects
• user / usage test plan
• measurements required
• questionnaires used
• interview questions
• tasks to be completed
• presentation of results.

3. Outlook

Study the following Ergonomic checkpoints:

• Workstation design (checkpoints 51–63)
• Premises (checkpoints 73–84)
• Work organization (checkpoints 106–132)

In order to master this chapter, solve the following tasks:

• Select an activity for which you would design a breakthrough device usable in everyday life. Produce device criteria on your own, interview your acquaintances and produce an improved version based on their opinion. What modifications were required and why?

• Select products and consider in each case when and how users can be involved in product design.

• Search the Internet for methods of plan development in different cultures.

Visit the following homepages:

• http://www.designingforhumans.com/idsa/methods/
• http://en.wikipedia.org/wiki/User-centered_design
• http://www.usernomics.com/ergonomic-marketing.html

Chapter 10. Ergonomic quality of products

Today, quality is a key word accepted by all as a positive value, with attempts to obtain / achieve a higher quality and tendencies to make sacrifices many times. In an everyday sense, high quality means a quicker, more modern, smaller, more reliable, more durable design; however, quality experts have worked out several different concepts of quality.

Quality: compliance with specifications

Based on Crosby’s definition of quality, corporate-level specifications must be defined and carried into effect. This approach ensures that products of the same quality are commercially available (within the standard distribution specified), but there is no guarantee that these are the products expected by consumers. Products produced on the basis of inexpedient specifications will not be suitable for everyday use, e.g. shoes manufactured accurately but made of a pervious material will certainly get soaking wet in the rain.

Quality: suitability for use

Juran’s definition focuses on users; this definition refers to the content of the specifications. Pursuant thereto, quality means compliance with consumers’ worded and unsaid demands, referring to habits, needs and expectations of use and including both circumstances of use and consumers’ values.

1. Ergonomic criteria

When characterizing products, factors can be classified into five main groups; out of them, the factors of safety - efficiency - convenience/comfort are deemed as ergonomic quality criteria, shaded in Figure 37.

Without striving for completeness, some typical quality criteria are summarized in a tabular format.

<table>
<thead>
<tr>
<th>Safety</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>• doesn’t cause burns</td>
<td>• fit for purpose</td>
</tr>
<tr>
<td>• doesn’t cause an electric shock</td>
<td>• high terminal output</td>
</tr>
<tr>
<td>• doesn’t cut or scratch the skin</td>
<td>• adjustable in grades</td>
</tr>
</tbody>
</table>

Figure 37. Product quality criteria

Ergonomic quality of products

- the material is not toxic
- small pieces thereof cannot be swallowed and cannot cause suffocation
- multi-functional with several accessories
- size to fit user’s size
- durable

<table>
<thead>
<tr>
<th>Comfort</th>
<th>Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>easy to handle</td>
<td>pleasant special scent</td>
</tr>
<tr>
<td>easy to assemble and store</td>
<td>cheery voice</td>
</tr>
<tr>
<td>instructions easy to understand</td>
<td>fine to touch</td>
</tr>
<tr>
<td>automatic functions</td>
<td>matching color and form</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>low price</td>
</tr>
<tr>
<td>low consumption</td>
</tr>
<tr>
<td>free repairs for two years</td>
</tr>
<tr>
<td>cheap spare parts</td>
</tr>
</tbody>
</table>

In spite of the fact that product development procedures are only supplied to ergonomic aspects, the issues of costs and aesthetics will also be shortly discussed as they inevitably surface in user interviews and information thus emerging is expedient to utilize in marketing activities.

The importance of these five factors is different for various special areas: For instance, aesthetics if prioritized in form design, while in prime cost design, cost is in contrast with the other four aspects. The relative importance of aesthetic, cost-oriented and use-related (ergonomic) aspects is also influenced by product type. Ergonomics aspects are in focus in the design of products requiring high performance and reliability while aesthetics and cost efficiency dominate in small personal objects (gifts). Interconnections of the three approaches are shown in Figure 38.

![Figure 38. Focal points of product quality](image)

2. "Focus group" method
There are many difficulties involved in specifying the (ergonomic) quality of products:

- in general, there is no system of quality criteria for the given product type, so
- criteria must be specified for each product separately; moreover,
- different factors can come into play in different user groups,
- at different levels of importance.

The solution is to involve users; they can provide assistance, by using the "focus group" method, in converting the trio of safety / efficiency / comfort / (aesthetics) / (cost) into specific criteria.

Focus group: a small group (8-15 people) set up from the targeted user group by sampling, contributing to the evaluation of products and services by voicing their opinion.

3. Identification of system of criteria

Before starting a survey, information must be collected as usual to identify the user group and characteristic uses of the product and to produce, by profession, a preliminary system of quality criteria (group sessions should not be an unpleasant surprise).

In order to get to know real opinions, interviewees must be selected properly: they should really come from our targeted users and represent different approaches and opinions of the user group. Participants can be selected e.g. at the point of sale or use, from a mailing list or based on sales statements. To get a representative sample, attempts should be made, at a minimum, to reach a uniform combination of "age", "gender", and "circumstances of use".

Several diverse groups can also be organized, e.g. from different age groups; at such instances, information can be collected on several products within a survey series based on the principle of variations. A "focus group" consists of 8-15 people because this is the ideal headcount for creative work, and this group size can be managed effectively by methods for small group management. The first task of the group is to familiarize with the problem: the product, the product concept or the product idea. It is expedient to make available products of similar design and function to the group to facilitate brainstorming.

By continuing the group session with a creative technique, e.g. brainstorming, a number of quality aspects can be specified, and the group should select the criteria to be used further on. When formulating criteria, you should aim for the following:

- the wording of criteria should be clear and concise, with no further explanation required;
- criteria should cover all the major features of the subject of investigation;
- the scope and depth of criteria should be uniform;
- aspects should be answerable and answers should be informative (e.g. a negative answer to the question "Are you satisfied with the length of the cable?" does not reveal whether shorter or longer cables should be produced);
- the number of criteria should range between 10 and 20 because answers can be expected to so many questions, on the one hand, and on the other hand, a relatively varied picture can be outlined.

In order to verify the system of criteria, it should be identified whether they primarily refer to safety, efficiency or comfort. There are frequent overlaps in the last two categories (which does not impair the quality of evaluation); but aspects of cost and aesthetics should be disregarded in ergonomics assessment even if they are included in the survey to be used for e.g. marketing considerations later on.

4. Inquiry

The next step of the method is to evaluate the importance of aspects and product quality. It is expedient to produce an evaluation sheet for this purpose, starting with an importance rating of criteria and followed by a
satisfaction survey per product according to the criteria. (Warning: importance is to be rated only once, and a
given product type should be evaluated in the products section.)

Users need to specify both importance and satisfaction along a five-grade scale.

• Question on importance:

  How important do you think it is that the terminal output of a hairdryer should be as high as possible?

  1 not important
  2 at all
  3 absolutely
  4 important
  5

• Question on satisfaction:

  In your opinion, to what extent a DSG-12 type hairdryer meets the requirement of the highest possible
terminal output?

  1 not at all
  2 absolutely
  3 yes, absolutely
  4

5. Evaluation

It is expedient to produce a table for processing data, with separate columns for users’ answers on importance
and satisfaction and each criteria separately per line.

• Number of ergonomics criteria in the given product category: $K$

• Number of assessors: $S$

• Number of suppliers (product versions: $A$

• To check, the total number of all raw data is $D=K \cdot S(A+1)$

The importance of each of the criteria is the average of users’ evaluations on the importance scale. Thus,

• if the importance of ergonomic aspect $i$ according to assessor $k$ is: $F_{i,k}$

\[
F_i = \frac{1}{S} \sum_{k=1}^{S} F_{i,k}
\]

• the importance of aspects $i$ will be:

The average of satisfaction is again calculated for each aspect and product version, but no variable for "average compliance" is generated. Theoretically, a variable for "current supply level" could be generated, but it should rather be avoided. Satisfaction figures are interpreted in view of importance values (comparatively in case of several versions), and the quality of this "average product" is highly influenced by the way of selection of the product versions and suppliers evaluated.

• The compliance of ergonomic aspect $i$ according to assessor $k$ is: $M_{i,k}$ (the product version is not indicated as each calculation is always repeated)

\[
E_i = \frac{1}{S} \sum_{k=1}^{S} M_{i,k}
\]

Satisfaction with the product version evaluated according to aspect $i$: $E_i$: 

Created by XMLmind XSL-FO Converter.
Further processing and interpretation should be preceded by arranging data into a chart, with lines representing ergonomics considerations again, the first column to show the importance figure and the ensuing columns to include the satisfaction figures of product versions.

6. Importance vs. satisfaction diagram

As a result of user survey, importance and satisfaction figures were managed to be associated with ergonomic criteria for each product version. A suggestive picture of the product can be obtained by the graphic representation of figures: each point in the figure corresponds to one aspect (aspects should be named or numbered, with annotations around the graph). Location of the points, the spread of the point cloud, or points sticking out determine product rating: strengths, weaknesses, and features to improve.

In a value analysis approach, the value of satisfaction coincides with the value of importance in an ideal case. This ideal domain corresponds to the diagonal of the graph and the shaded are beside it.

The diagram can be divided into four areas by inserting average importance and satisfaction values.

![Diagram](image)

Figure 39. Results of "Focus group" method

High importance – high satisfaction

In an aspect important for users, the product was rated high in terms of the criteria included here. These are strengths recognized and demanded by users as well. These product features must be kept up; their further improvement may result in a competitive advantage.

Low importance – low satisfaction

This area includes aspects not considered to be important by the users surveyed. This may arise from the fact that the product has been evaluated by several user groups on the basis of an identical system of criteria and their preferences differ; or that focus group members disagreed; or that other aspects proved to be even more important. Aspects of low importance should be filtered out by preliminary testing to precede the large-scale satisfaction survey. Points of importance and satisfaction in this area indicate proper product design as it does not contain redundancies.

High importance – low satisfaction

Aspects classified here suggest deficiencies: something appears to be worse in the product than would be expected by users. The magnifying glass in the graph represents the importance of further testing and improvement.

Low importance – high satisfaction

Ergonomic quality of products

Products rated higher than necessary based on aspects classified in this domain cannot be downgraded ergonomically: quality deterioration is not recommended. This overperformance can come from an overestimation of importance, or can be secondary proceeds from a technical or technological solution. Nevertheless, this strength should be exploited and its importance reevaluated in users’ consciousness by advertising and highlighting the property on the packaging.

Evaluation of ergonomics aspects can be followed by strategy selection for each aspect how to forward the product to the domain of "high importance – high satisfaction" (except for those within the low importance – low satisfaction domain).

Animation 6: Importance - satisfaction

7. Positioning

In a marketing-oriented approach, all five product quality aspects (safety, efficiency, comfort, aesthetics, cost) are taken into consideration in evaluation. Two indicators are generated, one of them includes criteria associated with cost and the other includes criteria (for utility value) associated with all other aspects. In this case, compliance can be determined according to the nature of the aspects by both inquiry and measurement (e.g. consumption), and importance plays a dominant role in generating these indicators. The method is intended for product comparison to study relative positions.

Results can be plotted in a cost vs. utility value diagram (Figure 40) where the regression line or the assessment of the "best realistically conceivable product" can constitute a basis for evaluation if a sufficient number of product versions is investigated.

It may be expedient to conduct further statistical analyses for positioning, in the course of which opinions by answers provided by similar interviewers can be grouped or the opinions of different user groups can be compared.
8. Outlook

Study the following Ergonomic checkpoints:

- Hand tools (checkpoints 18–31)
- Machine safety (checkpoints 32–50)

In order to master this chapter, solve the following tasks:

- Identify ergonomic quality criteria for your favorite product with your friends.
- Assess your favorite product and substitute products of similar functions by involving at least twenty interviewees.
- Produce and evaluate an importance vs. satisfaction diagram and position the products.

Visit the following homepages:

- http://www.sztnh.gov.hu
- http://www.nfh.hu/
- http://www.ergoware.com/
- http://www.ehs.utoronto.ca/services/Ergonomics/products.htm
Chapter 11. Product use analysis techniques

Usability tools have been developed for exploring differences between planned and real product use. In a broader sense, they include methods related to or assisting the exploration or contrivance of product use.

This approach focuses on product usability, interpreting product quality based on the following product features:

1. Learnability: the system must enable the user to reach an acceptable performance level within a certain time
2. Effectiveness: A given percentage of users must demonstrate acceptable performance levels in respect of certain tasks, under specific environmental conditions
3. Attitude: Human expenditures to reach an acceptable performance level – fatigue, stress, frustration, discomfort and dissatisfaction – must remain acceptable
4. Flexibility: The product must be suitable for performing other tasks other than those specified originally
5. Perceived usefulness or usability of the product: ‘the best indicator of the usability of a product is whether it is used’
6. Appropriacy to task: in a usable product, system functions are in line with users’ needs and expectations

The assessment of product use departs from actual user behavior; therefore developers must trace it back from behavior analysis why product use was successful or fruitless. In this approach, a chair is good if people sit on it and if not, the chair should be modified in some way so that people should sit on it. A number of techniques have been developed to explore this desirable mode of use and existing weaknesses in order to influence product use and enable to data collection as required. Use of these methods is rated as a significant competition factor; therefore literature sources discuss earlier methods more in detail and newer ones just in part, introducing their theoretical basics only.

Figure 41 shows a system – though not comprehensive – for product usability evaluation. The structure of this chapter greatly relies on Hom’s setup.

Three groups plus one are identified in the classification:

1. Inquiries involve user contribution with methods used in natural circumstances.
2. Inspection methods are intended to find out about behaviors without user involvement.
3. Testing involves methods in pre-arranged circumstances with user collaboration.
   +1 Related techniques include loosely connected methods to support usability evaluation.

In practice, a complex procedure is developed for collecting information, with several different methods complementing each other.

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1. Inquiries

Inquiries are conducted in real conditions of use, with real users involved. These methods include procedures to ensure user control from the beginning of product development (brainstorming) to the very end (final product evaluation).

It should always be kept in mind in the design of inquiries that a representative sample of users should be involved and data required to specify the group of users later on should be recorded.

1.1. Contextual inquiry

Contextual inquiry is a self-evident method of design for specific people in a new area. At the same time, the highest hazard in this method is that it is self-evident because it makes people forget that to achieve good results, it must be prepared thoroughly, applied consistently and the respective rules must be observed.

This method is intended to explore the circumstances of use of an already existing product, generally to improve the product itself or to develop a related product. In practice, the method requires the designer to regularly visit the place of use during development, to collect observations there, exchanges ideas with users, discussing his thoughts and plans with them. A key issue is to select users involved as they must be well-versed in handling the product, they must be closely familiar with the product, they must cooperate, they must be creative, they must possess basic technical skills, etc. This is a personal relationship where users are partners in development and they also tell their ideas about the product coming from earlier product use; they assess designers’ ideas and provide useful feedback. This method can be applied by a designer who is open to partners’ reactions, is not condescending towards partners, and accepts reflections.

The method will actually function if the designer goes on a field visit with a definite purpose, making plans in advance on what to observe, what to ask or discuss. Roles should not be mixed up: development is the task and responsibility of the designer; to this end, the validity of user opinions should also be considered as involvement is not equal to unconditional acceptance.

The method can be used profitably in an early stage of development if design work is required to be started in a new special field or if there is a person among users who is known to have been involved in product transformation as a user, or who is expected to have a considerable influence on the assessment of design results.

This method is also suitable for exploring special uses in addition to regular and proper use, e.g. uses for different purposes than planned or the use of aids, and uses with other than the method planned.

The contextual inquiry method can be used in the design of production equipment, individual workstations, or even for interior decoration.

1.2. Field observation

Sometimes an excellent product idea is revealed to you while having a shower or during a sleepless night, or you just realize that it has been in front of you for a long time. Field observation is a systematic improvement of
this, leading to the market rollout of practical products which would evolve themselves anyway in a primitive manner, such as fridge magnets or pinboards.

Field observation is recommended to explore product ideas and needs in the early design stage. This is a "voyeur" method. Users should be doing their jobs as if there were no observers (cameras, microphones, etc.) there; but in the meantime the activity (product use) is observed in a way to resemble excavations into an activity situation rather than into the past.

Observers record and analyze the activity depending on their resources – technique, time, number of staff – and the tolerance of the receiver organization in order to find a new product idea. They record the tools used, as well as situations, manners and causes of use. A number of ideas can be generated by the subsequent analysis of photos, arrangement plans and inventories on site if the following questions are asked one by one: "why is this here"? "why does this have to be used at all?", "can this be really used".

Familiarization with informal relationships can also be important in design for groups, including seating arrangement at meetings, distribution of tasks, etc.

1.3. Interviews and focus groups

Everybody knows what a good hairdryer is like. However, developers also know that Everybody doesn’t know what a good hairdryer is like, but Everybody knows what he himself considers to be a good hairdryer. Accordingly, designers can expect to ask some people and find out what they think and this can be an appropriate point of departure to design an acceptable hairdryer for people who think similarly to interviewees (the planned group of users).

In product development, an interview means to obtain information about users’ opinions on the product through questioning. Answers provide information on product-related opinions, expectations, criteria and evaluations. An interview is not a digressing conversation but the structured discussion of pre-formulated purposeful questions. In their answers, interviewees are free to expound their opinions, which are processed subsequently by text analysis. Interviews provide opportunities to ask more than one user and interesting information can be collected by influencing communication (questions to help, body language, etc.).

Interviews can be conducted in all development stages as questions can be formulated at any time and can be used for asking several people. Interviews are typically used for needs analysis during preliminary planning and after sales.

Several people at the same time can be invited from the group of users in order to get information on product-related views: group interviews thus conducted are termed as focus groups.

1.4. Surveys and questionnaires

Surveys and questionnaire techniques are similar to interviews in that they are intended to explore users’ views. For surveys, however, more questions are prepared which can be answered shortly and are not in need of further interpretation, and these questions, the order of questions, and the instructions pertaining to the questions are strictly adhered to, including rules on the omission of questions or jumping between questions.

In the course of surveys, questions as above are addressed verbally (face to face or by phone) to carefully selected interviewees. As regards surveys, the large work of compiling the list of questions is required by the fact that survey questions can be asked by individuals not competent in the subject and having only general questioning skills, and that answers are also simple to process. This way even several thousands of interviewees can take part in a survey, yielding a mass of data possible to be analyzed by statistical methods as well. High numbers of interviewees also enable to break down the sample, so the analysis of differences based on demographic features is a general phenomenon.

Interviews involve few questions, few interviewees, a lot of afterwork; while surveys involve more detailed preparations, many questions, many respondents, and much less afterwork per interviewee. Both methods have their proper place; it is not obvious that surveys would yield more valuable information. By reason of statistical processing, surveys seem to provide more objective data, but the errors and basic assumptions programmed in compiling the list of questions will still remain. In contrast, interview subjects can make statements much more freely and can divert the conversation towards areas not touched upon in the list of questions.
A thoroughly developed survey form properly equipped with instructions can be used by respondents themselves. These survey forms to be filled in individually are termed questionnaires.

Theoretically, surveys and questionnaires can be used in each stage of development; the difficulty lies in low levels of disposition to answer.

Various types of questions can be used in questionnaires:

- **Open questions** are used to request respondents to expound their opinions freely in words, perhaps to give reasons for their earlier answers. Answers are evaluated subsequently by text analysis; categories are generated from comments of similar content, to be followed by checking for their frequency of occurrence and a summary of answers substantially different from the others.

- **Nominal data** are generated when the most or the least whatever version must be selected from various versions or versions must be put in a sequential order. Such data include colors (green vs. blue), brands or other names. After processing, nominal data are generally used for producing frequency diagrams, e.g. that most respondents (45%) liked the blue version.

- **Ordinal data** are in a sequential order as a matter of course, but differences between neighbors are not constant. These data indicate that one of them is bigger than the other, e.g. that a sergeant is ranking higher than a corporal. If coupled with other questions, ordinal data can be used to identify relatively simple tendencies, e.g. to present satisfaction levels in function of educational qualifications or settlement size.

- **Interval data** are constant differences between neighbors: e.g. Celsius scale, dB scale. As it is an infrequent phenomenon that the absolute zero value of an interval scale does not exist or is outside the scope of everyday thinking, this variable is rather rarely used in practice.

- **Questionnaires** frequently ask for numerical data or classifications. Numerical data are generated at these instances, where proportions can also be interpreted in addition to differences. Such data include amounts of money, minutes, the five-grade scale for schooling, etc. Such questions are popular because users can be characterized by numerical data by using statistical methods, and correlations can also be identified. Results can be shown highly visually, e.g. in a histogram or scatterplot. However, you should be on the lookout for errors: statistical and spreadsheet softwares often yield results quicker than to be thought over and operations are executed even at instances when they should not, e.g. when there is an inadequate distribution or sample number.

- **Yes/no questions** are posed many times, involving dichotomic variables. Some variables like this in the list of questions can serve for breaking down the sample. A checklist is actually a survey questionnaire consisting of only yes/no questions.

During the survey, even before completing the questioning part, you should be pretty specific about the data you would like to obtain, what correlations you would like to check for and the impact of what variables you are looking for. If a question is left out of the list of questions or is difficult to process, it will be difficult to rectify it subsequently. Correlations and differences cannot be searched for in the mass of data subsequently, either, as statistics have hidden errors and accordingly, correlations and differences are usually yielded by a mass of data (just like a blind man may perchance hit the mark). If research is not purposeful and pre-planned but the causes of appearing correlations are sought for, it is easy to fall victims of calculation errors. (In respect of twenty scaled questions, a variance or factor analysis should be performed rather than the calculation of all correlations.)

Being aware of the fact that this method fits in to a more complex system of investigations, the following steps should be executed in conducting a survey:
1.5. Journaled sessions

Behavior-based inquiries and tests are most convincing for designers among methods to involve users. In these procedures, tasks corresponding to the intended purpose of the product are completed and further improvements are based on the analysis and interpretation of behaviors produced by real users (activities, product use). These methods differ in the selection of tasks, the circumstances and location of implementation, and the way of recording data. In practice, analyses are performed by several methods after the series of tasks to be completed with the product is designed, and a number of supplementary investigations – e.g. questioning by questionnaires – are also conducted.

The "Journaled sessions” and "Screen snapshots” methods were originally developed for software analysis. These methods are discussed among investigations because in the case of softwares the testing support function can be built into the product itself, so these tests can be performed at the actual location of product use, without the personal involvement of the investigator. In case of relatively simple products, data can be collected for similar purposes in an experimental arrangement using video technology and by developing forms.

"Journaled sessions” are intended to record product (prototype) use (users’ steps) automatically. Subjects receive the product (prototype) with a series of tasks to be executed. As users have to solve the tasks alone, they will have successful and failed interventions and they will finish testing the product at a certain point of the series of tasks (hopefully at the end).

Sessions are journaled in the background, hidden from users; components of user vs. product interaction – product states and user responses thereto – can be retraced from them. Journals are returned to the investigator, providing opportunities for detailed analyses, e.g. performance indicator calculations, walkthrough route disclosure and product use strategy identification.

After the integration of the logging function and the instructions to present the task series, the next step is to collect textual remarks. Automatic input boxes can be requested for explaining task difficulties or giving reasons for solutions, and these text-based responses are then annexed to the journal.

"Journaled sessions” can be used when an operable product version already exists. At this stage they are suitable for screening basic functional errors and exploring preferences.

1.6. Self-reporting logs

Upon individual completion of the pre-determined task series, subjects can be asked to summarize their experiences and difficulties in writing. In self-reporting logs, respondents expound their thoughts freely, therefore product usability evaluations, use conditions, or user needs and preferences are revealed by text analysis. Processing of responses requires more energy due to the "understatement” of instructions.

Self-reporting logs basically constitute a paper-and-pencil method, but it can be supported by word processor or sound recording technologies.

1.7. Screen snapshots
Screen snapshots can be recorded easily for software evaluation, but photo-type images of display content can be made in case of other products as well. This technique is also associated with the completion of a previously specified series of tasks; screen snapshots can be made at critical points based on the task series, on the one hand; on the other hand, subjects can have the opportunity to make screen snapshots at points considered to be important by them.

Interface errors can be identified on the basis of screen snapshots only, but a comprehensive analysis can be performed using self-reporting logs and journaled sessions.

Similarly to the previous two procedures, this method requires to have an operable product version.

2. Inspection

Inspection methods, user experience, rules to describe user behavior are intended to enforce requirements to protect user interests – without user presence. In respect of these methods, primary information collection is forgone for a quicker and cheaper result, but most product errors can be screened this way as well by real experts.

2.1. Heuristic evaluations

Heuristic evaluations are intended for the expert inspection of the prevalence of usability principles. The reliability of this method depends on expertise as it is only based on experts’ personal experience. The quality of evaluation is improved by increasing the number of experts (3 to 6 people) and by repeating the investigation (to be performed at least twice).

Experts invited for evaluation include ones with remarkable experience in a special field corresponding to the function of the product and/or in interface design. Experts assess the product individually, based on heuristics, precisely covering each display and control, button and aperture, their location, design and implementation.

Experts produce a report to record their remarks and recommendations. Evaluation can be accelerated by dictating their remarks in the meantime (this absolutely resembles to an autopsy), and can be made more efficient by setting up evaluation categories in advance and classifying defects therein. (The path from a report to the use of categories is nothing but the formalization of knowledge, that is, methodology development.)

A heuristic evaluation can be performed in any phase of development, but only if experts have something to form an opinion about.

2.2. Cognitive walkthrough

Cognitive walkthrough is intended to evaluate possible user behaviors by experts. This method essentially means that experts attempt to predict how users would solve product-related tasks or what would be a problem for them based on the product, a prototype, or even graphic sketches or specifications.

In preparation for a cognitive walkthrough, the tasks to be solved with the product should be specified and broken down into subtasks. Experts try to find out on the basis of the user interface what users can pay attention to, what they can think and do while watching it. This method can be used for identifying conditions that make it more difficult to achieve the goal, to complete the task, to use the product, if there are any misleading or missing displays or arrangements. The procedure includes an assessment of the importance of the deficiencies revealed and a presentation of methods for correction.

A cognitive walkthrough is a practical method because it can be applied all throughout the development process; it is quick, low-cost and efficient. Reliability of this method can be improved in the way described at heuristic evaluation.

Another version of a cognitive walkthrough is when several experts perform the analysis together; in this case, group synergies further improve the effectiveness of pluralistic cognitive walkthrough.

2.3. Formal usability inspection
Formal usability inspection is not a method suitable for independent assessment, but rather a project management methodology to facilitate cooperation in the development team. It is intended to structurally integrate usability assessment into the development process, to separate development roles, to formalize testing phases, and to provide quality assurance for development (It is similar to the PRINCE methodology in IT development).

Constructors are biased towards their works: they do not recognize their defects, and do not or hardly accept criticism. The first step is to separate the assessor’s role from the designer’s role; assessors should be invited from another department or external experts should be hired for evaluation. In the course of evaluation, the product version is inevitably criticized, but designers tend to protect ”their children” and to explain the cause of the error. According to the philosophy of this method, designers will not recite this explanation in case of each piece sold, so there s no point in this type of defense during evaluation: defects must simply be corrected. According to the fundamental assumption of this method, many evaluations are required and the product evolves in the meantime.

The following must be designated for a formal usability inspection:

- four to eight inspectors to perform evaluations;
- a registrar to perform administrative tasks;
- a moderator to conduct evaluation sessions (e.g. to prevent debates and personal remarks);
- the owner to represent developers.

In practice, the owner delivers the current product version to the registrar; the registrar forwards it to the evaluators and evaluations form their opinions. The evaluation session is conducted by the moderator, the registrar writes up the minutes, and the evaluators frame a common standpoint on the product. The owner answers to the questions raised but there is no room to make excuses; moreover, this session is not intended to solve problems either by the owner or by others). The session is to crystallize tasks, to identify their importance, to specify deadlines and persons in charge. After the session, the development process goes on, with new solutions and evaluations to be produced for the next occasion.

### 2.4. Feature inspection

Typical series of steps (scenarios) to identify the required product functions can be deduced from the destination of the product, from the tasks required for solution. Feature inspection is intended to check these functions specified on the basis of planned (conceived/regular) use.

This method essentially involves experts to inspect the availability and usability of the functions required in a product status where it is made necessary according to the scenarios. It must be revealed if there is a function missing, or it is available from the wrong place, or its signage or mode of operation is inappropriate, etc. Feature inspection is closely associated with the preparation of user documentation as the way of executing each function must be described therein, too.

A feature inspection should be employed in the midst of the development process, following functionality identification.

### 2.5. Consistency inspection

Although consistent appearance and operation are important aspects even within a product, consistency inspection comes into play in the design of product lines when identical operation of several functions (products) must be ensured. Although products are developed by different teams, product line uniformity and consistency must still be ensured, including the utilizability of experiences with one product on another. In order to ensure uniformity, the solution of one of the design teams must be adopted by the others, with the one gaining ”prestige” and the others having extra work to do. Consistency inspection is nothing but a secret voting by the decision making team on the designer teams, based on expert opinions. Uniform solutions must be decided on in an early stage of development.

### 2.6. Standard inspection
Product compliance with local standards and regulations is required to be inspected during development. It is expedient to hire local experts (with more extensive knowledge of current regulations and knowledge of the locality) on each market to use this method. They should check for potential product integration with other products.

In view of its importance, standard inspection is a milestone in the middle phase of design.

2.7. Guidelines

Tools to be used by developers as well can be produced by the recording of aspects suitable for evaluation and the systematization of expertise. Guidelines include the tasks to be performed in the course of development and evaluation by using a detailed methodology. Guidelines show it step by step what, how, and why designers should do in order to reach the target set.

2.8. Checklists

Checklists are to check the series of tasks or the result by a pre-defined approach. Checkpoints are fixed, and "yes or no" decisions must be made about completion. In general, "yes" answers express compliance in checklists, and the series of activities may only be continued if the answer is positive.

The use of checklists simplifies processes, making them controllable and enabling safe execution even with less experience.

Guidelines and checklists are really useful because they make expert work comprehensive and safe, substituting individual experience by collective knowledge.

3. Testing methods

Some usability assessment methods require considerable instrumentation; these should be implemented in laboratory conditions. In order to ensure real conditions of use, mobile data collection systems are applied many times and experiments are performed in the field.

3.1. Thinking aloud protocol

Some per cent of people are talking to themselves hardly audibly (mumbling) while they are thinking (solving a task). This is the basis for the "thinking aloud protocol" method, where thoughts are expressed intentionally -- after some practicing -- and the audio material is recorded by a laryngophone. Scraps of speech thus detected can be used to reconstruct the method for solution and to identify difficulties and product handling inconsistencies. The "thinking aloud protocol" method gives some insight into the subject’s thinking, with conceptual models and problem solving strategies to reveal.

If subjects are well-versed in thinking aloud, the method can be implemented easily; it can be implemented at any time in the course of development in possession of any testable material.

3.2. Co-discovery method

Co-discovery is a method close to thinking aloud from the viewpoint that in this case, subjects also talk while using the product, but this one is much more lifelike than the previous one. It is a natural human reaction to ask for help when facing difficulties and to cope with the task together, discussing opportunities and hindrances. This method involves problem solving by inexperienced users together or inexperienced users with expert user assistance, tackling pre-defined tasks. The process of solving the task series is (video)recorded and used for exploring solution strategies and identifying handling difficulties.

An advantage of the co-discovery method is that participants motivate each other to raise more ideas and enrich evaluation results.

3.3. Question and answer protocol
The “question and answer protocol” can be considered as the root of the “journaled sessions”, "self-reporting logs”, and “co-discovery” methods. Here, the list of tasks specified is performed by the investigator and the subject together, asking about difficulties, the options for solution identified, as well as for the cause and aim of interventions executed. It highly depends on the investigator’s behavior to what extent a lifelike situation is managed to be set up.

3.4. Performance measurement

In a traditional engineering way of thinking, objective and measured data seem more reliable than data based on questioning or evaluation, therefore attempts to apply objective measurement methods in product use as well are just natural.

In certain cases, developers are required to meet a performance target (e.g. to design a corkscrew to open a bottle with in 5 seconds). In such a case, a specifically measurable attribute must be selected to reflect the quantity actually measurable. Typical measurements include time, error rate, and intervention frequency, though mental stress or eye movement complexity to scan an image are all measurable.

Measurement procedures should be treated cautiously, with dependent and independent variables to be selected carefully, identity of circumstances to be ensured, and measurement errors to be taken into consideration. In brief, you must pay the price for data gained by measurements, revealed in both methodological basics and instrumentation.

A properly performed measurement can serve as a basis for checking design plan implementation, comparing our product with the competition, tracing product evolution, and selecting the best product version. Measurements can be performed on completely functional products; models or even prototypes are unsuitable.

4. Prototypes

Several procedures are known to be used for implementing usability evaluation methods or as a supplement thereof, including prototype production. Various prototypes can be produced in the course of the development process for testing and evaluation, with considerable differences in levels of elaboration and operability. The scope of modeling is as follows:

- A horizontal prototype presents the product in its entirety, but in an inoperable state
- A vertical prototype realizes an operational functional unit in detail

Prototypes can be distinguished on the basis of the level of elaboration as well:

- Prototypes can be distinguished on the basis of the level of elaboration as well:
  - A detailed prototype is realistic in terms of looks and operation, etc.

The application of sophisticated prototypes shortens the time of development and modeling. It is self-evident to transfer the usable components of earlier prototypes into the next version (recycling), or to develop and use prototype components from which the prototype of the current product version can be produced.

Rapid prototyping is a technique where users assemble products from partial elements, reaching the product version ideal for them by starting from a given set of elements. In such cases, the versions produced can be compared in terms of functionality, manageability, and price perhaps.

5. Outlook

Study the following Ergonomic Checkpoints:

- Hand tools (checkpoints 18–31)

In order to master this chapter, solve the following tasks:

- Select a hand tool and propose three methods of evaluation. Give reasons for which method should be used under which circumstances.
• Identify the strengths and weaknesses of the software you are using for reading this educational material based on systematic evaluation.

• Produce a prototype of more advantageous educational software based on your experience.

Visit the following homepages:

• Usability.gov

• http://www.usabilitynet.org/tools/methods.htm

• http://www.dgp.utoronto.ca/~hunt/telechi/hcitools.html

• Usability day

• http://hci.ece.upatras.gr/
Chapter 12. Case studies

1. Case of the worn fodder silo

At a poultry farm, dry feed was stored in a wall-mounted steel container of 5 m³. The material was fed by chuting (down-spouting) through a pipeline on a weekly basis, and it was opened through an outlet pipe on the side of the container on an hourly basis.

The old container got worn out around the outlet opening; therefore a decision was made to replace the area affected. In the course of container inspection it was also revealed that this opportunity would be better to be used for the replacement of supporting structures as well; furthermore, it would be high time to check the inside of the container and repair it if required.

1.1. Circumstances

1.1.1. Locations

Work is done at an own site expediently installed for the purpose, at a workshop and at the site of a third-party enterprise; passenger and freight transport are both performed between the two sites by motor vehicles.

1.1.2. Stakeholders (those endangered)

• Those who perform the work: locksmiths, welders, truck drivers, trolley drivers, crane operators, and their managers.

• Cooperators: specialists involved in container maintenance at the poultry farm, supplier of the workshop.

• Those staying within scope: poultry farm workers, those to perform other tasks at the workshop, visitors.

1.1.3. Operations and technologies applied.

• Organizational and control operations: engineering survey and design, materials procurement, specification of welding technology, work organization.

• Metallurgic activities: arc welding, oxygen cutting, hammering, grinding, boring, milling, speed-cutting, screwing.

• Materials handling: moving basic materials, workpieces, tools, and equipment manually and by machine (trolley, crane and truck).

• Operations for safety: takeover and design of work area; health and safety training; tasks related to the safety of welding, fire protection, work in confined spaces, and freight transport on public roads.

• Ancillary activities, e.g. cleaning.

1.1.4. Tools applied for work

• Gas welding equipment (burner / welding torch), acetylene / oxygen cylinders, cylinder valves, hoses).

• Welding torch and cutting torch holder.

• Arc welding equipment (Power supply for welding (transformer), welding cables, (between power supply and electrodes and between power supply and work pieces), electrode fixer, workpiece fixer).

• Welding equipment (fitting tools).

• CNC milling machine.

• Speed cutter.
• Electric drill.
• Hand tools and accessories (hammer, fork spanner, extension cable).
• Trolley.
• Truck.

1.1.5. Materials
• Heavy and extensive iron container.
• Basic materials of steel.
• Material residues within the container and on surfaces.
• Auxiliary materials of welding.
• Gases used for welding.
• Materials generated in the course of welding.

1.1.6. Worksite accessories
• Workbench, scaffolding.
• Local lighting.
• Tool stand.
• Material storage stand.
• Ladder, platform.
• Pallet.
• Chair.

1.1.7. Working environment components
• A specific part of the structure
• Traffic routes
• Information and warning signs
• Locker room, bathroom, canteen, resting place (fixed or mobile)

1.1.8. Safety tools
• Welding hood an apron
• Knee-guard
• Welding mask
• Safety shoes
• Glasses against flying objects
• Earplugs
• Protective gloves
• Protection against falling (five-point strap with the rope required for fastening and accessories)
• Air composition gauge
• Means of rescue

1.2. Hazards

All hazards occurring at work must be explored by analysis in respect of the specific workers, tools, materials and technologies, etc. concerned. The example shows a great number (and variety) of hazards; a detailed description of circumstances provides assistance in their collection. Hazard groups from the example of silo maintenance:

• Hazards from materials (material of electrodes, welding gases, etc.).
• Hazard of work overground (fixing the container after reassembly).
• Hazards of materials handling by machines (trolley driving, public road transport, craning).
• Fire hazard (in the course of welding).
• Electric shock hazard (in the course of arc welding, to use local lighting).
• Light effects and visual requirements.
• Hazards related to the temperature of materials (hot an cold iron).
• Metal working hazards (e.g. flying, falling parts, cuts, vibrations to impact hands).
• Noise (from metal working operations or activities in the environment).
• Hazards of working in a confined space (work in the inside of the container).
• Hazards of changing sites (takeover and signage of area, establishing work environment, etc.).
• Hazards of work organization (e.g. procedures missing or failing to comply with legal regulations, omission of inspection and maintenance).
• Missing staffing conditions (invalid licenses, missing qualifications, insufficient headcount).
• Hazards of human behavior (observing rules, perceiving risks, strategies to reduce hazards, customs of protective equipment use).
• Hazards of clothing and protective equipment (e.g. a welding mask reduces the visual area, earplugs reduce hearing, aprons reduce the range of motion).
• Factors leading to musculoskeletal disorders or injuries during work.

Warning! The list of hazards above does not include welding risks in detail. All stakeholders are supposed to reduce hazards in order to create the conditions for safe work not representing a health hazard. Risk assessment at work is a legal obligation of employers; but as it is a special professional operation, it is recommended to ask for the assistance of health and safety experts.

A number of ergonomics hazards are also to be found in the description of the case. Some examples in the order of operations:

1.2.1. Crib production

• Hazards of on-site survey: travel to site and work in a foreign terrain.
• In case of computer-aided engineering design, hazards include **office work (with a monitor)**.
• Materials procurement hazards involve carrying iron pieces into the workshop, representing manual materials handling.

• Use of the cutting machine involves machine tending; hazards may include bad posture, exertion and manual materials handling during work.

• In the use of speed cutter as a hand tool, wrong posture, exertion, vibration affecting the hands and manual materials handling may occur.

• Cutting is noisy, and it is a good solution here to reduce the number of those within the scope by a work organization measure (afternoon shift only for cutting).

• Mould production to be used for manufacturing the crib, the new outlet tube and the container door are completely metal working operations, with bad posture, exertion, vibration affecting the hands, noise, and manual materials handling are to be taken into account as hazards.

• As regards craning, hazards include bad postures typical at fastening, in addition to crane operator’s loads.

1.2.2. Dismounting the silo

• The first hazards can be produced by deficiencies of takeover of the work area when performing work at a foreign site. There are many aspects, including the designation and enclosure of the area, transfer of energy connections, coordination of salvage plan, issuance of license for lighting a fire, and waste management.

• Transfer of tools (welding equipment, gas cylinders, etc.) to the site (and back) involves risks of manual materials handling.

• Supporting consoles were cut through overhead, requiring a very bad posture, to be added to by having to hold the long blowpipe, by the inconvenience of wearing personal protective equipment, and by the intellectual and fine motion requirements arising from the task.

• Shaping the crib on site is a complex metal working activity, accounting for hazards of bad posture, exertion, vibration affecting the hands, noise, and manual materials handling. Worse conditions should be expected in case of site work than at worksites carefully planned for permanent use, if design receives less attention due to its occasional character.

• The crib – and the blowpipe and the rod for welding by gas flame – must be held and precision movements must be performed with them. When completing the task, wearing personal protective equipment can be inconvenient. Approaching the welding area can be associated with bad posture, possibly with the use of a platform or ladder.

• Human errors, deficiencies in preparing the work area, and failure to observe welding rules led to the tilting of the container.

• The underestimation of hazards and time constraints posed yet another hazard, offset by the worksite manager’s commitment to safety.

• Deficiencies in working conditions – e.g. the manner of storage of tools, personal belongings and health and safety documentation, sanitary rooms and locations for recreation, first aid kits – might pose further hazards.

1.2.3. Tank repair

• Removal of the old outlet tube requires a bad posture; in the meantime, the blowpipe must be held and the inconveniences of wearing personal protective equipment must also be taken into account together with intellectual and fine motion requirements arising from the task.

• The internal reinforcement of the container involves all the hazards of work in a confined space and of welding. Constrained posture because of shortage of space is particularly critical.

• In order to weld up the new outlet tube and to reinforce the container with ribs, the blowpipe and the rod must be held in inconvenient postures and movements of high precision must be performed with them. When
completing the task, wearing personal protective equipment can be inconvenient. Approaching the welding area can be associated with bad posture, possibly with the use of a platform or ladder.

- When unscrewing the door of the creephole, torque had to be exerted in bad postures.

The description does not include certain hazards at each occurrence, so for instance hazards at the mounting of the silo were already indicated at dismounting and reinforcing the silo.

For example, depending on work arrangements, the work of welders can be limited to performing the welding operation only; it can be supplemented by preparations and follow-up works required for welding as well as by other metal working activities; and it can be highly diversified, including materials procurement and the initiation of new entrants.

The example included supplementary activities to welding (preparations, checking, materials handling, follow-up works). These works usually entail working with hand tools, materials handling, inconvenient (many times motionless) postures, exertion and precise movements, and personal protective equipment must be used.

A welding procedure essentially comprises the generation of a controlled heat effect, and the movement of materials at, to and from the area of operation. Welding quality is determined by the welding procedure (energy source, extension) and the materials, as well as by the duration of the heat distributions generated during the operation. Very important activities ancillary to welding include identification of the appropriate technology, procedure and sequence, and the selection of tools and equipment.

The quality of welding depends on the motions of the welder during the execution of the welding operation; therefore the series of movements following from the technology must be performed as accurately as possible. The ergonomics hazards of welding arise from this series of movements, namely the relative position of the tool, the hands, the shoulders, the neck, the head and the gaze, and the exertions and motions of the parts of the body affected. This actually comprises the progressive and oscillatory motion followed by the sight that generates the weld or the cut.

In order to attain an ideal unity of the tool, the hands, the shoulders, the neck, the head and the gaze, both the worker and the workpiece must be in a convenient position compared to each other, taking into account any hindrances and possibilities of support within the workspace. The position of the tool, the hands, the shoulders, the neck, the head and the gaze relative to the area of operation can be all the better, the more appropriate posture can be ensured by the rest of the body; e.g. in a confined space, the area of operation is more accessible by taking up more inconvenient postures of the legs and the trunk. Thus, further ergonomics hazards arise from ensuring an appropriate position for the unity of the tool, the hands, the shoulders, the neck, the head and the gaze as an operational unit and the area of operation specified on the workpiece.

Further loads during welding are represented by the movement of workpieces: these are reduced according to the general rules of manual materials handling.

1.3. Maintaining posture

Posture during work ensures access to the welding area. The aim is to reach a proper reciprocal position of the unit of the tool, the hands, the shoulders, the neck, the head and the gaze versus the workpiece. Postures diverging more from natural postures and maintained for prolonged periods pose more serious hazards, increased even more by motionless positions and pressure and heat conditions at places of support.

1.3.1. Welding postures

When designing work postures, natural standing or sitting positions should be attempted to be taken up and the alternation of postures should also be ensured if possible. Welding can also be performed in an appropriate position if the welding area is in front of the worker between hip and elbow height and the worker can move freely back and forth. In this case the trunk does not need to lean and twist, no bending, no forcing the head backward, and no constrained positions of the legs are required, therefore excess loads can be avoided. As welding progresses, the appropriate position can be reached by moving the workpiece or the worker changing positions.

In the example, workpieces could be positioned at the welding workstation in the workshop when producing the mould, the ribs, the crib, and the new outlet tube.
Many times during welding it is made impossible by the circumstances to adjust the workpiece as required for taking up an ideal posture, e.g. because of the size of the workpiece to be welded or because it is built in. In the example, this hazard arose due to the properties of the welding area in welding the crib and the ribs.

In such cases, the worker can be placed to the required location by supporting the body and can even be moved as the welding area changes. Support is appropriate if it is evidenced to cause no further impairment, meaning that the part of the body supported is braced evenly along the largest possible surface and soft parts are not compressed. Cushioned support can be applied to brace the knees or the hip, as a seat pan or a back support, while it is not acceptable to brace the abdomen while leaning forward.

Environmental restraints and obstacles can lead to constrained postures when the convenient reciprocal position of the unit of the tool, the hands, the shoulders, the neck, the head and the gaze versus the workpiece cannot be realized by a natural posture. In such cases, it even requires exertion to maintain the posture, representing an increasing hazard with the passing of impact time. Environmental obstacles can restrict the welding posture as well, which in turn can cause deterioration in welding quality, either by the wrong position and motion of the rod or the blowpipe, or by poor visibility. In the example, the internal reinforcement of the container had considerable environmental restraints.

Figure 42. Typical postures during welding and their hazards
Occasionally, this activity is also acceptable for short periods if the worker’s support and traffic are otherwise safe; however, if the activity is prolonged, a detailed analysis must be performed by involving an expert and welding conditions must be improved.

In the course of welding, the main hazards related to maintaining posture are as follows: the trunk leant forward, the neck leant forward and strained back, the trunk or the neck twisted, the trunk bent, kneeling and squatting.

1.3.2. Practical tricks and tips

• Plan the welding posture. If it is feasible, use positioning (and fastening) devices to bring the workpiece into the adequate position.

• If you work with an assistant or several people work on site, cooperate so that everybody can work in the best possible posture.

• Stand facing the welding area and do your welding jobs between hip and elbow height on a horizontal surface. As the welding progresses, step sideways or move the workpiece to be able to face it continuously.

![Figure 43. Positioning devices](image)

• The workpiece or the welder can also be moved by machinery, such as a turntable or a scissor lift.

• Clear up the working area. Remove obstacles preventing the adequate postures.

• Take up the appropriate posture. Hold your back straight, possibly in a vertical position, and avoid twisting and tilting the spine.

• Alternate standing and sitting positions if possible. Try to do your work by moving steadily, without sudden motions and static postures.

• Open the mask by hand. A nodding move is also a sudden tug for the neck, representing an unnecessary load.

• Apply supports verified to be appropriate for holding and supporting the body. Remember to support the legs, the knees, the buttock, the back and the hand (the non-welding but propping one) as well.

• Diagnose incipient diseases. Accumulating locomotor disorders can develop anywhere due to bad postures during welding; however, initially they are accompanied by discomfort and pain so treatment can be started before the trouble gets more serious.

• Store tools at easily accessible places. It is also a load to reach for a tool and to put it down; avoid needless stretching.

1.4. The welding operation

In order to perform the welding operation, the series of motions proceeding from the technology should be performed as accurately as possible. Hazards arise from the relative position of the tool, the hands, the shoulders, the neck, the head and the gaze, as well as from exertions and movements of the parts of the body affected. Influencing factors include the following:

• the method of heat generation (technology) to determine the tools;

• movement of various materials at, to and from the area of welding;

• weight and weight distribution of handheld tools;

• grip design, operation of controls;

• operating length of a handheld tool, that is the distance of the welding operation from the fingertips;
• direction of the welding line and the required speed of progress;
• swing width caused by the welding gap, it is not there at cutting and spot welding;
• the weld pattern determined by the welding technology of the materials concerned;
• the accuracy required;
• the interruptibility of welding, namely the minimum length to be completed at one go;
• workpiece handling.

1.4.1. Welding motions

Welding is the progressive and oscillatory movement of the hand followed by eyesight. It is made particularly difficult by the fact that the stable position of the hand and fine hand movements must be ensured while welding tools and materials must be held; and that there is no support at the place of the operation and all this must be performed while wearing protective equipment.

In order to hold the tool and the weight of the hand itself, both the extensor and flexor muscles of the upper limb are required to work simultaneously, which represents a load even in itself; however, keeping a motionless posture is definitely harmful. The hazard is greater if the handheld tool is heavier or if cables must also be held. Muscles working against each other can provoke vibrations – tremors – in the upper limb. If the welding area does not move (e.g. the tube is turned by machinery), the hand can be supported without any impairment as evidenced.

The oscillating motion required to produce a weld comes from a very large number of repeated motions of the lower arm and the wrist, and it is coupled with exertion by reason of holding the tools. This represents a major ergonomics risk if the position of the wrist is bad: it is flexed in, strained in or out e.g. because of grip design. The range of wrist motion is affected by the required width and pace of oscillation, so oscillation at a quicker pace and wider welds represent more serious hazards. The rate of exertion is affected by the weight distribution of objects held in the hand and the force dynamics generated in the area of welding.

n of the execution of movements. Higher precision involves a higher vision requirement, so the eyes can get closer to the area of welding, which entails a change in posture. The accuracy of motion and the load resulting from execution is also affected by the distance of the welding operation from the fingertips. At a distance of up to a few centimetres the task of targeting with the tool is no more difficult than having to touch the target area with a fingertip. (Pencil length does not affect writing, either.) At greater distances targeting needs special attention, for instance when the consoles supporting the container were cut by a long cutting blowpipe in the example. Access was provided by the long blowpipe, but due to the great distance between the hand and the place of operation only a low-precision cut was possible. As the operating distance increases, oscillation width can be ensured by smaller wrist rotation, therefore it is worth trying greater distances when developing individual welding techniques.

Operation of equipment controls also entails exertion by the hands. Solutions are better where controls are operated in a natural posture requiring minimum exertion. It may occur that controls must be operated e.g. at the knee rather than on the handpiece.

Holding and moving the workpiece and welding equipment operation also require exertion and various postures to increase loads on the hands.

Stress on the two hands is not necessarily identical: their motion, exertion and position are all different. In operations requiring both hands, the smarter hand is used to execute a high-precision task and the secondary hand to perform tasks of support or requiring power. In case of extensive experience it is conceivable that the roles of the two hands are exchanged, thereby the loads on the two hands can be balanced.

Welding risks also depend on the proportion and distribution of breaks. Continuous impact time is determined by the interruptibility of welding; any increases therein will aggravate the situation. The longer is the shift of welding and the higher is the proportion of time devoted to welding, the higher the risk will be.
1.4.2. Practical tricks and tips

A solution for reducing the risks of manual welding is mechanization; in the absence thereof, risks of this operation can be reduced by applying a high-quality apparatus, appropriate methods and organizational arrangements.

- Use a light and handy handpiece. Grip diameter and shape should enable the hand, the wrist and the lower arm to be in a natural position during operation.

- Reduce loads from connecting cabling. Cables should be connected flexibly to handpieces, they should be easy to move, possibly balanced or moved by a balancer or by a mechanized solution.

- Controls should be easy to operate. Natural posture and small force should be required for their operation; status should be clear, controls easy to recognize and separate.

- Use welding devices. Fasteners, clamps, workpiece movers facilitate operations, making them simpler and less exacting. In addition to health protection, their use results in a reduction of manufacturing time and costs and improvements in productivity and quality as well. They can redeem one hand or even an assistant to handle the workpiece.

- Use practical devices. Workpieces should be put in place, fixed and replaced quickly; placement, adjustment, fastening, clamping and other components should be controllable by small exertion and fastening trajectories should be short.

- Monitor the signs of your hand. Recognize early symptoms just like in the case of other parts of the body.

- Restrict loads and make them evenly distributed. Take a break between welding sessions and possibly perform other types of tasks in addition to welding.

- Apply a lower arm support. A support evidenced to be appropriate can be useful for the lower arm as well, relieving from burdens and assisting in holding the position, thus protecting your health and enabling longer welding sessions.

- Develop your welding techniques consciously. Make efforts to reach a natural posture of the hands, the wrists, the lower arms, the shoulders and the neck.

- Keep your hands loose. A cramped hand and posture represent extra loads in themselves and make it even more difficult to execute the operation.

- Select good protective equipment. Lighter, easier-to-manage protective equipment affecting motion to a lesser degree increase ergonomics risks less.

Ergonomics factors of a welder’s workstation include:

- worker’s physical abilities;
- weight of the blowpipe;
- shape of tools;
- working position;
- body mechanics during welding operations;
- protective equipment used for welding;
• workspace (dimensions, lighting, temperature, noise, vibration, etc.);
• working method;
• physical work requirements (lifting, rotation, reach);
• intellectual job requirements (motivation, attention, focusing).

2. Pram users and data use

It is special to define the group of pram users because more than one users can be identified simultaneously. Users include parents, on the one hand, who push, lift, fold up, adjust, etc. the pram, and children on the other hand, who get in and out and travel in the pram in various postures.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Parent</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>18-60 years</td>
<td>0-3 years</td>
</tr>
<tr>
<td>Gender</td>
<td>mainly females but males as well</td>
<td>both girls and boys</td>
</tr>
<tr>
<td>Expertise</td>
<td>no expertise</td>
<td></td>
</tr>
<tr>
<td>Regional features</td>
<td>European users</td>
<td></td>
</tr>
<tr>
<td>Intelligence</td>
<td>general flair for technology</td>
<td>developing</td>
</tr>
<tr>
<td>Abilities</td>
<td>capable for independent activities</td>
<td>limited motion</td>
</tr>
<tr>
<td>Motivation</td>
<td>need for transport / storage</td>
<td>increased interest</td>
</tr>
<tr>
<td>Other</td>
<td>pregnancy, weakness can occur</td>
<td>increased need to sleep</td>
</tr>
<tr>
<td>Hand dominance</td>
<td>both right and left handed</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Pram user groups

Data on age, gender and regional characteristics are used for dimensioning prams in a secondary fashion, meaning that relevant body measurements are retrieved from tables. Spread in the body measurements of parents can be compensated by providing options for adjustment, e.g. in case of the length of the pushing handles. The body dimensions of children (together with their physiological features) change considerably, which can be offset by designing various versions and by applying accessories.

The gender of the child can influence the color of the pram selected, so it is advisable to design a version with several colors to go with.

Parents cannot be expected to have originally existing high-standard knowledge of pram operation, therefore easy manageability should be a target to achieve. A high degree of functionality expected many times – e.g. it should be collapsible, it should have a sunshade – requires parents to have considerable operational skills even in case of handling solutions intended to be simple, therefore opportunities to master the knowledge required must be provided e.g. in the form of user instructions, a training CD, a video or a personal presentation. Regional features also play a part in this since textual explanations must be published in the national language and locally used signage must be applied.

Regional features affect pram design in respect of weather conditions (e.g. typical temperatures, probability of precipitation); areas of use in terms of road and traffic conditions influence shock absorption and wheel diameter.

Parents can be assumed to be capable for independent activities, meaning that they can execute movements and they are intellectually able to perform tasks related to road traffic with small children in a pram. It is difficult to carry other packs while pushing a pram, so it is expedient to prepare the product for this in advance, which is particularly justified by the mass of accessories required for children.
By reason of children’s limited faculties of motion, it is expedient to design a fastening option (seat belt), and sufficient access room must be provided for parents to tend their child. The increased interest of children can be satisfied by ensuring a broad panorama (with an option of conversion towards the parent or the outside world); on the other hand, toys to draw their attention can be fixed in their surroundings. Then again, interest is extended to the pram itself, so it must resist children’s discovery attempts (e.g. for disassembly). As the child may spend a long time in the pram, it should enable a variety of postures.

Examples have been shown in the above for secondary utilization of the group of users since the information disclosed is available from e.g. statistical and anthropometric tables and books on psychology. Primary tools can be used when such information is not accessible. Such information would most probably include hand diameter data of Hungarian children aged 0-3 years, which could be determined e.g. by measurements performed in the waiting rooms of childcare facilities. The user group serves as a basis for selecting samples for usability analysis, so for instance young mothers with children are invited from the playground to test a prototype of a pram under development.

3. Selection of office furniture

When the central building of Hungarian telecom company MATÁV was built in 1998, a tender was invited for furniture supply. Six applicants were granted the opportunity to present each of the chairs, desks and cabinets in a model office in the development area. Preliminary testing of furniture was already a tradition at MATÁV as chairs were tested systematically on an on-going basis at the Error Reports Unit and a “model office” was also operated at the Call Center for months. Furniture was tested by a team from the Department of Ergonomics and Psychology of BUTE (Miklós Antalovits and Gyula Szabó); Figure 45 shows the investigation process.

In view of the activities expected to be performed in this central office building, seven product categories were selected parallelly:

- **A:** Administrator’s computerized workstation
- **B:** Meeting room and workstation to support team work
- **C:** Secretary’s workstation
- **D:** management – individual – workstation
- **X:** Employee chair
- **Y:** Middle management chair
- **Z:** Guest chair

Focus group members were selected from among future users to represent organizational units, management levels and activities expected. After team building, the first session started with training for the specificities of office activities and ergonomics issues related to furniture and chairs. This was followed by the generation of ergonomics criteria in the group. Separate lists were produced for furniture and chairs, respectively; criteria were accepted by majority agreement.
In the short break, voting slips were produced, where the importance of criteria was evaluated at a five-grade scale (1: not important at all – 5: very important) individually by participants.

The second session was conducted in the model office where the presentation of tasks was followed by several hours of familiarization and testing. Self-contained booklets were produced for each participant for evaluation, with criteria included in a descending order of importance.

For the sake of clarity, the category (A-Z) was indicated on each piece of furniture and – as the impact of brand names was intended to be reduced in the determination of ergonomics quality – the manufacturer’s code as well:

Each product by each supplier had to be evaluated according to a five-grade scale in terms of each aspect (1: not satisfied at all, 5: fully satisfied). The work of the focus group was terminated after submitting the booklets.

Scores were summarized in several formats:

- Traditional comparisons per category and importance vs. satisfaction diagrams and tables on individual products were produced and interpreted as usual.
Table 3. Assessment of ergonomics criteria for employee chair "X"

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Importance</th>
<th>Manufacturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Adjustability to body</td>
<td>4.92</td>
<td>3.91</td>
</tr>
<tr>
<td>1. Comfort</td>
<td>4.58</td>
<td>3.82</td>
</tr>
<tr>
<td>1. Proper airing</td>
<td>4.33</td>
<td>4.09</td>
</tr>
<tr>
<td>1. Stability</td>
<td>4.17</td>
<td>4.36</td>
</tr>
<tr>
<td>1. Adjustability</td>
<td>3.50</td>
<td>4.36</td>
</tr>
<tr>
<td>1. Aesthetics</td>
<td>3.25</td>
<td>3.45</td>
</tr>
<tr>
<td>1. With or without an elbow rest</td>
<td>3.17</td>
<td>3.36</td>
</tr>
<tr>
<td>1. Harmony with furnishings</td>
<td>3.17</td>
<td>3.36</td>
</tr>
<tr>
<td>1. Accessibility of controls</td>
<td>2.83</td>
<td>4.18</td>
</tr>
</tbody>
</table>

Text notes:
Person 1: The color of the upholstery of chairs should be turquoise if possible (by no means claret or red).
Person 2: Adjustable elbow rest height is an advantage.

Figure 46. Importance vs. satisfaction diagram of employee chair "X"
Figure 47. Importance vs. satisfaction diagram of employee chair "X" per supplier

- The simple average values of satisfaction grades on the three most important criteria, calculated per furniture category and supplier – were projected to a 100-grade scale. By arranging these figures in a table, the order according to the most important criteria can be examined, in a form resembling the expression of compliance in percentage and also evident for those not interested in testing details.

- If $F_1$, $F_2$, and $F_3$ are the three most important criteria, then the satisfaction $E_{fr}$ of the highest importance for the product concerned will be:

$$E_{fr} = \frac{\sum \sum M_{i,k}}{3 \cdot S} \cdot 20$$
Table 4. Assessment of major ergonomics criteria along a 100-grade scale (detail)

- When generating weighted indicators, total weighted satisfaction was calculated by multiplying average satisfaction values – calculated by furniture category and supplier – with the value of importance. The theoretical maximum thereof is 25 (primary importance and total compliance) and the minimum is 1 (not important at all and absolutely inappropriate); higher parameter values represent higher importance and quality based on the aspect concerned.

- Value of weighted satisfaction $E_s$:

$$E_s = \sum_{i=1}^{S} E_i F_i = \sum_{i=1}^{S} \left( \frac{M_{i,k}}{S} \right) \left( \frac{F_{i,k}}{S} \right)$$

Table 5. Weighted sums of ergonomics criteria assessment (detail)

- In an ideal case, importance and satisfaction values are identical in respect of each of the criteria; therefore average deviations (in the positive direction, where the value of satisfaction exceeds the importance figure corresponding to the aspect concerned) from the optimum case were also calculated. (No absolute deviation or mean square error was taken into consideration, so the evaluation was not improved by "overperformance".)

- The value of difference $E_d$ will be:

$$E_d = \sum_{i=1}^{K} (E_i - F_i) = \sum_{i=1}^{K} \left( \frac{S}{M_{i,k}} - \frac{S}{F_{i,k}} \right)$$
Table 6. Differences in the assessment and importance of ergonomics criteria (detail)

<table>
<thead>
<tr>
<th>Furniture category</th>
<th>Bidders</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Administrator’s workstation</td>
<td>-0.78</td>
</tr>
<tr>
<td>Z. Guest chair</td>
<td>0.14</td>
</tr>
</tbody>
</table>

4. A development process

At a leading international corporation the process of product development is as follows:

- Know-how phase: collect, generate, and apply know-how in many areas
- Concept phase: identify the way to subsequent product generation
- Phase to follow the launch of a product line: leading to the rough specifications of a product line;
- Phase after release: The product is ready for shipment.

It is interesting to observe that the volume of development is so big that product lines are mentioned rather than products, and the variational approach is applied to both power and functionality. This presentation of the development process keeps secrets behind the scenes: guesses can only be made on how mystically a product is designed and produced somewhere between phase three and phase four.

In the course of product development, user testing is applied for the following purposes:

- Know-how phase:
  - testing to generate new concepts and original ideas;
  - testing to select first basic ideas and concepts;
  - investigate existing problems;
  - testing to answer specific questions.
- Concept phase:
  - testing to answer specific questions;
  - testing to decide on compliance with acceptance criteria;
  - testing to select ideas and concepts;
  - testing to identify usability problems.
- Phase to follow the launch of a product line
  - testing for final concept details, verification of implementation method.
- Phase after release
  - investigation of problems and remarks;
  - finalization of usability criteria.

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• investigation of problems.

The list shows that tests are initially used for seeking ways and means, for generating ideas; afterwards focus is shifted to feedback – selection and responses to specific questions –; and finally, testing is intended for inspection.

5. Missile system testing and evaluation

In the course of acquisitions, ergonomics principles are enforced by Human System Integration (hereinafter: HSI), whereby musculoskeletal disorders and injuries are prevented as early as in the acquisition phase based on the instruction on the execution of acquisitions\(^2\). HSI is a comprehensive management and technical strategy to ensure that the criteria for human performance (from planning to headcount, capability and training requirements), health and safety prevail throughout the design and development process of the entire system.

Enforcement of the ergonomics requirements set out here in respect of each service is stipulated by the standard on the criteria for human factor design. This standard details the features of human versus machine interfaces of equipment, including the layouts of facilities, systems and equipment as well as the design of displays and controls. Although this standard also serves as a basis for risk assessments, it not only serves for safety but also for high-level deployability, high performance and efficiency. The objective of applying ergonomics principles during design is as follows pursuant to the standard stipulating the consideration of human factors during design\(^3\) and the related supplementary guidelines\(^4\):

• ensure the performance required by operator, supervisory and maintenance staff;
• reduce the experience and personal properties and training time required;
• reach the required reliability level of human versus machinery systems.

The navy acquisition instruction\(^5\) requires that both health and safety and human systems integration requirements are met. This latter is regulated in detail by the command on Navy Personnel Human Systems Integration (NAVPRINT)\(^6\), setting out procedures and document contents to be executed and developed in the course of acquisitions.

The aim of the Human Engineering and Ergonomic Risk Analysis Process (hereinafter: HEERAP), a joint project by the Defense Security Commission of Inquiry and the Navy was to coordinate ergonomics, health and safety and acquisition processes more precisely. The HEERAP facilitates the identification, analysis and mitigation of personal injuries due to design; design based on it results in operability, maintainability, inhabitability, transportability / portability, and installability / erectability.\(^7\)

The procedure essentially involves the completion of a personal injury risk matrix of the following content after a personal injury risk analysis:

• functions to be realized;
• the task itself;
• human to machine connections;
• ergonomic risks;
• sources of hazards;
• strategies to reduce hazards.

\(^2\)DoD 5000.02 Operation of the Defense Acquisition System. Department of Defense. Instruction Number: 5000.02
\(^3\)MIL-STD-1472F Design Criteria Standard, Human Engineering, Department Of Defense US, 23 August 1999
\(^5\)INST 5000.2D Implementation And Operation Of The Defense Acquisition System And The Joint Capabilities Integration And Development System SECNAV Instruction 5000.2D
\(^6\)OPNAVINST 5310.23 Navy Personnel Human Systems Integration, (NAVPRINT)
\(^7\)Human engineering and Ergonomic (HE&E) Risk Analysis Process (HEERAP) Final Report, April 30, 2008
The HEERAP project involved extremely detailed analyses and hundreds of risk situations were documented in the Navy in the system above.

The high-reliability systems of NASA – e.g. the missile defense system – must be tested in the course of the development process regulated. Testing objectives:

- To ensure that requirements are met, that is to demonstrate that the system complies with the specifications.
- To demonstrate that the design complies with ergonomics requirements, e.g. arrangement of controls, ranges of reach, display modes, signage.
- To check for meeting performance criteria in user-dependent cases. This is definitely performed by user involvement already, and its significance lies in the fact that the system examined must perform tactically critical tasks even with the most poorly performing operator within the require time.
- To perform quantitative measurements of performance factors depending on the human versus machinery connection to enable comparisons between various operator interfaces.
- To identify defects of operation and design to outline further improvements required.

Figure 48 shows the development model applied by NASA. By reason of the area of operation, no political / management decision to substitute market research is represented here, but the very starting point is systems design and development is ended by an operable system (according to this philosophy, it is enough to produce only one missile defense system).

Testing is performed by using models from the very first moment of development; technical solutions are examined in the course of development testing; functional testing of prototypes is started during testing for details; control tests are performed by simulation beside the functional system.

As regards UK military procurements, enforcement of ergonomics principles is ensured by the Human Factors for Designers of Systems Defence Standard. In the approach of this standard, the integration of human factors covers connections between two out of the three components of defence capabilities – processes, people and equipment –, namely the latter two. Part 3 of the standard includes detailed technical guidance on systems safety (Section 10), work equipment (Section 15), and workplace design (Section 13).

6. Software ergonomics assessment

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\(^6\)Meister D.: System effectiveness Testing, HHF 10.1
\(^7\)MoD 00-250 Human Factors for Designers of Systems Defence Standard 00-250 Issue 1, Ministry of Defence, 23 May 2008

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In one of the stages of phone-in information services development, the software to support the work of call center operators was also evaluated. This research yielded considerable software ergonomics results, but the structure of the investigation is also interesting from the methodology point of view.

Figure 49 shows the course of events. The primary research objective was to demonstrate that software analysis can result in proposals on the operator interface to increase performance. Besides, opportunities for the joint implementation of various assessment methods were explored together with the congruence of results from different sources.

The investigation focused on observing the product use related behaviors of actual users by measurement, video and sound recording and questioning methods. The survey was conducted in the framework of a field study at one of the worksites used for the activity anyway; the technical equipment required was installed there and subjects working with the software were asked to attend.

In addition to providing the location, the participants and the technical conditions, the survey scenario also had to be drawn up, consisting of the tasks to be executed and the data recording schedule. Tasks were compiled on the basis of activity analysis, meaning that client calls were forwarded to operators and they had to manage those calls according to the rules governing their work. Some weaknesses of the software were revealed by the preliminary inspection – execution of fictitious tasks –, therefore tasks were construed which required the use of the software routine causing the problem. This solution ensured that all 15 subjects used the routine concerned and enabled us to identify functions causing difficulties to few people (insufficient user knowledge / user errors can be inferred here) and functions causing difficulties to the majority of subjects (this can be a program error). Pre-defined client requests were read out by the investigator’s assistant from a designated telephone number. Pre-defined tasks comprised all our preliminary assumptions about software errors, therefore upon their completion, each subject was reconnected to the call distribution system of the call center and they received further tasks (calls) therefrom in a random fashion. Finally, the number of calls handled per person went up to fifty, corresponding to about one hour of work.

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Izsó, L.; Mischinger, G. (Eds.); Palotai, S.; Szabó, Gy. 1997: A belföldi számítógépes tudakozó szolgáltatás (CDAS) szoftverének ergonómiai vizsgálata. (Összegző tanulmány.) (Ergonomic survey of the CDAS software used in computerized domestic information services. (Summary study.). 48 pages + annexes. Technical University of Budapest, Department of Ergonomics and Psychology.
Before starting on the tasks, participants were informed that the software was subject to testing and that the investigation entailed no consequences whatsoever on them: their supervisors would not be notified of their results. Before starting on the series of tasks they filled in a questionnaire on their experiences another personal characteristics and data recording devices (electrodes, microphones) were installed.

In the course of resolving tasks, subjects were videoed in the test arrangement shown in Figure 49 (in a front view, so that both their bust and their hands on the keyboard could be seen), with the voice of the subject and the client (the assistant presenting the query), and the contents of the computer screen also recorded. The program running on the computer – beside the software studied – recorded keystrokes and mouse clicks and the ISAX physiological data collection system recorded the subject’s ECG signals.

Immediately after executing the tasks, subjects reported on their observations related to the tasks and software management difficulties in another room; this was followed by the investigator replaying the video recording and inquiring about certain behavioral elements. This act of reporting was also videoed.

Video and audio materials were analyzed in laboratory conditions. When the videos on task completion were analyzed, a utility software was used for determining time data associated with actions properly describing the activity (specifying question, data search, response) in case of each inquiry and each subject. These data were processed statistically and supplemented by textual answers to complete software analysis; our evaluation and development proposals were illustrated by screen snapshots, video clips, and data charts.
Parallelly with time analysis, the software was also analyzed by the INTERFACE software inspection system. This method is essentially based on software product features (computerized data recording, sitting work). In the selection of methods, the more extensive instrumentation demand of INTERFACE is opposed to prolonged video analysis; nevertheless, identical results were yielded by the two methods in our case.