2021

Principles and Guidelines for Human Factors/Ergonomics (HF/E) Design and Management of Work Systems

JOINTLY PREPARED BY

INTERNATIONAL ERGONOMICS ASSOCIATION (IEA)

INTERNATIONAL LABOUR ORGANIZATION (ILO)

IEA International Ergonomics Association

International Labour Organization

Special Preface

This draft document was prepared over the past 20 months (August 2018-April 2020) by a dedicated team of expert writers, reviewers, and representatives from the International Ergonomics Association, the International Labour Organization, and other institutions and organizations that recognize the critical need for Human Factors/ Ergonomics principles and guidelines in the design and management of work systems.

The completed Principles and Guidelines document is intended to serve as a technical basis for the ILO to develop an international labour standard on workplace good practice on human factors/ergonomics. To prepare for this, IEA and ILO representatives agree that the content of *Principles and Guidelines for HF/E Design and Management of Work Systems* should be disseminated as soon as possible so that the important principles embodied in this document can be promoted and applied by HF/E practitioners and feedback and experiences can be received and collected, which will be important for its final publication by the ILO and for the ILO's standard setting work on workplace human factors/ergonomics. This draft version therefore is pre-published by IEA. We welcome comments from all stakeholders.

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Note from IEA: Very special and heartfelt thanks are given to Dr. Shengli Niu, Senior Specialist, Labour Administration, Labour Inspection and Occupational Safety and Health Branch (LABADMIN/OSH), ILO, Geneva, and champion of HF/E. He is responsible for initiating, guiding, and supporting the development of this work in accordance with ILO's vision and priorities for the future of work from occupational health and safety as well as HF/E perspectives.

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Preface

The world of work today comprises a wider disparity in work situations than ever before, resulting from the simultaneous processes of globalization of economies and new information, communication, and automation technologies affecting work, nations and their societies. Massive numbers of people are confronting significant labour changes caused by new phenomena throughout the world, impacting work situations as well as quality and productivity in organizations. The juxtaposition between the digital economy on one hand and informality and technology on the other (recognizing that in some economies informality is as high as 80-90%) needs to be taken into account. These disparities pose new challenges and opportunities with respect to human factors/ergonomics in work systems. Because of the wide range of work situations, standards and guidelines must address not only worker safety, health, wellbeing, and sustainability issues that range from musculoskeletal disorders or injuries resulting from physiological, biomechanical, cognitive, psychological, and relational threats from old practices, but also new challenges presented by information technology, robotics, artificial intelligence, and digitalization. Moreover, the impact and rhythm of the introduction of these global phenomena are different for countries and world regions and their labour practices.

Given the diverse nature of these challenges and opportunities, it seems imperative to define and characterize concepts and recommendations that can be universally adapted and that allow for a consensual approach, ensuring that people are always given priority in the design of their work and throughout its performance. The contribution of this publication is an analytical, systems view of work - *work systems* - their design, management and sustainability from the perspective of human factors/ ergonomics (HF/E).

The mission of the International Ergonomics Association (IEA) is to elaborate and advance HF/E science and practice, and to expand its scope of application and contribution to society to improve the quality of life, working closely with its constituent societies and related international organizations. IEA shares a proactive social justice perspective with ILO (International Labour Organization), and the belief that "It is imperative to act with urgency to seize the opportunities and address the challenges to shape a fair, inclusive and secure future of work with full, productive and freely chosen occupations and decent work for all" as cited in the ILO Centenary Declaration for the Future of Work (2019).

The ILO Centennial Anniversary offers a singular opportunity for implementing a systems approach to HF/E design and management of decent work for all. The human-centred agenda outlined by the ILO Global Commission on the Future of Work (2019) highlights HF/E issues such as the requirement for safe and healthy work conditions and the need to harness and manage technology to ensure that the human is always in command. The recent Declaration of the ILO Centenary on the Future of Labour offers a significant number of topics and sectors of interest for which HF/E Principles and Guidelines can have immediate application. Decent work for all must be sustainable for both the worker and the organization. What individuals do for work should be interesting and challenging, providing conditions to develop knowledge and skills and also to improve cooperation among colleagues, organizational leaders, and worker organizations. The centrality of work for each person can be a preferential path to achieve personal and collective goals, to promote health and security, to build a life full of meaning and a rich narrative based on work as actually done in phase with professional values and citizenship. Moreover, the realization of successful and sustainable organizations depends largely on the management of high-quality HF/E to maximize performance and sustainability through balancing organizational functions and the wellbeing of its workers.

One of IEA's contributions to achieving the future of work we desire as a society is through the delineation of Human Factors/Ergonomics Principles and Guidelines for HF/E design and management of work systems in this publication. Dedicated and careful attention to the HF/E systems perspective in the design and management of work will facilitate opportunities for decent and sustainable work, better quality of working life, effective OSH practices, proactive organizational justice, and improved social dialogue worldwide while enabling better work system performance – and thus will help to achieve the future of work we all want.

Executive Summary

ILO (International Labour Organization) and IEA (International Ergonomics Association) share the goals of improving worker wellbeing, occupational safety and health (OSH), and the sustainability of workers and of work systems. Effective Human Factors/Ergonomics (HF/E) is indispensable to support our life and work in the 21st century; without attention to HF/E in design, work systems will not support the sustainability of workers, organizations, or societies. This document is intended to make explicit the value proposition of HF/E focused on worker wellbeing and rights to competent authorities at the national, regional, and city levels, employers and workers' organizations, and other main stakeholders of work system design, through the contribution of principles and guidelines for the design and management of HF/E in work systems. The document can provide assistance to competent authorities and decision makers at the national, regional, and city levels and employers who want to ensure worker and organizational safety, health, wellbeing, and sustainability. These principles and guidelines for HF/E design and management of work systems apply across all sectors and occupations and underlie the creation of decent work, characterized by economic, psychological, and occupational security, safety and health as well as equal opportunity and treatment for women and men (see Bibliography).

Principles for HF/E design and management of work systems presented in this document are:

Principle 1: Ensure worker safety, health, and wellbeing in the optimization of work systems as a top priority;

Principle 2: Design and manage work systems to ensure organizational and worker alignment, continuous evaluation and learning, and sustainability;

Principle 3: Create a safe, healthy, and sustainable work environment from a holistic perspective, understanding and providing for human needs;

Principle 4: Account for individual differences and organizational contingencies in the design of work;

Principle 5: Make use of collective, trans-disciplinary knowledge and full participation of workers for designing systems, detecting problems, and creating solutions for HF/E in work systems.

These principles are strongly inspired by and reflect many of the provisions already set out in various ILO Conventions, Recommendations and Codes of Practice. They focus on respecting the individual and social integrity of workers, on creating safe and healthy workspaces, and on providing decent work opportunities so that people at work can express themselves freely, apply their knowledge and experience, and be heard with attentiveness at the workplace.

HF/E guidelines are evidence-based action strategies derived from empirical research. They describe ways to integrate physical, cognitive, and organizational HF/E into the design and management of work systems to ensure worker safety, health, and wellbeing and to enhance worker and organizational performance, effectiveness, and sustainability.

Guidelines for HF/E design and management of work systems presented in this document are:

Guideline 1: Use a systems approach

Guideline 2: Consider all relevant characteristics of workers

- 2a. Consider demographic characteristics, physical and cognitive capabilities and limitations
- 2b. Provide workers with appropriate tools, training, and control to perform work
- 2c. Design work systems to be safe and to engage people in ways that maximize worker and work system safety and sustainability

Guideline 3: Apply Participatory HF/E methodologies

Guideline 4: Incorporate proactive measures to ensure worker safety, health, wellbeing, and sustainability

Guideline 5: Tailor HF/E design and management of work systems to characteristics of the organization

Guideline 6: Sustain a continuous learning process for evaluation, training, refinement, and redesign.

This document also includes information and recommendations for implementing the guidelines for HF/E design and management of work systems. Joint commitment to these principles and guidelines among competent authorities at the national, regional, and city levels, employers, workers and their representatives is necessary to achieve the objectives of this document.

Introduction

ILO and IEA share the goals of improving worker wellbeing, occupational safety and health (OSH), and the sustainability of workers and of work systems. The achievement of decent and productive work for all is a substantive goal of the ILO mission. The fulfillment of goal number 8 of the UN Millennium Development Goals for Sustainable Development, "Decent Work and Economic Growth," is an essential objective for the ILO. ILO and IEA recognize that the goal of decent work for all cannot be accomplished without consideration of Human Factors/Ergonomics (HF/E). Effective HF/E is indispensable to support our life and work in the 21st century; without attention to HF/E in design, work systems will not support the sustainability of workers, organizations, or societies. This document is intended to make explicit the value proposition of HF/E to the main stakeholders of work system design.

Work systems are comprised of humans, the tasks they do, the tools and technologies they use, the organization of the work, and the work environment. HF/E contributes to safe and sustainable work systems through a unique combination of three drivers of intervention: (1) it takes a systems approach; (2) it is design-driven; and (3) it focuses on optimizing two closely related outcomes, performance and well-being. HF/E encompasses not only physical OSH but also the cognitive and psycho-social aspects of work. It further contends that these various aspects cannot be viewed in isolation but rather must be viewed as a complex interaction among all the elements of a work system.

The philosophical foundation of HF/E (see Annex 1) is congruent with that of the ILO, as all members of the HF/E community recognize the need for participation of all stakeholder in system design groups (i.e., Participatory HF/E). HF/E reflects a holistic perspective toward workers and work systems, considering the interrelatedness of human, technical, and environmental components and the potential effects of work system design changes on all parts of the system.

Moreover, HF/E simultaneously contributes to the economic health and sustainability of organizations by enhancing worker wellbeing, capability and sustainability, maximizing performance, and reducing direct costs as well as indirect costs from productivity losses, quality deficiencies, and employee turnover. HF/E design in work systems is simply and unquestionably good business (see Annex 2).

This document focuses on the essentials of the concept *work system*, taking into account the consideration of all relevant HF/E factors during each of three different consecutive phases of the system: 1) conception and design; 2) regular operational management; and 3) the most challenging situation, which is system sustainability over time. In each phase, the HF/E principles provide the underlying value or rationale for the recommended HF/E guidelines, and the HF/E guidelines provide direction for ***what should be done*** to ensure high-quality HF/E during that stage.

The HF/E principles and guidelines in this collaborative document provide the basis for high-quality HF/E design and management of work systems across all sectors and occupations. Competent authorities/ institutions at the national, regional, and city levels are the most influential stakeholders in this process and have the responsibility to establish coherent policies and regulations concerning the design and maintenance of HF/E in work systems, to publish and disseminate these guidelines to employers and workers at all levels, and to act as a driving force in their implementation. Management requires shared understanding of the ideas in this document and collaboration among influential stakeholders, employers, managers and workers.

1. Objectives, Scope, and Target Audience

1.1 Objectives

The primary objective of this document is to provide to governments, employers, worker organizations and other stakeholders high-level guidance for the creation of HF/E-related policies, standards, and regulations at national, regional, and organizational levels to:

(1) Apply HF/E principles and guidelines to work systems design and management in order to establish and operate high-quality productive and sustainable work systems;
(2) Enhance worker sustainability and occupational wellbeing, safety, and health (OSH); and
(3) Protect workers against adverse workplace HF/E-related risk factors.

This document should create a basis for:

(1) Establishing coherent national policies and regulations based on principles and guidelines for HF/E work systems design and management;
(2) Establishing the roles and duties of competent authorities and stakeholders for HF/E work systems design and management;
(3) Implementing a HF/E systems approach and a holistic perspective for the design and management of work;
(4) Guiding governments, organizational leaders, managers, and supervisors in the management and monitoring of HF/E in work systems to ensure effective implementation and use of HF/E principles and guidelines in traditional as well as new and non-standard forms of work; and
(5) Promoting the implementation of a HF/E systems approach to the design of work with the goal of ensuring worker wellbeing and sustainability.

1.2 Scope

The scope of this document includes the design and management of work systems across all formal and informal sectors and occupations from the perspective of HF/E. In particular, it specifies:

(1) Roles and responsibilities of government officials and heads of government agencies, regulators, competent authorities, employers' and workers' organizations, and other stakeholders;
(2) General principles for HF/E design and management of work systems across sectors and occupations;
(3) Guidelines for HF/E design and management of work systems across sectors and occupations, including HF/E approaches for designing, implementing, validating, and evaluating work system performance for continuous improvement and sustainability; and
(4) Information and direction for implementing guidelines for HF/E design and management of work systems.

1.3 Target Audience

The primary intended audiences for this document are stakeholders who are *system influencers* and *system decision makers* (see glossary) including:

(1) Decision makers on policies, standards and regulations for workplace safety and health at the national level, government officials, heads of governmental agencies that monitor work at a national level (e.g., OSH inspectors and legal binding job contracts inspectors), representatives of workers' and employers' organizations, professional institutions, top-level leaders of employers' organizations such as manufacturers and service providers; persons involved or who have input in the creation of relevant legal, official, or binding instruments such as laws, standards, declarations, regulations, codes of professional conduct, codes of practice, operational job or work instructions; and

(2) Relevant partners and stakeholders at a national level such as national governmental officers or provincial or state level officials in federal countries; leaders from the private sector; research and academic staff in universities; non-governmental or non-profit organizations involved in advocacy for safe and healthy work environments; national HF/E societies; high-level organizational managers and supervisors, mid-level managers and supervisors who interact directly with workers, and members of OSH committees, as well as members from the worlds of justice (e.g., judges, prosecutors), education (e.g., heads and academic members from universities and vocational training institutes), and professional institutions from the main founding HF/E disciplines such as medicine, psychology, engineering, or sociology.

Incorporation of the principles and guidelines in this document into national policies and regulations will benefit stakeholders at all levels including those above as well as *system experts*, or qualified HF/E professionals and people with appropriate training, experience, knowledge, and expertise who contribute to HF/E design and management of work systems, and *system actors*, the workers who will interact with these work systems. Table 1.1 illustrates the interactions among the concepts in this document, stakeholders, and potential contributions.

Table 1.1. HF/E concepts in this document, stakeholders, and potential contributions.

HF/E Concept	Institutional Level of Relevance	Type of Institutions	Ways/Tools for Implementation	Target Audience/Stakeholders
• Principles	• National	• Government agencies • Employers organizations • Workers organizations	• Policies • Laws • Declarations	• Competent authorities • Policy makers and regulators • Government officials • Inspectors • Employers' representatives • Workers' representatives • Private sector leaders • Research and academics • Mid-level managers • Supervisors • OSH committees • Workers • HF/E professionals and designers • Maintenance and purchasing personnel • Manufacturers and suppliers • Sales and marketing personnel • Clients and customers
• Practices	• Regional (provincial)	• Federations • Councils	• Standards • Decrees • Position papers	
	• Sector specific	• Industry • Commerce • Non-governmental or non-profit organizations • Chambers • Unions	• Regulations • Codes of conduct • Codes of practice • Educational requirements	
	• Organization	• Enterprise • Academic units	• HF/E requirements • Codes of professional conduct • Operation manuals • Task procedures • Work system specifications	

2. Responsibility and Accountability

2.1 Roles and responsibilities of competent authorities, employers, and workers

This document provides high-level guidance to the following stakeholders and urges them to become aware of their responsibility for promoting HF/E design and management of work systems:

(1) Competent authorities/institutions at the national, regional, and city levels have responsibility and accountability for policy level decisions concerning HF/E in the design and management of work systems. Government policy makers and regulators at the national and/or state levels should create, enforce, and continuously monitor, evaluate and refine a coherent specific policy defining HF/E provisions and protections for workers. Policies and regulations should be consistent with HF/E principles and guidelines outlined in this document. Policies should be formulated via the ILO tripartite approach.

(2) Employers have the responsibility to adhere to HF/E principles and guidelines in the design and management of work systems, and to tailor these principles and guidelines to the specific conditions and needs of the organization and characteristics of the workers. Using a systems approach, they should take into account the physical, cognitive, organizational, and external environmental characteristics of the work. Input from workers and labour unions should be obtained through participatory HF/E. The organization is then responsible for providing appropriate HF/E information, equipment, and training to workers.

(3) Workers and their organizations should be consulted in the formulation of HF/E policy at the organization level and should be involved in the design and management of work systems that will promote physical and psychological health, safety and wellbeing and facilitate performance for their members. Worker representatives should be knowledgeable concerning HF/E principles and guidelines in the design and management of work systems.

(4) Workers should be empowered and involved in the design and management of work systems. They carry the most knowledge about how operations work, where problems are, and what can go wrong. They are essential contributors in any HF/E improvement process.

2.2 Roles and responsibilities of other stakeholders

Other stakeholders also have roles and responsibilities related to worker wellbeing and user needs and will benefit from HF/E design and management of work systems, including:

- **HF/E professionals and designers:** HF/E professionals and designers are responsible for initiating, guiding, and implementing HF/E design and management of work systems.
- **OSH professionals**: Specialists in occupational medicine and occupational safety and health practitioners are responsible for organizational OSH programmes.
- **Maintenance personnel**: Effective HF/E in equipment design and regular maintenance of equipment will ensure more consistent operation and fewer emergency maintenance events.
- **Purchasing personnel**: Equipment that is best suited to a task will have lower life-cycle costs than poorly matching equipment.
- **Manufacturers, importers, and suppliers**: These groups need to understand the HF/E considerations with goods and technology transfer and specific requirements of customers in different regions of the world.
- **Sales and marketing personnel**: Marketing can help understand customer needs and problems customers have with competing products and services and can help communicate these to design teams in ways that lead to innovative new products that better meet customer needs.
- **Human Resources and training personnel**: Specialists in instructional technology, design, and training can integrate HF/E principles and guidelines to produce well-designed software, materials, and educational procedures.
- **Clients and customers:** Clients and customers provide resources to the organization and may participate in the development and delivery of products and services. Their understanding and consideration of HF/E design and management in work systems will impact the quality of products and interactions between internal and external stakeholders (see Bibliography).

3. Principles and Guidelines for HF/E Design and Management of Work Systems

3.1 HF/E Principles

The *principles* for HF/E in work systems outlined in this document articulate basic HF/E values that underlie the creation of decent work. These principles describe ***five fundamental prerequisites*** for HF/E design and management of work systems to ensure worker safety and health and to enhance worker and organizational effectiveness and sustainability. They apply across all sectors and occupations. These principles are rooted in HF/E essential values that are consistent with those of ILO: humans as assets, technology as a tool to assist humans, promotion of quality of life, respect for individual differences, promotion of social dialogue, and responsibility to all stakeholders.

The HF/E principles for the design and management of work systems focus on essential system components. First, all principles put the primary focus on the human beings, the only living components of the system. From this point of view, HF/E principles are human-centric in that they emphasize the value of human integrity, taking care of individual health, safety and well-being of workers (Principle 1), as well as collective human characteristics (Principles 3 and 4).

Second, the HF/E principles underline the importance of involving workers and taking advantage of their knowledge and expertise during the design, evaluation and maintenance of work systems (Principle 5). Last but not least, they emphasize a sustainable balance between business goals of organizations and the individual and collective social needs and aspirations of their workers (Principle 2).

It is important to explicitly state the underlying principles for this document, as joint commitment to them among competent authorities at the national, regional, and city levels, employers, workers and their representatives is critical to achieve the objectives of the document. Moreover, the importance of HF/E design and management of work systems must be recognized in national and organizational culture and aligned with the vision and concept of decent work.

Principles for HF/E design and management of work systems are:

Principle 1: Ensure worker safety, health, and wellbeing in the optimization of work systems as a top priority;

Principle 2: Design and manage work systems to ensure organizational and worker alignment, continuous evaluation and learning, and sustainability;

Principle 3: Create a safe, healthy, and sustainable work environment from a holistic perspective, understanding and providing for human needs;

Principle 4: Account for individual differences and organizational contingencies in the design of work systems; and

Principle 5: Make use of collective, trans-disciplinary knowledge and full participation of workers for designing systems, detecting problems, and creating solutions for HF/E in work systems.

3.2 HF/E Guidelines

Guidelines for HF/E in work systems incorporate and build on the principles above. These guidelines describe ***what should be done*** for HF/E design and management of work systems to ensure worker safety and health and to enhance worker and organizational effectiveness and sustainability. These guidelines can and should be adapted to the context, evolving technologies, and new forms of work as they emerge. Competent authorities at the national, regional, and city levels, employers, and workers' organizations should rely on these guidelines to direct and evaluate policy and rules/regulations and to evaluate HF/E within organizations. They should promote and support them in HF/E design and management of work systems. Employers should use these guidelines to direct HF/E design and management of work systems within their organization. Well-designed work systems evidence commitment to the *principles* and application of the *guidelines* below.

Guidelines for HF/E design and management of work systems presented in this document are:

Guideline 1: Use a systems approach;

Guideline 2: Consider all relevant characteristics of workers;

2a. Consider demographic characteristics, physical and cognitive capabilities and limitations;

2b. Provide workers with appropriate tools, training, and control to perform work;

2c. Design work systems to be safe and to engage people in ways that maximize worker and work system safety and sustainability;

Guideline 3: Apply Participatory HF/E methodologies;

Guideline 4: Incorporate proactive measures to ensure worker safety, health, wellbeing, and sustainability;

Guideline 5: Tailor HF/E design and management of work systems to the organization; and

Guideline 6: Sustain a continuous learning process for evaluation, training, refinement, and redesign.

Table 3.1 below illustrates the relationships among HF/E principles and these guidelines. Each guideline is strongly connected to one or more principles. All of the principles are relevant in some way to the guidelines (Figure 3.1). Incorporating HF/E practices into work system design and management contributes to positive outcomes for employees and organizations.

Table 3.1. Relationships among HF/E Principles and Guidelines

	Principle 1	**Principle 2**	**Principle 3**	**Principle 4**	**Principle 5**
Guideline 1	XX	XX	XX	XX	XX
Guideline 2	XX	x	XX	XX	x
Guideline 3	XX	XX	XX	XX	XX
Guideline 4	XX	XX	XX	x	x
Guideline 5	x	XX	x	x	x
Guideline 6	x	XX	x	x	XX

XX = highly relevant

x = somewhat relevant

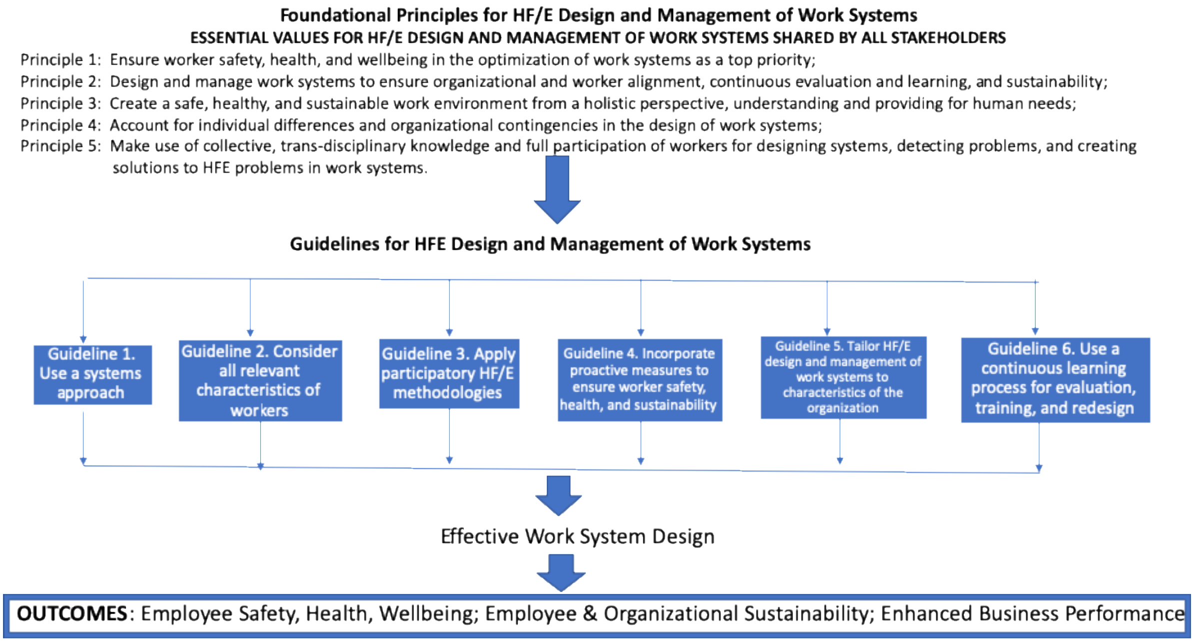

Figure 3.1. Principles, practices, and outcomes for HF/E design and management of work systems.

This document also includes specific information and recommendations on how to implement the guidelines and evaluate their success (see Chapter 4 and Annexes 2-6). Employers should use them to guide HF/E design and management of work systems within their organization and are responsible for instructing and training their workers and managers to apply them. Competent authorities at the national, regional, and city levels, employers, and workers' organizations should use the information and associated recommendations to evaluate HF/E design and management of work systems across all types of organizations.

4. Implementing HF/E Guidelines

Chapter 4 provides guidance for implementing guidelines in HF/E design and management of work systems. Competent authorities at the national, regional, and city levels and employers should ensure that the HF/E guidelines found in this document are implemented by qualified HF/E professionals or individuals with appropriate training, experience, knowledge and expertise. The relationship among the HF/E principles, guidelines, and outcomes is shown in Table 3.1 and Figure 3.1.

Guideline 1. Use a systems approach

Most work systems function through dynamic interactions among various human individual and/or collective aspects (i.e., physical, cognitive, psychosocial, and organizational) and relevant technical elements (e.g., hardware, software), as well as environmental, task, and organizational characteristics. Therefore, a systems approach that acknowledges the importance of a holistic perspective, context, interactions among humans and their working environment, and purpose in understanding the nature of the system and emergent characteristics is necessary. The need for a systems approach to HF/E in work design and management should be recognized and incorporated into national policy making and organizational standards. Competent authorities at the national, regional, and city levels and employers should ensure that a systems approach to HF/E design and management of work systems is accomplished by a capable and multidisciplinary team consisting of qualified HF/E professionals and/or individuals with appropriate training, experience, knowledge, and expertise.

This section includes recommended processes for implementing a systems approach.

4.1.1 A systems approach to HF/E design and management of work systems typically involves use of a structured, step-by-step, iterative process model such as the PDSA (Plan, Do, Study, Act) cycle or the Conceptual Work System Design Model (Annex 3 presents several relevant models)**.** These and similar models consider work system elements – humans, tasks, tools and technology, the work environment, and organizational characteristics – from a holistic perspective. The same type of approach should be used for continuous learning, evaluation, and refinement of work systems (see Section 4.6 and WISE model, Annex 5). Communication between HF/E specialists and experts in other disciplines is essential, both for setting policy for HF/E in work systems and for implementing policy within organizations.

4.1.2 The systems approach should be supported by sufficient resources (e.g., budget, time) and personnel. Competent authorities and decision makers at the national, regional, and city levels and employers should ensure that adequate resources and personnel are allocated to the design and management of HF/E in work systems. Work design that considers the physical, cognitive, psychosocial, and organizational needs of workers may seem more expensive but will improve performance, worker sustainability and wellbeing, and reduce the potential for injuries and incidents over the long run.

4.1.3 A work system designed using the HF/E systems approach should be continuously monitored and evaluated for suitability, validity, and impact on workers and the organization. It is important to ensure that the proposed work system design is correct and valid before it is implemented and as it is managed. Appropriate trials and tests must be carried out depending on the operational complexity and potential risks of the work system.

4.1.4 The proposed work system design should be optimised with due considerations given to the balance between human wellbeing and system performance. Generally, there is no absolutely correct solution. Optimization depends on the goals of the design and also on available resources.

Risks of not using Systems Approach:
~ Imbalance and ineffective or hazardous work system due to misalignment of elements in the system
~ Failure to identify potential risks and hazards ahead of time and possible emergence during system use.

Benefits of Systems Approach:
~ Multiple perspectives taken into account and appropriate trade-offs are ensured
~ Functioning of the system as a whole is addressed
~ Maximizes buy-in from stakeholders and avoids placing too much emphasis on a single system component in isolation

The following need to be embedded in the HF/E systems approach:

(1) Worker behaviours and activities in actual work conditions are reflected in the design. Special attention needs to be given to operational behaviours and activities under possible emergent risks such as stress and ambiguity. These considerations stemming from realistic working conditions are extremely important in the case of designing a new work system, where actual workers' behaviours and realistic activities are not yet known simply because the work system is still in the design stage.

(2) Continuous follow-up evaluations are made to assess and refine the work system design. Outcomes provide feedback to the organization, creating a mechanism for evaluation of possible emergent risks and continuous improvement (see Figure A3-1); and

(3) Validation and continuous monitoring of HF/E implementation are led by a multidisciplinary team. Consultation with qualified HF/E professionals or individuals with appropriate training, experience, knowledge and expertise is a prerequisite.

4.1.5 Recommendations for evaluation before and after a work system design is implemented should be incorporated into national and organizational policies. Continuous improvement to work systems through monitoring and refining practices is at the heart of the HF/E systems approach. Therefore, incorporating policy recommendations for evaluation before and after a work system design is implemented is essential to effective implementation of HF/E in work systems.

Guideline 2. Consider and design for all relevant characteristics of workers

The importance of a match between worker characteristics and work system requirements, an essential goal of HF/E and a key requirement for HF/E design and management of work systems, should be recognized and incorporated into national policy making and organizational standards. Competent authorities at the national, regional, and city levels and employers should ensure that policies and regulations for the design and management of HF/E in work systems incorporate the need for a holistic perspective that aligns with human physical and cognitive capabilities and accommodates all relevant human characteristics, including culture, knowledge, experience, needs, capabilities, and limitations. These guidelines should be implemented by qualified HF/E professionals or individuals with appropriate training, experience, knowledge and expertise.

This section includes relevant guidelines for aligning worker characteristics and work design: the most critical human attributes to be considered; tools to enhance human performance; and HF/E strategies and processes for worker safety, health, wellbeing, and sustainability.

2a. Consider demographic characteristics, physical and cognitive capabilities and limitations

4.2.1 Demographics of the workers should be taken into consideration in the design and management of work systems, especially during the conceptual stage. Individual characteristics such as age, societal background and expectations, gender, and diversity can make a difference in how people perform in their work.

4.2.2 Human physical capabilities and limitations should be considered in the design of work systems. Anthropometric tables of worker population by country, region, or locale should be used or created as needed to ensure accurate accommodation for relevant features. This is especially critical when work systems are designed in different and distant places from where they will be actually used. Technological features in work systems should ensure adequate response to human capabilities and limitations and therefore reduce potential organizational and human failures. The concept "anthropotechnology" (see Bibliography) is a useful tool to take into account.

HF/E strategies to account for physical capabilities and limitations across industries and occupations include:

(1) Fit the work task to human capabilities and goals, not only the human to the task;

(2) Minimize concurrent, long duration and/or high magnitude physical exposures (force, repetition, awkward/static posture, mechanical compression, vibration). Specifically:

   a. Minimize the duration of exposure to whole body vibration and hand-arm vibration (WBV & HAV).

   b. Ensure that work/rest recovery cycles within a work shift minimize fatigue.

   c. Reduce static loads and physically stressful postures.

   d. Minimize peak force requirements and the percentage of time spent in forceful exertion.

(3) Design work systems to accommodate a wide range of worker physical sizes and individual differences;

(4) Make reasonable adjustments to work systems to accommodate workers with limitations or disabilities;

(5) Consider human capabilities and limitations in relation to varying work demand and workload (task + workstation + environment) across workers and time -

> ***Risks of ignoring worker characteristics:***
> *~ Use of badly designed work systems increases the chance of errors and poor quality of work*
> *~ Users of poorly designed work systems may experience physical or cognitive overload and accompanying stress, making work unsustainable over time*
>
> ***Benefits of aligning worker characteristics with work systems:***
> *~ Ensures that systems are safe and maximizes worker wellbeing and sustainability*
> *~ Enhances worker performance*
> *~ Reduces injuries due to poor human-system mismatch*

a. Ensure the exposure to environmental stressors such as noise and high temperature are maintained within safe levels

b. Ensure the physical work environment is appropriate for the requirements of the task

c. Ensure appropriate work scheduling (daily, weekly, and seasonal) to avoid fatigue and consequences of sleep disruption or deprivation; and

d. Ensure special precautions to safeguard the safety and health of lone workers; and

(6) Incorporate a holistic perspective that acknowledges the influence of cognitive, psychosocial, work organization, socio-technical, and environmental factors in the physical design of work.

4.2.3 Human cognitive capabilities and limitations should be considered in the design of work systems. Cognitive aspects of workers include perception, memory, reasoning, information processing, and decision making. Insufficient attention to these requirements can cause stress and jeopardize psychological health as well as the ability to perform work tasks.

HF/E strategies to account for cognitive capabilities and limitations across industries and jobs include:

(1) Design information systems for ease of comprehension, using for example coding techniques such as size, shape, color, and position to indicate the meaning of numerical values displayed on screens or dials -

   a. Design work systems to present information and data in a way that is consistent with how humans process information and compatible with the training and mental abilities of users

   b. Use multiple modes for information when possible. Because humans have limited visual processing capacity, other sensory modes such as auditory and tactile displays should be used to facilitate identification and attention, especially when the visual channel is highly loaded. Ensure that the most critical information is saliently presented

   c. Facilitate pattern recognition in display design. Humans can process information quickly when it corresponds with a pattern, or deviates from an expected pattern

   d. Design work systems to correspond with cultural rules of thumb or movement and conceptual compatibilities or stereotypes. Examples include rotate clockwise for 'on' or 'increase,' red for danger or unsafe, arrows for direction;

(2) Design equipment to default to a safe mode during normal operation and maintenance. Examples include 'lock-out' switches in high tension equipment so that the system does not operate during tasks when the operator might be at risk;

(3) Design new work systems so that skills transfer as much as possible from previous systems. This will enhance learning, reduce training time, and minimize opportunities for errors;

(4) Design work systems to support appropriate cognitive behaviour and avoid errors in problem-solving and decision making. High-quality HF/E fosters a match between information presented by the system and the type of cognitive response required. A feedback component should be designed into work systems so the operator can assess the accuracy and effectiveness of decisions and actions; and

(5) Incorporate a holistic perspective that acknowledges the influence of physical, psychosocial, work organization, socio-technical, and environmental factors in the cognitive design of work.

4.2.4 Occupational psychosocial factors should be considered in the design and management of HF/E in work systems**.** For example, exposure to psychosocial risk factors should be controlled through proper allocation of functions between workers and technology to ensure optimal workload and performance, and avoidance of conflicting job demands. Special considerations must be made to protect at-risk and lone workers. HF/E design in work systems should be consistent with the ILO Violence and Harassment Convention (2019) and should act as a firewall against these abuses, as well ensure opportunities for improved job control as well as the avoidance of stress, hostility, depression, hopelessness. These factors have been associated with physical as well as psychological health, particularly heart disease. (See also Sections 4.2.8, 4.2.9, and Annex 4 on function allocation).

4.2.5 As the workforce grows older, general characteristics of aging should be taken into account in the design and management of HF/E in work systems**.** Aging changes include physical decrements in aerobic capacity, general health, visual and aural acuity, strength for lifting and gripping, reaction time, ability to move limbs and joints freely, tolerance for heat and cold, and capability to recover from physical work and slips or trips. Additionally, older workers may have cognitive decrements in short-term memory and less tolerance for paced work. Work system design as well as training should be adaptive to these changes. Success factors for effective training programmes for the adult workforce, including practice periods, behavioral reinforcement, and positive training effects should be incorporated into the instructional design.

2b. Provide workers with appropriate tools, training, and control to perform work.

4.2.6 Workers should be provided with the appropriate tools to perform work and communicate as needed**.** The purpose of tools is to make work easier (physically and cognitively) and improve productivity. This means that physical and cognitive capabilities and limitations should be considered. Having all stakeholders engaged in the tool selection process is key, as a holistic HF/E perspective requires attention to organizational, cultural, and environmental factors as well as human characteristics. HF/E principles and guidelines can guide the process of selecting, training for, evaluating and maintaining tool selection. Competent authorities at the national, regional, and city levels and employers should ensure that the work tool selection and implementation is accomplished by people with the appropriate knowledge and expertise. Annex 4 provides recommendations for tool selection.

4.2.7 Workers should retain an adequate degree of control over their work**.** Knowledgeable worker control and guidance should be incorporated into work system design especially with respect to factors such as starting and stopping, the pace of the work, autonomy, and decision making. Clear, unambiguous instructions and procedures should be designed based on HF/E graphic design guidelines. Workers should be aware of these procedures and trained to deal with emerging, unexpected situations.

4.2.8 Allocation of task functions between workers and automated tools should be based on appropriate HF/E models (see Annex 4). It is important to give careful consideration to which task elements are assigned to the human worker versus the automation to avoid overly rigid, unworkable, or 'leftover' allocation. Central to HF/E work system design is the specification of a clear and unambiguous role for the operator to provide the basis for a meaningful job. From this point of view, functions should be allocated to automated systems only if they are separable from the operator's role and do not conflict with it.

Risks of inadequate or inappropriate tools, training, and control:
~ Injuries due to poor tool design
~ Lost production due to quality errors
~ Errors caused by pain, fatigue, inappropriate posture
~ Need for retraining
~ Absenteeism and poor morale
~ Increased maintenance and repair costs

Benefits of providing proper tools, training and control:
~ Improved performance and quality of work
~ Reduced scrap rate
~ Enhanced worker health, safety, wellbeing, and productivity
~ Enhanced organizational effectiveness

4.2.9 Work systems increasingly involve technological tools, such as robotic, intelligent, and autonomous systems (RIAs), artificial reality/virtual reality (AR/VR), and wearable (exoskeleton) devices. These tools have the potential to greatly reduce risks in the short term at work but introduce new considerations and challenges for human cognition as well as potential physical risks of long-term use. They should be incorporated into work system design in ways that facilitate human performance and do not hinder it. ISO standards (e.g., ISO 9241) and draft Technical Report ISO/CD TR 9421-810 address some of the cognitive and physical issues inherent in these technologies, such as the time it takes the human to become situationally aware enough to take control successfully if the automation process fails, how to maintain human worker skill levels needed to take control when the need arises, or how to ensure that these tools will not increase cognitive workload. When appropriately incorporated into work system design, these technologies can enhance worker capability to a great extent. Moreover, mobile devices such as phones and tablets enable workers to communicate with co-workers and to perform some tasks remotely rather than sitting at a desk in an office.

HF/E requirements to enhance positive effects of technology in the work system and mitigate any negative effects include:

(1) Workers should be appropriately trained to have knowledgeable control over technological tools;

(2) Technological tools should be transparent in their functioning so that the worker can understand, observe and predict system behaviours and actions;

(3) Technological tools should not increase physical or cognitive workload;

(4) Technological tools should not distract the worker from work activities;

(5) Factors such as facility and workstation design should be considered when using AR/VR and other wearable sensors;

(6) Technological tools should be based on appropriate understanding of human capabilities and limitations, especially when they monitor worker behaviours and states; and

(7) Technological tools should enhance workers' awareness of the situation and keep workers 'in the loop' to facilitate manual system takeover when needed.

2c. Design work systems to be safe and to engage people in ways that maximize worker and work system safety and sustainability

4.2.9 Work system safety and sustainability are critical factors for HF/E. Work systems should engage workers in positive ways and should not generate risks or dangers for the people who are involved in their operation. Sustainable work systems are essential for long term worker wellbeing and performance as well as for productivity and quality. Sustainable work systems also enable workers to contribute effectively to economic and other goals and afford resilience for workers and organizations.

Work demand should be balanced with human capacity. Balancing work demand and human capacity allows for the optimization of productivity and quality while minimizing the risk of negative outcomes such as fatigue, discomfort, stress, or injury. HF/E requirements include:

(1) Maximize the safety, health, and wellbeing of workers while enhancing productivity;

(2) Consider estimated workload required to accomplish a task as well as individual differences in load capacity prior to design;

(3) Ensure that the introduction of technological tools occurs along with training on their use and does not increase physical or cognitive stress;

(4) Design tasks to increase the diversity and age range of people who can perform them;

(5) Consider the environmental, economic, socio-political and cultural factors that may impact worker capacity and sustainability; and

(6) Incorporate HF/E risk assessments into organizational safety audits.

Guideline 3. Apply Participatory HF/E methodologies for HF/E design and management of work systems

Participation of all stakeholders is essential for effective implementation of HF/E in work system design**.** The participation of the worker is a critical part of the work system and thus the performance of the system is dependent on the wellbeing and performance of the worker. The importance of Participatory HF/E methodologies in work design and management should be recognized and incorporated into national policy making and organizational standards. Competent authorities at the national, regional, and city levels and employers should ensure that Participatory HF/E in work design and management is managed by qualified HF/E professionals and people with appropriate training, experience, knowledge and expertise.

This section provides the essential elements of Participatory HF/E methodologies. More information can be found in Annex 5 and in the Bibliography.

4.3.1 The implementation of HF/E in work system design and management should involve employers, workers and their representatives, external advisors, internal HF/E specialists, and safety and health committees where they exist**.** Summoning and incorporating a diversity of expertise in different aspects of the design and operation of a work system is especially important when it is complex in nature, requires many workers for its operation, and/or the risks of faults in its operation are very high. This approach will facilitate understanding by all parties of the work that is will be done, the difficulties involved, and the ways in which workers may compensate to face the discrepancy between the prescribed work tasks and the actual work situation, and also may enhance the collective perspective and cooperation. This section includes suggested processes for implementing Participatory HF/E, illustrated in Figure 4.1 below. Step-by-step toolkits such as those shown in Annex 5 can be useful to guide the process.

> ***Risks of not using Participatory HF/E methods:***
> *~ Work system design does not address the needs of workers who will use it*
> *~ Workers cannot use or do not accept work system*
>
> ***Benefits of Participatory HF/E methods:***
> *~ Maximized 'buy-in' from all of the stakeholders involved with the work system and its components*
> *~ Avoidance of a single point of view perspective on the work system*
> *~ Higher levels of worker engagement, commitment to change, and ownership of the resulting work system design or redesign*

4.3.2 Workers should be engaged in the design or redesign of their own work, workplaces, or introduction of new technologies. Workers know about many of the complex interactions among physical design factors in their workplace, how their work is organized and the psychosocial conditions that affect their work, and how their lifestyle and influences outside the workplace can affect their safety and wellbeing. Workers and employers can jointly learn the merits of HF/E actions through effective practices in their own or similar workplaces. Participatory steps can lead to planning and implementation of multifaceted HF/E practices for the local context.

The following participatory approach is suggested:

(1) Seek out, select, and involve workers starting from the planning stage of work design or redesign and encourage suggestions;

(2) Focus on benefits of applying HF/E measures in improving safety, health, wellbeing, and working conditions;

(3) Organize workplace-level dialogue among workers and employers about priority actions by utilizing locally adapted HF/E toolkits;

(4) Engage workers to pilot changes and provide feedback about the improvement process;

(5) Listen to feedback, incorporate suggestions and communicate decisions before large scale implementation of changes; and

(6) Recognize and reward workers for their involvement.

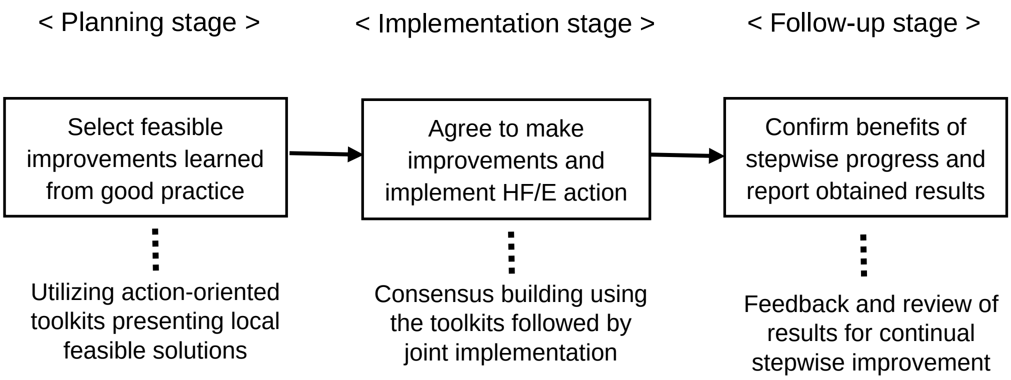

Figure 4.1. Examples of participatory steps for implementing HF/E measures.

Guideline 4. Incorporate proactive measures to ensure worker safety, health, wellbeing, and sustainability

To make the HF/E systems approach effective, it is important to recognize that taking every opportunity for proactive measures is essential to promote physical and psychological health and avoid adverse incidents, injuries and harm to workers. Proactive measures include early consideration of HF/E in work design and process improvement, as well as identifying and addressing early symptoms of injury or harm to workers. Proactive measures should also be taken to address new emerging and disruptive technologies in the workplace, such as intelligent or autonomous automation, artificial intelligence, or robotics, and new, non-standard work arrangements by applying HF/E principles and guidelines in this document. Competent authorities at the national, regional, and city levels and employers should ensure that key aspects of an effective and proactive programme are addressed and implemented by qualified HF/E professionals and people with appropriate training, experience, knowledge and expertise. It is critical that these stakeholders emphasize the need for a culture focused on reporting and learning.

4.4.1 HF/E should be considered early on in work system design, especially when introducing new tasks, workspaces or environments**.** It is better to promote proactive HF/E programmes such as Prevention through Design (identifying problem areas and implementing solutions ahead of time) rather than to rely on reactive measures (addressing problems after they have occurred).

Considerations at this stage of a work system design include:

(1) Involve all stakeholders that will interact with the new space or task;

(2) Assess organizational readiness for change (see Annex 1);

(3) Strive to identify and understand the culture, educational background and technical profile of the workers that will operate and maintain the new work system;

(4) Incorporate feedback from stakeholders who perform similar tasks or have similar workspaces;

(5) Incorporate HF/E principles and guidelines as new emerging technologies are introduced into work systems; and

(6) Involve HF/E knowledge workers/consultants in the planning stage and every phase thereafter.

4.4.2 Proactive programmes are essential to promote physical and psychological health and avoid work-related adverse incidents, injuries, and harm to workers and should be developed in parallel with work system design**.**

Key aspects of such programmes include:

(1) A clear goal, supported by all stakeholders, that problems in work system design will be reported, recorded, and addressed;

(2) Information to workers about the nature, signs, and symptoms of MSDs (musculoskeletal disorders) and/or potential psychosocial factors, and why it is so critical to address them as early as possible;

(3) Clear and concise information on the reporting process with regular encouragement to engage in the process as needed;

(4) Support engagement from supervisors and managers at all levels with no threats of negative consequences for reporting problems;

(5) Clear communication channels with OSH committees or occupational health services;

(6) Immediate response to the report of symptoms that includes problem management, exposure/hazard assessment, and control/mitigation of exposures using the hierarchy of controls (see Annex 6);

(7) Problem reports combined with assessment of work tasks, workstation, workspace, work organization, and work environment to determine the need for job analysis and redesign.

Risks from lack of proactive measures:
~ Factors such as lack of training, lack of knowledge or understanding of the relevant regulations;
~ Pressure to complete tight task deadlines without any breaks;
~ Risk of fatigue and exhaustion caused by excessive working hours;
~ Psychosocial risks such as work-related stress resulting from the precariousness of the employment, ratings assigned to workers from employers or clients, intensity of work, interruptions and distractions making concentration difficult;
~ Quality deficits and production problems
~ Physical and psychosocial risks of related to the work with computing technology and mobile devices.

Benefits of proactive measures:
~ Jobs and work environments that support worker physical, cognitive, and psychosocial needs
~ Addressing of safety and health issues before they become unmanageable, expensive, or require expensive long-term treatment
~ Ensuring balance among work system components to support worker wellbeing and performance

4.4.3 New ways of working and varied forms of employment and work can create special situations that should be addressed**.** This is particularly important where there is relative informality of work arrangements and workplaces.

HF/E guidelines should be proactively incorporated into new types of work systems to mitigate HF/E risks. Work should be adaptable to the worker population, including those who have special needs, and also should be adaptable in time according to the development of technology and the evolution of human capacities, age, abilities, biological rhythms, etc. Adaptable refers not only to physical issues, but also to changes over time in workers' conditions. Giving workers a degree of autonomy to regulate their own activities and production will mitigate stress or anxiety that may result if they are not empowered to make changes to reduce physical and psychological risks.

Promoting movement and postural variation through work systems design in sedentary occupations can facilitate worker safety, health, wellbeing, and sustainability by incorporating opportunities for movement into work systems. For example, open offices may have architecturally designed workspaces that encourage and support varied work postures and activities, such as standing conference desks, huddle areas with soft seating, exterior pathways for walking to meetings, and alternative workstations with dynamic components. These various workspace configurations should support a range of office and computer tasks and encourage individuals to vary and adopt healthy computing postures to promote effective task performance. Introduction of activity-promoting innovations in the office and computing workplace should follow recommendations for tool selection, equipment and workplace facility design and should be accompanied by appropriate training and follow-up evaluation.

4.4.4 Opportunities and encouragement should be given for contractors and labour supply agents to adhere to HF/E principles and guidelines. As assurance processes, contractors' forums may be established with appropriate terms of reference. These forums should be guided by HF/E experts and focus on the following:

(1) Ensuring that work systems and processes in contracting agencies are consistent with HF/E principles and guidelines;

(2) Sharing effective practices and lessons learned; and

(3) Promoting innovation to drive continuous improvement and create a legacy of collaboration and management of the escalation of key risks and issues.

Guideline 5. Tailor HF/E design and management of work systems to characteristics of the organization

The implementation of HF/E in work system design and management will vary depending on the characteristics of the organization, including its technological, personnel, and external environmental subsystems. Competent authorities at the national, regional, and city levels and employers should ensure that policies and regulations for the design and management of HF/E in work systems include a tailored approach and incorporate guidance for aligning work systems with relevant organizational characteristics outlined in this section.

This section outlines organizational characteristics that are relevant and should be considered for HF/E design and management of work systems.

4.5.1 Type of organization should be identified and taken into account, as it will impact the design of a work system. Traditional hierarchical organizations will have different needs and requirements than, for example, regional and local industries such as agriculture, forestry, or handicraft. The specific characteristics of the organization will guide the adoption of different HF/E design aspects and components of the system.

4.5.2 The subsystem(s) of the organization that will be involved and impacted should be identified and taken into account**.** Information on the subsystems that should be considered in the design and management of HF/E in work systems is included in Annex 1.

4.5.3 The size of a target organization should be identified and taken into account. Characteristics of a work system should be tailored to the size and level of resources available to the organization. These will impact organizational readiness, ability to implement changes, and strategies for work system design. Large organizations, medium-size organizations, and small organizations have different characteristics. Small organizations, for example, rely on different resources than medium or large organizations and work on a smaller scale. Workers in small organizations have a broad understanding of the work and its impact on the organization and can have a greater impact on cost reduction and productivity than in larger organizations.

Although it is important for enterprises of all sizes to acknowledge, understand, and work with local cultures and resources, it is even more critical for small organizations to do so. Strategies for implementing HF/E in work systems within small organizations should recognize and account for the advantages of small size and capitalize on local knowledge, low-cost solutions, and resources.

> ***Risks of sufficient/ insufficient attention to organizational factors:***
> *~Risk of failure (non-adoption) of the system as a whole and rejection of work design changes by front-line staff and managers*
> *~ Errors from work environment factors such as poor job design, poor error correction systems*
> *~ Costs due to increased turnover of workers*
>
> ***Benefits of paying attention to organizational factors:***
> *~ Enhanced employee health, wellbeing and performance*
> *~ Better adoption of innovations and changes*
> *~ Improved employee-management relations*
> *~ Early detection of conflicts to detect effective resolutions*

To best utilize local knowledge and resources:
(1) Engage local people to make HF/E improvements;

(2) Build on local good practices;

(3) Use local, low cost practical improvements;

(4) Use locally adjusted training (e.g., train-the-trainer);

(5) Provide immediate feedback for workers' ideas and initiatives - recognize and reward HF/E improvements stemming from them;

(6) Build HF/E competencies into the organization through local professional organizations and resources including universities; and

(7) Engage local authorities (e.g., city or regional officials) to support changes proposed at the small organization level.

4.5.4 The maturity and readiness of the organization should be assessed and taken into account. Organizations will vary in their ability and readiness to implement comprehensive changes to HF/E in the design and management of work systems. Organizational readiness is impacted by many factors including the status of national, regional, and city policies and regulations related to HF/E, and in turn will impact strategies for integration of HF/E into work systems. Stages of organizational maturity and status of HF/E integration are discussed in Annex 1. Organizations can audit their level of maturity and progress over time using the organizational readiness tool given in Annex 1, which also specifies recommendations for HF/E integration.

4.5.5 HF/E principles and guidelines should be applied to remote work systems, such as telework or flexible workstations in off-site or satellite work offices**.** Technological tools such as mobile devices and the Internet of Things (IoT) have made it possible for many work tasks to be accomplished remotely and virtually. The safety and health of remote workers as well as their ability to be productive and effective should be protected through application of HF/E principles and guidelines to these jobs.

4.5.6 Special considerations apply to the design and management of informal work and new forms of work, including platform work, crowd work, and work on demand in the 'gig economy.' Potential HF/E risks to these workers should be addressed through a HF/E systems approach. Considerations to recognize and take into account include:

(1) The need for a HF/E systems approach to ensure the safety, health, wellbeing, and sustainability of informal workers, who typically do not have access to organizational resources and protections and are high risk for adverse events;

(2) The need for a HF/E systems approach to define, design and evaluate jobs of the gig economy in order to create appropriate work systems;

(3) The responsibilities of all actors (i.e., employers, contractors, and workers) for the implementation of these new types of labour practice and how HF/E issues can be incorporated and addressed within those responsibilities. Unionization, worker centres, cooperatives, and online forums represent initiatives aimed at encouraging communication and contact between workers, engaging with employers, and increasing workers' political and legal consciousness about opportunities to advocate for their rights and improve workplace standards;

(4) The need to embed HF/E principles and guidelines in the hands and minds of all actors through education and training; and

(5) How HF/E as a discipline can help workers to protect their life at work and to advocate for themselves when involved in these new labour practices.

Guideline 6. Sustain a continuous learning process for evaluation, training, refinement, and redesign of HF/E in work systems

The design and management of HF/E in work systems is an ongoing process. Organizational characteristics, societal norms, regulations, popular opinion, and technologies will change over time, and new scientific evidence may emerge. Training and continuous monitoring/feedback/refinement according to input from workers and other stakeholders are essential components of effective implementation of HF/E in the design and management of work systems and will be important for economic as well as safety, health, and wellbeing outcomes (see Annex 2 and 3). Competent authorities at the national, regional, and city levels and employers should ensure that policies and regulations for the design and management of HF/E in work systems include practices for continuous evaluation and improvement, implemented by qualified HF/E professionals and people with the appropriate knowledge and expertise.

This section contains a set of guidelines for continuous learning, training, and evaluation of HFE design and management of work systems.

4.6.1 Create a process for reporting, evaluating, and continuous learning by providing information, education, and updated training. An iterative approach and step-by-step process centred on HF/E principles and guidelines such as the PDSA cycle or similar process may be used (see Annex 3). Collect information and use feedback to refine HF/E in work systems and to design training in anticipation of relevant social and technological trends and changes. Training is an essential component of effective implementation of the HF/E systems approach in the design and management of work systems. Training should engage the trainees such that they are active participants and have sufficient opportunities for practice.

> ***Risks of not using continuous learning approach:***
> *~ Danger of repeating earlier mistakes*
> *~ Failure to capitalize on early learning during projects and other work redesign initiatives*
> *~ Obsolescence of work system design due to failure to update for changing conditions*
>
> ***Benefits of continuous learning approach:***
> *~ Informative feedback on work system performance allows for timely modifications*
> *~ Improvements to system design, training programs, and work processes*
> *~ Improved morale and job satisfaction, less absenteeism and turnover when the employer is responsive to workers' needs when making work system modifications*
> *~ Positive organization climate and appreciation of HF/E efforts*
> *~ Essential for organizational excellence*

Key components of an effective training programme include:

(1) Training for work systems that includes and builds on input from all stakeholders;

(2) Training workshops and programmes adapt to local industries and workplaces;

(3) Engagement and contribution of all stakeholders in the development, implementation and assessment of the work systems and training;

(4) Active buy-in of all stakeholders regarding the need, purpose and expected outcomes of the training;

(5) Simulation of future work system use (equipment and procedures) during training with opportunities for feedback on proper use;

(6) Appropriate integration of new tools, technologies, techniques etc. with acknowledgement of potential temporary reductions in productivity requirements as changes to the work system are assimilated; and

(7) Assessments during training and post training to ensure outcomes have been met and the work system is functioning smoothly.

Importantly, training should not be used as the primary strategy to control a hazard or reduce exposure or as a substitute for hazard mitigation (see hierarchy of controls diagram, Annex 6). Exposure reduction through elimination, substitution, redesign or administrative controls should be accomplished as primary interventions.

4.6.2 Continuous monitoring and refinement should take place to ensure that work systems are functioning as intended and the goals of training have been met. Continuous monitoring, feedback, and refinement are essential components of effective implementation of HF/E design and management of work systems. Systematically monitoring work systems from HF/E perspective during regular, daily operations will help ensure that the procedures for use, maintenance and service respond to the real situations in which the systems are installed and functioning and will also ensure both productivity and welfare of workers.

4.6.3 The actual conditions of use inevitably change over time - for example, changes in management styles, personnel turnover, periodic maintenance tasks, and higher demands for increased productivity - and can alter the effective functioning of the work system. The work system may be sold to other companies and/or exported to other countries. Systematic, long term monitoring of work system functioning from HF/E perspective helps to identify and fix possible operational deviations, ensuring appropriate operational and human sustainability. An audit inspection based on HF/E principles and guidelines is essential in those cases.

4.6.4 It is highly recommended that those involved in meaningful HF/E actions or improvements are rewarded and recognized. Recognition of individual and/or collective efforts is an essential part of the promotion of HF/E actions in organizations worldwide.

5. Glossary

In this document, the following terms and definitions are assigned these meanings (Sources can be found in the Bibliography):

Competent authority/ Institution: A government department or other institution at the national, regional, or city level with the responsibility and authority to issue regulations, orders or other instructions having the force of law. Competent authorities may be appointed with responsibilities for specific activities, such as for the implementation of national policy and procedures for protection of workers via implementation of HF/E in work systems.

Contractor: A person or an organization providing services to an employer at the employer's worksite in accordance with agreed specifications, terms and conditions.

Crowd work: A form of work constituting a "gig-economy;" Employment that "uses an online platform to enable organizations or individuals to access an indefinite and unknown group of other organizations or individuals to solve specific problems, or to provide specific services or products in exchange for payment." (https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/--- travail/documents/publication/wcms_443267.pdf, Eurofound, 2015).

Decent work: Work that includes substantive elements corresponding to the ILO Decent Work Agenda: employment opportunities, adequate earnings and productive work, decent working time, combining work, family and personal life, stability and security of work, equal opportunity and treatment in employment, safe work environment, social security, and social dialogue, employers' and workers' representation. (https://www.ilo.org/global/topics/decent-work/lang--en/index.htm)

Employer: Any physical or legal person that employs one or more workers.

Gig economy: Gig-economy includes mainly two forms of work: "crowd work" and "work on-demand via apps." See "crowd work" and "work on-demand."

HAV: Hand-arm vibration.

HF/E: See "human factors/ergonomics"

HF/E Integration Plan (HFI): Organizational plan that defines the work and activities needed to achieve a goal such as the implementation of HF/E in work systems.

HF/E graphic design guidelines: Set of coherent graphic visual, auditory, or sensory information that informs the design of a work system and that allows understanding of its regular operation, risks and dangers, its start-up, its control and its interruption as necessary.

Hierarchy of controls: System used to minimize exposure to hazards. In order of effectiveness, the controls are

1. Elimination
2. Substitution
3. Risk transfer
4. Engineering controls
5. Administrative controls
6. Personal protective equipment (least effective)

Holistic: Supporting coordinated design and taking into account all system elements, e.g., human physical and cognitive characteristics, interfaces, training, support materials, the work environment.

Human-centered work system: A work system is centered on the human if the physical and cognitive capacities as well as the knowledge and experience necessary to operate it have been duly taken into account for its conception, design, operation and maintenance. Human-centered work systems also consider individuals' welfare, motivation, interest and sustainability.

Human Factors/ Ergonomics (HF/E): The scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human wellbeing and overall system performance. HF/E employs three substantive drivers of intervention: (a) it takes a systems approach; (b) it is design-driven; and (c) it focuses on optimizing two closely related outcomes, performance and wellbeing. HF/E can be described as a trans- disciplinary, user-centric 'bundling science,' in that it integrates and applies theory, principles, and data from many relevant disciplines to the design of work systems, considering the complex interactions between the human and other humans, the environment, tools and equipment, and technology.

Internal organizational elements: Elements comprised of the psychosocial factors (e.g., job design, job demands, decision latitude), team and social interactions, and the organizational culture including attitudes toward safety, health, and wellbeing.

Knowledge worker: Workers whose main contribution is their knowledge, acquired through formal training, as applied to develop products and services, and whose primary job involves using computer and office related technologies to accomplish information-related job tasks.

Macro-ergonomics: A sociotechnical framework for studying the issues associated with large-scale organizational change. Macroergonomics is concerned with the optimization of work systems through consideration of relevant social, technical, and environmental variables and their interactions.

Meaningful job: The activity that a worker carries out and and is understood by him or her to be significant in terms of its magnitude, contribution, value and consequences.

MSD: Musculoskeletal disorder (Work-Related Musculoskeletal Disorder – WMSD).

Non-standard work system: Work system involving employment in the form of, for example, part-time work, temporary work, labour on demand via employment agencies or apps, subcontract work, crowd work, or platform work.

Occupation: A person's usual or principal work or business, especially as a means of earning a living; vocation.

Operational excellence: A state that involves systematic collaboration among all levels of an organization or business and requires purposeful participation of every level and every person in the organization, from executives to the employees producing the product in order to optimize performance of all activities of the organization or business.

OSH: Occupational safety and health.

Organization: A company, operation, firm, undertaking, establishment, enterprise, institution or association, or part of it, whether incorporated or not, public or private, that has its own functions and administration. For organizations with more than one operating unit, a single operating unit may be defined as an organization.

Organizational design: The structural design and hierarchy of an organization (complexity, formalizations and centralization) and processes.

Organizational learning: A learning process that is necessary for the development, success and long-term-sustainability, especially for participatory HF/E programmes. It includes a cybernetic learning process requiring support systems, policies and procedures to support feedback control by employees.

Participatory HF/E: An approach to the implementation of change or new technology in organizational systems that requires end users to be highly involved in developing and implementing the intervention. Active involvement of people in the planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes to achieve desirable goals, reduces risks to safety and health and improves productivity.

Platform work: An employment model in which organizations or individuals use an online platform to access other organizations or individuals to solve specific problems or to provide specific services in exchange for payment.

Psychosocial: Involving psychological and social/environmental aspects. Psychosocial aspects of work systems include work demand, autonomy/control, and support of others (social support).

Risk: A combination of the likelihood of an occurrence of a hazardous event and the severity of injury or damage to the health of people caused by this event.

Remote work system: System in which an employee works from an alternative worksite.

Sociotechnical systems: Dynamic, open work systems with permeable boundaries. Sociotechnical systems in organizations are composed of (a) a technological subsystem, (b) a personnel, psycho-social subsystem, (c) the external environment that interacts with the organization, and (d) the organizational design. These work systems are continually evolving in response to multiple internal and external influences.

Stakeholders: Persons or organizations that can affect, be affected, or perceive themselves to be affected by a HF/E decision or activity. In this document the following four groups of stakeholders are distinguished to facilitate understanding:
~ System influencers – e.g., competent authorities such as governments, regulators, standardization organizations at national and regional levels.
~ System decision makers – e.g., employers and managers, those who make decisions about requirements for the system design, purchasing system, implementation and use;
~ System experts – e.g., professional HF/E specialists, professional engineers and psychologists who contribute to the design of systems based on their specific professional backgrounds;
~ System actors – e.g., employees/workers, product/service users, who are part of the system and who are directly or indirectly affected by its design and who, directly or indirectly, affect its performance. (see Dul et al., 2012 in Bibliography)

Stress: A physical, mental, or emotional factor that causes bodily or mental tension, such as the adverse reaction people have to excessive pressures or other types of demand placed on them at work. Stresses can be external (from the environment, psychological, or social situations) or internal (illness, or from a medical procedure).

Sustainable workers: Individuals in work systems that support the energy, capabilities, vitality, and resources required to achieve organizational performance demands over the long term, at the same time maintaining economic and mental health on and off the job.

Sustainable work systems:	Work systems that consider the requirements of all stakeholders, are consistent, satisfactory, and operational over the long term without compromising the needs of future generations, and focus on a balance among worker needs such as effective use of competencies and skills, learning, motivation, innovation, short-term, static efficiencies such as productivity and profitability, and long-term dynamic efficiencies such as learning and innovation.
Systems approach:	Systematic, analytical procedure that examines and takes into accounts for interactions among persons, tasks, tools and technologies, physical environment, and organizational conditions rather than concentrating on an individual part of it.
Task (Work task):	Activity or activities required to achieve an intended outcome of the work system
Telework:	Working from home or other off-site location through virtual devices that are linked to the employer's office. Typically, teleworkers report to the worksite on a regular basis.
WBV:	Whole body vibration.
Worker:	Any person who performs work, either regularly or temporarily, for an employer.
Workers and their Representatives	Where reference is made in this document to workers and their representatives, the intention is that, where representatives exist, they should be consulted as the means to achieving appropriate worker participation. In some instances, it may be appropriate to involve all workers and all representatives. Workers' representatives may be individuals who are recognized as such by national law or practice, including: Trade union representatives, designated or elected by trade unions or members of such unions Elected representatives, who are freely elected by workers of an organization in accordance with provisions of national laws or regulations or of collective agreements and whose functions do not include activities typically recognized as the prerogative of trade unions in the country concerned.
Worker sustainability:	See 'sustainable workers."
Work on demand:	A form of work in the gig-economy, in which the execution of traditional working activities such as transport, cleaning and running errands, and also forms of clerical work, is channeled through apps managed by firms that also intervene in setting minimum quality standards of service and in the selection and management of the workforce.
Work organization:	The way work is organized to accommodate people's psychological and social needs
Workplace:	Area where workers need to be, or to go, on the instruction of an employer to carry out their work. A workplace need not be a fixed location.
Work system:	A system that involves one or more humans interacting with some form of (a) tools and technologies, (b) internal physical and psychosocial organizational environment, (c) external environment, and (d) organizational conditions.
Work task:	See "task."
Work tool:	Hardware, software, object, or implement to facilitate the performance of work tasks.

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Annex 1. Human Factors/Ergonomics (HF/E)

HF/E can be described as a multi-disciplinary, user-centric integrating or 'bundling science,' in that it applies theory, principles, and data from many relevant disciplines to the design of work systems, taking into account the complex interactions between the human and other humans, the environment, tools and equipment, and technology to enhance human performance and wellbeing in the world of work (Wilson, 2000). The philosophical foundation of HF/E is congruent with that of the ILO, first because as a science it focuses on achievement of high-quality, motivating jobs, work, and output (Di Martino & Corlett, 1988), and second because its practitioners recognize the need for participation of all stakeholder groups (i.e., participatory HF/E) in system design. Multiple HF/E methodologies are available for the creation and evaluation of effective work systems, addressing not only their physical demands and constraints but also cognitive and psycho-social aspects of living and working as well as the sociotechnical attributes of the organization comprised of its personnel, technological, and operational characteristics (Hendrick, 2008).

With respect to the design and management of work systems, HF/E has three primary interrelated spheres of investigation and intervention: Physical HF/E, Cognitive HF/E, and Organizational HF/E. Additionally, HF/E can focus on *microergonomic* aspects of design - including design of the procedures, the context, and the equipment and tools used to perform tasks – as well as *macroergonomic* aspects of design – including the work organization, types of jobs, technology used, and work roles, communication and feedback. These various aspects cannot be viewed in isolation but must be considered in a systems perspective. HF/E reflects a holistic perspective toward the design of products and systems, considering the interrelatedness of human, technical, and environmental components and the potential effects of system design changes on all parts of the system.

Physical HF/E

Physical HF/E is the study and evaluation of the physical demands of performing work on the muscles, joints and cardio-respiratory system of the human body, with a focus on identifying, quantifying and controlling the risk of discomfort, pain and injury resulting from those demands. 'Work' is typically defined as the physical demands from occupational tasks and activities of daily living and is generally independent of accidents and other acute safety issues.

Physical HF/E utilizes knowledge in biomechanics, anthropometry, physiology, epidemiology, and psychophysics to understand the human capacity to perform work. Physical demands cause exposures that must be quantified and assessed for risk of a negative impact on the musculoskeletal and cardiovascular systems and typically include force/torque, repetition, inappropriate posture, vibration, and contact pressure. The magnitude and duration of each exposure, and the combination of concurrent exposures, contribute to risk. The approach to quantifying and assessing risk from physical exposures has been well documented; validated assessment tools should be used for surveillance, job design (or re-design), and individual accommodation. Various individual difference factors such as general health, age, gender, work experience, and prior injuries can place individuals at varying levels of risk for fatigue and/or tissue injury resulting from work-related demands and should be considered when balancing work demand with worker capacity.

Physical HF/E is a critical pillar in the systems approach to maintaining a safe and healthy work environment that facilitates both the wellbeing and productivity of the workforce. It is exemplified by human- task-system interface design that accounts for the physical capacity of humans.

Why is physical HF/E important?

Applying physical HF/E into the (re)design of work systems leads to a reduction of the burden of injury and disability on all stakeholders, increases the number of people who can physically perform certain tasks/jobs, retains women and aging workers, and increases net revenue by reducing costs associated with worker absence, increasing productivity and quality by controlling fatigue and discomfort, and eliminating losses from rehiring and retraining.

When Physical HF/E is ignored or insufficiently prioritized, workers may suffer from injuries or disabilities and lose the ability to work to support themselves and their families. This will have further negative consequences for other family members, particularly dependents who are elderly or young, due to subsequent long-term negative consequences on family poverty and child labour. Consequently, employers will suffer financial losses from reduced job satisfaction, reduced productivity, reduction in quality of work, poor job satisfaction, reduced general health, and increased turnover. The indirect costs of inattention to HF/E associated with rehiring, retraining, loss of productivity and increases in workers compensation rates can even lead to business failure. From a societal level, failure to focus on Physical HF/E in a work system can have serious implications on human suffering, health care costs and worker compensation costs, and can lead to a reduced workforce, increased reliance on welfare systems, increased poverty and a reduction in the educated workforce.

Cognitive HF/E

Cognitive human factors/ergonomics is the application of HF/E theories and principles to the design of tasks requiring sensation, recognition and processing of information to carry out work safely and efficiently. Cognitive HF/E is concerned with mental processes such as perception, memory, reasoning, and decision making, as they impact interactions among humans and other elements of a work system (see https://iea.cc).

Why is Cognitive HF/E important?

Many work tasks are becoming physically less demanding and mentally more demanding as operators control increasingly automated systems, often using new information and communication technology (ICT), robotics, artificial intelligence, and digitalized networks. Automation and artificial intelligence increase the separation between operators and the work itself, which is represented symbolically. When cognitive HF/E is applied correctly, employees can detect the information they need to carry out their tasks, understand the significance of the information and the behaviour of the system at any time. In particular, they can understand the way the work system responds to their actions and make accurate predictions about future system behaviour to facilitate decisions and actions. Effective cognitive performance is sustainable.

Effective cognitive HF/E results in tasks designed with an understanding of what can and cannot be expected of workers. Sufficient, appropriate information is provided during task performance so that operators understand the state of the system and the nature and causes of any problems. The information provided about system performance prompts appropriate decisions and responses from operators to ensure efficient and safe operation. New systems are designed to encourage positive transfer of learning from previous systems. Training time and errors are minimized.

Cognitive HF/E takes advantage of the strengths of human information processing and compensates for weaknesses. For example, humans:

- Have limited capacity to process information
- Are good at recognizing patterns in information displays
- Use ‘rules of thumb’ to simplify decision making
- Develop ‘models’ of how systems work to enable them to predict what will happen next.

In badly designed systems, warnings or signals are missed, misinterpreted or poorly understood because the effort to understand them is too great, especially if some of the knowledge required is lacking. Continued use of badly designed cognitive systems increases the chance of errors. Additionally, users of poorly designed work systems may experience cognitive overload and accompanying stress. This means that management of the system is not sustainable over time.

Organizational HF/E

The guidance from the physical and cognitive aspects of HF/E are the result of many decades of research on what humans are capable of doing, how we can improve peoples’ performance physically and mentally, and how to analyze, design and evaluate work systems. The organizational aspects of human factors/ergonomics emerged more recently when HF/E practitioners recognized that good design alone is not sufficient to realize good performance. Other human, social and environmental factors must also be considered. To fully realize the benefits of HF/E, it is necessary to create and maintain dynamic harmony between humans and tools/machines in the context in which human-machine interaction occurs.

The interactions between human bodies and machines – or between human minds and information from machine systems - happen in a context, usually an organization. Important features of human- systems interaction appear in three primary areas:

- Technological subsystem
- Personnel or human subsystem
- External environment (see Work System Conceptual Model in Annex 3)

Technological subsystem. This includes the range, number and complexity of technologies that the organization uses to achieve its mission. It varies from a single individual working with a machine or tool to large groups of people interacting with and influencing very complex computer systems.

Personnel or human subsystem. This includes the matches among:

1. Design of work systems with demographics such as age, values, diversity, gender, and body size;
2. Peoples' skills and abilities and formalism (using rules, procedures, controls) or professionalism (relying on education, norms, socialization, and expected behavior patterns); and
3. The psychosocial factors such as how people process information, motivators, disincentives and the design of the work system.

External environmental subsystem. Factors surrounding the organization can influence the effectiveness of the ergonomics implementation. These include: socioeconomic, educational, political, culture, and legal realms.

Dynamic interaction among elements of subsystems
There is mutual interdependence among these subsystems, which means that making a change in one aspect may influence other parts of the work system. Considering how each of these subsystems influences the other is a key feature in organizational ergonomics. If done well, organizations can optimize each of these systems and the sum of each of these parts will be greater than the whole.

Why is organizational HF/E important?
HF/E guidelines for designing the physical and cognitive aspects of work are based on science and evidence-based work through many decades. However, putting a recommendation into practice depends on more than the merits of the idea; it also depends on the context to which it is applied and how it is perceived by those who are affected by the change. Ensuring that recommendations and changes in work organizations are effective demands an understanding of the technology, the people and the environment in a holistic, integrated manner. Moreover, when physical and cognitive ergonomics are used for purposes of humanizing work and creating human-centred work systems these scientifically determined principles become even more powerful in terms of meeting an organizational purpose.

When work systems are designed for human use rather than to serve a technological need, people are more likely to be engaged. This engagement gives users a better understanding of the system and will likely lead to greater acceptance. Humans are also more likely to be interested and support an idea that improves their individual and collective lives at work.

In physical and cognitive HF/E, practitioners ask questions about human capabilities, limits and requirements. Designing human-centered work systems demands that we go further and care about the welfare, motivation, interest and sustainability of humans performing tasks. Thus, the focus moves away from simple efficiency or cost to effectiveness of the human and system in the long run. Unnecessarily dangerous, dirty, boring, and error-prone tasks degrade the total organizational system performance over time. Work that is compatible with human needs will likely improve human performance.

Integration of the organizational and technological needs with human capabilities, skills, and needs leads to a joint improvement of the total work system. Rather than focusing exclusively on either the technological or system needs (e.g., efficiency, cost) or human needs (e.g., comfort, ease of use), seeing these as interlocking pieces enables us to advance both simultaneously. When there is a compatibility between human and technological subsystems, synergies occur that can lead to better organizational performance including improved productivity, satisfaction, longer tenure, and fewer injuries. Joint optimization should be a conscious effort in designing human-centred work systems. Failing to consider physical or cognitive human compatibilities in work systems can lead to errors, accidents, degraded performance, and decreased satisfaction. This is evident in popular consumer products, poorly designed tasks, or distasteful jobs. However, even when these principles are used they may not be effective if they are not embedded in an organization or work system. The context must be taken into account.

Work systems that are designed to optimize technological aspects at the expense of humans make people feel subservient to machines. This creates an isolation and decreases the chances that people will be willing to work and to participate in improving future states of the system. While this technologically-based strategy may be cost effective in the short run, it can have longer term adverse effects on peoples' motivation to work or be invested in the system.

Considering the human as an afterthought in the design of a work system leads to "leftover design." When humans and technology are not considered jointly, humans are often given tasks that the technology cannot do, that the initial design overlooked, or emergent problems that cannot be solved. These are tasks that people may be ill-suited to perform, leading to a bad fit that can likely increase errors, degrade performance, cause disengagement or boredom, and create jobs that are hard to fill.

Humans are the most variable and therefore least predictable component in work systems. Failing to integrate human characteristics, needs and abilities into an organization's sociotechnical system poses greater risk for more variability and different responses to organizations. How people react to the sociotechnical system is as important as the system itself.

Stages of organizational maturity and readiness for HF/E integration

Depending on organizational characteristics such as size and maturity, organizations may be at different stages with respect to their readiness for organization-wide HF/E interventions. HF/E principles and guidelines are applicable across sectors and industry types; however, specific methods guiding the integration of HF/E into work systems should be tailored to the readiness of the organization. Some organizations will not have the resources or expertise to change overnight but can adopt a maturity model to guide the process of integration. Organizations can use the maturity model to understand the HF/E systems already in place and plan future strategy with the emphasis on using HF/E to add value and lower costs.

There are four general stages in organizational maturity.

Reactive Stage: The organization implements HF/E interventions to deal with specific problems in existing systems or departments, possibly using independent consultants with appropriate certification. HF/E is a tool for dealing with problems such as accidents or injuries or when the performance of a system is unsatisfactory or quality is below standard.

Calculative Stage: HF/E is considered during short-term planning of small-scale activities. The costs of implementing effective HF/E, possibly obtained by competitive tendering, are weighed-up against the risks of proceeding without HF/E input. HF/E is always considered when drafting budgets but may be traded-off following a cost-benefit analysis.

Proactive Stage: HF/E is increasingly embedded in a wider range of organizational functions; is considered in audits and in the early stages of planning. The specification of bespoke HF/E requirements for human-centred work systems is given a priority in accordance with organizational policy and all new projects have a HF/E Integration Plan.

Generative Stage: HF/E is fully integrated into long-term strategic planning against clearly defined organizational objectives and embedded in organizational roles – organizations are the 'owners' of HF/E and the creators of resultant human-centred work systems.

Designing a Human Factors/Ergonomics Integration Plan

HF/E Integration Plans should be tailored in accordance with the resources available to execute the plan. HF/E Integration plans (also called human factors integration plans, or HFIs) define the work needed to achieve a goal such as the implementation of HF/E in work systems. A typical HF/E Integration (HFI) Plan should include:

(1) A definition of the goal to be achieved;

(2) The main milestones and deadlines for their achievement;

(3) The available resources; and

(4) Expertise and responsibilities required and the means of assurance (Widdowson & Carr, 2002).

A 'HF/E Focus' or HF/E specialist/expert should oversee the execution of the plan to meet project deadlines. The HF/E Integration plan should include these elements:

(1) The issues to be addressed in the project;

(2) Identification of any constraints that limit HF/E design or implementation in work systems, such as:
   - a. Pre-selected or legacy equipment;
   - b. Fixed staffing levels;
   - c. Limitations on training capacity;
   - d. The organizational context in which the system is operated; and
   - e. Safety constraints;

(3) The activities that will be conducted to analyse and mitigate HFI issues;

(4) The planned process of HFI involvement in development. This should include a work breakdown for specialist HF/E activities, tied to appropriate activities in the overall project plan;

(5) Constraints or dependencies to and from other development activities:
   - a. What HF/E inputs are needed by developers, by when;
   - b. What aspects of the design are considered and when;

(6) Constraints or dependencies to and from separate development contracts;

(7) Plans for user involvement, e.g., scheduling of human factors assessments of designs; Prototyping activities, User Trials, Simulations, etc.;

(8) The method for monitoring and controlling progress against the plan;

(9) Processes, mechanisms and forums for considering human factors trade-offs; and

(10) Plans for updating the HFI Plan.

A HF/E integration plan should be implemented at all organizational levels and divisions, and across management sub-systems. Several strategies will increase the probability that HF/E Integration will be successful, including:

1) Define the purpose and value of implementing HF/E;
2) Promote application of effective HF/E principles;
3) Evaluate risk factors;
4) Collect and provide feedback on HF/E-related data;
5) Prioritize and choose specific problems to solve;
6) Articulate why these specific problems should be fixed;
7) Implement an organizational-level HF/E programme with controls;

8) Ensure that top management openly commits to the plan;
9) Take advantage of locally available improvements;
10) Plan sustained actions – make improvements that will last;
11) Involve and train management and workers; and
12) Maintain involvement and gain feedback on effectiveness.

Annex 2. The Business Case for HF/E Design and Management of Work Systems

HF/E is good for business. With HF/E based improvements organizations can see increases in efficiency, decreases in quality problems, improved implementations of new technologies and many organizational benefits such as improved communication in the workplace.

The reason for this is illustrated in Figure A2-1. Applying HF/E in design, or via continuous learning and process improvements, will result in a better workplace with reduced perceptual, mental or physical demands in workers. Improved conditions will improve worker wellbeing and comfort as well as reduce fatigue levels. This, in turn, will improve the employee's work performance. Easier tasks are performed faster and more reliably. Fatigued workers make more mistakes and are subject to more accidents. As much as 41% of quality problems in operations are associated with worker fatigue.

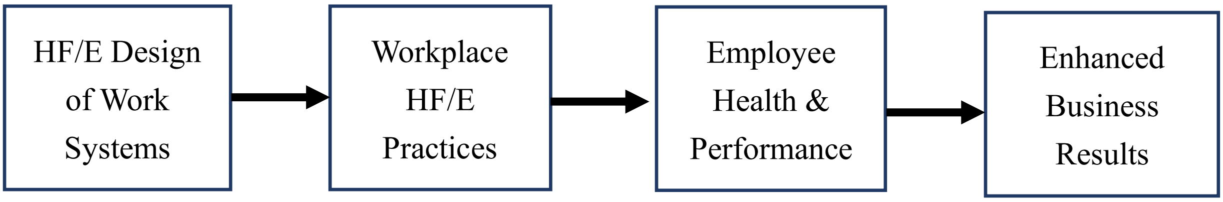


Figure A2-1: Workplaces that are designed with HF/E principles have better employee performance and produce better business results.

Organizations with poor HF/E will experience higher injury and absence rates. Direct injury costs, for the treatment of workers, is a fraction of the indirect costs of managing, investigating, accommodating and overcoming process disturbances caused by the loss of an experienced worker. These indirect costs are sometimes called "hidden" costs as they can be hard to isolate in the accounting system. Current estimates place indirect costs at 5-10 times the direct costs of caring for injured employees. On top of these are the costs associated with presenteeism – when workers are working in pain but remain on the job. Workers who are in discomfort and pain are less productive and make more mistakes with poor quality as a result. Presenteeism is also many times more expensive than absenteeism costs which are just the "tip of the iceberg" of the costs associated with poor HF/E.

Organizations that have good HF/E in their workplaces experience lower turnover as employees stay longer and do not take early retirement. This saves on hiring and training costs and means that, in general, the workforce is more experienced and more knowledgeable about the business practices and customer needs. These organizations deliver services and goods to customers more reliably and enjoy better labour relations. Good work conditions and high reliability products can improve a company's public image and trust in the brand. This in turn can improve sales as customers prefer goods made under healthy working conditions. Studies with consumers show a willingness to pay a premium for goods made under good working conditions. This is particularly noteworthy: HF/E can both reduce costs and increase the value of product for the customer allowing for higher prices – thus supporting increased profitability on both sides of the accounting ledger.

The benefits from HF/E can be reaped by including human considerations already in the design of products, purchasing of equipment and tools, design of workstations, and the daily management and operations of the work system. Considering HF/E in the early design stages is much cheaper and easier than trying to retrofit changes to an existing system. While the payoff of re-active changes is usually highly profitable – including HF/E in design stages yields even more benefits. To be successful and sustainable, HF/E design and management of work system needs to have a permanent place in the organization, aligned with the enterprise vision, part of the organizational culture, and on the budget financial sheet.

Ultimately using HF/E in design and management of workplaces is simply good business.

Annex 3. HF/E Systems Approach and Design Models

The application of the HF/E Systems Approach Framework requires the use of appropriate system design models to characterize relations between humans and other parts of the system in advance. Appropriate system design models should be used to identify, restructure, and characterize the relations among various elements that need to be considered in the design of HF/E in work systems. This annex contains several well-established models that can be used in the systems approach for HF/E work system design, implementation, and evaluation for continuous learning.

PDSA Cycle

Plan-Do-Study-Act (PDSA) Cycle (Figure A3-1, also known as PDCA, plan–do–check–act or plan–do–check–adjust) is an iterative four-step management method used in business for the control and continuous improvement of processes and products. It is also known as the Deming circle/cycle/wheel, the Shewhart cycle, the control circle/cycle, or plan–do–study–act (PDSA, Tague, 2005; Moen, Nolan, & Provost, 1991).

The PDSA cycle focuses on the core of change, as well as the translation of ideas and intentions into action. As such, the PDSA cycle and the concept of iterative tests of change are central to many Quality Improvement (QI) approaches, including the model for six sigma and total quality management (Brannan, 1998; Schroeder et al., 2008).

The four steps cover:

1. Plan – Proposing a plan and working out ways in which it can be tested;
2. Do – Implement the change idea (e.g., a HF/E intervention) and reflect on how well it is progressing;
3. Study – Analyse the data and capture key learnings;
4. Act – Share reflections on key learnings and decide to implement (or abandon) the original plan further.

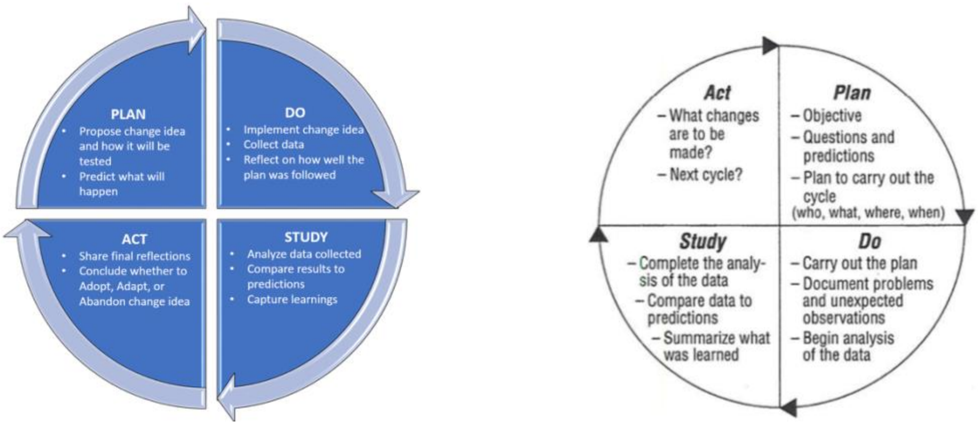


Figure A3-1: PDSA Cycle – two versions (Tague, 2005; Moen, Nolan, & Provost, 1991)

Conceptual Work System Design Model

Figure A3-2 shows one macroergonomics work system model illustrating the sub-systems, internal and external environment, all surrounded by permeable boundaries. This model can be used to determine influences on organizational performance and wellbeing outcomes within a work system. The Macroergonomics Framework can be considered as a Complex Approach, as different levels that modulate work are put in evidence and can be correlated in order to conceive and to manage working situations and people. Different points of view can be put in evidence and the perspective of what actually people do, that is peoples' activities, can be considered as a sort of synthesis correlating the working characteristics and task with personal and collective characteristics.

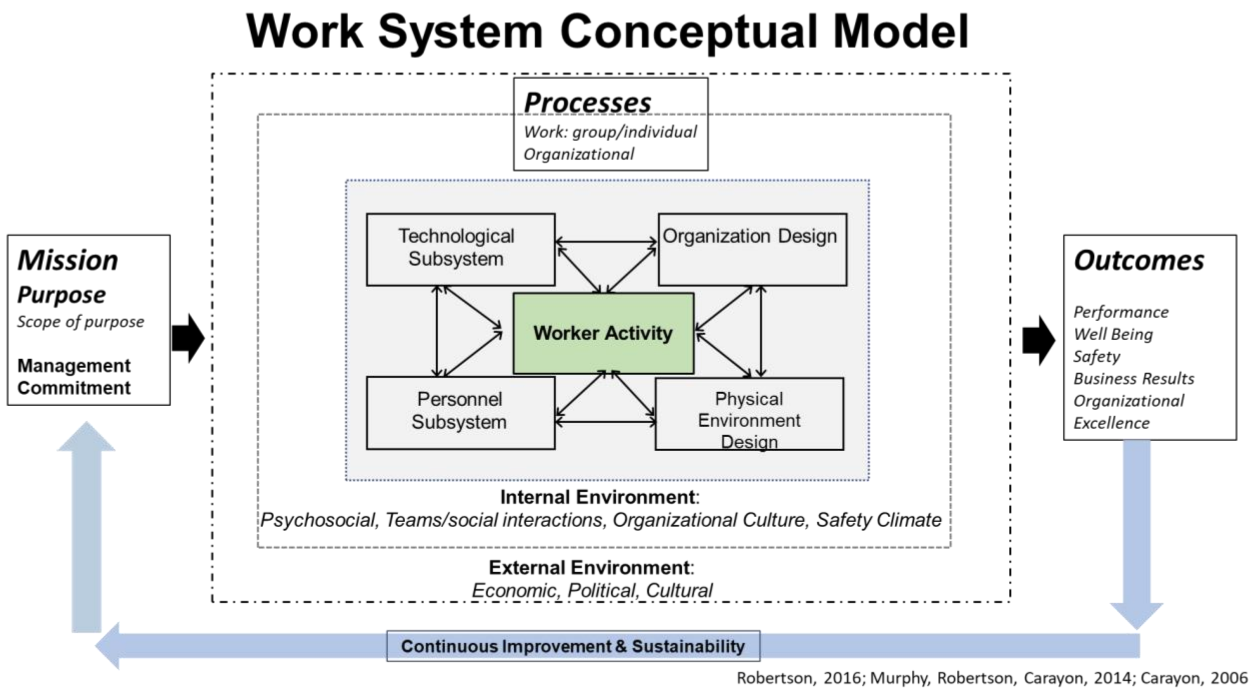


Figure A3-2. A conceptual model of integrating HF/E in work systems

The work system consists of the technological and personnel subsystems and their joint optimization, as well as the organizational design and the physical environment, with worker activities in the center. The design and characteristics of the work system influence the organizational performance, safety, and wellbeing outcomes. (Robertson, 2018; Carayon, 2012; Hendrick & Kleiner, 2002).

Similar work system models may also be applied to new ways of working such as telework, as shown in Figure A3-2.

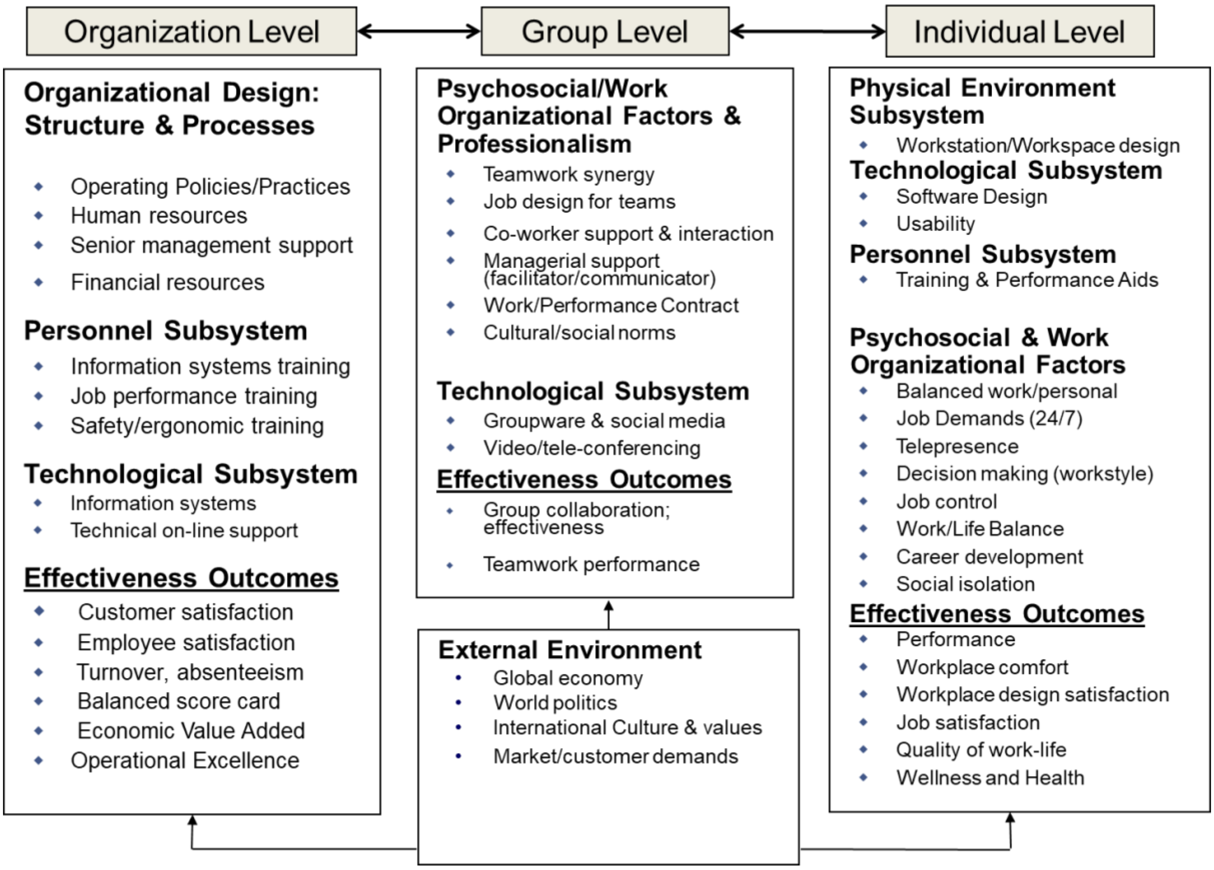


Figure A3-3. Work systems conceptual model as applied to Telework (Robertson & Maynard, 2016)

Work Activity Framework

Work activity framework states that the activity of a person uses their body and intelligence as they are needed to achieve successive goals within specific conditions. Work Activity includes a visible aspect (behaviour) and non-visible aspects (perceptions, emotions, memory, knowledge, reasoning, decision-making, control of movements, etc.). The Work Activity at a given moment is a response to a number of determining factors:

(1) The "production" objectives and the subsequent tasks to be performed. The rules that define the activity (different sources of prescription) etc., and the way the person has interpreted them;
(2) The equipment available, the working conditions, the characteristics of the item and the materials, the environment, time constraints, organization of work and production;
(3) The physical characteristics as well as the psychological (and social) condition of the person;
(4) The individual's abilities and knowledge, that is acquired through training or experience within a variety of situations;
(5) The individual's motives, values, other goals that they are seeking to achieve;
(6) The available collective resources;
(7) The way in which management is present and leads; and
(8) The values and cultures of the groups to which person belongs.

Through the activity, the worker seeks to achieve the set targets, but by considering variabilities (or diversity of worker's expertise, age, experience) that arise, such as:

- Variations in context, in the state of the process and the materials, the available equipment, the collective resources (absenteeism, expertise, confidence) and the product (quality, characteristics);
- Variation in their own conditions (day/night, tiredness, pain, etc.).

Sometimes, these various objectives are not easily compatible. Rules from different departments may be partially contradictory. An incident can include an unusual combination of events, where there may be a procedure for dealing with each event, but not for when these events are combined. The operator and the work team will have to sort through the instructions and merge them to build a response which will be the best adapted to the real situation.

Activity is, therefore, not just the simple execution of the prescribed procedure; it includes creativity, analysis, interpretation, and diagnosis, such as:

- in some cases, the procedure has been followed according to instructions, but the activity has provided added value (verification of the environment and conditions of application, knowledge of the reactions of the materials, or non-compulsory intermediary checks);
- in other cases, there is a gap between the activity and the procedure. That is, several reasons can explain this, such as: the procedure is unclear, incomplete, all variations cannot be anticipated by the procedure, or the situations is too complex to be framed by procedures;
- differences in relation to the procedure cannot always be treated in terms of non- conformity. It is most important to consider in what way the procedure can be a resource for the activity.

Annex 4. Recommendations for Work Tool Selection

Having appropriate tools for a job is critical for worker safety, health, wellbeing, and sustainability. This Annex contains recommendations for important elements to consider when creating or procuring job tools for workers.

(1) Tools should be chosen to address the worker population appropriately encompassing at least 75% of the female or minority population or accommodating a specific individual if dedicated to one employee;

(2) Tools should be assessed for usability, effectiveness, efficacy, and user preference, based on evidence if possible. The goal of any tool (software, hardware or handheld) should be to:

a. Reduce exposures, errors and inefficiency; and

b. Improve performance, productivity and/or comfort

(3) New tools should typically undergo review, pilot testing, and regular subjective and objective assessments as they are more broadly introduced to the workforce;

(4) When introducing new technologies, care should be taken to match the skills, knowledge, abilities, motivation and interests of the people who will use them. Analyse what the people need to accomplish the task and be successful (knowledge, skills, abilities, motivation, and interests), assess whether people possess these competencies, and evaluate matching between humans and other elements of the system. If a mismatch exists, what needs to be changed? Possible changes are:

a. Upgrade competencies and qualifications through training, experience, practice or participation;

b. Give people alternatives and time to adapt to the changes;

c. Give people an opportunity for advancement, promotions; and

d. Recruit and select new people into the organization.

(5) When introducing new tools, identify aspects of work tasks that will be impacted by the change and evaluate and control for potential negative consequences.

Allocation of Function between Humans and Machines
Dating from the early 1950s, allocation of function was a structured approach to deciding how best to allocate system functions to human operators or machines, based on the strengths and weaknesses of both. For example, simple repetitive tasks or synthesis of large amounts of data are best done by machines whereas the ability to improvise and respond flexibly is best done by humans. In modern systems, allocation of function is a key part of the early design process that involves deciding on the level of automation and mechanisation a system should have. In the case of automation, considerations of how flexible the automation should be a paramount because there are many benefits to enabling operators to take control of automated systems at appropriate times, not least to prevent skill-fade and ensure readiness if the automation fails. Further, decisions about allocation of function are really decisions about job design. Central to good job design is the specification of a clear an unambiguous role for the operator to provide the basis for a meaningful job. From this point of view, functions can be best allocated to automated systems if they are separable from the role and do not conflict with it.

Current research (Roth et al., 2019; Feigh & Pritchett, 2014; Johnson et al., 2018) provides a range of factors that should be considered by designers when making function allocation decisions, including:

1. Humans should be assigned a coherent set of tasks (avoiding “leftover” allocation) – criteria are task completeness, variety, and opportunities for learning;
2. Workload spikes and extreme lows should be avoided during long durations;
3. A match between human responsibility and authority (i.e., do not make the human responsible for something that the machine controls);

4. Avoidance of overly rigid or unworkable allocations that lead to workarounds and/or disuse
5. Avoidance of “brittle” automation that may fail abruptly; and
6. Humans should not be faced with excessive or untimely interruptions from the automation.

Annex 5. Participatory HF/E

Participatory HF/E employs a systems approach to HF/E design and management of work systems, as well as for developing integrated safety and health solutions. This annex includes several well-established approaches to Participatory HF/E.

WISE Approach

The ILO training package on Work Improvement in Small Enterprises (WISE) has been widely applied as participatory methods for improving safety, health and working conditions at small-scale workplaces. As mentioned in the Global Strategy on Occupational Safety and Health, Conclusions adopted by the 91th International Labour Conference in 2003, the ILO is promoting wider application of WISE and other participatory action-oriented programs. The WISE training has proven effective for facilitating practical and low-cost solutions using available resources in different local situations. The training procedures follow the ILO Guidelines on Occupational Safety and Health Management Systems (ILO-OSH 2001). By using the approach, direct participation of workers and employers has been promoted in applying wide-ranging HF/E measures.

The training process applying WISE methods is based on the following principles:

(1) build on local practice;

(2) focus on achievements;

(3) link working conditions with other management goals;

(4) use learning-by-doing;

(5) encourage exchange of experience; and

(6) promote workers' involvement.

Applying these principles, WISE training is conducted by means of simple procedures comprising:

(a) learning local good practices,

(b) group discussion on feasible improvements, and

(c) implementing and reporting immediate improvements.

A wide range of HF/E measures covered include materials handling, workstation design, physical environment, welfare services and work organization. The planning and implementation of practical improvements are facilitated by the use of action-oriented training tools, such as good examples of locally achieved improvements and action checklists listing feasible solutions. The combined usage of these tools has proven to support the participatory steps leading to prioritized actions.

The WISE approach is promoted jointly by the ILO and the IEA in varied job situations particularly in developing regions. The approach is made accessible through the *Global Manual for WISE* (ILO, 2017). The practical improvement actions proven useful through WISE methods are compiled in the ILO/IEA publication "Ergonomic Checkpoints: Practical and Easy-to-implement Solutions for Improving Safety, Health and Working Conditions" Second Edition (ILO, 2010). Similar training packages have proven useful for participatory improvement of working conditions in agriculture, construction, garment, health care and other work areas.

***Total Worker Health*® Programme Approach**

To engage employees in designing integrated solutions that address a wide range of work environment, work organization, safety, and employee health issues, a process tool was developed to help organizations to adopt and implement *Total Worker Health*® programme approach. The CPH-NEW Healthy Workplace Participatory Programme (HWPP) online toolkit was created by the University of Massachusetts and is designed specifically to help employer organizations adopt and implement a *Total Worker Health*® programme approach. The HWPP Toolkit was developed to engage employees in designing integrated solutions that address a wide range of work environment, work organization, safety, and employee health issues.

The Intervention Design and Analysis Scorecard (IDEAS) tool is the seven-step process at the heart of the Healthy Workplace Participatory Programme. Through this tool, employees identify the root causes of work-related safety and health concerns, and design appropriate interventions. https://www.uml.edu/Research/CPH-NEW/Healthy-Work-Participatory-Programme/generate-solutions/default.aspx. The steps are shown in Figure A5-1 below and the roles in the iterative process are shown in Figure A5-2.

Figure A5-1. Intervention, Design, and Analysis Scorecard: Healthy Workplace Participatory Program

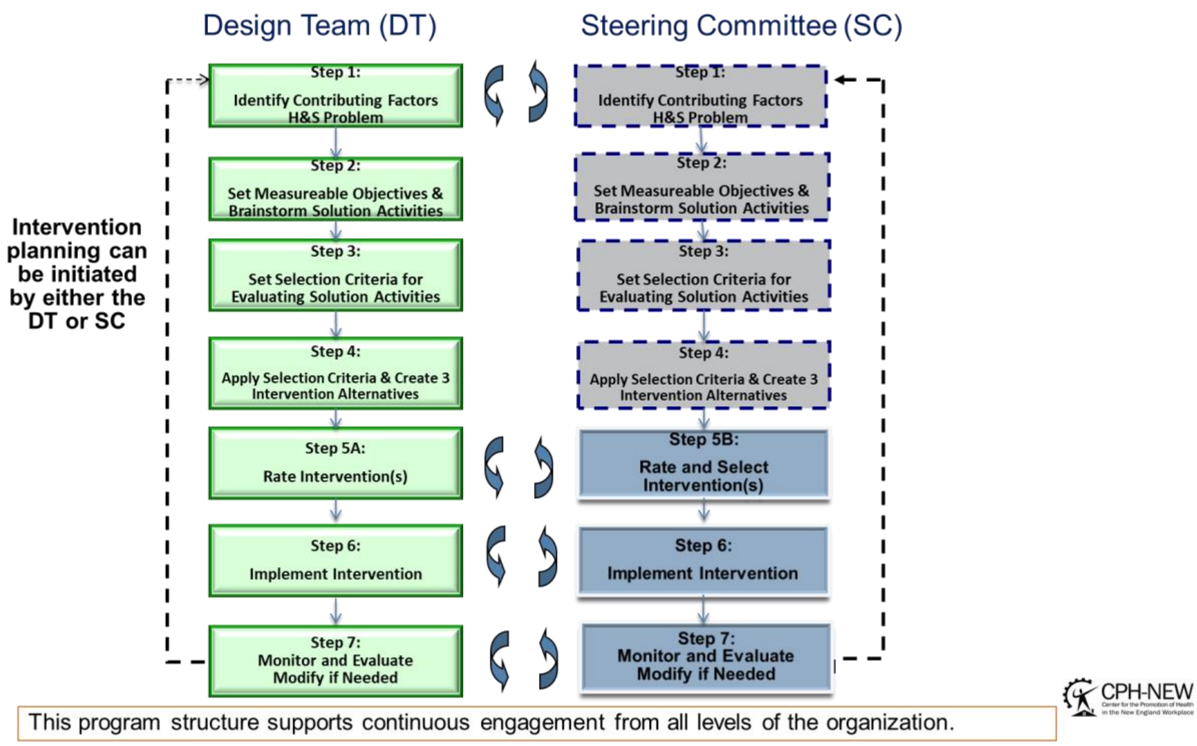
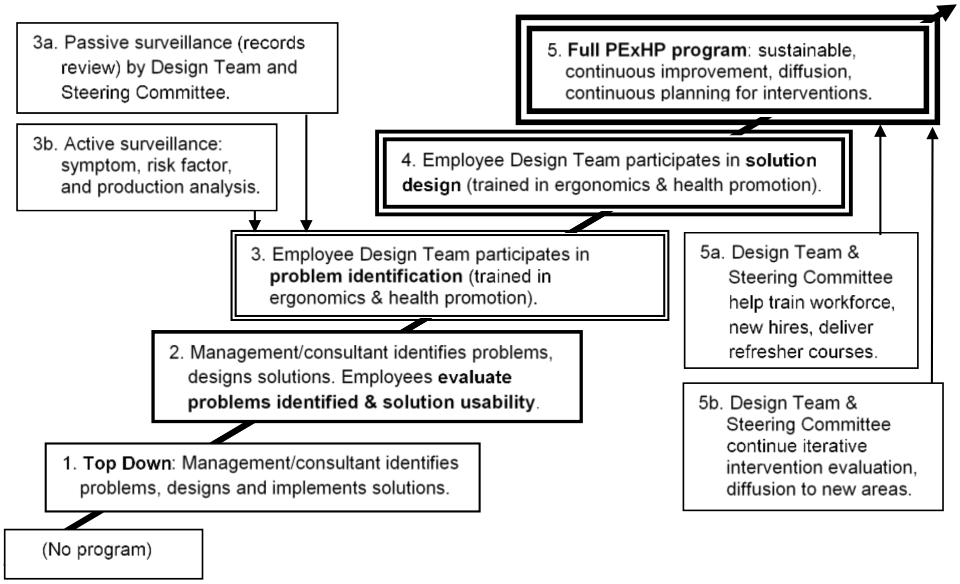


Figure A5-2. IDEAS steps as conducted in participative, iterative process (Henning & Robertson, 2018; Robertson et al., 2015)

Participatory HF/E and Organizational Maturity
The specific design of Participatory HF/E may vary according to factors such as the size of the organization or its stage of maturity (see Annex 1). A hierarchical taxonomy showing how worker participation can vary widely in occupational safety and health programme is shown in Figure A5-3. At the lowest level of this five-level participatory hierarchy are "top-down" OSH initiatives that originate from management, sometimes in consultation with OSH professionals. In this case, employees are not involved with the identification and prioritization of OSH problems or issues or with the design of the interventions to address them. Interventions developed in this "top-down" manner are not expected to be fully effective for several reasons. One is that interventions proposed by management will not have benefitted from employee expertise, and at this lowest level of participation, employees cannot make substantive adjustments to address noted shortcomings which could spell failure. Additionally, the lack of participatory involvement also makes it less likely that employees will be motivated to support the intervention, and there is also the risk of rejection or even outright opposition.

Figure A5-3. Hierarchical taxonomy for participatory HF/E (Henning, Robertson, & Dugan, 2018)



Moving upward in the participatory hierarchy, employee participation in the intervention design process increases as employees have opportunities to expand or refine an OSH problem that management has decided to target and are also given opportunities to make adjustments to any intervention plan put forward by management. At this mid-level position in the participatory hierarchy, however, the role of employees is limited to consultation only, and this makes it highly unlikely that either the focus of an intervention or its implementation plan can be influenced or changed by employees in any major way.

At the top of the hierarchy, in a fully participatory programme, the comprehensive forms of management support for employee participation go well beyond employee consultation. Here, employees are given access to existing surveillance data and can initiate additional data collection efforts, are able to prioritize OSH problems/issues, and also take a lead role in intervention design and implementation efforts to address these priorities. Employees are also granted access to subject matter experts pertaining to a problem or issue (e.g., indoor air quality experts) to gain a more thorough understanding of factors contributing to it, and later in the intervention design process when selecting among intervention alternatives. Forms of management support are more programmatic at this level of the participatory hierarchy because employees must be able to meet regularly over long periods to engage in OSH problem/issue identification and intervention design in addition to having access to subject matter experts. This sustained level of participatory activity as part of a programme dedicated to continuous improvement can be contrasted with static or stand-alone participatory projects for which employee participation ends upon project completion (Haims & Carayon, 1998).

Annex 6. Proactive Injury Prevention Programme Surveillance

Proactive organizational programmes should focus on the identification and management of physical symptoms at their onset to reduce the severity of work-related MSDs. Monitoring workers using a systems approach for detecting early symptoms of physical injury should be an integral part of organizational OSH programmes.

This Annex provides resources and tools for work system surveillance.

Measures protecting the safety, health, and wellbeing of workers should be recognized as a responsibility by the organization and should be addressed through immediate treatment of symptoms and injuries incurred during the performance of work tasks. Symptoms and minor injuries are important precursors of more grave incidents/accidents, and therefore should be continuously monitored and analysed. Use appropriate methods based on a systemic approach to identify the origins and causes of accidents.

Prior injury data should be analysed to identify jobs that experience a high incidence or severity of injuries and prioritize them for redesign. For the purpose of analysis, proper coding of injuries and normalization of data are important. Jobs or tasks should be analysed to quantify exposures. Active surveillance tools and sampling/recording methods should be used across the organization to identify physical hazards/exposures that may be excessive and require additional measurement and assessment. Figure A6-1 shows an overview of a proactive physical HF/E programme overview.

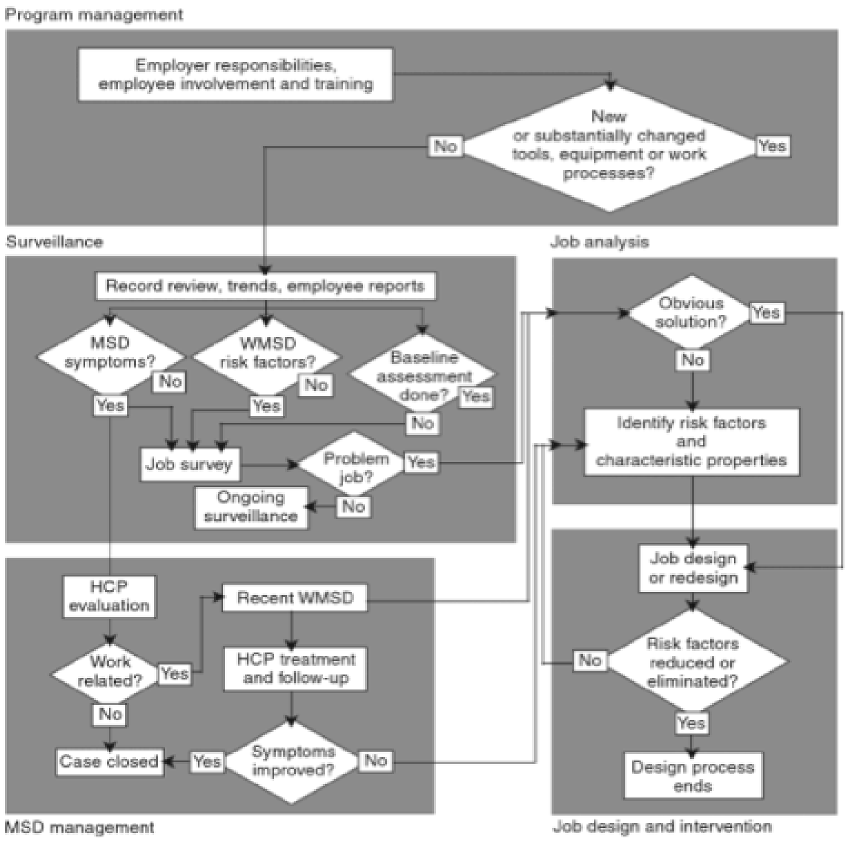


Figure A6-1. Physical HF/E Programme Overview

Surveillance Checklists

The tools and measures below are resources for a proactive HF/E programme.

- BS EN 1005-2:2003+A1:2008 Safety of machinery. Human physical performance. Manual handling of machinery and component parts of machinery
  https://shop.bsigroup.com/ProductDetail/?pid=000000000030179205
- Health & Safety Executive HSE Risk Assessment Worksheets
  http://www.hse.gov.uk/msd/pdfs/worksheets.pdf
- Kodak Ergonomics Checklist
  http://www.mhi.org/downloads/industrygroups/ease/checklists/ergonomic-checklist-for-material-handling.pdf
- Washington State Safe Patient Handling Gap Analysis Checklist
  http://www.wsha.org/wp-content/uploads/Worker-Safety_Gap_Analysis_Checklist.pdf
- Washington State Caution & Hazard Zone Checklist
  http://personal.health.usf.edu/tbernard/HollowHills/WISHA_Checklist_20.pdf

Manual Material Handling Risk Assessment Methods

- ACGIH Lifting TLV
  American Conference of Governmental Industrial Hygienists (ACGIH) (2004), Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices, Cincinnati, OH
  https://www.acgih.org/forms/store/ProductFormPublic/2019-tlvs-and-beis
- Lift/Lower Calculator
  http://worksafebcmedia.com/misc/calculator/llc/
- Garg Metabolic Equations
  Garg, A., Chaffin, D.B., Herrin, G.D., (1978) Prediction of metabolic rates for manual materials handling jobs, *American Industrial Hygiene Association Journal, 39(8*): 661-674.
- ISO 11228-1:2003: Ergonomics - Manual handling - Part 1: Lifting and carrying
  https://www.iso.org/standard/26520.html
- ISO 11228-2: Ergonomics - Manual handling - Part 2: Pushing and pulling
  https://www.iso.org/standard/26521.html
- ISO 11228-3:2007: Ergonomics - Manual handling - Part 3: Handling of low loads at high frequency
  https://www.iso.org/standard/26522.html
- Potvin, J.R, Ciriello, V.M., Snook, S.H., Maynard, W.S., Brogmus, G.E. (2021). The Liberty Mutual Manual Materials Handling (LM-MMH) Equations, *Ergonomics*.
  https://doi.org/10.1080/00140139.2021.1891297
  https://libertymmhtables.libertymutual.com/
- Liberty Mutual (Dempsey) Metabolic Equations
  Dempsey, P.G., Ciriello, V.M., Maikala, R.V, O'Brien, N.V. (2008). Oxygen consumption prediction models for individual and combination materials handling tasks, *Ergonomics, 51(11):*1776-1789.
- LMM: Lumbar Motion Monitor.
  Marras, W. S., & Allread, W. G. (2004). Lumbar motion monitor. *Handbook of human factors and ergonomics methods.* CRC Press (pp. 163-170.

- Manual Handling Assessment Charts (MAC) (U.K.)

www.hse.gov.uk/msd/mac/index.htm

- Mital et. al. (1993) Tables & Corrections

  Mital, A. (2017). *Guide to manual materials handling*. CRC Press
- MSD Hazard Identification Tool: Ontario MSD Prevention Guidelines

  https://www.msdprevention.com/resource-library/view/msd-hazard-identification-tool-computer-workstation.htm
- Revised NIOSH Lifting Equation (1991)

  Waters, T.R., Putz-Anderson, V., Garg, A. and Fine, L.J, Revised NIOSH equation for the design and evaluation of manual lifting tasks, *Ergonomics*, *36(7):* 749-776, 1993

  https://www.cdc.gov/niosh/docs/94-110/default.html

Upper Limb Risk Assessment Methods

- ACGIH TLV for Hand Activity Level (HAL)

  American Conference of Governmental Industrial Hygienists (ACGIH). Threshold limit values and biological exposure indices for 2019. Cincinnati: ACGIH, 2098.

  https://www.acgih.org/forms/store/ProductFormPublic/2019-tlvs-and-beis
- ACGIH Upper Limb Localized Fatigue TLV

  https://www.acgih.org/forms/store/ProductFormPublic/2019-tlvs-and-beis
- Hand Force Estimating Worksheet: Ontario MSD Prevention Guidelines

  https://www.msdprevention.com/resource-library/view/hand-force-estimation-worksheet.htm
- ISO 11226:2000: Ergonomics - Evaluation of static working postures

  https://www.iso.org/standard/25573.html
- ISO/TS 20646:2014: Ergonomics guidelines for the optimization of musculoskeletal workload

  https://www.iso.org/standard/63231.html
- MAE Equation: Maximum Acceptable Effort

  Potvin, J.R. (2012). Predicting maximum acceptable efforts for repetitive tasks: an equation based on duty cycle, *Human Factors. 54(2),* 175-188.
- ManTRA: Manual Task Risk Assessment

  http://ergo.human.cornell.edu/cumantra2.htm
- Revised OCRA (Occupational Repetitive Actions) Method
- RCRA: Recommended Cumulative Recovery Analysis

  Gibson, M., Potvin, J.R. An equation to calculate the recommended cumulative rest allowance across multiple subtasks, Association of Canadian Ergonomics Conference, Niagara Falls, 2016
- REBA: Rapid Entire Body Assessment

  Hignett S, and McAtamney L."Rapid Entire Body Assessment (REBA)", *Applied Ergonomics*, *31(1):* 201-205, 2000
- RULA: Rapid Upper Limb Assessment

  McAtamney, L. and Corlett, E.N. RULA: A survey method for investigation of work-related upper limb disorders. *Applied Ergonomics*, *24(2),* 91-99, 1993.
- Revised Strain Index

  Garg, A., Moore, S., Kapellusch, J.M. (2016). The Revised Strain Index: an improved upper extremity exposure assessment model. *Ergonomics*, 912-922.
- Z412-17 - Office Ergonomics — An Application Standard for Workplace Ergonomics

  https://www.orderline.com/z412-17-office-ergonomics-an-application-standard-for-workplace-ergonomics

Computer-Based Risk Assessment Methods

- 3DSSPP: 3D Static Strength Prediction
  https://www.humantech.com/services/3d-sspp/
- Delmia by Daussalt Systemes
  https://www.3ds.com/uploads/tx_3dsportfolio/2012-11-20-Ergonomics-Analysis-Datasheet.pdf
- DUET Method
  http://duet.pythonanywhere.com/
- HandPak
  https://potvinbiomechanics.com/handpak/
- Jack
  https://www.plm.automation.siemens.com/store/en-us/trial/jack.html
- LiFFT Method
  http://lifft.pythonanywhere.com/
- Santos Lite
  http://www.santoshumaninc.com/wp-content/uploads/2018/11/Products-Santos-Lite.pdf
- Santos Pro
  http://www.santoshumaninc.com/wp-content/uploads/2018/11/Product-Description-20181126-Santos-Pro.pdf

Internet Resources

- MSD Prevention Guideline for Ontario
  https://www.msdprevention.com
- Thomas E. Bernard Ergo Tools
  https://health.usf.edu/publichealth/tbernard/ergotools
- Health and Safety Executive: information about health and safety at work
  https://www.hse.gov.uk
- Safe Work Australia
  https://www.safeworkaustralia.gov.au

Resources related to Psychosocial Risk Factors

- Bongers PM, Kremer AM, ter Laak J. (2002). Are psychosocial factors, risk factors for symptoms and signs of the shoulder, elbow, or hand/wrist?: A review of the epidemiological literature. *Am J Ind Med; 41*:315– 42.
- COPSOQ (Copenhagen Psychosocial Questionnaire) - https://www.copsoq-network.org/assets/Uploads/COPSOQ-network-guidelines-an-questionnaire-COPSOQ-III-131119-signed.pdf
- **Effort-Reward Imbalance Tool**
  https://www.uniklinik-duesseldorf.de/fileadmin/Fuer-Patienten-und-Besucher/Kliniken-Zentren-Institute/Institute/Institut_fuer_Medizinische_Soziologie/Dateien/ERI/ERI_Psychometric-New.pdf
  Siegrist J, Starke D, Chandola T, Godin I, Marmot M, Neidhammer, Peter R (2004) The measurement of effort-reward imbalance at work: European comparisons. *Social Science & Medicine, 58*:1483-1499.

Tsutsumi A and Kawakami N (2004) A review of empirical studies on the model of effort-reward imbalance at work: reducing occupational stress by implementing a new theory. *Social Science & Medicine, 59*:2335-2359.

- Job Content Questionnaire, https://www.jcqcenter.com/

  de Araújo T. M. & Karasek, R. (2008). Validity and reliability of the job content questionnaire in formal and informal jobs in Brazil. *Scandinavian Journal of Work, Environment & Health,* 52.
- ILO Stress Checkpoints - https://www.ilo.org/wcmsp5/groups/public/@ed_protect/@protrav/@safework/documents/instructionalmaterial/wcms_177108.pdf
- ILO. (2016). Workplace Stress: A collective challenge. Geneve: International Labour Organization:http://www.ilo.org/wcmsp5/groups/public/---ed_protect/--- protrav/---safework/documents/publication/wcms_466547.pdf
- https://www.ilo.org/global/topics/safety-and-health-at-work/areasofwork/workplace-health-promotion-and-well-being/WCMS_108557/lang--en/index.htm

Annex 7. List of Contributors and Overview of Review Process

***Expert participants and observers** attended the initiating meeting at IEA2018, the IEA Triennial Congress. ILO representive Dr. Shengli Niu and IEA Executive Committee members met to discuss and plan the collaborative document. Florence, Italy, 29 August 2018.*

Mr. Gabriel Barone, Consultant, Ergonomics, Industrial Hygiene & Safety (Argentina)

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*Prof. Juan Carlos Hiba, IEA Future of Work Committee Chair; Asociación de Ergonomia. Argentina; National University of Rosario (Argentina)

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*Dr. Michelle Robertson, IEA Communications and Public Relations Committee Chair, Executive Director, Office Ergonomics Research Committee; Lecturer Northeastern University, University of California, Berkeley; Research Specialist, University of Connecticut (USA)

Dr. Shengli Niu, Senior Specialist on Occupational Health, SafeWork, ILO, Geneva (Switzerland)

* denotes IEA writing group member

A second meeting was held at the annual conference of the Chartered Institute of Ergonomics and Human Factors (CIEHF). The IEA writing group reviewed a preliminary draft of the document and made revisions and plans for refinement. Stratford-upon-Avon, United Kingdom, 29-30 April 2019.

*The revised document was sent to **remote external expert reviewers** listed below, who provided suggestions and wrote text for the subsequent draft.*

Ms. Christine Aickin, HF/E Safety Consultant (Australia)

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Dr. Andrew Todd, IEA International Development Committee Chair; Senior Lecturer, Department of Human Kinetics and Ergonomics, Rhodes University (South Africa)

A third meeting was held at the Human Factors and Ergonomics Society Annual Meeting. At this meeting, ***Dr. Shengli Niu****, ILO representative, the* ***IEA writing group listed above****, and external expert reviewers participated in the revision of this document on Principles and Practices for HF/E Design and Management of Work Systems. Seattle, WA, USA, 31 Oct-1 Nov 2019.*

External expert reviewers who participated in this meeting and contributed to the document are listed below.

Ms. Andrea Hiddinga, Chair Strategic Partnership Committee & Past-President, Industrial Occupational Hygiene Association (IOHA) (Netherlands)

Prof. Kazutaka Kogi, IEA Past-Treasurer, International Commission on Occupational Health (ICOH) (Japan; note, Prof. Kogi also participated in earlier remote review)

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The draft document was reviewed and approved by ***Dr. Shengli Niu*** *at ILO Headquarters in Geneva in February, 2020, and sent for final review to* ***a selected sample of 14 writers and reviewers*** *for comments, edits, and approval. March, 2020.*
Reviewers of the document Principles and Practices for HF/E Design and Management of Work Systems are listed below.

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The approved draft document was published on the IEA and ILO websites and comments were invited.

The draft was revised according to suggestions in June, 2021, to create this final version.