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Ergonomic principles in the design of work systems

Principes ergonomiques de la conception des systèmes de travail

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 6385 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 1, *Ergonomic guiding principles*.

This second edition cancels and replaces the first edition (ISO 6385:1981), which has been technically revised.

Introduction

Technological, economic, organizational and human factors affect the work behaviour and well-being of people as part of a work system. Applying ergonomic knowledge in the light of practical experience in the design of a work system is intended to satisfy human requirements.

This International Standard provides a basic ergonomic framework for professionals and other people who deal with the issues of ergonomics, work systems and working situations. The provisions of this International Standard will also apply to the design of products, e.g. consumer products.

In the design of work systems in accordance with this International Standard, the body of knowledge in the field of ergonomics is taken into account. Ergonomic evaluations of existing or new work systems will show the need for, and encourage attention to, the role of the worker within those systems.

Ergonomic principles in the design of work systems

1 Scope

This International Standard establishes the fundamental principles of ergonomics as basic guidelines for the design of work systems and defines relevant basic terms. It describes an integrated approach to the design of work systems, where ergonomists will cooperate with others involved in the design, with attention to the human, the social and the technical requirements in a balanced manner during the design process.

Users of this International Standard will include managers; workers (or their representatives); and professionals such as ergonomists, project managers and designers who are involved in the design or redesign of work systems. Those who use this International Standard may find a general knowledge of ergonomics (human factors), engineering, design, quality and project management helpful.

The term “work system” in this International Standard is used to indicate a large variety of working situations. The intention is to improve, (re)design or change work systems. A work system involves a combination of people and equipment, within a given space and environment, and the interactions between these components within a work organization. Work systems vary in complexity and characteristics. Some examples of work systems are: a machine with a single person; a process plant including its operating and maintenance personnel; an airfield with users and personnel; an office with its workers; and computer-based interactive systems. The observance of ergonomic principles applies also to the installation, adjustment, maintenance, cleaning, repair, removal and transport of work systems.

The systems approach in this International Standard gives guidance to the users of this standard in existing and new situations.

The definitions and ergonomic guiding principles specified in this International Standard apply to the design of optimal working conditions with regard to human well-being, safety and health, including the development of existing skills and the acquisition of new ones, whilst taking into account technological and economic effectiveness and efficiency.

While the principles in this International Standard are oriented to the design of work systems, they are applicable to any field of human activity, e.g. in the design of products for domestic and leisure activities.

NOTE This International Standard is considered to be the core ergonomic standard from which many others on specific issues are derived.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
allocation of functions
process of deciding how system functions shall be implemented, by humans, by equipment and/or hardware and/or software

2.2
design population
designated group of workers delimited as a percentile range of the general population, defined according to relevant characteristics, e.g. gender, age, skill level, etc.

2.3
ergonomics
study of human factors
scientific discipline concerned with the understanding of interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance

2.4
job
organization and sequence in time and space of an individual's work tasks or the combination of all human performance by one worker within a work system

2.5
system function
broad category of activity performed by a system

2.6
work environment
physical, chemical, biological, organizational, social and cultural factors surrounding a worker

2.7
work equipment
tools, including hardware and software, machines, vehicles, devices, furniture, installations and other components used in the work system

2.8
worker
operator
person performing one or more tasks within the work system

2.9
work fatigue
mental or physical, local or general non-pathological manifestation of excessive strain, completely reversible with rest

2.10
work organization
sequence and interaction of work systems fitted together to produce a specific result

2.11
work process
sequence in time and space of the interaction of workers, work equipment, materials, energy and information within a work system

2.12
workstation
combination and spatial arrangement of work equipment, surrounded by the work environment under the conditions imposed by the work tasks

2.13
work strain
internal response of the worker to being exposed to work stress depending on his/her individual characteristics (e.g. size, age, capacities, abilities, skills, etc.)

2.14
work stress
external load
sum of those external conditions and demands in the work system which act to disturb a person's physiological and/or psychological state

2.15
workspace
a volume allocated to one or more persons in the work system to complete the work task

2.16
work system
system comprising one or more workers and work equipment acting together to perform the system function, in the workspace, in the work environment, under the conditions imposed by the work tasks

2.17
work task
activity or set of activities required by the worker to achieve an intended outcome

3 Designing work systems

3.1 General principles

In the design process, the major interactions between one or more people and the components of the work system, such as tasks, equipment, workspace and environment, shall be considered.

These interactions create demands on the worker that together constitute the work stress. This work stress will result in reactions within the worker, depending on her/his individual characteristics (e.g. size, age, capacities, abilities, skills, etc.) called work strain. Work strain will result in impairing (e.g. work fatigue), or facilitating effects (e.g. skill development), thus affecting the individual characteristics of the worker in a feedback loop.

NOTE Work stress and work strain have a neutral interpretation in ergonomics and no negative connotations.

Ergonomic work system design aims at optimizing work strain, avoiding impairing effects and promoting facilitating effects. Unimpaired human performance at the same time will often improve system effectiveness and efficiency, thus contributing to another important goal of ergonomic work system design.

Work system design should consider human beings as the main factor and an integral part of the system to be designed, including the work process as well as the work environment.

Ergonomics shall be used in a preventive function by being employed from the beginning rather than being used to solve problems after the design of the work system is complete. However, it can be successfully employed in the redesign of an existing, unsatisfactory work system.

The most important decisions that have consequences in the design are made at the beginning of the design process. Therefore, ergonomic efforts should be greatest at this stage. Ergonomic contribution to the work system design shall continue throughout the design process. However, the level of input can vary from being fundamental and extensive during the analysis of the system needs (“formulation of goals”) to fine-tuning when the completed system is being implemented (“realization, implementation and validation”). Sufficient attention shall be given to the application of ergonomic principles until late in the design process in order to prevent negative effects such as: delays in projects; extra costs for adaptation; a lower design quality; and worse usability.

Workers shall be involved in and should participate in the design of work systems during the process in an effective and efficient manner. In work system design, a participatory approach is essential in order to avoid sub-optimal solutions, because the experience of workers provides an indispensable knowledge base. The design process shall therefore, wherever possible, involve workers in all stages.

It is recommended to design a work system for a broad range of the design population in order to meet the needs of workers with various characteristics, including people with special requirements, as far as possible. Thus the development of special solutions for individuals can be minimized.

The work system design process (3.2) can be divided into the following phases:

— formulation of goals (requirements analysis) (3.3);

— analysis and allocation of functions (3.4);

— design concept (3.5);

— detailed design (3.6);

— realization, implementation and validation (3.7);

— evaluation (Clause 4).

These phases will be explained in the relevant clauses or subclauses.

3.2 Work system design process

“Designing” refers to an iterative and structured process of a number of design phases, which results in a new design or a redesign. A multidisciplinary design team best accomplishes this process. This is relevant for all phases of the design process. Activities involved in the phases of the design process are analysis, synthesis, simulation and evaluation.

Each of the many variables is likely to influence others. Decisions concerning, for instance, the allocation of different functions to people or equipment; the design of any interface; and the training requirements, all interact to an extent which will make it necessary for the system designer to evaluate alternatives before reaching the final decision.

This process of evaluating suitable alternatives is likely to be iterative until sufficient information is gathered for each area. The marshalling and final consideration of the information is then conducted in the following stages of the design process. It shall be ensured that appropriate methods and techniques are applied in the realization of a new work system design.

NOTE See ISO/TR 16982.

3.3 Formulation of goals (requirements analysis)

In the case of a new design, the analysis of system requirements will involve the acquisition of information regarding the production or performance requirements of the work process, together with the characteristics and limitations of the people who will be working in the new system. Where equivalent or similar systems already exist, this will also entail the identification of information regarding ergonomics problems occurring with these existing work systems, either from existing sources or from studies conducted for the purpose. Appropriate ergonomic methods and techniques for this purpose imply the use of evaluation tools for working conditions, observations on the spot, interviews, etc.

After gathering and analysing this information, a program of demands, requirements and specifications shall be created, which includes work system specifications relating to the performance, safety, health and well-being of the workers as well as the technical performance requirements for the new system.

Each aspect, element and component (see 3.6) of the work system, which can influence the human or system performance, when operated, shall be described including both operation and maintenance.

3.4 Analysis and allocation of functions

Having established the requirements for the new system, the first step in this stage is to establish those functions which are to be fulfilled by the work system in order to meet these requirements. Once these have been established, decisions shall be taken about how to allocate these between people and equipment. This

is to ensure that each function is performed in an efficient manner with due regard to the work system design considerations previously identified (see 3.3).

This will involve analysing the capabilities and limitations in fulfilling the requirements of the system of both the human and technical elements of the planned system. This analysis and the subsequent allocation of functions to workers or equipment should create tasks and jobs, which have a positive effect on health, well-being and safety as well as achieving the desired level of performance.

Appropriate ergonomic methods and techniques for this purpose include schemes, evaluation tools, human (computer) models and laboratory tests. Function allocation shall result in tasks and jobs, which are in accordance with the ergonomic principles specified in this International Standard.

3.5 Design concept

Once such decisions have been made, the functions allocated to either humans or to technical solutions shall be transformed into a design concept, which shows the structure of the work system and the interactions between the components. Any such concept shall be developed with due regard to a human-centred approach.

Those functions, which are allocated to workers, should be transformed into a list of demands for the design of tasks, jobs and work organization. These demands form the basis for the design of these components.

Those functions allocated to equipment should be transformed into a list of demands for the design of work equipment, work tools (including software), workstation and work environment. These demands form the basis for their design or selection.

Ergonomic methods and techniques that can be used for this purpose include simulation and task analysis techniques; scale models and mock-ups; and group discussions.

NOTE Detailed information about the human-centred approach can be found in ISO 13407.

3.6 Detailed design

This subclause will examine the design of the components, which together form the designed work system, in order to provide for a better understanding of the range and needs of ergonomic work system design.

In the design of a work system, the design of the following components shall be addressed:

— design of work organization (3.6.1);

— design of work tasks (3.6.2);

— design of jobs (3.6.3);

— design of work environment (3.6.4);

— design of work equipment, hardware and software (3.6.5);

— design of workspace and workstation (3.6.6).

The components shall be designed with due regard to the interdependencies among them. The above-mentioned sequence does not imply that this is a mandatory sequence for the design process. Iterations are normally required to achieve optimal solutions.

3.6.1 Design of work organization

Individual jobs and work systems have effects on each other. Consideration shall therefore be given to the extent to which various work systems, e.g. within companies, create constraints and pressures on other work

systems. The impact, which these can have on the performance of the work organization and all the work systems as well as on workers, should be taken into account.

Consideration shall be given to the extent to which the relationships between the different elements in a work system can have an effect on the work stress of the individual. Thus, many of the factors described in 3.6.6 can also have a significant influence when considered as part of the way the combination of work processes is organized.

If these result in undesirable outcomes relative to system requirements, alternative design solutions shall be sought.

3.6.2 Design of work tasks

When transforming functions allocated to the human into work tasks, the designer shall achieve the following goals:

— recognize the experience and capabilities of the working population;

— provide for the application of an appropriate variety of skills, capabilities and activities;

— ensure that the work tasks performed are identifiable as whole units of work rather than fragments;

— ensure that the work tasks performed make a significant contribution to the total work system, which can be understood by the people involved;

— provide people with an appropriate degree of autonomy in deciding priority, pace and procedure;

— provide sufficient feedback in meaningful terms to those performing the work task;

— provide opportunities for the development of existing skills and the acquisition of new skills with respect to the work tasks concerned;

— avoid overload as well as underload of the worker, which may lead to unnecessary or excessive strain, fatigue or to errors;

— avoid repetitiveness, which may lead to unbalanced work strain and thus to physical disorders, as well as to sensations of monotony, satiation, boredom or to dissatisfaction;

— avoid working alone without opportunities for the worker for social and functional contacts.

NOTE See also ISO 9241-2 and ISO 10075-2.

3.6.3 Design of jobs

Jobs shall be designed to facilitate the goals of the work system whilst achieving an optimal overall level of work stress on the workers for the design population. If, due to design restrictions, individual tasks cannot be designed in accordance with 3.6.2, compensation, which shall result in an optimal level of work stress, shall be achieved by appropriate job design.

Imbalance of work stress and the capacities of the design population will result in overload or underload and thus to impairing effects on the workers, which shall be avoided by appropriate job design.

NOTE See also ISO 9241-2 and ISO 10075-2.

The overall level of physical and mental work stress depends not only on the factors considered in other subclauses, e.g. 3.6.2, but also on the combination of the individual tasks within a job, the content and repetitiveness of operations and the workers' control over the work process.

Attention shall thus be directed to achieve the goals set out in 3.6.2 (work task design) also in the design of jobs and, if this does not result in adequate jobs, to implement one or more of the following methods in order to improve the quality of the job:

— adequate breaks, organized or non-organized;

— change of activities as, for example, job rotation among people on an assembly line or in a team working within a group;

— having one person (instead of several people) perform several successive tasks belonging to the same system function (job enlargement), for example performing different assembly operations in a sequence;

— having one person (instead of several people) perform successive tasks belonging to different system functions (job enrichment), for example, assembly operations followed by quality checks performed by the person who also removes defects.

3.6.4 Design of work environment

The work environment shall be designed and maintained so that physical, chemical, biological, and social conditions have no adverse effect on people but serve to ensure their health, as well as their capacity and willingness to perform the tasks under consideration.

Wherever possible, both objective and subjective assessments should be used to determine conditions. As well as ensuring that environmental conditions remain within recognized limits for the maintenance of health and well-being, attention should also be given to the extent to which the design of the environment can influence safe and efficient task performance. For example, inappropriate acoustical background can mask an acoustical signal whereas appropriate lighting can enhance the performance of visual inspection tasks. Wherever possible, the worker should be able to influence the conditions in her/his work environment (e.g. lighting, temperature, ventilation).

It should be recognized that social, cultural and ethnic factors may influence the acceptability of work and work organization. These influences can be wide-ranging, including such diverse issues as dress requirements; substances used in the work process (for instance of animal origin); and the hours and days of work. Wherever possible, these should be taken into account in designing the work system. Social and family pressures can also influence safety and performance. For example, concerns over family problems may cause distraction, predisposing workers to errors. Possible avenues for amelioration include designing workplaces to minimize the potential for human error or, where concentration is vital, providing additional social support.

3.6.5 Design of work equipment, hardware and software

In view of the tendency to make tasks increasingly mentally demanding, emphasis shall be given to the mental as well as the physical/mechanical aspects related to the equipment.

In general, the interface provides for decision-making, information transfer or communication between people and equipment. The main components are displays and controls. These may be conventional devices or may relate to the components of a visual display terminal. An interface shall be designed to match human characteristics.

— An interface should provide adequate information to allow a rapid overview, as well as providing information concerning detailed parameters.

— In principle, those elements which most need to be reached shall be where they can most easily be reached and operated, and those which most need to be seen shall be where they can most easily be seen.

— Signals, displays and controls shall function in a manner likely to reduce the probability of human error.

— Signals and displays shall be selected, designed and laid out in a manner compatible with the characteristics of human perception and the task to be performed.

— Controls shall be selected, designed and laid out in such a way as to be compatible with the characteristics (particularly of movement) of that part of the body by which they are to be operated and the task to be performed. Skill, accuracy, speed and strength requirements should be taken into account.

— Controls shall be selected and laid out in a manner compatible with population stereotypes, the dynamics of the control process and its spatial representation.

— Controls shall be close enough to facilitate correct operation where they are to be operated simultaneously or in quick succession. However, they shall not be so close as to create a risk of inadvertent operation.

3.6.6 Design of workspace and workstation

3.6.6.1 General

The design shall be such as to allow people both postural stability and postural mobility.

People shall be provided with a base, which is as safe, secure and stable as possible from which to exert physical energy.

Workstation design shall include consideration of body dimensions, posture, muscular strength and movement. For example, sufficient space should be provided to allow the task to be performed with good working postures and movements; opportunities for variations in posture; and to allow for easy access.

Body postures shall not cause work fatigue from prolonged static muscular tension. Alterations in body postures shall be possible.

3.6.6.2 Body dimensions and body posture

Attention shall be paid primarily to the following.

— The design of the workstation should take into account any constraints imposed by the body dimensions of those likely to work in it together with any clothing or other necessary items.

— For prolonged tasks, the worker shall be able to alternate between sitting and standing. If only one of these postures must be chosen, sitting is normally preferable to standing, although standing may be necessitated by the work process. For prolonged tasks, crouching or kneeling postures shall be avoided.

— If high muscle strength must be exerted, the chain of force or torque vectors through the body shall be kept short and simple by allowing suitable body posture and providing appropriate body support. This applies in particular for tasks requiring high precision of movements.

3.6.6.3 Muscular strength

Attention shall be paid primarily to the following.

— Strength demands shall be compatible with the physical capacities of the worker and should take into account scientific knowledge on the relationships between strength, frequency of exertion, posture, fatigue, etc.

— The design of the work shall be such as to avoid unnecessary or excessive strain in muscles, joints, ligaments, and in the respiratory and circulatory systems.

— Muscle groups involved shall be strong enough to meet the strength demands. If strength demands are excessive, auxiliary sources of energy should be introduced into the work system or the task should be redesigned to use more powerful muscles.