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CONTENT AREA NO 1 ERGONOMICS PRINCIPLES & ERGONOMICS IN DESIGN

Project Title
Ergonomic workplace design for workers with disabilities and their long-term employment

Project Acronym: **ERGOART**

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Lesson information

Description of content area

This module focuses on the fundamental principles of ergonomics and human factors. Students will learn how to design workstations, tools, and tasks to fit the capabilities and limitations of workers with disabilities. The module includes introduction of techniques for analysing work demands, assessing physical, cognitive, and organizational aspects of jobs, and identifying potential ergonomic risks.

Learning outcomes

- Attitudes: commitment to creating inclusive work environments.
- Knowledge of ergonomic principles and nature of design process.

Terms

Well-being – sustainable internal state resulting from satisfaction of the physical and cognitive needs of the worker during their activity

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

Ergonomics (or 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

Worker – person performing one or more activities to achieve a goal within a work system

Work organization – interacting work systems acting to produce a specific overall outcome

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

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

Work environment – physical, chemical biological, organizational, social and cultural factors surrounding a worker

Workspace – volume allocated to one or more persons in the work system to complete the work task

External workload (or work stress) - external conditions and demands in a work system which influence a person's physical and/or mental internal load

Work strain – internal response of a worker to being exposed to external work load depending on their individual characteristics (e.g. body size, age, capacities, abilities, skills, etc.)

Usability – extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use

Human-centred design – approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying ergonomics and usability knowledge and techniques

Accessibility – extent to which products, systems, services, environments and facilities can be used by people form a population with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use

Allocation of functions – process of deciding whether system functions will be implemented by humans, by equipment and/or hardware and/or software

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

Work task – activity or set of activities required of the worker to achieve an intended outcome

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

Work fatigue – impairing non-pathological manifestation of work strain, completely reversible with rest

Target population – people for whom the design is intended, specified according to the relevant characteristics

System function – a broad category of activity performed by a system

Necessary or additional reading

ISO 11064 - Provides examples of how to apply ergonomic design to control centres.

ISO/TR 16982 -Lists methods and tools for applying ergonomic principles in interactive systems.

ISO/TR 18529 - Offers guidance on ergonomics for designing computer-based systems

Questions for discussion and/or self-assessment

1. What are the key principles of ergonomics, and why are they important in workplace design?
2. What are the key objectives of applying ergonomics in workplace design?
3. Which ergonomic principles are most important when designing for a diverse population?
4. What is the purpose of a work demands analysis, and how does it contribute to workplace safety?
5. How can analysing physical, cognitive, and emotional demands improve job design?
6. How do you determine whether a task should be allocated to humans or automated systems?
7. What roles do adjustable furniture or equipment play in reducing ergonomic risks?
8. Why is iterative evaluation and monitoring critical for maintaining ergonomic work systems?
9. What role does worker feedback play in designing ergonomic solutions?
10. How can ergonomic design principles help address disabilities and performance impairments in the workplace?

Introduction

Humans have always relied on their ability to adapt their surroundings to ensure survival and enhance quality of life. In most parts of the world, humans could not thrive or even survive without making purposeful changes to their environment. Housing is one of the most essential examples of this adaptation. Shelter provides protection from harsh weather, extreme temperatures, and predators, offering a safe space for rest, nurturing families, and fostering communities. From ancient caves to modern skyscrapers, the evolution of housing reflects our ingenuity in adapting to diverse climates and terrains.

Humans are not alone in modifying their environments. Many animals make similar adjustments to suit their needs. Beavers, for example, build complex dam systems to create ponds that serve as shelter and food sources. Birds craft nests to protect their eggs, termites construct towering mounds to regulate temperature, and ants dig intricate underground colonies for shelter and resource storage. These examples illustrate that the drive to shape one's environment for safety, comfort, and sustainability is shared across species.

What sets humans apart is the scale and sophistication of our adaptations. Unlike other animals, which rely primarily on instinct and natural materials, humans leverage tools, technologies, and systems to transform their surroundings. Our modifications extend far beyond basic needs. Housing and clothing protect us, but innovations such as heating systems make winters bearable, while air conditioning provides relief during extreme heat. Roads and transportation networks connect distant places, facilitating travel and commerce. Healthcare infrastructure ensures access to treatments that prolong and improve life. Even everyday items, like ergonomic chairs and noise-canceling headphones, address specific needs, enhancing comfort and productivity.

Our unparalleled ability to adapt the environment to our needs has positioned us as the most advanced species in this regard. However, achieving steady progress in improving the quality of human life requires more than instinct or improvisation—it demands a scientific approach. Ergonomics, the applied science of designing systems and products for human well-being and efficiency, plays a pivotal role in this process. By integrating ergonomic principles, we can ensure that advancements in our surroundings continue to support both survival and well-being, driving sustainable improvements in the quality of life.

1. The ergonomics approach

1.1. What is ergonomics?

In simple terms, ergonomics helps make things safer, healthier, and more efficient for humans. Ergonomics, as defined by the International Ergonomics Association, is both a science and a profession. It focuses on understanding how people interact with different elements in a system, such as with machines, tools, environments, or other people. The goal is to design systems that improve people’s well-being, make tasks easier, and enhance overall performance.

1.2. What Does Ergonomics Do?

Ergonomics works by considering how people interact with their surroundings and the tools they use. This could involve:

- Making tasks easier to perform.
- Ensuring equipment is safe and comfortable.
- Improving environments so they support health and well-being.

To do this, ergonomics looks at many factors, including:

- The purpose of a system or product: What is it meant to do?
- The people using it: Who are they, and what are their needs or abilities?
- Tasks to be performed: What do people need to accomplish?
- Constraints: What limits or challenges exist?
- The environment: How do physical, organizational, or social factors affect interactions?
- Life cycle changes: How will needs or conditions evolve over time?

By addressing all these elements, ergonomics ensures that systems are designed to work well for humans while also performing efficiently.

2. Principles of ergonomics

2.1 Why Are Ergonomics Principles Important?

Ergonomics principles are essential because they form the foundation for creating designs that truly meet human needs. Unlike other approaches, ergonomics focuses on optimizing both human well-being and system performance. This means designing tools, environments, and systems that are safe, easy to use, and comfortable, ensuring they align with the capabilities and limitations of the people using them.

By applying ergonomics, designs can be evaluated and improved systematically to fit human requirements. This approach enhances safety, health, and productivity while making systems more effective and efficient. Without the application of ergonomic principles, it becomes much harder to achieve long-lasting improvements, leading to potential risks, inefficiencies, and discomfort for users.

The core of ergonomics is a human-centered approach. It prioritizes designing systems, products, and services to fit the characteristics and needs of the intended users, rather than expecting people to adapt to poorly designed systems. This approach considers:

- The intended target population: Who will use the system or product, taking into account diversity in age, abilities, and other factors.
- The task or goal: What is the system, product, or service meant to accomplish, and what tasks are involved?
- The environment: Where and under what conditions the design will be used, including physical, social, and organizational factors.

This human-centered focus ensures that designs are practical, effective, and comfortable for the people interacting with them. From an ergonomics perspective, relying solely on selection (choosing the "right" person for the task) or training (teaching people to adapt) is not enough. While some level of training may still be necessary, it cannot replace the need for well-designed systems, products, or services. Proper design minimizes the burden on the user, reducing the need for extensive training or adaptation.

A critical aspect of ergonomic design is involving the people affected by the design throughout the entire process. This includes their participation in evaluating designs and providing feedback at different stages. Early and ongoing user involvement ensures that solutions are optimized to meet real-world needs and challenges. It also increases the likelihood of success, as the design is shaped by those who will use it.

Ergonomics principles are not just about improving individual products or tasks, they contribute to better overall system performance and human well-being. By focusing on people’s needs and systematically applying ergonomic concepts, we can achieve designs that are both functional and sustainable. This scientific, human-centered approach is key to ensuring steady and meaningful improvements in the quality of life for all.

2.2. The first principle: know the user

When designing systems, products, or services, it is essential to identify and clearly describe the target population. The human population is incredibly diverse, with significant variations in physical dimensions, biomechanical capabilities, sensory abilities, and cognitive functions. Ergonomics acknowledges this diversity and focuses on designing for a specified target population rather than attempting to cater to every individual or the entire population.

In defining the target population, it is crucial to avoid discrimination or unfair treatment based on factors such as gender, age, or disability. This aligns with global standards like the International Labour Organization (ILO) Convention No. 111, which emphasizes the importance of equality. A fair and inclusive approach ensures that the design process accommodates as broad a range of users as possible without unfairly excluding or disadvantaging any group.

To create effective designs, the characteristics of the target population relevant to the design must be identified. These characteristics can include factors such as:

- Physical dimensions: body dimensions, weight, and reach.
- Sensory abilities: vision, hearing, and tactile perception.
- Cognitive abilities: memory, decision-making, and information processing.
- Skills and knowledge: levels of literacy, technical expertise, and prior experience.

Additionally, it is essential to account for the range of variations within the target population. For example, some users may have limited visual abilities, while others might require designs that support specific physical constraints.

Consider that using average values when designing for a diverse population often fails to meet the needs of most users. Ergonomics addresses this by considering a range of values within the target population. Commonly, designs aim to accommodate at least 90% of users by using the 5th and 95th percentiles for key characteristics. This means that the smallest 5% and the largest 5% of users are not included in the primary design, but adjustments or additional features can sometimes accommodate these extremes.

In safety-critical situations, a wider range is often required. For example, designs may use the 1st and 99th percentiles to ensure maximum safety and inclusivity. This approach accounts for users with the most extreme physical characteristics, as overlooking them could result in serious safety risks.

By clearly identifying and describing the intended target population and considering their diverse characteristics, designers can create products, systems, and environments that are both inclusive and effective. This principle ensures that designs not only meet the needs of most users but also promote fairness and safety for everyone within the defined population range.

2.3. The second principle: focus on the task

Effective design must prioritize the nature of the task and its impact on the people performing it. This is known as **task-oriented design**, which ensures that tasks are well-suited to human capabilities and limitations. At its core, task-oriented design involves deciding how functions and responsibilities are allocated between humans and technology, ensuring a balance that optimizes performance and safety.

Poorly designed tasks can lead to significant problems, both for the individual performing the task and for the system as a whole. These problems cannot be solved by merely improving technical components. Instead, the consequences of task design must be carefully considered, including how it affects the people involved and the overall performance of the system.

Task-oriented design also recognizes that there is often a gap between how a task is designed to be performed and how it is actually performed in real-world situations. Variations in context, procedures, equipment, products, or materials can influence how people carry out tasks. Designing with these variations in mind ensures the system remains flexible and effective, even when circumstances change.

Tasks that are appropriately designed have several key qualities:

- Safety and effectiveness: They can be performed safely and effectively by the target population, both in the short term and over time.
- No harmful effects: They do not cause short- or long-term physical or mental impairments for the user.
- Skill development: They provide opportunities for users to develop their skills and capabilities, fostering growth and competence.

To achieve task-oriented design, tasks and their related activities must be thoroughly identified and described. This analysis should include:

- Inputs and outputs: What goes into performing the task and what is expected as the result.
- Human requirements: The capabilities, skills, and knowledge needed to perform the task successfully.

This level of detail ensures that the design supports both the individual performing the task and the system's overall goals.

In human-centered design, it's important to differentiate between goals and tasks. **Goals** refer to the intended outcomes or results. **Tasks** are the series of activities required to achieve these goals. For example, a goal might be to "assemble a product," while tasks include actions like "aligning components," "tightening screws," or "performing quality checks." Goals can be broken down into sub-goals, and tasks can be divided into sub-tasks, creating a hierarchy that reflects the complexity of the activity.

At the most granular level, tasks consist of individual activities, which are further broken down into actions. An action is a single event, such as identifying a visual signal, generating an idea, or pushing a button. These individual actions combine to form larger activities, which together make up the tasks required to achieve a goal.

To ensure a strong focus on the task, ergonomists use a method called **task analysis**, with Hierarchical Task Analysis (HTA) and Cognitive Task Analysis (CTA) being the most common approaches. By breaking down tasks into their components—such as inputs, outputs, required actions, and associated human capabilities, task analysis grounds the design process in the realities of what users actually do. This method helps identify potential challenges, variations in how tasks are performed in real-world conditions, and the specific skills or knowledge required. As a result, designers can create tasks that are safe, efficient, and appropriately tailored to the target population. Moreover, task analysis aids in the effective allocation of responsibilities between humans and technology, ensuring that the overall system supports user performance while minimizing risks and adverse effects.

By focusing on the nature of the task, task-oriented design ensures that systems are not only functional but also safe, efficient, and adaptable to real-world conditions. It's a critical principle in human-centered design that leads to better outcomes for both individuals and systems as a whole

2.4. The third principle: design for real-world environments

Understanding the **environmental context** is crucial for effective design. This includes identifying and describing the physical, organizational, social, and legal environments in which a system, product, service, or facility will be used, as well as defining the range of conditions within these environments.

The physical environment encompasses factors such as temperature, lighting, noise, spatial layout, and furniture. These attributes directly influence the usability, safety, and comfort of a design. The organizational and social environment includes work practices, organizational structures, and cultural attitudes, all of which can impact on how people interact with the design.

In some cases, the environment is a fixed contextual factor that cannot be changed. For example, a remote outdoor location may have extreme weather conditions that designers must consider. In other cases, environmental factors are part of the design itself and can be modified or optimized. For instance, lighting in a workspace can be designed to reduce glare and improve visibility. When environmental factors are part of the system, product, or service, they must be included in the design process to ensure the outcome is functional and effective.

When the environment cannot be changed, its characteristics must still be accounted for in the design. Failure to do so can impair system performance or usability, especially if design decisions are based solely on capability data measured in neutral or ideal conditions. For example, a ticket machine intended for outdoor use must be designed to work effectively under various environmental conditions, such as darkness, bright sunlight, or extreme temperatures.

The effects of environmental factors become even more significant when people are already working near the limits of their capabilities. Ignoring these factors can lead to decreased performance, discomfort, or safety risks. Designers must ensure that their solutions are not only effective in controlled settings but also adaptable to the realities of the intended environment.

Guidelines and standards can provide valuable insights for considering environmental factors in design. For example:

- EN 12464: Addresses lighting in indoor and outdoor environments.
- ISO 15265: Focuses on thermal environments in workplaces.
- ISO 24500: Provides guidance for designing environments for elderly and disabled persons.

By considering these factors, designers can create systems, products, and services that work well in real-world situations, making them practical, safe, and easy to use. Designing for the environment isn't just about how something works, it's about ensuring it fits the conditions and challenges where it will be used.

2.5. The fourth principle: measure what matters

Evaluating the success of any design requires using clear and established **ergonomics criteria**. This is true whether or not the design process itself followed an ergonomics-based approach. These criteria ensure that the design meets essential human-centered goals and performs effectively in its intended context.

Ergonomics criteria focus on three main areas:

- Human performance: How well users can carry out tasks, including any improvements in skills, abilities, or knowledge resulting from the design.
- Health, safety, and well-being: Whether the design supports physical and mental health, minimizes risks, and enhances overall comfort and safety.
- User satisfaction: How enjoyable, intuitive, and user-friendly the design feels, especially in consumer products.

The relative importance of these criteria depends on the nature of the design. For example:

- In consumer products, user satisfaction often takes a higher priority, as positive experiences drive usability and market success.
- In work systems, health and performance criteria are typically more critical to ensure safety, productivity, and long-term user well-being.

Effective evaluation is not a one-time task, but it is an iterative process that should be integrated into the entire design cycle. Designers must test the design at various stages, comparing outcomes against ergonomics criteria to identify and address issues early. This continuous improvement approach helps refine the design, ensuring it evolves to better meet user needs.

Evaluation should consider both immediate and long-term impacts. For example, a new workstation might improve short-term productivity but could lead to physical strain over time if not properly assessed. Taking a holistic view ensures that designs support users effectively not just in the moment, but throughout their interaction with the system, product, or service.

By focusing on measurable, human-centered criteria, we can ensure that the solutions are safe, effective, and satisfying, ultimately improving both performance and user experience. In short, criteria-based evaluation is the cornerstone of designing solutions that truly work for people.

3. Ergonomics in the design process

3.1. Overview about the ergonomic design process

To ensure good ergonomics, it’s important to think about it from the very beginning of the design process and keep it in mind throughout. This means paying attention to how people will use the product or system and applying ergonomic principles to avoid problems.

Here’s what this involves:

1. **Start with Ergonomic Goals.** Set clear ergonomic criteria (guidelines) for the design. These are like rules to make sure the design will be comfortable, safe, and easy for people to use.
2. **Include Ergonomics at Every Stage.** Both early ideas (concepts) and detailed plans should follow these ergonomic criteria.
3. **Think About Real Tasks and Users.** Consider what people will actually do with a product or service and how they’ll interact with a product, service or environment.
4. **Involve Users.** Talk to the people who will use the product (or people like them) to get their input. This helps identify potential problems early.
5. **Test and Improve.** Test the design with real users doing realistic tasks. Based on their feedback, make changes to improve the design. Everything, including the original requirements, can be revised if needed.
6. **Allow Flexibility.** The design process should allow for adjustments and improvements as new issues or opportunities arise.

The term **work system** is a fundamental concept often referenced in discussions about ergonomics in design. Work system refers to a wide variety of working situations, including permanent and flexible workplaces. Work systems vary in complexity, ranging from temporary setups to long-term environments. Examples of work systems include production systems like machine operators working with machinery, transportation systems such as drivers operating vehicles, support systems like maintenance technicians using work equipment, and commercial settings such as office workers at workstations.

When designing work systems, it's important to consider how workers interact with different parts of the system, such as other workers, tasks, tools, workspace, and the environment. These interactions create demands on the person, known as the external workload. How a person reacts to these demands depends on their individual traits, like their size, age, abilities, and skills. This reaction, called work strain, can have either negative effects, like fatigue, or positive effects, like improving skills. Over time, these effects can influence the person’s abilities and create a feedback loop that impacts their performance and well-being. Ergonomic work system design focuses on balancing the demands of work to reduce negative effects like fatigue and encourage positive outcomes like skill improvement. When people can work comfortably and effectively, it not only benefits them but also makes the whole system run more smoothly and efficiently, achieving another key goal of ergonomic design.

Ergonomic principles should be applied throughout the entire life cycle of a work system, from initial planning and development to implementation, maintenance, and eventual decommissioning. This proactive approach ensures that ergonomics is used preventively to address potential issues from the start, rather than being introduced later to fix problems after the system is fully designed. While ergonomics can be effectively used to redesign unsatisfactory work systems to improve functionality and safety, the most critical design decisions are typically made at the very beginning of the process. As such, it is crucial to prioritize the application of ergonomic principles during these early stages. Consistent attention to ergonomic principles throughout the design process, including the final phases, helps prevent issues such as project delays, additional costs for adaptations, reduced design quality, and poor usability. By maintaining this focus, the resulting work system is more likely to be efficient, user-friendly, and safe for workers.

A participatory approach is essential in work system design. Workers (whether involved in construction, maintenance, operation, or supervision) offer valuable insights and experience. Their involvement in all stages of the design process helps ensure practical, user-centered solutions. This human-centered approach also ensures that work systems are inclusive and accessible to a broad range of users, including those with special requirements.

The design process typically follows these phases:

1. Formulation of goals (requirements analysis).
2. Analysis and allocation of functions between humans and technology.
3. Design concept development.
4. Detailed design of specific components.
5. Realization, implementation, adjustment, verification, and validation.
6. Evaluation and monitoring during and after deployment.

Designing is a step-by-step process that often requires going back and making adjustments before arriving at a final design or redesign. The work system design process covers all stages of the system's life cycle, from initial idea and development to implementation, use, maintenance, and eventual decommissioning. At each stage, verification is needed to ensure that the design meets the required goals. This process is best carried out by a team with diverse expertise, including engineers, operators, ergonomists, safety specialists, and management. Key activities during the design process include analyzing needs, creating solutions, testing them, and evaluating results. Decisions in one phase, such as assigning tasks to people or machines, designing interfaces, or planning training, often affect other parts of the system. This means designers need to consider and test different options before finalizing their choices. Evaluating these options usually involves several rounds of refinement to ensure that all aspects are thoroughly addressed.

Since work systems can change or evolve over time, the design process must remain flexible. Applying appropriate methods and techniques is essential to creating a system that adapts to future needs and continues to function effectively.

3.2. Formulation of goals

The first phase in the design process is understanding what the new work system needs to achieve and setting clear goals. This starts with gathering information about the system's requirements, such as the tasks it will involve, the expected performance outcomes, and the environment where it will be used. It’s also essential to consider the abilities, needs, and limitations of the people who will work within the system.

If similar systems already exist, it's helpful to look at their ergonomics issues and identify problems. This can be done by reviewing existing data or conducting new studies. Common methods for collecting this information include evaluating working conditions, conducting on-site observations, and interviewing users and other stakeholders.

Once all the relevant information has been gathered and analyzed, a detailed list of demands, requirements, and specifications is created. This list should include:

- Performance requirements: What must the system accomplish?
- Safety, health, and well-being considerations: How will the system protect and support workers?
- Technical performance needs: The operational standards the system must meet.

It's also important to describe every aspect of the work system that can affect people or overall performance. This includes both day-to-day operations and long-term maintenance needs. Taking the time to clearly define these requirements in the beginning ensures that the system is designed to be safe, efficient, and user-friendly from the start.

3.3. Analysis and allocation of functions

3.3.1. General approach

Once the requirements for the new system are established, the next step is to identify the functions the system must perform to meet these requirements. A function is a broad category of activity performed by a system, this could be anything the system needs to achieve, such as processing materials, maintaining safety, or monitoring performance. Note that there is a difference between system function and work task, the latter means an activity or set of activities required of the worker.

After identifying these functions, the next task is to decide how to divide them between the workers and technology. This allocation must ensure that each function is performed effectively and efficiently while keeping in mind the design considerations established earlier.

A natural instinct might be to allocate all functions to technology, especially given recent advancements in artificial intelligence. However, humans will continue to play an essential role in the workplace, even as automation advances. While many repetitive or procedural tasks can and should be automated for efficiency and accuracy, other tasks requiring higher-level cognitive skills (planning, monitoring, decision-making) remain best suited for humans.

Automation, though powerful, is not a universal solution. Its feasibility depends on factors such as task complexity, technological limitations, and cost. Humans excel in areas like creativity, adaptability, and problem-solving, while machines outperform in tasks requiring speed, precision, and endurance. Therefore, careful consideration is needed to decide which tasks are best performed by humans, machines, or a combination of both.

To illustrate, some tasks, like hazardous or high-force activities, may be better suited for machines. Conversely, tasks like supervision or maintenance often rely on human dexterity, decision-making, or sensory skills. Many tasks, however, fall into a grey area where either humans or machines could perform them. For these situations, a systematic analysis is essential to assign tasks in a way that ensures safety, efficiency, and job satisfaction.

This allocation process must take into account factors such as technical feasibility, worker safety, cost-effectiveness, and job design principles. A well-balanced allocation can enhance productivity while also creating meaningful and engaging roles for workers.

Modern efforts to simplify task allocation began with Paul Fitts (1912–1965), who in 1951 compiled a list comparing the capabilities of humans and machines. Known as the Fitts List, it highlights areas where humans and machines excel:

According to the original Fitts List (Fitts, 1951):

- **Humans are better at:** 1. Detecting small amounts of visual or acoustic energy. 2. Recognizing patterns in light or sound. 3. Improvising and adapting to new procedures. 4. Storing large amounts of information for long periods and recalling relevant details when needed. 5. Reasoning inductively (drawing general conclusions from specific observations). 6. Exercising judgment in uncertain situations.
- **Machines are better at:** 1. Responding quickly to control signals and applying great force with precision. 2. Performing repetitive, routine tasks without fatigue. 3. Storing information temporarily and erasing it completely when needed. 4. Reasoning deductively (solving problems using established rules and computations). 5. Managing highly complex operations and multitasking effectively.

The Fitts List remains a useful framework, but it is important to remember that technology has advanced significantly since 1951. Modern machines, especially with the advent of artificial intelligence, can now rival or surpass humans in many areas once thought uniquely human, such as pattern recognition and certain types of decision-making. This highlights the dynamic nature of function allocation: it must evolve alongside technological advancements.

While the Fitts List offers general guidance, it has limitations for practical engineering design. The criteria are broad and non-quantitative, making them difficult to apply directly. In reality, systems engineers typically do not systematically analyze and weigh each function to determine whether it should be performed by humans or machines. Instead, the typical approach is to automate everything that can be mechanized, leaving the remaining tasks for human operators. This strategy, while seemingly counter to the ideal human-centered approach, has a logical foundation:

- Machines can perform many tasks faster, more reliably, and with fewer errors than humans.
- The high cost of human labor makes automation economically attractive.

However, this method introduces a critical responsibility for ergonomists or human factors specialists. Their role is to ensure that the tasks left for humans are within human capabilities. If a task exceeds human limits, it must be redesigned to match what people can realistically and safely do.

Hybrid systems, combining human and machine roles, are now the most common workplace setup. Determining the appropriate division of functions in these systems is key to avoiding inefficiencies, safety risks, and unnecessary costs. A structured approach, supported by task analysis is crucial for achieving this balance.

In summary, effective task allocation involves not only deciding who or what performs a task but also designing systems that support long-term human-machine collaboration while promoting worker well-being and organizational success.

3.3.2. Practical suggestions

To make decisions about task allocation, a set of key questions (outlined in Figure 1) must be addressed. These questions focus on several key factors: decision-making, physical ability, safety and economic considerations.

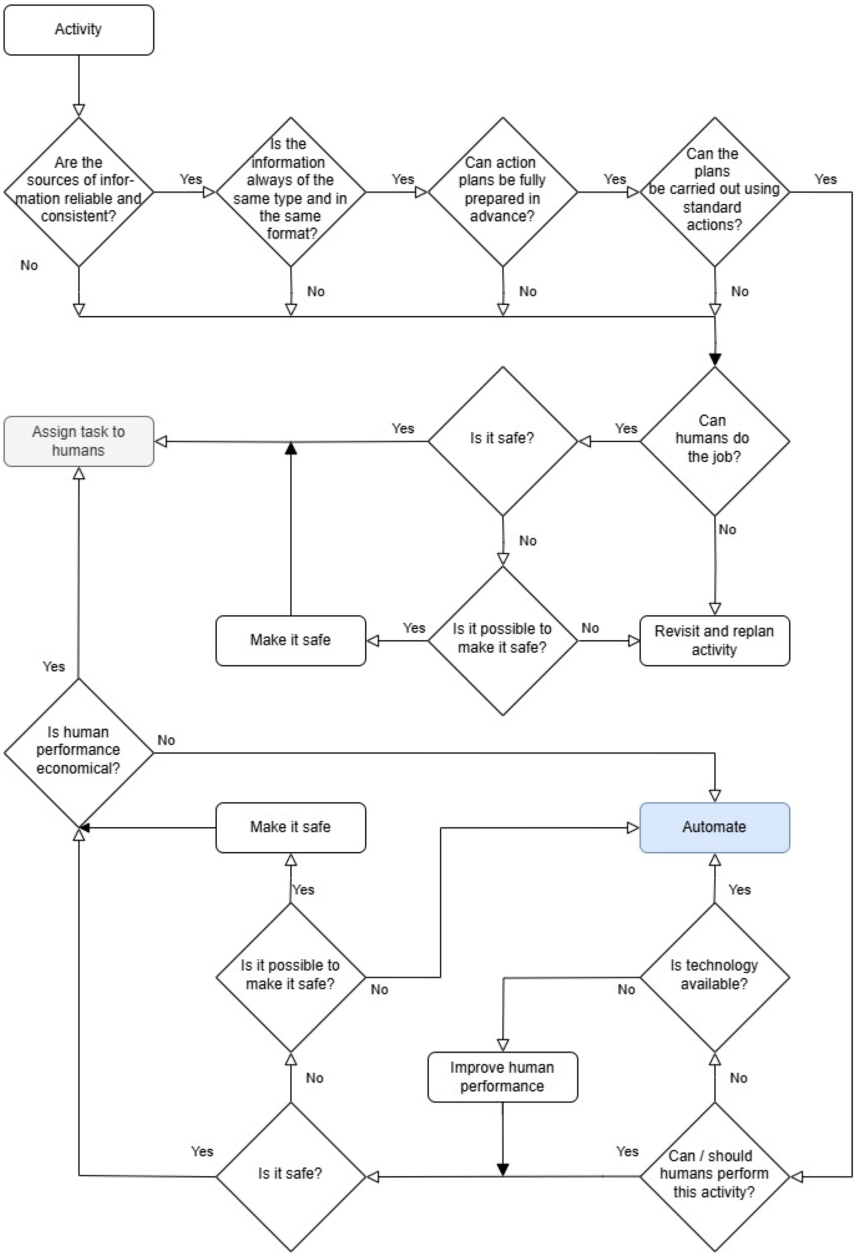

Figure 1. General flowchart for task allocation.

Complex Decision-Making and Experience. If a task requires complex decision-making or significant experience, it should be assigned to humans, as current technology often cannot match human capabilities in these areas. However, as artificial intelligence advances, automation may become a feasible, though potentially costly, option in the future.

Physical Ability. A detailed assessment must compare human physical capabilities to those of automated equipment for each task. If humans are capable of performing the task, further analysis is needed. If humans are incapable, the task should be assigned to automated equipment.

Organizations must also decide whether to design tasks for "humans in general" or specifically for their workforce. For companies with high turnover or seasonal staff, designing tasks for a general population makes more sense. For companies with stable long-term staff it's better to consider the specific workers likely to perform the task.

Safety. If both humans and automation could perform the task, safety becomes the deciding factor. A detailed safety analysis should assess the likelihood and severity of potential harm to human operators. If performing the task is unsafe for humans but automation can handle it, the task should be automated. If neither option is safe, the task must be reanalyzed and redesigned to find an alternative solution.

Economic Considerations. If safety is not an issue and both human and automated options remain viable, the decision should be based on economic factors. Systematic economic analysis, using techniques like cost evaluation of alternatives, can help determine the most cost-effective solution.

By addressing these factors—complexity, physical ability, safety, and cost—organizations can make informed, practical decisions about task allocation that balance performance, safety, and efficiency.

3.4. Design concept

After deciding how functions will be divided between humans and technology, the next step is to create an initial design concept for the work system. This concept outlines the system's structure and how its components (tasks, equipment, and environment) interact. A human-centered approach is essential at this stage to ensure the design meets the needs of the workers who will use it.

For the functions allocated to workers, this phase involves creating a list of requirements for designing tasks, jobs, and the overall work organization. These requirements ensure that the tasks are clear, manageable, and align with workers' abilities, promoting health, safety, and efficiency.

For the functions allocated to equipment, a similar list of requirements is created to guide the design or selection of tools, machines, software, workstations, and the work environment. These requirements ensure that the equipment and environment support effective performance while being safe and easy to use.

To develop the design concept, several ergonomic methods and techniques can be employed, such as:

- Simulation and task analysis techniques: These help predict how workers and equipment will perform in the proposed system.
- Scale models and mock-ups: Physical or virtual representations of the system allow designers to visualize and test interactions between components.
- Group discussions: Collaboration with stakeholders, including workers, helps refine the concept by incorporating their insights and addressing potential issues.

3.5. Detailed design

3.5.1 General

In the detailed design phase of a work system, each component of the system is carefully planned and developed. These components include: design of work organization, design of work tasks, design of jobs, design of work equipment and interfaces, design of workspaces and workstations.

These components must be designed while considering their interconnections. For example, changes to task design might influence the layout of a workstation, or updates to equipment might require adjustments to job roles. The design process is rarely linear and typically requires multiple iterations to refine and balance these elements, ensuring an optimal solution.

System design is inherently a flexible process. A work system evolves from its initial concept to its actual implementation, often undergoing significant changes based on new insights, constraints, or feedback. Designers must remain adaptable, revisiting and refining earlier decisions as needed.

The detailed design process doesn't end when the design is finalized. It extends into the implementation phase and is particularly important during the initial period of use. Early feedback from real-world operation can reveal unforeseen challenges, allowing for adjustments that improve functionality and usability.

3.5.2. Design of work organization

Individual jobs and work systems influence each other, and it's important to understand how different work systems within a single company can create constraints or pressures on each other. These interactions can affect the overall performance of the work organization, the effectiveness of the work systems, and the well-being of workers.

Whenever possible, the design should also consider the broader context, including the impact of company related factors (such as policies or production processes) and external factors (such as social, cultural, or regulatory influences).

It's crucial to evaluate how the relationships between various elements in a work system contribute to the external workload experienced by workers. For example, the design of workspaces and workstations not only affects individual tasks but can also impact the organization of work processes. If these relationships result in negative outcomes, such as increased stress or decreased performance, alternative design solutions should be considered to better align with system requirements and provide better support for workers.

3.5.3. Design of work tasks

When creating tasks for workers based on the functions they need to perform, the designer should aim to achieve the following:

- Make tasks meaningful: Ensure that each task contributes clearly to the overall goals of the work system and can be easily understood by the workers.
- Create whole tasks: Design tasks as complete units of work, rather than fragmented pieces, so workers can see the purpose of their efforts.
- Acknowledge workers' experience and skills: Take into account the abilities, knowledge, and expertise of the people performing the tasks.

- Incorporate variety: Include a mix of skills, activities, and responsibilities to keep tasks engaging and appropriately challenging.
- Allow autonomy: Give workers some control over how they prioritize, pace, and complete their tasks.
- Encourage skill development: Provide opportunities for workers to improve existing skills and learn new ones related to their tasks.
- Promote interaction: Avoid isolating workers by ensuring they have chances for social and functional connections with others.
- Balance workload: Prevent overloading workers, which can lead to fatigue and errors, as well as underloading them, which can cause boredom and dissatisfaction.
- Reduce repetition: Avoid overly repetitive tasks that can cause physical strain, boredom, or a sense of monotony.
- Provide feedback: Ensure workers receive meaningful feedback about their performance to help them stay engaged and improve.

3.5.4. Design of jobs

Jobs should be designed to align with the goals of the work system while ensuring the demands on workers are balanced to optimize performance. If individual tasks cannot fully meet the principles of good task design due to limitations, job design can help achieve the desired balance. It can also be used to address mismatches between the workload and the capabilities of workers, avoiding negative effects like fatigue or strain.

The overall workload for a job is influenced by more than just individual tasks. It also depends on factors like how tasks are combined, the repetitiveness of the work, and how much control workers have over their tasks and processes.

If task and job design don’t result in a manageable workload, additional strategies can improve the quality of the job. These include:

- **Breaks**: Providing adequate organized or informal breaks during work.
- **Activity changes**: Introducing job rotation, such as workers on an assembly line switching tasks or team members rotating roles.
- **Job enlargement**: Allowing one person to perform several related tasks within the same system function. For example, a worker could perform multiple steps of an assembly process.
- **Job enrichment**: Expanding responsibilities by including tasks from different system functions. For instance, a worker could perform assembly tasks and then inspect the quality of their work, fixing defects if needed.

3.5.5. Design of work environment

The work environment should be designed and maintained to minimize the negative effects of social, physical, chemical, and biological factors on workers' health, safety, and well-being. A well-designed environment should also support workers' ability and motivation to perform their tasks effectively.

Both objective measurements (e.g., temperature, noise levels) and subjective feedback (e.g., workers' perceptions) should be used to assess conditions. It’s important to keep environmental conditions within recognized safety and health limits while also considering how the environment affects task performance. For example:

- Poor background noise control might obscure important audio signals.
- Proper lighting can enhance accuracy in visual tasks like inspections.

Wherever possible, workers should have control over certain environmental factors, such as adjusting lighting, temperature, or ventilation, to suit their preferences.

Social, cultural, and ethnic factors also play a role in how work and work organization are perceived and accepted. For instance, dress codes, materials used in the work process, and work hours can vary in importance depending on cultural norms. These factors should be considered in the design of the work environment to ensure inclusivity and acceptance.

Additionally, social and family pressures can impact safety and performance. Workplaces can address these challenges by minimizing the potential for errors in design or by providing extra support in areas where focus and concentration are critical.

3.5.6. Design of work equipment and interfaces

When designing work equipment, it’s important to consider psychological factors in addition to physical and mechanical aspects. This ensures that the equipment is not only functional but also intuitive and user-friendly.

Interfaces are key elements of human-equipment interaction that support decision-making, communication, and information exchange. Interfaces typically consist of displays (to show information) and controls (to operate the equipment), which may include physical devices or computer-based tools like hardware and software. These interfaces should be designed to align with human abilities and needs. The following paragraphs describe the key Principles for Interface Design.

Clear and accessible Information: Interfaces should provide a quick overview of critical information, as well as detailed data when needed. Displays must be easy to see, and controls must be easy to reach and operate. For instance, frequently used controls should be placed within easy access, while emergency stop buttons may require different placement for safety.

Compatibility with human perception: Signals, displays, and controls should be designed and arranged based on how humans perceive and process information. For example, visual signals should be clear and placed where they’re easily noticed, while controls should be intuitive to use for the task.

Minimizing errors: Controls and displays should function in ways that reduce the chances of human error. This includes clear labels, logical layouts, and responsiveness that matches the user’s expectations.

Ergonomic operation: Controls should be designed to fit the body part used to operate them, considering factors like strength, accuracy, and speed. For example, foot pedals should be sized and positioned for comfortable use by most people.

Logical layouts: Controls should be arranged to match natural human behavior, such as population stereotypes (e.g. turning a knob clockwise to increase volume). They should also account for how tasks are performed, particularly when controls need to be operated simultaneously or in rapid sequence.

Avoiding accidental operation: Controls should be positioned to prevent unintentional use, especially those with critical functions.

The design of software-based interfaces, such as touch screens, should also follow these guidelines. Information layouts and screen controls should be intuitive and match human capabilities.

3.5.7. Design of workspaces and workstations

General principles

Workspaces and workstations should be designed to allow workers both **stability** and **mobility**. A secure, stable base should be provided to help workers exert physical energy safely and effectively. The design should consider body size, posture, strength, and movement, ensuring:

- Enough space for good working postures and movements.
- Opportunities to change posture during tasks.
- Easy access to equipment and tools.

Workers should not be forced into prolonged, uncomfortable postures that cause fatigue. The ability to adjust posture is essential to reduce muscle tension and strain.

Body dimensions and posture

Workstation design must accommodate the body dimensions of all likely users, including considerations for clothing or equipment they might wear. For tasks requiring long periods of work:

- Workers should be able to switch between sitting, standing, or intermediate postures, such as using a sit/stand chair.
- Sitting is generally preferred, though standing may be necessary for certain tasks.
- Crouching or kneeling should be avoided for prolonged tasks.

Workstations are typically designed for either sitting or standing, but there are four main scenarios to consider:

1. **Worker's choice**: Whenever possible, it is ideal to provide the option for both sitting and standing to accommodate worker preferences and task requirements.
2. **Sitting**: A seated workstation is appropriate when:
    a. A stable body position is needed for tasks requiring accurate control or fine manipulation.
    b. Tasks involve light, continuous manual work or close visual tasks requiring prolonged focus.
    c. Foot controls are necessary (unless used infrequently or for short periods).
    d. The majority of the workday involves standing.
3. **Standing**: A standing workstation is preferable when:
    a. Tasks involve handling heavy or bulky loads.
    b. Frequent movement away from the workstation is required.
    c. There is no knee room beneath the equipment.
    d. Front-to-back space is limited.
    e. The workstation involves a large number of controls or displays.
    f. The majority of the workday involves sitting.

4. **Support Seat**: A support seat is suitable when there isn't enough space for a normal chair, but some support is still desirable for the worker.

By carefully considering these scenarios, workstations can be designed to meet the specific needs of the task and the worker, enhancing comfort and productivity.

Table 1 provides guidelines to help determine the most suitable scenario. Job and workplace characteristics are evaluated in pairs to determine the preferred workplace setup: sitting, standing, or standing with a chair available. In some cases, multiple workplace options may be suitable for a given task combination, but the most appropriate choice is identified and recommended.

Table 1.Choice of workplace type by task variables (Chengalur, 2004)

Parameter	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
(1) Heavy load or forces	ST	ST	ST	ST	ST	ST	ST	ST/C
(2) Intermittent work		ST	ST	ST	S or ST	S or ST	S or ST	S or ST
(3) Extended work envelope			ST	ST	ST	ST	ST	ST/C
(4) Variable tasks				ST	ST	ST	ST	ST/C
(5) Variable surface height					S	S	S	S
(6) Repetitive movements						S	S	S
(7) Visual attention							S	S
(8) Fine manipulation								S
(9) Duration >4 hr								

Note: S = sitting; ST = standing; ST/C = standing, with chair available.

Body dimensions play a crucial role in determining the appropriate workstation dimensions, particularly the height of the work surface. For standing workstations, both the worker's elbow height and the nature of the task must be considered.

- Precision tasks: The work surface should be set above elbow height to enhance eye-hand coordination and improve accuracy.
- Tasks requiring muscular effort: The work surface should be set below elbow height to allow the worker to utilize the weight of their upper body for added strength and efficiency.

Tasks requiring high muscle strength should allow a posture that keeps the "chain of force" through the body short and simple, with adequate support. Height-adjustable work surfaces can help accommodate different body sizes and allow workers to alternate between standing and sitting. Regular posture changes and breaks are valuable for preventing fatigue.

CEN ISO/TR 7250-2 provides statistical summaries of body measurements for various ISO populations. For information on engineering applications of body measurements, refer to Kroemer et al. (2020).

Muscular strength

The physical demands of tasks must align with the worker's capabilities, considering factors like strength, posture, and frequency of exertion. Work should be designed to avoid unnecessary strain on muscles, joints, ligaments, and the respiratory and circulatory systems. Tasks requiring high strength should engage strong muscle groups. If demands are excessive, tools or equipment should be introduced to assist the worker, or the task should be redesigned to reduce strain.

The way muscles handle force depends on whether the force is applied intermittently for a short time (dynamic work) or over a longer period (static work). In the case of static work endurance largely depends on the percentage of the muscle's maximum strength being used, called the percentage of maximum voluntary contraction (%MVC).

Muscles need oxygen to keep working during static tasks. However, when muscles contract harder, the blood vessels within the muscle get compressed, reducing blood flow and oxygen supply. This lack of oxygen causes the muscles to get tired more quickly.

The relationship between the level of effort and how long muscles can endure is very nonlinear: At maximum effort (100%MVC), endurance is only a few seconds before muscle strength drops sharply. At 50%MVC a worker can maintain the force level for about 1 minute before fatigue sets in. At around 15% of maximum effort, endurance can last much longer, almost indefinitely.

Schaub et al. (2015) provide a comprehensive muscular strength atlas. Additional guidelines on the use of muscular force can be found in EN 1005-3.

Body movement

Movement is key to avoiding fatigue and discomfort. Tasks should:

- Balance movements to prevent prolonged immobility.
- Ensure the frequency, speed, and range of motions are within safe limits for the body.
- Avoid requiring excessive strength for precise movements over long periods.

Although developed nearly a century ago, Frank Gilbreth's (1868-1924) motion economy principles, particularly those related to the use of the human body, remain highly relevant for workspace and workstation design today.

Both hands start moving at the same time - to maximize efficiency, both hands should begin their motions simultaneously. This ensures a balanced workload and avoids wasted time.

Hands should only be idle during rest breaks - both hands should stay active during work and remain idle only during planned rest periods. Idle hands during tasks result in inefficiency.

Symmetrical movements of hands – hand movements should be symmetrical, directed either toward the body or away from it. Symmetry reduces strain and creates a natural balance, making tasks easier to perform.

Utilize momentum - take advantage of natural inertia in movements to save energy. Avoid unnecessary accelerations or decelerations, as they require extra effort. Let the motion flow naturally whenever possible.

Prefer smooth, continuous movements over sharp changes - Instead of straight-line movements with abrupt changes in direction, use smooth, curved motions. These are less tiring and more efficient.

Minimize the use of body segments - use as few body segments (like fingers, wrists, or arms) as possible to perform movements. This reduces overall energy expenditure and prevents unnecessary strain.

Thumb and middle finger are strongest - leverage the thumb and middle finger for tasks requiring strength. The index finger, ring finger, and pinkie are weaker and should not be subjected to prolonged strain.

Coordinate tasks for hands and feet - tasks that involve foot movements should be designed so they can be performed simultaneously with hand movements. However, coordinating hand and foot movements requires extra effort and can be challenging, so it should be carefully considered.

Avoid using foot pedals while standing - foot pedals are less effective when used while standing. Design tasks so pedals are used while seated for better efficiency and control.

Grip tools using the closest finger segments to the palm - for maximum strength and control, grip tools with the finger segments closest to the palm (the proximal phalanges). This ensures a secure grip and reduces fatigue during prolonged use.

For a more detailed discussion of motion economy principles, see Freivalds and Niebel (2014).

Tools and guiding devices can help simplify movements and improve task execution. Workers should also be encouraged to change positions regularly, especially in sedentary jobs, as lack of movement can lead to discomfort and pain.

3.6. Realization, Implementation, Adjustment, Verification, and Validation

Realization involves building, producing, or purchasing the new technical components of the work system and installing them in their intended location. This is the stage where the design becomes a physical reality.

Implementation focuses on carefully introducing the new work system to everyone involved, especially the workers who will use it. This includes providing clear information and training where needed. If transitioning from an old system to a new one, there should be a well-defined process for managing the change, including a backup plan in case unexpected issues arise.

The initial period of use is considered the final design phase, often called the **adjustment phase**. During this time, adjustments may be needed to refine and optimize the work system. Identifying necessary changes (along with their causes, impacts, and risks) is critical for improving the system. Neglecting this phase can lead to accidents or operational failures.

Adjustments during this phase may include:

- **Technical changes**: Modifying the system to better fit the final location or environment.
- **Organizational changes**: Managing resources, designing procedures, and addressing organizational levels.
- **Worker-related changes**: Allowing workers to apply their experience, training, and skills to handle risks and unexpected challenges.

Supporting this adjustment phase ensures the system achieves acceptable performance and smooth integration into its working environment.

Documentation tailored to the intended users should be provided, along with training and instructions for workers. Proper training helps workers adapt quickly and effectively. While good ergonomic design minimizes the need for extensive training, it's essential to provide any necessary instruction to help the system reach its full potential.

Verification ensures that the work system meets the specified requirements, including design features and overall functionality. This can involve reviewing documentation, inspecting components, and testing the system.

Validation confirms that the system performs as intended without compromising workers' health, safety, or well-being. If the system fails to meet these criteria or negatively impacts workers, it must be redesigned. Workers should actively participate in the validation process, as their feedback is invaluable. A system that achieves its performance goals but harms workers in any way does not meet ergonomic standards and must be adjusted or redesigned.

3.7. Keeping It on track: evaluation and monitoring of work systems

3.7.1. The approach

When applied correctly, ergonomics enhances the performance and effectiveness of a work system while protecting workers' health, safety, and well-being. However, the process doesn't end with the implementation of the work system. Evaluation and monitoring are still essential steps to ensure the system continues to function as intended and remains effective over time.

After the work system is realized and implemented, it should be evaluated to compare the intended goals with the actual results. This overall evaluation helps identify lessons learned and areas for improvement. Monitoring should also continue over time to prevent long-term declines in system performance or negative impacts on worker health and well-being. The overall evaluation should be conducted once the system has stabilized.

Evaluation should focus on ensuring a healthy, sustainable foundation for long-term worker performance. It involves assessing the following key criteria:

- **Health and well-being**: Ensuring the system supports workers' physical and mental health.
- **Safety**: Identifying and mitigating risks.
- **System performance**: Measuring efficiency and productivity.
- **Usability**: Confirming the system is user-friendly and supports effective interactions.
- **Cost-benefit**: Assessing economic impacts and benefits of the design.

In practice, this includes recording problems and experiences as a basis for making corrections, adaptations, or further improvements.

3.7.2. Examples of evaluation approaches

1. Health and Well-being:
   a. Medical check-ups or health surveillance.
   b. Physiological measurements.
   c. Surveys or subjective feedback from workers.
   d. Psychological assessments using validated tools.
2. Safety:
   a. Assessing system reliability regarding safety.
   b. Tracking errors, unsafe behaviors, near-misses, and accidents.

    c. Conducting hazard identification and risk assessments.
3. System Performance:
    a. Checking for defective products (qualitative evaluation).
    b. Measuring productivity (quantitative evaluation).
4. Usability: Usability involves assessing how effective, efficient, and satisfying the system is for workers. For a detailed breakdown of these measures, ISO 9241-11 provides useful definitions and guidelines.
5. Cost-Benefit: Semi-quantitative models can assess the financial impact of the new design. For example, improved work conditions may reduce sickness absence, minimize production losses, or lower maintenance costs. Positive outcomes like these can be directly translated into cost savings.

3.7.3. Ergonomic assessment as part of evaluation

Beginning of the assessment

Ergonomic assessment ideally begins with task analysis, a method used to understand how tasks are performed. Task analysis involves breaking a task into its individual steps or components to identify what is required for successful completion. By breaking tasks into several levels of subtasks, task analysis makes it easier to identify the root causes of problems that people may encounter within a work system.

There are several ways to perform task analysis, but two of the most popular techniques today are Hierarchical Task Analysis (HTA) and Cognitive Task Analysis (CTA). Methods like the Systematic Human Error Reduction and Prediction Approach (SHERPA) (Stanton & Young, 1999) build on HTA by using an error taxonomy to predict potential errors within the HTA sub-goal hierarchy. These approaches provide valuable insights for improving both the design and performance of work systems.

Task analysis is beneficial in two scenarios:

- Existing Systems: It helps establish a common understanding of current processes and identify issues.
- Design Processes: It supports decisions such as function allocation by providing a detailed breakdown of tasks and subtasks.

For those looking to perform HTA, Stanton (2006) offers detailed guidelines to assist with the process. Task analysis serves as an essential starting point for improving system performance and worker well-being.

Ergonomic assessment in existing work systems

In existing work systems, ergonomic assessment often begins by identifying the prevalence of musculoskeletal disorders (MSDs), as pain and discomfort in the musculoskeletal system are among the most significant occupational health problems in the developed world. Two widely used questionnaires for assessing the prevalence of musculoskeletal issues are the **Nordic Musculoskeletal Questionnaire** (Kuorinka et al., 1987) and the **Cornell Musculoskeletal Discomfort Questionnaire** (Hedge et al., 1999).

To establish the link between musculoskeletal issues and work, tools focusing on awkward postures, manual material handling, or repetitive upper limb motions are often used. Examples of these tools include:

- **REBA (Rapid Entire Body Assessment)** – Evaluates risks associated with whole-body postures (Hignett & McAtamney, 2000).
- **KIM-ABP (Key Indicator Method for Awkward Body Postures)** – Assesses physical workloads with a focus on awkward postures (BAuA, 2019).
- **MAC Tool (Manual Handling Assessment Charts)** – Evaluates manual handling tasks (HSE, n.d.).
- **RAPP Tool (Risk Assessment of Pushing and Pulling)** – Focuses on risks associated with pushing and pulling tasks (HSE, n.d.).
- **ART Tool (Assessment of Repetitive Tasks)** – Analyses repetitive upper limb motions (HSE, n.d.).

In addition to musculoskeletal issues, cognitive workload should also be considered. The **NASA-TLX (Task Load Index)** (Hart & Staveland, 1988) is a popular tool that evaluates overall individual workload and identifies the key contributing factors, including: mental demands, physical demands, temporal demands, performance, effort, frustration.

Ergonomic assessment to support the design process

When developing a new work system, European standards provide guidance similar to the role of assessment tools in evaluating existing systems. These standards are specifically focused on ergonomic considerations for machinery and its use:

- EN 1005-2: Provides guidelines for designing machinery and its components with considerations for manual handling.
- EN 1005-3: Recommends force limits for safe machinery operation.
- EN 1005-4: Guides the evaluation of working postures and movements related to machinery use.
- EN 1005-5: Describes preventive risk assessment methods for repetitive handling at high frequency.

These standards help ensure that new work systems are designed to minimize risks and prioritize worker health and safety. Beyond standards, various simulation tools can provide valuable insights into ergonomic risks within the design phase of a work system.

3D SSPP Software: This tool predicts static strength requirements for tasks like lifting, pressing, pushing, and pulling. It simulates tasks using posture data, force parameters, and male/female anthropometry. The output includes the percentage of men and women with sufficient strength for the task, spinal compression forces, and comparisons to NIOSH guidelines, providing a clear picture of potential ergonomic challenges.

HumanCAD (NexGen Ergonomics) and Siemens Process Simulate: These advanced tools offer a detailed understanding of workflows and help assess key ergonomic factors, including:

- Reach zones and workspace clearance: evaluate whether workers can comfortably and safely access tools or controls.

- Posture and fatigue analysis: identify potential risks associated with awkward postures or repetitive strain.

By combining these simulation tools with established standards, designers can effectively create systems that are safe, efficient, and ergonomically sound.

Assessments to include people with performance impairments and disabilities

When designing for inclusivity, the first step is deciding whether the goal is to accommodate one individual (e.g. home office) or a broader group of people (e.g. public transport, public areas).

The "Ergonomics for One" approach focuses on addressing the specific and often unique needs of individuals with disabilities. It involves the following steps:

- Assessing individual capabilities and limitations: evaluate the person's physical abilities and constraints to determine suitable ergonomic solutions.
- Providing Specific Assistive Devices: develop and implement customized tools, devices, or environmental modifications tailored to the individual’s specific disability.
- Participation and feedback: involve the user in the design process to ensure that solutions are practical, effective, and acceptable.

The "Ergonomics for One" approach emphasizes creating personalized solutions to improve the quality of life and enhance the work capabilities of individuals by addressing their unique needs and abilities.

When designing for larger groups, it is useful to categorize performance impairments and disabilities based on human capabilities. These categories help simplify the design process by grouping common challenges:

- Information impairments: include sensory deficits in vision, hearing, or touch (tactile perception), which affect how information is received and processed.
- Coordination impairments: relate to difficulties in controlling body movements, including gross motor skills (e.g., arm and leg movement) and fine motor skills (e.g., hand and finger control).
- Power Impairments: involve limitations in the strength and force required to perform tasks, restricting the ability to exert necessary force.
- Manipulation impairments: affect the ability to handle and manipulate objects, requiring precision and dexterity.
- Ambulation impairments: impact mobility and the ability to walk or navigate different environments.

These categories often overlap, with impairments in one area affecting overall task performance. Understanding them helps ergonomists design solutions that accommodate a wide range of disabilities. Kroemer (2005) introduced Problem Identification Matrices (PIMs) as tools for identifying and addressing issues that people with disabilities encounter when using systems and devices. PIMs help link system requirements with human capabilities and limitations, highlighting areas that need improvement. See Figure 2 for a general outline of a PIM.

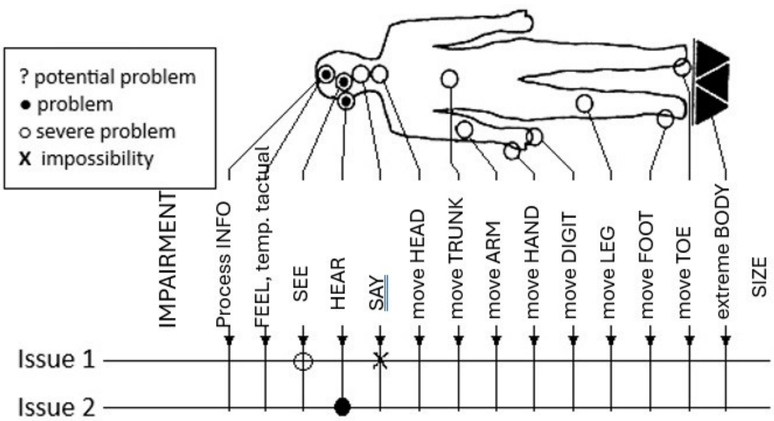

Figure 2. General outline of a problem identification matrix (modified from Koroemer 2005)

Examples of PIM Applications:

1. Communication Systems: Identify issues related to the use of visual and auditory signs and signals, such as the location and size of signs, and challenges faced by individuals with hearing and vision impairments.
2. Workstation Controls: Identify problems associated with the activation of controls, such as force and precision requirements, the size and location of devices, and the complexity of motions needed.
3. Plumbing Fixtures: Highlight issues related to the use of bathroom fixtures, such as the height of sinks, toilets, and shower curbs, and the clearance needed for wheelchair users.

PIMs allow designers to pinpoint design elements requiring ergonomic improvements to enhance accessibility for people with disabilities. For a detailed explanation and examples of PIMs, refer to Kroemer (2005).

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