EARASHI

Embodied AI/Robotics Applications for a Safe, Human-oriented Industry

Tailored Guidelines or inclusive design and Ethics in industry

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Executive Summary

This document “Tailored guidelines for inclusive design and Ethics in industry”, offers a comprehensive guide to fostering inclusivity and accessibility in our changing society. The document is structured into seven distinct chapters, each offering valuable insights and guidance on various facets of inclusive design and diversity.

Section 2 provides an overview of the profound impact of an ageing population on product, service, and environment design. It discusses the challenges and opportunities posed by this demographic shift, including increased life expectancy, rising dependency levels, and the emergence of the Silver Economy. The section emphasizes the importance of Inclusive Design as a driver for innovation, highlighting the need to accommodate the diversity of sensory, motor, and cognitive abilities in an ageing workforce. Overall, it underscores the importance of creating inclusive and accessible solutions to meet the needs of our evolving society.

Section 3 addresses the challenges posed by legislation and identifies key areas where accessibility features are most needed. The section also introduces standards for Human-Centered Design and Inclusive Design. It highlights Inclusive Design as both a human rights issue, aligned with the Convention on the Rights of Persons with Disabilities, and a strategic business opportunity. Additionally, it emphasizes that Inclusive Design benefits not only individuals with permanent impairments but also those with temporary or situational limitations.

Section 4 of the document focuses on diversity and intersectionality in product and service design. It highlights the importance of considering a wide range of variables beyond just capabilities, including sex, gender, race, and various social factors.

Section 5 of the document explores various methods, tools, and equipment used in the field of Inclusive Design. It emphasizes the importance of incorporating diversity into design processes and provides insights into specific resources and methodologies. The document outlines the DBZ methodology, the practical applications of the Inklugi framework, and the empathetic tools that can empower designers to create universally accessible solutions.

Section 6 showcases case studies and projects that exemplify successful implementations of inclusive design principles. A literature review reveals that there is a lack of knowledge about inclusive design in industry, with most examples focusing on ergonomic, biomechanical, and occupational risk assessments. These diverse examples offer valuable insights into best practices and the tangible benefits of prioritizing inclusivity.

Section 7 discusses guidelines for accessibility and ethics applied to robotics. It presents accessibility guidelines and ethical principles for robotics, along with an example of ethical risk assessment.

This document serves as a valuable resource for designers, policymakers, and stakeholders seeking to create industrial environments that are accessible, inclusive, and ethical. By addressing the challenges posed by an ageing population, exploring the nuances of inclusive design, embracing diversity and intersectionality, and offering practical methods and case studies, this document equips readers with the knowledge and tools necessary to champion inclusivity and accessibility in their respective industrial domains.

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1. INTRODUCTION

This document presents the theory related to Inclusive Design and Ethics in industry. It has been elaborated in the frame of the Horizon Europe project EARASHI (https://earashi.eu/), WP2 "*Human centred industry learning paths and didactic material*". This is the public version of the deliverable D2.2 "*Tailored guidelines for inclusive design and Ethics in Industry".*

Firstly, an introduction about the ageing of the population and its' implications on the design of product, services and environments is presented. Secondly, the standards on Human-Centered Design and Inclusive Design and the definitions of the main terms necessary for the discipline are presented. Then, the social and strategic dimensions of Inclusive Design are introduced, i.e. the value it can bring to society by responding to unresolved needs and rights, and also highlighting new business or innovation opportunities.

On the fourth point, the diversity of capabilities is framed within an intersectional framework where other variables that shape people's reality are also explained. Abilities, sex, gender and race, are factors that interact with each other and influence the opportunities or barriers that a person encounters in different areas of life and also in the work environment.

Once theoretical concepts have been introduced, the methodologies and tools available to address inclusive design and accessibility in the design process of new products and services are presented.

Then, case studies related to Inclusive Design and accessibility on the industry environment are reviewed.

Finally, accessibility guidelines and ethical principles for making work environments more inclusive are presented.

2. AGEING POPULATION

In this section, an introduction about the ageing of the population and its' implications on the design of product, services and environments is presented.

The ageing of the population is one of the most important challenges facing society today. International organisations such as the World Health Organisation (WHO) and the United Nations (UN) are constantly monitoring demographic changes. They have been warning for years that projections for the coming decades confirm the trend towards an ageing population.

KEEP IN MIND

"The world's population is ageing at an accelerating pace. Between 2015 and 2050, the proportion of the world's population over the age of 60 will double from 12% to 22%. The population over the age of 60 will outnumber the population under the age of 5."
World Health Organization, 2021

The projections for the years 2050 and 2100 are far from the pyramid that population data depicted in the 1950s, which is positive since the pyramid shape means that, seven decades ago, children and young people of all ages were dying every year (Figure 1). However, this change in age distribution will mean that there will be more octogenarians and nonagenarians in the world than ever before. For example, between 2000 and 2050, the number of people aged 80 and over is expected to triple to 426 million (WHO, 2021). Thus, for the first time in Spain, people over 60 years of age outnumber those under 14 (SEGG, 2017). United Nations projections tell us that in 2050, 38% of the Spanish population will be over 60 years of age (United Nations, 2017).

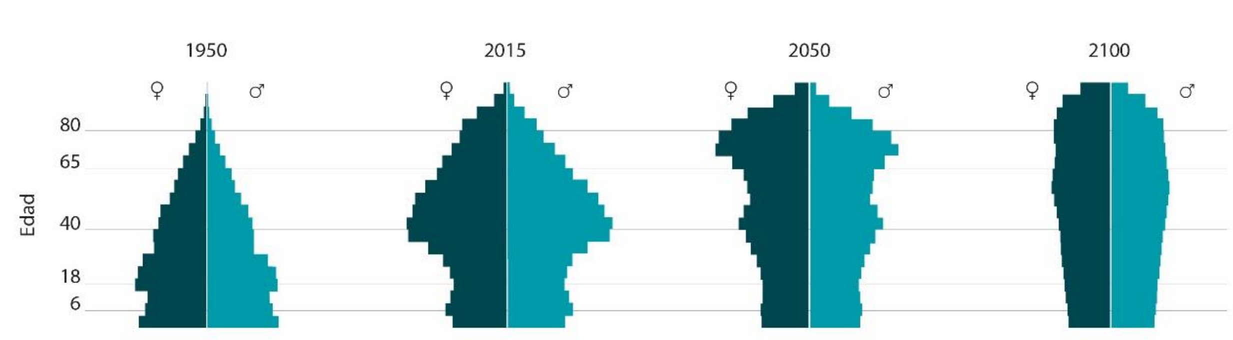

Figure 1 Population projections in Spain (UN, 2017)

The main reason for the ageing of the population is the increase in life expectancy due to advances in medicine and the accessibility of public health services in recent decades. Life expectancy in Spain has gone from around 40 years in 1900 to 80.9 years for men and 86.2 years for women in 2019 (INE, 2021). It can be said that life expectancy at birth in Spain has doubled in the space of a century.

However, living longer does not mean living disability-free. The number of people in a situation of dependency increases with age, so the ageing of the population may lead to a considerable increase in the number of people in a situation of dependency.

In addition, life expectancy is increasing globally. Figure 2 shows life expectancy at birth by country according to data from the World Health Organization (WHO, 2018). But while life expectancy is lower in some developing countries, WHO (2018) states that demographic change will be faster and more intense in low- and middle-income countries. For example, it took 100 years for France's population aged 65 and over to double from 7% to 14%. In contrast, in countries such as Brazil and China, the doubling will occur in less than 25 years.

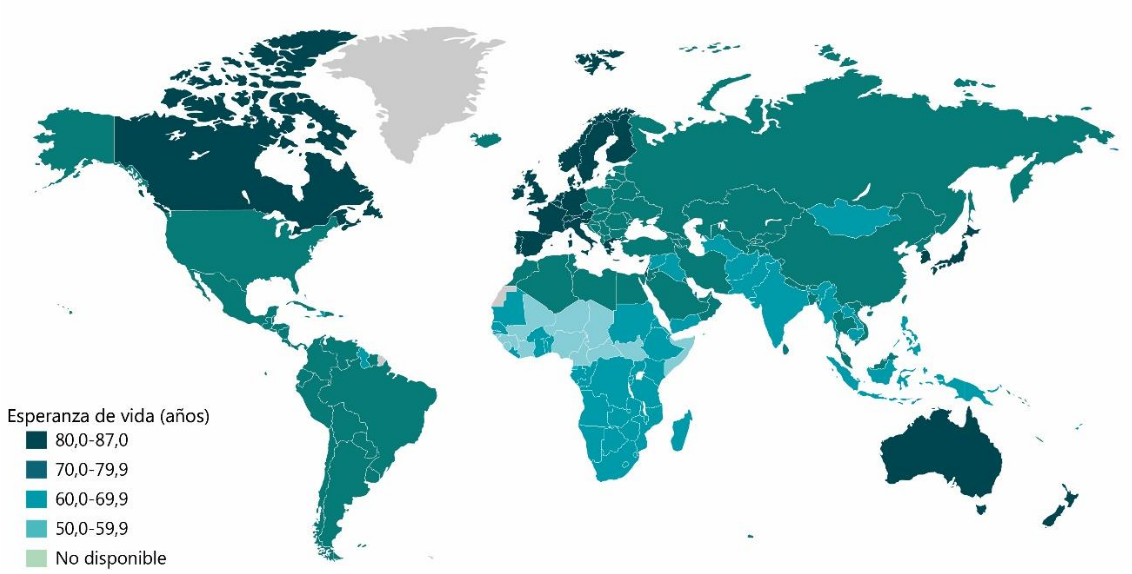

Figure 2 Life expectancy at birth by country (WHO, 2018)

The map shown in Figure 2 represents the average life expectancy of both sexes, however, women live on average 6-8 years longer than men.
WHO (2015) warns in its report about some consequences of population ageing. The need for long-term care is increasing. It is predicted that by 2050, the number of older people who are unable to care for themselves will increase fourfold in developing countries.
At the same time, people reach old age in increasingly better health, and it can be said that a 70-year-old today is younger than a 70-year-old 50 years ago (Yanguas Lezaun, 2021). But each person ages differently and, thus, today we can find people in their 70s who are totally dependent, as well as people over 90 who are independent and have a very high vitality and commitment to life and society. However, in broad terms, it can be said that dependency levels increase progressively from the age of 65 onwards. Illnesses that used to mean death are becoming chronic and, as a result, although people are living longer, this does not mean that they live in an optimal state of health, and many of them have to live in a situation of dependency.

In addition to the social challenges of increasing life expectancy, it is clear that the ageing of the population also brings new opportunities. On the one hand, the life cycle is lengthening and it is possible to live longer and consequently do more things. In consequence, the senior market is beginning to represent a real business opportunity, giving rise to the Silver Economy.

The business opportunity of the Silver Economy will be a reality for companies in a wide range of sectors. From the assistive technologies sector to the tourism sector, from real estate to home care. The size of the market segment of the over-55s, is estimated to be comparable to the world's third largest economy in a few years' time if it were a country. Companies targeting the more active senior public who are eager to play an active role in building a life purpose after retirement, such as those targeting the public of people in a situation of dependency and in need of long-term care, can grow considerably. A previously unattractive market segment is attracting more and more attention in the business world.

But beyond the economic interest, the growth of interest in the ageing market is also an opportunity for companies to understand the value of Inclusive Design as a driver for innovation. Ageing brings with it effects on people's health and intrinsic capacity that often lead to greater or lesser difficulties in using the products and services around them. There are certain age-related changes, such as presbyopia, and certain diseases whose prevalence begins to be significant after the age of 35 or 40. These changes can affect people's intrinsic capacity and can lead to difficulties in carrying out basic activities of daily living and in using the products and technologies around them. Diversity in sensory, motor and cognitive abilities is increasing in work environments as age-related changes begin before retirement age. It is therefore necessary to apply Inclusive Design approaches when designing the work environments.

In addition, employment, due to its remunerative dimension, since its function is intrinsically linked to paid work, is a fundamental instrument of social inclusion and human development. Moreover, when it is of sufficient quality, work is a means of unleashing people's potential, creativity, innovation and imagination. It is essential for human life to be productive, useful and meaningful. It enables people to earn a living, is a channel for participation in society, provides security and confers a sense of dignity.

New technologies can be an opportunity for the inclusion of diversity in the workplace or, on the contrary, they can create new barriers for some people. For this reason, the need to adapt physical, digital and relational environments to the aging population also extends to the aging workforce.

So far, designs aimed at seniors or older people are often based on stereotypes and therefore it is necessary to use specific tools to integrate ageing aspects in innovation and design processes in order to know first-hand the existing diversity in terms of capabilities, but also the real needs, desires and motivations of the aging workforce.

With the aim of ensuring inclusivity in the design of products, services and environments, i.e. to integrate diversity and accessibility into Human-Centered Design approaches, the Inclusive Design approach emerges.

3. INCLUSIVE DESIGN

As mentioned in section 2, Inclusive Design merges to integrate diversity and accessibility into Human-Centred Design approaches. But as the European accessibility act underlines, current national accessibility requirements relating to specific products and services differ from Member State to Member State, and sometimes within a Member State (where there are accessibility requirements at regional/local level). This leads to a fragmentation of the single market, increasing the burden on industry for making accessible products and services available to consumers. National accessibility requirements differ in terms of coverage (to what and to whom they apply), on the level of detail and on the technical details themselves.

This difference in coverage also means that for some products or services, some Member States may have established detailed rules whereas in others there are no rules in place. The current divergence in national legislation is likely to increase in the future, as Member States have committed to implementing the general provisions of the United Nations Convention on the Rights of Persons with Disabilities, to which the EU is also a party.

Member States implement these provisions in different ways at national level. There is currently no EU-wide coordination of national legislation regarding the accessibility of products and services. In particular, there is no common definition on how products and services should be made accessible. Provisions in some EU laws that require certain products or services to be accessible imply that Member States will develop accessibility requirements to meet these obligations, and in the absence of coordinated action there is a risk of varying approaches and requirements.

Economic operators who would like to sell their products or services in other Member States may face additional costs related to understanding the various rules applicable and, more significantly, to adapting their product/service to meet the requirements of a particular national or even regional market. This prevents them from making best use of economies of scale, and means that they cannot fully benefit from the size of the single market. Products and services produced for a limited number of consumers are more expensive, as economic operators cannot benefit from larger markets, which would allow them to absorb the fixed costs of accessibility features. Costs of adapting products or services to differing national requirements may be especially burdensome for small and medium-sized enterprises (SMEs).

The largest number of reported issues has concerned the built environment, transport and ICT, including the web. These areas are key components for the accessibility of services. It identifies the products and services for which accessibility features are most needed, in areas where there is most legislative divergence and greatest market fragmentation, or where there is a very strong likelihood that these will occur, with consequential risks to the working of the single market:

− computers and operating systems;

− digital TV services and equipment;

− telephony services and related terminal equipment;

− eBooks;

− self-service terminals including ATMs, ticketing and check-in machines;

− eCommerce;

− banking services;

− passenger transport services, including air, rail, bus and maritime;

− hospitality services.

The divergence of accessibility legislation and related single market issues in areas such as public procurement and European Structural and Investment funds is expected to increase. While accessibility requirements have become obligatory in the new European frameworks, the relevant EU law does not define what accessibility means and what it entails, leaving this to be defined in national or sector-specific rules.

However, there are different standards that help companies implement Human Centred Design Processes and Inclusive Design. In this section, firstly the international standard on Human Centred Design Process for Interactive Systems ISO 13407:1999 is described. Since this approach lacks specific tools to integrate the diversity of users throughout their processes, the British Standard 7000-6:2005 Part 6: Managing Inclusive Design is also be presented. After the explanation of the standards, the main terms related to Inclusive Design and its' social and strategic dimensions are explained.

ISO 13407:1999 International Standard on Human Centred Design Process for Interactive Systems

The international standard on Human-centred design is an approach to interactive system development that focuses specifically on making systems usable. It is a multi-disciplinary activity which incorporates human factors and ergonomics knowledge and techniques. The application of human factors and ergonomics to interactive systems design enhances effectiveness and efficiency, improves human working conditions, and counteracts possible adverse effects of use on human health, safety and performance. Applying ergonomics to the design of systems involves taking account of human capabilities, skills, limitations and needs.

Human-centred systems support users and motivate them to learn. The benefits can include increased productivity, enhanced quality of work, reductions in support and training costs, and improved user satisfaction. Although there is a substantial body of human factors and ergonomics knowledge about how such design processes can be organized and used effectively, much of this information is only well-known by specialists in these fields. This International Standard aims to help those responsible for managing hardware and software design processes to identify and plan effective and timely human-centred design activities. It complements existing design approaches and methods.

The standard describes four principles of human-centred design:

1. Active involvement of customers.
2. Appropriate allocation of function.
3. Iteration of design solutions.
4. Multi-disciplinary design.

And four key human-centred design activities

1. Understand and specify the context of use.
2. Specify user and socio-cultural requirements.
3. Produce design solutions.
4. Evaluate designs against requirements.

The standard itself is generic and can be applied to any system or product.

British Standard 7000-6:2005 Part 6: Managing inclusive design

Inclusive design is comprehensive, integrated design which encompasses all aspects of a product used by consumers of diverse age and capability in a wide range of contexts, throughout the product's lifecycle from conception to final disposal. Its ultimate goal is to meet the needs of all such consumers and is based on the principle that appropriate access to information, products and facilities is a fundamental human right. Inclusive design needs to be a key element in an inclusive business strategy. This standard provides a strategic framework and associated processes by which business executives and design practitioners can understand and respond to the needs of diverse users without stigma or limitation.

Inclusive design recognizes diversity by addressing the ability and preferences, for example, of people who:

- Have impaired vision and/or hearing (including colour blindness, etc.);
- Are from different cultures (with different languages, values and/or customs);
- Have language and/or speech impairments (resulting in difficulties with reading, comprehension and in expressing oneself);
- Have physical limitations (whether due to temporary or permanent reductions in strength, movement and/or co-ordination; allergies, sensitivity to electromagnetic radiation, etc.);
- Are of different ages;
- Have varying cognitive abilities;
- Have different dietary requirements for medical reasons or through choice;
- Have different requirements because of their gender.

By determining the capability demands of a product on users, it is possible to identify and quantify those who have difficulty with, or cannot use it. Designing products to lessen such demands can attract valuable additional market sectors often excluded by competitors. Indeed, satisfaction is more likely throughout the customer base when usability is ensured for all in the target market population.

The true accessibility of products is determined by the accessibility of their weakest component whether packaging, instructions, interface, after sales service and so on. Concentrating attention on one component while neglecting others is likely to result in a product that is weak overall.

DEFINITION

Inclusive Design: The design of products, services and environments that are accessible to and usable by as many people as reasonably possible, regardless of their age, sex/gender, sensory, cognitive and physical abilities and cultural background, without the need for adaptation or specific design (British Standard Institution, 2005).

a) Disability: is a condition resulting from the interaction between persons with foreseeable permanent impairments and any barriers that limit or prevent their full and effective participation in society on an equal basis with others.

b) Impairment: reduction in a person's functional capability: that is, the ability to perform actions or accomplish tasks

c) Equality of opportunity: is the absence of any direct or indirect discrimination on the basis of disability, including any distinction, exclusion or restriction which has the purpose or effect of impairing or nullifying the recognition, enjoyment or exercise by persons with disabilities, on an equal basis, of all human rights and fundamental freedoms in the political, economic, social, labour, cultural, civil or any other field. Equal opportunity is also understood to mean the adoption of positive action measures.

d) Positive action measures: are those of a specific nature consisting of avoiding or compensating for the disadvantages derived from disability and aimed at accelerating or achieving the de facto equality of persons with disabilities and their full participation in the spheres of political, economic, social, educational, labour and cultural life, taking into account the different types and degrees of disability.

e) Independent living: is the situation in which the person with disabilities exercises decision-making power over his or her own existence and actively participates in the life of his or her community, in accordance with the right to free development of the personality.

f) Social inclusion: is the principle whereby society promotes shared values for the common good and social cohesion, enabling all persons with disabilities to have the opportunities and resources necessary to participate fully in political, economic, social, educational, occupational and cultural life, and to enjoy living conditions on an equal basis with others.

g) 'Universal design or design for all' means the activity whereby environments, processes, goods, products, services, objects, instruments, programmes, devices or tools are, wherever possible, conceived or designed from the outset in such a way that they can be used by all people, to the greatest extent possible, without the need for adaptation or specialised design. Universal design or design for all persons" shall not exclude assistive products for particular groups of persons with disabilities, where needed.

h) Reasonable adjustment: means necessary and appropriate modifications and adjustments to the physical, social and attitudinal environment to accommodate the specific needs of persons with disabilities that do not impose a disproportionate or undue burden, where needed in a particular case in an effective and practical manner, to facilitate accessibility and participation and to ensure to persons with disabilities the enjoyment or exercise on an equal basis with others of all rights.

i) Design for all: is the intervention into environments, products and services which aims to ensure that anyone, including future generations, regardless of age, gender, abilities or cultural background, can participate in social, economic, cultural and leisure activities with equal opportunities.

j) Mainstream product: product developed for use by the general population.

Finally, one of the most commonly used term, which will be repeated throughout the document, is also described in the following box.

DEFINITION

Universal accessibility: is the condition that environments, processes, goods, products and services, as well as objects, instruments, tools and devices, must meet in order to be understandable, usable and practicable by all people in conditions of safety and comfort and in the most autonomous and natural way possible. It presupposes the strategy of "universal design or design for all persons", and is without prejudice to reasonable accommodation to be adopted.

With those definitions in mind, we can explain the objective of Inclusive Design. The main goal of inclusive design is to maximise the audience for which a product or service is designed. Taking into account that some people will still need some specific technological aid or even personal assistance to be able to carry out the activities of daily life, it is a fact that most of the mainstream products and services could include a part of the society that nowadays is being forgotten. Those segments of the population that have been excluded and that could be included just by creating awareness within the design teams.

3.1 THE SOCIAL DIMENSION OF INCLUSIVE DESIGN

Inclusive Design is a matter or human rights. The 1948 Universal Declaration of Human Rights affirms that "All persons are born free, have equal dignity and equal rights, as they have reason and conscience, they should act in brotherhood with one another".

The 2006 Convention on the Rights of Persons with Disabilities is an international agreement adopted at the United Nations Headquarters in New York, and signed and ratified by all States. The main contributions of this agreement are:

- It includes disability in the context of human rights.
- It establishes the social model of disability.
- It recognises the right to self-determination.
- It recognises the right to participate in decisions that affect them.

General Comments are documents produced by the Committee on the Rights of Persons with Disabilities. They clarify the rights recognised in the Convention and serve as an interpretative guide for States.

Table 1: General Comments on the Convention on the Rights of Persons with Disabilities (UN, 2006)

General Comments on the Convention on the Rights of Persons with Disabilities	
General Comment No. 1: **Equal recognition under the law**	Assistance in exercising legal capacity should be based on the will and preferences of the person with a disability, rather than on what is considered to be his or her objective interest.
General Comment 2: **Accessibility**	Denial of access to the physical environment, information technologies, and facilities and services open to the public should be examined in the context of discrimination.
General Comment 3: **Women and girls with disabilities**	Member States should take measures to ensure the full and equal enjoyment of all human rights and fundamental freedoms by women with disabilities.
General Comment 4: **Inclusive education**	It involves a process of systemic reform for inclusion by implementing changes and modifications in the content, teaching methods, approaches, structures and strategies of education.
General Comment 5: **Independent living**	People with disabilities should have all the resources they need to control their lives and make all decisions that affect them.
General Comment 6: **Equality and non-discrimination**	Promoting equality and combating discrimination are cross-cutting obligations that are immediately enforceable, not subject to progressive enforcement.
General Comment No. 7: **Participating in the implementation and monitoring of the Convention**	States have an obligation to actively consult and involve persons with disabilities, through their institutions, before adopting laws, regulations and policies.
General Comment No. 8: **Work and employment**	The right to work is only demonstrated through freely chosen or accepted employment in an open and inclusive labour market.

These General Comments on the Convention on the Rights of Persons with Disabilities give us a general view on the social impact that Inclusive Design can have. Specifically, the General Comment number 8, on work and employment, highlights the right to work and describes how it is only demonstrated through freely chosen or accepted employment in an open and inclusive labour market.

3.2THE STRATEGIC DIMENSION OF INCLUSIVE DESIGN

As well as being a human rights issue, Inclusive Design is also a strategic discipline that can improve the competitiveness of businesses and the efficiency of public services. The following section explains the facts that highlight the strategic dimension of Inclusive Design.

The business case for adopting an inclusive approach to design is built around five key drivers and opportunities:

1. A better understanding of changing consumer needs, lifestyles, expectations and aspirations: to expand the consumer base, extend product lifecycles and develop brand loyalty.
2. A better alignment of an organization's consumer offer with its customers and markets (such as those due to population ageing, new legislation, technological change and the adoption of inclusive design by competitors): to boost turnover, market shares and returns on investment, hence profitability
3. A distinctive competency that creates competitive advantage: to create effective user-centred designs and better-integrated product ranges through the application of human factors principles. These encourage repeat purchases, guard against dissatisfaction due to limitations in usability and accessibility, and minimize the cost of servicing and returns.
4. An enhanced ability to identify and exploit opportunities for innovation and the benefits of products: to build and sustain corporate reputation and brand value during social and technological change by surmounting greater design challenges, developing distinctive user-friendly products and generating greater goodwill from powerful overlooked sectors.
5. A closer association between staff, investors, corporate values and mission: to maintain workforce loyalty (particularly in the context of a longer working life for employees, an ageing population and changing expectations with regard to retirement); to improve efficiency, enhance motivation and ensure that essential skills are retained within the company.

In sum, inclusive design makes business sense, reflects on the social responsibility of organizations, and provides visible signals of compliance with legislation.

In addition, opposite to what many people could deduce, Inclusive Design can benefit also people that has not any permanent impairment. People with temporary conditions or living different situations that limit their capabilities can be benefited by Inclusive Design. The Microsoft Inclusive Design team presented a Toolkit where those situations are explained as shown on Table 2.

Table 2: Microsoft Inclusive Design toolkit description of permanent, temporary and situational limitations (Microsoft, 2020)

	Permanent impairment	Temporary impairment	Situational limitation
Dexterity	People born with one arm	People that had an arm injury	New parent holding a baby in its arms
Vision	Blind people	People with cataracts	Car driver that is distracted with the phone
Hearing	Deaf people	People with an ear infection	Bartender that works in a noisy environment
Speaking	Non-verbal people	People with laryngitis	Foreign people with a heavy accent

They explain the situations where dexterity can be limited, for example, a person born with one arm means a permanent impairment, a person with an injury in the arm means a temporary impairment, and a new parent holding a baby in its arms means a situational limitation. Similar examples are presented for vision, hearing and communication abilities. Thus, Inclusive Design can benefit anyone at anytime and it is necessary to create awareness on that sense because those situations are easy to understand but they are hardly considered when designing new products and services.

4. DIVERSITY AND INTERSECTIONALITY

The integration of diversity in product and service design is often related to diversity of capabilities among the target users. However, there are other research teams that take into account other variables such as sex and gender like The Gendered Innovations department (Stanford University, 2009) and the more recent Intersectional design project launched by the same Stanford team (Jones et al., 2021) includes: age, disability, educational background, ethnicity, family configuration, gender, geographic location, race, sex, sexuality, social and economic status, sustainability. Image (Morgan, KP. 2018)

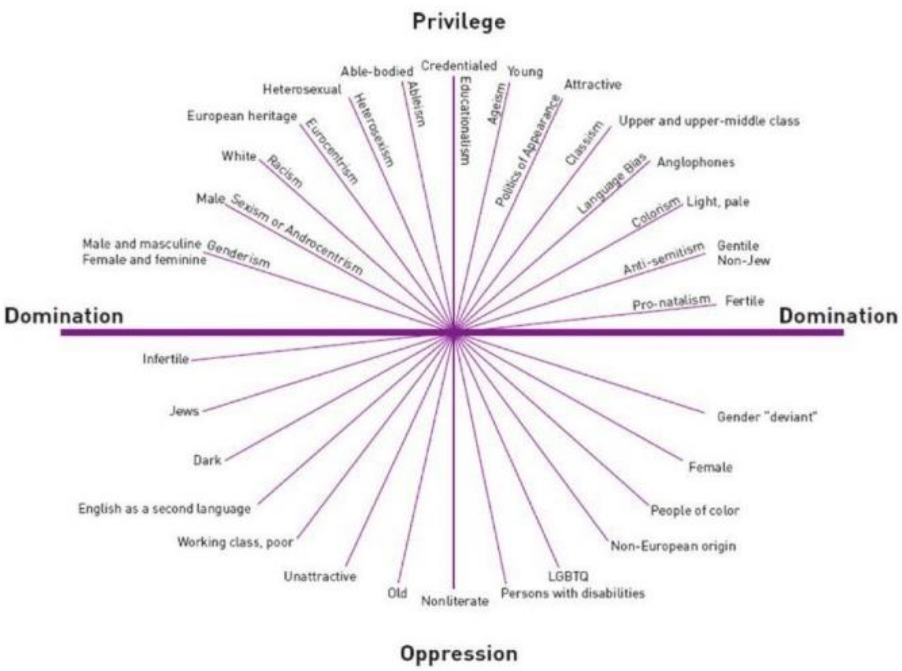

Figure 3 Morgan's privilege and oppression graph of intersectionality (Morgan, KP. 2018)

DEFINITION

Intersectionality: describes the ways in which systems of inequality based on gender, race, ethnicity, sexual orientation, gender identity, disability, class and other forms of discrimination "intersect" to create unique dynamics and effects. All forms of inequality are mutually reinforcing and must therefore be analysed and addressed simultaneously to prevent one form of inequality from reinforcing another. For example, tackling the gender pay gap alone – without including other dimensions such as race, socio-economic status and immigration status – will likely reinforce inequalities among women (Kimberlé Crenshaw, 1989).

For better understanding of the definition watch the video that TU Wien published on April 2021: https://www.youtube.com/watch?v=U4eRb1NM21A

Intersectionality have been researched in social fields such as sociology, psychology, social integration, law. However, it is not so common to find studies related to intersectionality in fields like engineering.

EXAMPLE

Analysing Gender and Intersectionality in Machine Learning:

Facial recognition systems (FRSs) can identify people in crowds, analyze emotion, and detect gender, age, race, sexual orientation, facial characteristics, etc. These systems are often employed in recruitment, authorizing payments, security, surveillance and unlocking phones. Despite efforts by academic and industrial researchers to improve reliability and robustness, recent studies demonstrate that these systems can discriminate based on characteristics such as race and gender, and their intersections (Buolamwini & Gebru, 2018).

Bias in machine learning (ML) is multifaceted and can result from data collection, or from data preparation and model selection. For example, a dataset populated with men and lighter-skinned individuals will misidentify darker-skinned females more often. This is an example of intersectional bias, in which different types of discrimination amplify negative effects on an individual or group. (https://genderedinnovations.stanford.edu/case-studies/facial.html)

In this section diversity of capabilities, sex and gender and race aspects are described in order to understand the multiple ways of exclusion that can be present in the design of products, services and working environments.

4.1 DIVERSITY OF CAPABILITIES

The International Classification of Functioning, Disability and Health (ICF), drawn up by the World Health Organisation (WHO), attempts to provide a coherent view of the different dimensions of health from a biological, individual and social perspective.

The medical model considered disability as a problem of the person directly caused by an illness, trauma or health condition, which requires medical care provided in the form of individual treatment by professionals. The treatment of disability was aimed at achieving a cure, or a better adaptation of the person and a change in his or her behaviour. Health care was seen as the primary issue and at the policy level, the main response was to change and reform health care policy.

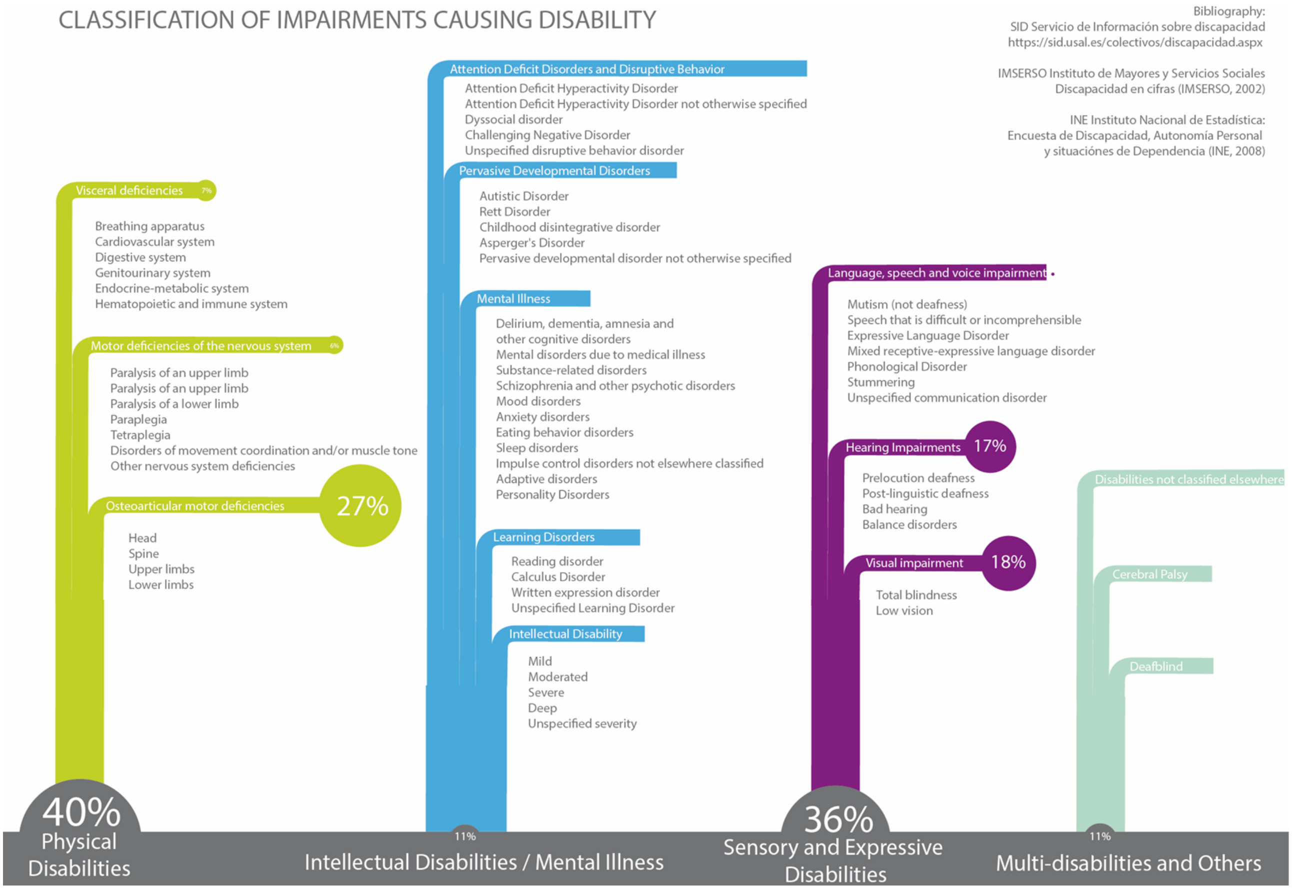

Figure 4 Classification of impairments causing disability

Nowadays the social model of disability, has gained importance. The social model of disability sees the phenomenon primarily as a problem of social origin and mainly as an issue centred on the full integration of people into society. Disability is not an attribute of the individual, but a complicated set of conditions, many of which are created by the social context/environment.

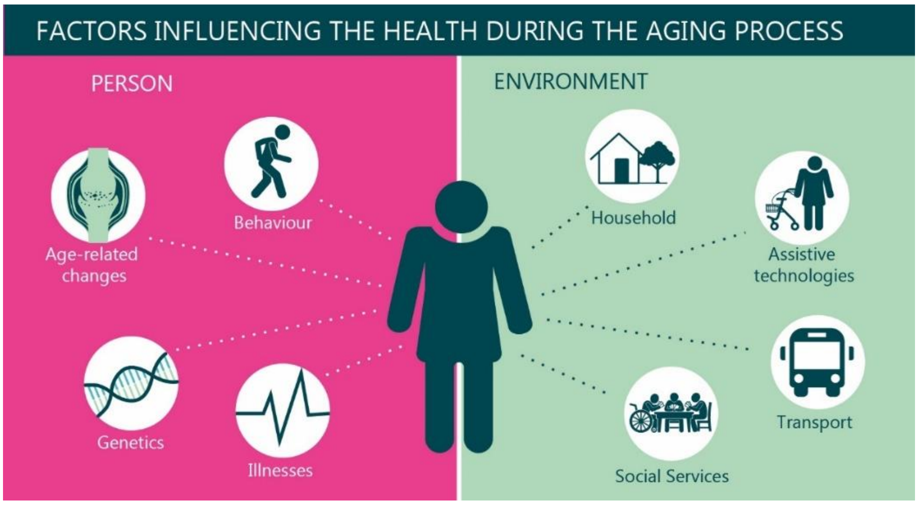

Figure 5 Factors influencing the health during the ageing process (WHO, 2017)

Therefore, management of the problem requires social action and it is society's collective responsibility to make the necessary environmental modifications for the full participation of people with disabilities in all areas of social life.

The health and intrinsic capacity of individuals varies with age due to internal factors such as genetics, disease, age-related changes and behaviour. However, health, intrinsic capacity and, above all, functional capacity are also affected by the type of housing, means of transportation, assistive technologies and social services available.

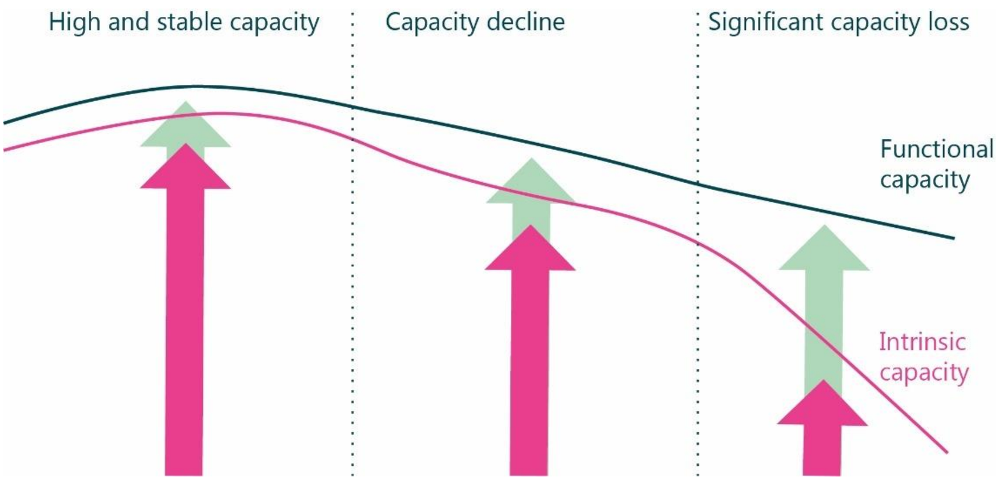

Figure 6 Evolution of intrinsic and functional capacity during the aging process (WHO, 2015)

As can be seen in graph 6, throughout the aging process, people tend to lose intrinsic capacity, but thanks to support products and services and the adaptation of environments, they can maintain their functional capacity for a longer period of time.

KEEP IN MIND

Intrinsic capacity is only one of the factors that will determine what a person can do. The other factor is the environment in which they live and their interaction with it. The environment offers a range of resources or poses a range of obstacles that will ultimately determine whether a person with a given level of capacity can do the things that he or she feels are important. This relationship between the individual and the environment in which they live, and how they interact, is known as **functional capacity**, which is defined as the health-related attributes that enable people to be and do what they value (WHO, 2015).

4.2 SEX AND GENDER

Sex refers to biology. In humans, sex refers to the biological attributes that distinguish male, female, and/or intersex. In non-human animals, sex refers to biological attributes that distinguish male, female, and/or hermaphrodite. In engineering & product design research, sex includes anatomical and physiological characteristics that may impact the design of products, systems, and processes.

Figure 7 Robot that responds only to mens voice

For example, there are robots in the market that are activated by voice and respond with a text. Some of those robots, like the one in the image 7, respond only to men's voice and remain inactive in front of women's voice. This incident may have happened because the robot was trained by male engineers responsible of its design and development. Engineers that were not aware of the importance of diversity.

Sex is complex, dynamic, context-dependent, and interacts with gender and other social factors (Ritz & Greaves, 2022).

Gender refers to sociocultural norms, identities, and relations that structure societies and organizations, and shape behaviours, products, technologies, environments, and knowledges (Schiebinger, 1999). Gender attitudes and behaviours are complex and change across time and place. Importantly, gender is multidimensional (Hyde et al., 2018) and, as explained before, intersects with other social categories, such as sex, age, socioeconomic status, sexual orientation and ethnicity. Gender is distinct from sex (Fausto-Sterling, 2012).

There exist examples related to products and services that do not include people from different sexes and others related to products and services that do not include gender aspects. The following two examples illustrate both the possibilities and how the inclusion of sex and gender variables can result in better quality and excellence of the research projects.

EXAMPLE

Crash tests. Crash test dummies are used in auto safety testing. These dummies vary by height and weight to represent human populations. The 50th percentile male dummy (a dummy modelling the average male body) is most commonly used. A 5th percentile female crash test dummy (representing the smallest 5th percent of the female adult population) was introduced in 1966, but this dummy is simply a scaled version of the 50th percentile male body and does not model female bodies. Still lacking is a 50th percentile female dummy that models female-typical injury tolerance, biomechanics, spinal alignment, neck strength, muscle and ligament strength, dynamic responses to trauma, and other female-typical characteristics. Consequently, women sustain more severe injuries than men in comparable crashes. (http://genderedinnovations.stanford.edu/case-studies/crash.html)

EXAMPLE

Smart Mobility. Mobility patterns tend to be gendered in terms of where, when, and why people take trips. Transportation planning—both for modes and infrastructures—often do not take into account diverse users' needs. For example, the need for safety can restrict mobility for specific women, gender nonconforming individuals, and the elderly. The, so called, Mobility of Care. National Household Travel Surveys underrate trips performed as part of caring work, i.e., doing errands to meet household needs or to accompany others. Reconceptualizing data collection to include caring work as a dedicated category allows transportation engineers to design systems that work efficiently for broader segments of the population. (http://genderedinnovations.stanford.edu/case-studies/mobility.html)

4.3 RACE

Race is a powerful social category forged historically through oppression, slavery, and conquest. Most geneticists agree that racial taxonomies at the DNA level are invalid. Genetic differences within any designated racial group are often greater than differences between racial groups. Most genetic markers do not differ sufficiently by race to be useful in medical research (Duster, 2009; Cosmides, 2003). Race is a social category. Humans vary remarkably in wealth, exposure to environmental toxins, and access to medicine. These factors can create health disparities. Krieger (2000) describes disparities that result from racial discrimination as “biological expressions of race relations” (see also Bailey et al., 2017; Churchwell et al., 2020). African Americans, for example, have higher rates of mortality than other racial groups for 8 of the top 10 causes of death in the U.S. (Race, Ethnicity, and Genetics Working Group, 2005). Although these disparities can be explained in part by social class, they are not reducible to class distinctions.

Taking into account the complexity of the term race, in this guide we will focus on the physical characteristics that identify humans with the different races. Different skin colours or face shape that can interact differently with the characteristics of some products and services creating situations of discrimination. Racialised people have not been part of user tests for some new technologies and that results on discriminatory products and services.

Dominique Apollon, a 45 years old man, vice president of research at Race Forward, an NGO dedicated to raising awareness about racial justice. Published a tweet in April 2019 that became viral and said: “It’s taken me 45 trips around the sun, but for the first time in my life I know what it feels like to have a band-aid in my own skin tone. For real I’m holding back tears. It's a product that said to me -We see you. You are valued-." This is a small example of how simple things can change the perception of people towards a product and also towards the treat that a company give to them.

Figure 8 Different skin Tru-colour band-aid

EXAMPLE

Soap dispensers. Soap dispensers don't work for people with darker skin. Why is that? The near-infrared technology does not bounce off the hand, close the circuit, and dispense the soap. More seriously, heart-rate monitors, even Fitbits, don't work for darker skinned people, which may put them at risk of serious conditions like heart disease. And pulse oximeters, used to measure oxygen levels in the blood, overestimate oxygen levels in the blood in patients with darker skin, putting them at risk for organ failure if supplemental oxygen is not provided. Oximeters can also be also inaccurate for women, whose fingers are typically smaller and geometrically different from men's. Black women may experience the highest error rates. (www.intersectionaldesign.com/form-and-fuction)

5. METHODS, TOOLS AND EQUIPMENT

In this section, specific methods, tools and equipment used in the field of Inclusive Design are presented. Standards explain the measures that a company should take in order to implement Inclusive Design processes, however, they describe very slightly the specific tools to include diversity into the design processes.

The most specific tool that the British Standard 7000-6:2005 presents is the 7-level model for countering design exclusion:

Developed specifically for the inclusive design of complex products and systems, such as those incorporating information technology (say, a smart home system), this 7-level model helps ensure that the final design:

- Can be accessed by a wide range of users;
- Meets users' expectations and other social requirements in ways that mean they are happy to use the product or system and do not feel excluded or stigmatised by it;

This model includes de following levels:

Table 3: 7-Level model for countering design exclusion (British Standard 7000-6:2005)

7-Level model for countering design exclusion	
Level 1	**Identifying user wants and aspirations.** Defining then verifying the complete problem, including social acceptability requirements.
Level 2	**Determining user needs.** Specifying the functionality to be provided then verifying the functional specification.
Level 3	**Facilitating user perceptions.** Introducing appropriate output/feedback mechanisms, then verifying that users can "perceive" (see, hear, etc.) the output from the product.
Level 4	**Ensuring users understand how to use the product.** Structuring interactions that match user expectations of how the product should behave, then verifying that users understand the product's behaviour.
Level 5	**Ensuring users can interact physically with the product.** Developing quality of control and user input, then verifying that the users can control the product without undue physical discomfort.
Level 6	**Verifying that the product does what is intended.** Evaluating the total product's functionality, usability and accessibility, then validating its practical acceptability.
Level 7	**Confirming that users are happy with the product.** Evaluating match user requirements then validating social acceptability.

Universal Design [UD] (Center for Universal Design, 2002)

The Center for Universal Design was a national research, information, and technical assistance center at North Carolina State University that evaluated, developed, and promoted universal design in housing, public and commercial facilities, and related products. This center was established in 1989 to improve the quality and availability of housing for people with disabilities, including disabilities that result from aging.

The authors, a working group of architects, product designers, engineers and environmental design researchers, collaborated to establish the following Principles of Universal Design to guide a wide range of design disciplines including environments, products, and communications. These seven principles may be applied to evaluate existing designs, guide the design process and educate both designers and consumers about the characteristics of more usable products and environments.

Table 4: The 7 principles of Universal Design (Center for Universal Design, 2002)

THE 7 PRINCIPLES OF UNIVERSAL DESIGN	
PRINCIPLE NAME	**GUIDELINES**
1. **Equitable Use** The design is useful and marketable to people with diverse abilities.	1a. Provide the same means of use for all users: identical whenever possible; equivalent when not. 1b. Avoid segregating or stigmatizing any users. 1c. Provisions for privacy, security, and safety should be equally available to all users. 1d. Make the design appealing to all users.
2. **Flexibility in Use** The design accommodates a wide range of individual preferences and abilities.	2a. Provide choice in methods of use. 2b. Accommodate right- or left-handed access and use. 2c. Facilitate the user's accuracy and precision. 2d. Provide adaptability to the user's pace.
3. **Simple and Intuitive Use** Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.	3a. Eliminate unnecessary complexity. 3b. Be consistent with user expectations and intuition. 3c. Accommodate a wide range of literacy and language skills. 3d. Arrange information consistent with its importance. 3e. Provide effective prompting and feedback during and after task completion.
4. **Perceptible Information** The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.	4a. Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information. 4b. Provide adequate contrast between essential information and its surroundings. 4c. Maximize "legibility" of essential information. 4d. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions). 4e. Provide compatibility with a variety of techniques or devices used by people with sensory limitations.
5. **Tolerance for Error** The design minimizes hazards and the adverse consequences of accidental or unintended actions.	5a. Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded. 5b. Provide warnings of hazards and errors. 5c. Provide fail safe features. 5d. Discourage unconscious action in tasks that require vigilance.
6. **Low Physical Effort** The design can be used efficiently and comfortably and with a minimum of fatigue.	6a. Allow user to maintain a neutral body position. 6b. Use reasonable operating forces. 6c. Minimize repetitive actions. 6d. Minimize sustained physical effort.
7. **Size and Space for Approach and Use** Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.	7a. Provide a clear line of sight to important elements for any seated or standing user. 7b. Make reach to all components comfortable for any seated or standing user. 7c. Accommodate variations in hand and grip size. 7d. Provide adequate space for the use of assistive devices or personal assistance.

Inclusive Design toolkit [IDT] (Clarkson et al., 2007)

The Inclusive Design Group from the Cambridge Engineering Design Centre (EDC) has undertaken fundamental and applied research to generate knowledge that improves the design process. The Inclusive Design Group researches the interplay between the demands products and services make of their users and the diverse range of capabilities of those users.

Their work is driven by practice. They are currently working with Jaguar Land Rover, BAE Systems, Morphy Richards, Transport for London, Proctor and Gamble, John Lewis, Stora Enso, Heathrow Airport and others to deliver on a variety of research topics relating to cognitive interaction and inclusive design.

In their words, product interactions place demands on the users' capabilities. Users may be excluded from using a product if any of its demands are higher than their capabilities. For example, a product with very small text requires a high level of vision capability. People with age-related long sightedness will be excluded from its use.

An initial assessment can be made by rating the demand on each capability on a scale from Low to High. To do this, there are various factors that should be considered:

Table 5: Capabilities classification and Factors that should be considered for an initial assessment of the demands (Clarkson et al., 2007)

Factors that should be considered for an initial assessment of the demand of each capability	
Capability	**Factors that should be considered**
Vision	Consider the size, shape, contrast, colour and placement of the graphical and text elements.
Hearing	Consider the volume, pitch, clarity and location of sounds produced by the product.
Thinking	Consider how much demand the product places on a user's memory, how much it helps the user to interpret its interface, how much attention it demands, and how much prior experience it assumes.
Reach and Dexterity	Consider the forces, movements and types of grip required to use the product. The demands will increase if tasks have to be performed with the hands reached above the head or below the waist.
Mobility	Consider whether the product requires the user to move around. If designing an environment or service, consider whether it provides suitable features to assist balance and support mobility aids.

They have developed an Inclusive Design Toolkit, along with audit tools and wearable simulators, to encourage designers to deliver more inclusive products and services.

The main audit tools developed by the Inclusive Design team are the following:

- Exclusion calculator. A tool to estimate the number of people unable to use a product or service because of the demands that it places on users' capabilities. The tool involves estimating demands on a range of capabilities, including vision, thinking and dexterity. https://calc.inclusivedesigntoolkit.com/
- Clari-Fi. A tool to simulate the challenges of viewing small images on mobile screens. https://clarifi.inclusivedesigntoolkit.com/

- SEE-IT. A tool to assess the visual clarity of text or graphics that are handheld. The tool involves examining visual clarity at different distances, and using this to estimate the proportion of the population who would be unable to see the design comfortably. SEE-IT is best used within a browser on a mobile device. https://seeit.inclusivedesigntoolkit.com/
- Cambridge Simulation Gloves. To simulate dexterity impairment.
- Cambridge Simulation Glasses. To simulate vision impairment.
- Impairment simulator software. To demonstrate the effects of vision and hearing impairments on image and sound files.

These tools help to quantify accessibility of existing products and services and prioritise improvements to make them more inclusive. The same tools can be used to quantify accessibility of prototypes during the different phases of the design process.

KEEP IN

Product interactions place demands on the users' capabilities. Exclusion occurs if the demands exceed the user capabilities, given the context. For example, a product with very small text requires a high level of vision capability. People with age-related long sightedness will be excluded from its use. The context is also important, people with a good vision capability can be excluded if the text is expose to sun light in a reflective material.

ADDITIONAL INFORMATION

Title: **Inclusive. A Microsoft Design Toolkit**

Source type: Toolkit

Description: A comprehensive introduction to the world of inclusive design. Guidelines that are the result of hundreds of hours of research and conversations with people.

Link:https://download.microsoft.com/download/b/0/d/b0d4bf87-09ce-4417-8f28-

5.1 DBZ METHODOLOGY, INKLUGI, EMPATHY

Our methodology fosters innovation by bringing together the human, technology and business domains, placing humans at the centre of the design process.

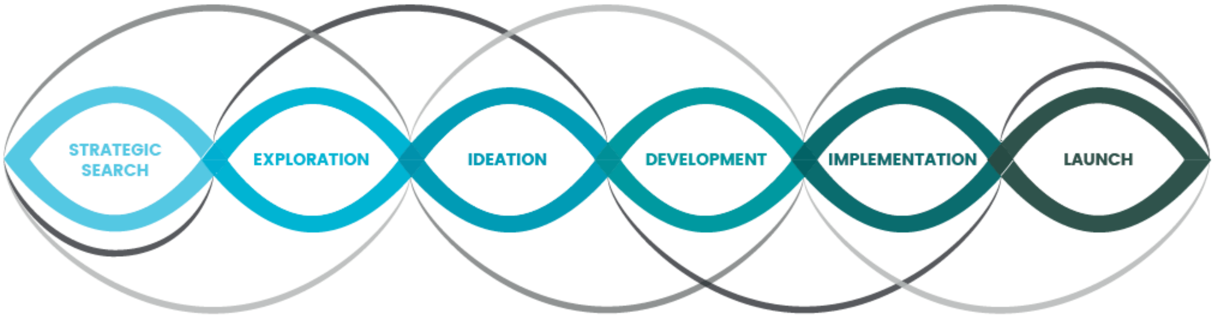

Figure 9 Human-Centered Design Methodology (DBZ-MU, 2014)

The DBZ-MU Methodology is based on the incorporation of incorporation of user knowledge during the 6 stages of the 6 stages of the process.

It starts with the **Strategic Search** and **Exploration**, whose objective is to detect, through the tools adopted by Design Thinking, new opportunities for products and services by specifying their characteristics in the design brief. In these phases, observations and dialogues with users to find problems, needs or concerns that may give rise to opportunities.

The next two stages, **Ideation** and **Development**, focus on generating solutions, first creating concepts and developing them through testing with Prototypes of various kinds. The involvement of the users in the generation and testing of the solutions and testing of solutions favors better solutions and facilitates decision decision making.

Afterwards, the **implementation** of the product/service idea and its subsequent product/service idea and its subsequent **Launch**.

Once the product/service is in the marketplace market feedback provides information for possible improvements. possible improvements.

The divergence and convergence processes are repeated at each stage, and the various phases overlap and feed back into each other. Throughout the process, the aim is for the result to be of value to people (customer/user), technologically feasible and viable from a business point of view.

People's needs, aspirations and skills are the starting point. In this way, the model helps to design products and services that are meaningful to the customer, viable from a business perspective and technologically feasible. Instead of starting from a technology when designing new products or services, the idea is to start from people's needs and select the most appropriate technologies and designs to meet those needs.

There are different ways of involving people depending on the role they are to play in each phase of the project: non-participating, informing, evaluating, generating and developing.

Does not participate: the user is considered without the need to participate, using tools such as passive observation, the Personas tool, the Customer Journey Map, etc...

Informs: The user shares his knowledge about his habits, experience, concerns, using interviews, participatory observation, diaries, etc...

Evaluates: the user adopts a critical attitude about a product or service in search of opportunities to improve it, using tests, interviews, etc...

Generates: the user identifies problems and/or proposes opportunities and solutions through creative sessions, brainstorming, etc...

Develops: the user develops the project by getting involved with the team internally or externally through Co-working, Lead User, etc...

Since 2010 the Design Innovation Center from Mondragon Unibertsitatea (DBZ-MU) have been working on the development of methods and tools to ensure the inclusion of diversity of capabilities in the human-centered design methodology.

INKLUGI TOOL FOR THE EVALUATION OF EXCLUSION

The first tool developed is INKLUGI tool for calculating the exclusion caused by products and services. Based on data from the Survey on Disability, Autonomy and Dependency Situations (INE 2008). In collaboration with Fundación ONCE, Elkartu and University of Cambridge. www.mondragon.edu/inklugi

Figure 10 INKLUGI tool, main interface (DBZ-MU, 2016)

The tool allows the design team to introduce the characteristics of a product or service and evaluates how many people are excluded from its use according to the capabilities that it demands.

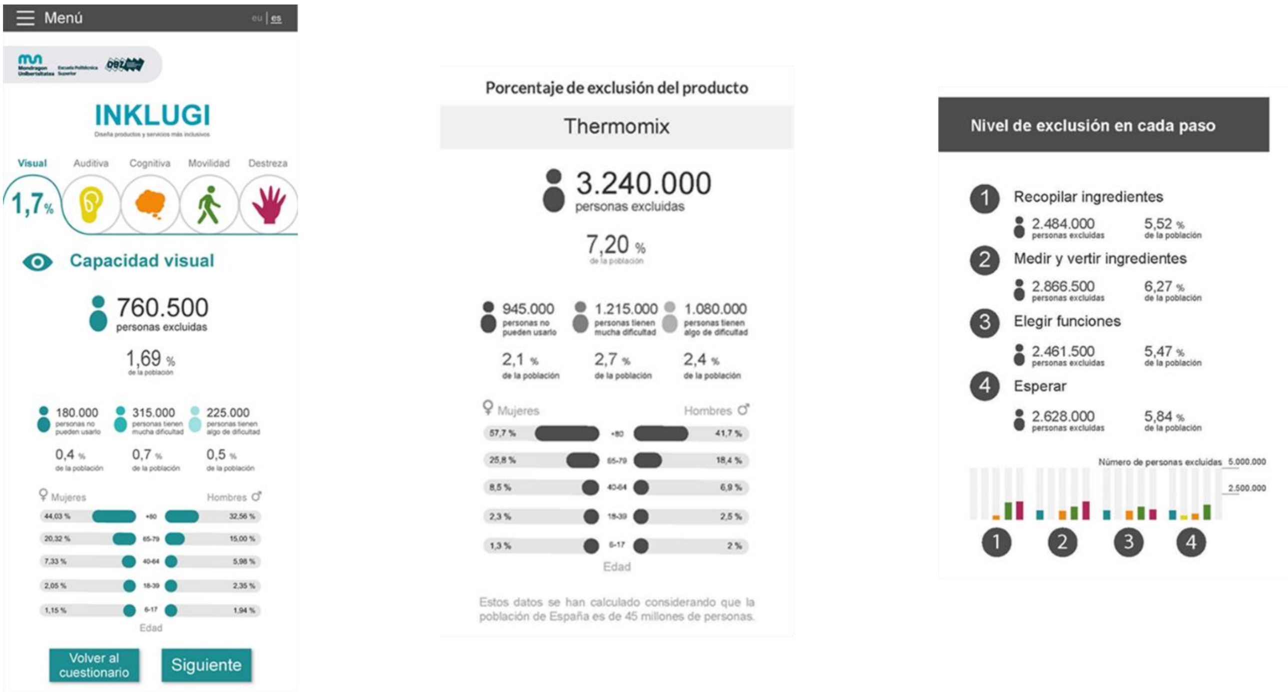

Figure 11 INKLUGI tool visualization of the evaluation results (DBZ-MU, 2016)

The capabilities that are evaluated are vision, hearing, cognitive, mobility and dexterity. This classification responds to the questions defined by the Washington Group Disability Questionnaire from the UN, so the survey EDAD (INE, 2008) has been considered a good data source for this tool.

INKLUDIRE SET OF GUIDELINES

The next tool that has been developed are the INKLUDIRE accessibility guidelines. It is a set of norms and guidelines identified at different levels and distributed according to each capability in order to make it easier to find the right guidelines for a certain product or service. It is a work in progress tool and it is not published yet. Figure 12 shows an overview of the quantity of norms and guidelines that it includes.

Figure 12 INKLUDIRE guidelines overview

EQUIPMENT FOR EMPATHY EXERCISES

In addition, the Design Innovation Center (DBZ_MU) provides the design teams with different tools to enhance empathy towards diversity. Equipment to build empathy include wheelchairs, walkers, crutches, and an ageing simulation kit composed of 6 different glasses simulating glaucoma, retinitis pigmentosa, cataracts and macular degeneration, etc. Harnesses and other fixing materials to simulate mobility impairments, gloves with electric pulses to simulate hands tremor, headphones to simulate deafness and a music device to simulate tinnitus.

In this way, designers can put themselves in someone else's shoes and test how difficult can be to use their products and services if they had a disability. Consequently they can identify the features that need to be improved to make their designs more inclusive.

Figure 13 Empathy equipment

ELDERPERSONAS

Elderpersonas helps to understand the diversity among the elderly, to empathize with them and to guide design teams in decision making. Elderpersonas is currently developed and applied in different case studies related to improve the accessibility in the grocery shopping services.

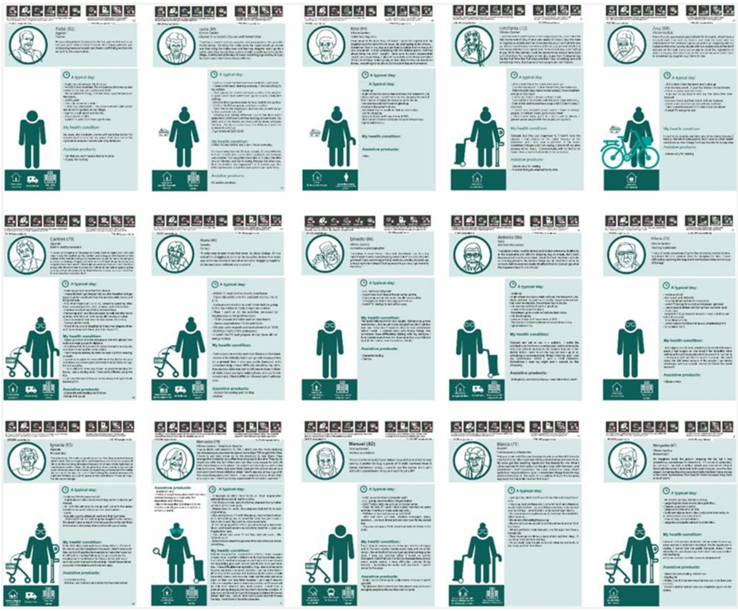

Figure 14 Elderpersonas profiles to understand diversity among elderly people

6. CASE STUDIES AND PROJECTS

In this section the application of inclusive design and accessibility in the industry environment is analysed. A literature review has been performed in order to identify the most relevant projects in this field. The results reflect a lack of knowledge about inclusive design in the industry environment and most of the examples found are oriented to ergonomic, biomechanics and occupational risks assessments.

6.1 CASE STUDIES AND PROJECTS RELATED TO INDUSTRY

Table 6 presents the case studies identified in the literature related to the design of inclusive workplaces and work environments taking into account the ageing workforce. The table summarizes the methods proposed in the different publications, the domains included, referring to the type of body characteristics, capabilities, characteristics of the environment or even protocols analysed, and finally, the sector or field in which these methods or tools have been tested. In the following subsections, their characteristics are described and critically analysed.

Table 6: Selected publications related to the design of inclusive workplaces

Authors	Method/Tool	Domains that are included	Validation sector or field
(Hussain et al., 2016)	*Postural evaluation methods (OWAS y REBA)*	Back, arms, legs, load, rapid changes of posture, unstable postures...	Construction, automotive, agriculture, nursing, poultry farming.
(Gonzalez & Morer, 2016a)	*UCAP*	User, product, activity, context	Knowledge industry
(Gonzalez & Morer, 2016b)	*InWoDG*	Physical, cognitive and emotional aspects of the user; Workplace components; Openness, collectivity, protocols and personalization of the context; Pre, during and post activities	Office
(Case et al., 2015; Marshall et al., 2022; Maurya et al., 2019)	*Digital Human Modeling (DHM)*	3D anthropometric data, work strategies, disability data	Furniture assembly
(Bühler, 2009)	*Ambient Assisted Working (AAW)*	Direct application of sensors, interaction with agents and/or assistance through mobile interface	Office and machinery maintenance
(Afacan, 2015)	*Survey and interviews*	Lighting, acoustic comfort, ergonomics, localization and navigation, air quality, thermal comfort	Office
(da Silva et al., 2022)	*Virtual reality and Digital Human Modeling*	Ergonomic and postural analysis combining virtual reality and digital human modeling	Automotive, aerospace, construction, industrial plants, energy industries, etc.

In the following paragraphs each of the identified methods and tools are briefly described.

Postural assessment methods (Hussain et al., 2016)

The first publication selected presents a model based on postural assessment methods traditionally used in the field of ergonomics. The authors state that people have different physical, psychological and cognitive abilities, and therefore respond differently to physical, psychological and organizational factors related to their occupational risks.

They also argue that older workers prefer jobs with lower workloads, as old age is associated with illness and reduced physical function related to work-related musculoskeletal disorders. However, they also conclude that there is evidence that there is no direct relationship between these disorders and age. Thus, differences between work techniques may also play an important role in the exposure of workers to occupational hazards. For example, they state that women more frequently use their hands above shoulder height, which is considered a risk factor for neck and shoulder injuries.

Quantitative factors such as forced working postures, vibrations and high peak loads and static loads, manual material handling and complex body movements also lead to a higher probability of work-related musculoskeletal disorders. In addition, they point out that in recent years psychosocial risks such as high job stress, dissatisfaction, lack of job control, high work demand, high mental pressure, inadequate support and the perception of an unsafe climate are being given more importance and contribute significantly to worsening musculoskeletal problems.

Thus, they propose two methods of postural analysis. First, the OWAS method describes the working posture in relation to the posture of the back, arms, legs and load. The usefulness of the OWAS method has been validated in numerous work environments, including sectors such as construction, automotive, agriculture, nursing or the poultry industry. This method is able to detect the level of discomfort and risk and to make appropriate recommendations for the improvement of work strategy and workplace design to minimize the risks of musculoskeletal disorders. Secondly, the REBA method is a postural assessment method to evaluate the severity of musculoskeletal risk based on forearms, arms, wrists, trunk, neck, legs and loads, muscle activity caused by static and dynamic postures, rapidly changing or unstable postures, and coupling effects. The REBA method has also proven useful in a wide range of professions.

Each worker adopts significantly different work strategies that affect the risk of musculoskeletal disorders. Highly skilled people adopt safer and more productive work strategies, while the less skilled are more vulnerable to risk factors in their work due to their poor work strategies. Manual load handling is the key area that poses the greatest cause of occupational risk for less skilled workers. Training in load handling strategies would be a useful strategy for promoting safe and productive work practices.

The authors state that both methods are useful in understanding the effect of diversity on safety and productivity at work. However, these methods only consider people's motor abilities, leaving aside the rest of the sensory, cognitive and psychological variables that characterize the aging of people.

Workstation design support tool for the inclusion of senior workers in the knowledge industry (Gonzalez & Morer, 2016a).

In this study Gonzalez and Morer address two global trends: the knowledge work trend and the aging population trend. These trends involve the inclusion of older workers in knowledge-related professions.

They state that there are many tools that contain relevant information but that there is a need to develop more appropriate tools oriented to industrial designers that cover the initial phase of the design process. They propose and develop a theoretical framework called UCAP, a guiding tool for the inclusive design of jobs, products and environments specific to the knowledge domain.

According to the Organization of Economic Co-operation and Development (OECD), knowledge industries are the manufacturing industry, financial services, business services, telecommunications, education and health services. In this knowledge sector, cognitive and emotional skills are very significant, while physical-sensory skills remain in the background. The need to accommodate the physical-sensory capabilities of older people in the knowledge industry makes the problem of ergonomics in terms of adjustments to workplace components more complex and challenging and affects workers of all ages.

New trends such as the growing demand for knowledge workers and mobility have brought about open and shared spaces where several people work simultaneously and have led to the emergence of activity-based workplaces, where several people share the same workstation in shifts. These trends add complexity to the problem of matching the components of a job to the needs of each individual. The authors note that the inclusion of older workers in jobs designed for younger people comes at a human cost and also affects the productivity and well-being of the workers and becomes a cost to the organization for which they work.

González and Morer conclude that it is necessary to create new tools to carry out more inclusive designs, because although design teams are motivated and committed to creating inclusive products, they often lack sufficient knowledge and experience in this area. They need specific methods, tools and criteria. Tools that address sensory aspects, techniques that address physical and cognitive aspects often fail because they are not user-friendly, visual, flexible, open, and pragmatic in representing and comparing the vision of designers and users.

The design of the new UCAP tool, proposed by Gonzalez and Morer, offers a new way to connect ergonomics research with designers' knowledge for the benefit of knowledge workers and makes possible the inclusion of older workers in the knowledge industry. It includes four categories of information: a) ergonomics and new human factors such as self-esteem, self-actualization and belonging, through transgenerational design which is inclusive design covering age-related changes, b) consideration of other agents: users, buyers, beneficiaries, external, c) systemic vision: user, context, activity and product and d) designers' needs throughout the design process: user-friendly, visual, flexible, open and pragmatic tools.

A priori this method seems more complete in terms of the domains it covers, but its level of development and scope of application is limited, since it presents only a theoretical framework applied to knowledge industries.

Ambient Intelligence in work environments (Bühler, 2009)

Ambient intelligence (AmI) has been adopted in the living environment and has been termed Ambient Assisted Living (AAL) offering positive care and support solutions for the elderly in the home. Bühler proposes that this approach may have an important field of application related to work. He argues that working people, while developing increased experience and skills over time, also need a tailored support system to maintain efficiency and effectiveness and elements of prevention and adjustment to address changes in their abilities.

Traditionally, only when a person with a disability joined the workforce was job accommodation considered. This reactive strategy is obsolete as today the entire infrastructure must be considered beforehand to make a workplace accessible. Ambient Assisted Work (AAW) offers a flexible approach to adapting workplaces for all people, including people with disabilities and the elderly in the workforce, from the design stage.

Búhler notes that industrial and work environments offer a high degree of infrastructure for networking and computational work, often much more so than private environments. Systems for access control, time optimization, process control, technological automation, asset traceability, work planning and tracking and computer-aided work, maintenance, etc. that combined with the company intranet can provide the basis for an advanced ambient intelligence (AmI) infrastructure with the potential to create a very flexible and supportive work environment for all people. The basis of ambient intelligence is that all systems are connected and intelligent sensors and actuators are able to exchange information to create a flexible and intelligent environment. Interaction with the working person can be done in several ways: through direct application of sensors and interaction with agents and/or operate through mobile interfaces.

Bühler present two hypothetical cases where AAW could be applied: a specific specialist working in an office environment and a person performing maintenance tasks in a workshop environment.

In the first case, intranet, biometric electronic access control systems, accessible workstations and accessible dynamic orientation, individualized software environment in the respective workstation, personalized mobile device, detection and support for people with memory loss through interaction patterns using intranet or personal coach that helps them to resume work would be used. Also a health telemonitoring device, warnings, alarms and immediate emergency support, sending queries to similar people to learn from each other and access to a shared database or wiki with previous solutions where experiences and adapted information from other people with the same disability are shared.

In the second case, a PDA-based maintenance support system would be used to guide the professional in a dynamic way, showing the necessary materials and tools, the location of the machine that needs maintenance. The PDA would indicate the safety measures and environment settings required to perform the task. Each step would be presented only after successful completion of the previous one. In case of specific problems, assistance would be offered via two-way video. Even people with learning-related disabilities could be enabled with such an interactive support system, for example, in the maintenance of printers and photocopiers.

Bühler argues that the basis of AAW can and should be implemented in the ambient intelligence infrastructure from the early stages of the design of work environments as it can support the needs of very different people and can help create work environments for all. However, their approach is hypothetical and has not been empirically validated.

Digital human modelling and the aging workforce (Case et al., 2015; Marshall et al., 2022; Maurya et al., 2019).

Case's team and Marshall's team recognize that age brings many positives, from increased experience, wisdom, loyalty, and motivation, but also recognize its inevitable consequences such as loss of skills, strength, mobility, vision, and hearing. They note that older workers are very different in terms of their physical, physiological and cognitive abilities and this affects job performance.

They further argue that work environments require the highest levels of productivity and the challenge of including older working people they raise as an important aspect of Inclusive Design and propose Digital Human Modelling (DHM) as a potentially useful method for implementation. They state that the assessment of occupational risks through the DHM method has been successful through ergonomic assessment based on virtual postures, however, Marshall et al. add that other aspects such as behaviour or comfort are underestimated.

Case et al. suggest the use of virtual environments to analyse the validity of a work strategy based on real data on older people's abilities. They present a case study in a furniture manufacturing company where assembly line workers were recorded to capture the variety of work strategies, methods, and procedures they used. They also used the SAMMIE tool to model the work environments including the sofas, tools used in assembly and other relevant elements. The selected postures were replicated by models representing 31 older people in SAMMIE developed by defining different anthropometric and ability data. It is verified how some of the people can complete the assembly using one of the strategies, but have problems in the rest of the working strategies. This allows them to promote the most appropriate practices for their templates, for example, for older people.

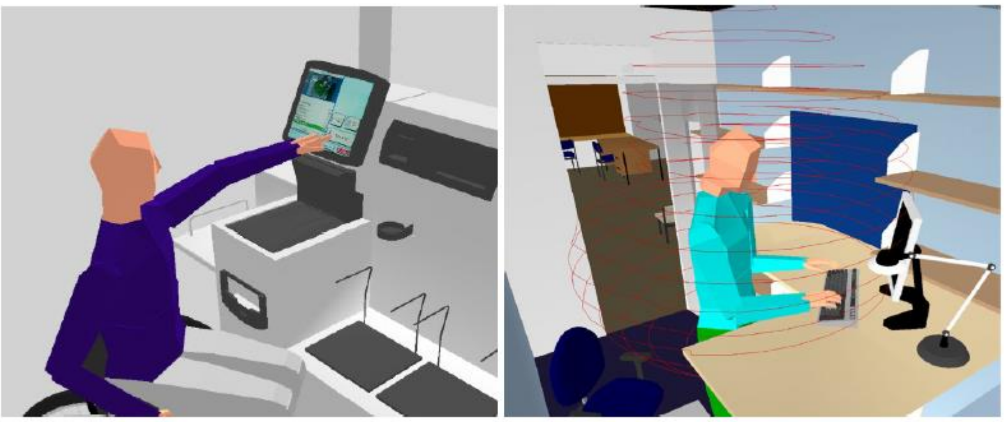

Figure 15 Digital human modelling (Marshall et al., 2022)

They argue that the usefulness of DHM underscores the importance of having more realistic data on human capabilities. In addition, Marshall et al. argue that DHM users should familiarize themselves with the tasks to be assessed and collect first-hand information by conducting tests with real people interacting with such products. They stress that it is important to keep in mind that the DHM provides information on what is possible or likely to happen in a given interaction, but generally does not provide findings as to what should happen to make that interaction more inclusive and comfortable. In addition, they warn about the risk of creating assessments that assume that all people act in the "right" way, whereas in reality other factors such as time, minimal effort or habits may play a role.

Recommendations for sustainable office environments (Afacan, 2015).

In this case Afacan develops a survey and a series of interviews among senior working people from three different companies. The aim of its study is to identify the factors that make sustainable buildings also inclusive environments for senior workers. He manages to identify six main factors that he says are interrelated and can significantly influence the productivity and well-being of older people.

The factors identified are: lighting, acoustic comfort, ergonomics, location and navigation, air quality, and thermal comfort. It describes the particularities that people develop with respect to these factors as they grow older.

This approach underlines that it is necessary to encompass a wide range of variables when assessing the Inclusive Design of work environments.

Virtual Reality and Digital Human Modelling (da Silva et al., 2022).

Da Silva's team discusses the combination of virtual reality and digital human modelling for ergonomic assessments in industrial product development. They observe an exponential development of patents and new technologies by major technology players such as Microsoft, Apple, Intel, Facebook, IBM and Bytedance. New technologies and devices with numerous potential applications.

Figure 16 Virtual Reality and Digital Human Modelling (da Silva et al., 2022)

The combination of virtual reality and digital human modelling makes it possible to evaluate ergonomic aspects dynamically by interacting virtual people with virtual environments performing different tasks. This would make it possible to include variables such as the behaviour or adaptation strategies of people as they experience a deterioration in their abilities, something that has not been implemented to date. On the other hand, they present numerous applications of this combination in sectors as diverse as the automotive, aerospace, energy, construction, etc. industries. However, they do not focus on the inclusion of people with disabilities or the elderly.

This approach has great potential for development. However, it still requires improvements in its application. On the one hand, digital human models require further development to capture the existing diversity, which would imply the need for more data collection or the recording of several real users performing these tasks. On the other hand, virtual environments are generally based on already implemented equipment and spaces, i.e., it would be convenient to use the combination of virtual reality and digital human modelling also in the initial phases of the design of working environments.

Conclusions from the literature review

The main conclusion extracted from the analysis of the literature related to the design of inclusive workplaces is that there is a lack of knowledge about inclusive design in the industry environment and that most of the examples found are oriented to ergonomic, biomechanics and occupational risks assessments. In addition, no model is identified that covers all the variables that characterize aging. There is a lack of anthropometric and biomechanical data in general and especially for people with disabilities or older people. It is necessary to include other variables that characterize aging, including adaptive work strategies and those variables may differ depending on the sector or field of work. Thus, there is a need for new lines of research to address the challenge of the aging workforce from the approach of Inclusive Design and accessibility of products, services and environments.

7. GUIDELINES

In this section a summary of the main guidelines on accessibility and ethics applied to robotics are presented. Robots are complex systems that integrate different technologies and types of interfaces. For this reason, and because of their increasing adoption in the world of industry as a collaborative agent with employees, the accessibility guidelines identified in the field of human-robot interaction are presented.

7.1 ACCESSIBILITY GUIDELINES

The following guidelines are implemented based on accepted accessibility guidelines, standards and recommendations in Human-Computer Interaction, such as, WCAG 2.0, BBC, FUNKA NU, IBM, WAI-ARIA, and PUX [1-6]. The guidelines can be used by developers and designers of social assistive robots, where the context of use is one user interacts with one robot. Table 7 present the summary of accepted accessibility guidelines. Then, each guideline is explained in detail.

Table 7: Summary of the accessibility guidelines

Perceivable **1. Multiple modalities for interaction** **2. Color and contrast** **3. Location of hardware and software components** **4. Alternatives for non-text element** **5. Blinking components** **6. Flashing visual content** **7. Displays** **8. Assistive technology and web interfaces**	**Understandable** **13. Predictable interaction** **14. Errors, help and feedback** **15. Natural voice** **16. Displays**
Operable **9. Hardware controls and physical operation** **10. Keys, Keyboards and Keypads** **11. Navigating on displays** **12. Time**	**General** **17. Adopting user's interaction preferences** **18. Reachable human support**

Perceivable

1. **Multiple modalities for interaction**
   User can operate the robot using different channels for input and output.
   a) Provide multiple modalities for interaction. For example: users with visual disabilities can operate the robot using keyboard or voice, users with hearing or speech disabilities can operate the robot using alternatives to speech input, or people who are tetraplegic can use vocal input, among others.
   b) Verify that all functions are accessible via keyboard, virtual keyboard, mouse, tactile displays, voice (Automatic Speech Recognition and Text To Speech techniques) or gestures (according the interaction modalities chosen).
2. **Color and contrast**
   Color is not the only way to distinguish keys, controls and labels or to convey information, and it is easy to distinguish foreground from the background.
   a) Make sure that color is not the only way to indicate hardware controls, keys and labels of the robot. This also applies to software widgets (buttons, labels, etc.) or for information displayed on the robot. For example: providing different visual means, such as, different shapes for hardware keys and controls, and text to describe the function of software components and widgets (buttons, labels, etc.) on the robot's display.
   b) Careful use of luminosity, contrast, and background audio. For example: text or diagrams, and their background, have a luminosity contrast ratio of at least 5:1; a mechanism is available to turn off background audio that plays automatically, without requiring the user to turn off all audio; text or diagrams, and their background, have a luminosity contrast ratio of at least 10:1; audio content does not contain background sounds, background sounds can be turned off, or background sounds are at least 20 decibels lower than the foreground audio content, with the exception of occasional sound effects.
3. **Location of hardware and software components**
   User can easily perceive and access robot's interfaces (hardware and software) components.
   a) Make sure the display of visual information is visible to people who are of short stature or seated in wheelchairs. Place interface components in a perceivable and accessible place, for example, place hardware buttons in the middle of robot's body.
   b) Design consistently, and group related elements together. For example, place software buttons and links horizontally, vertically or on a grid, and important objects at the top of the interface and the less important objects at the bottom.
   c) Avoid unnecessary information and objects. Use images only when necessary. Use short, descriptive headings to structure the information. Avoid abbreviations.
4. **Alternatives for non-text element**
   All non-text interface elements on robot's display and all spoken information must have accompanying text or synchronized alternatives for multimedia elements.
   a) Provide captions, description or labels for all non- text interface elements.
   b) For prerecorded and live multimedia, provide captions, audio descriptions, or sign language. For robot voice, provide text or sign language. Make sure that: If the purpose of

non-text content is to confirm that content is being operated by a person rather than a computer, different forms are provided to accommodate multiple disabilities; If non-text content is pure decoration, or used only for visual formatting, or if it is not presented to users, it is implemented such that it can be ignored by assistive technology; Captions, audio descriptions or sign language interpretation are provided for prerecorded or live multimedia.

5. **Blinking components**

For any blinking component on robot's interface (lights, display contents, etc.) the blinking stops after a certain period, or can be switched off by user.

Provide a mechanism to allow user to stop blinking, or specified the blinking times for the content to be a fixed number. Some guidelines recommend that content does not blink for more than three seconds.

6. **Flashing visual content**

Avoid flashing components on the robot's interface that are known to cause seizures.

Any flashing component should not exceed three flashes in one second. Red flash should be avoided.

7. **Displays**

Separation of content and presentation.

a) Make sure presentation and structure of the content is determined programmatically in code, so it can be rendered appropriately on different devices and for different audiences.

b) The meaning of colored information should also be clear without color through the context for example.

c) Do not rely on shape, size, location or color to represent the meaning of user interaction elements. Add a text label as well.

Large clickable areas, icons and objects on the interface are familiar and should appear clickable.

Use familiar icons, and design objects with clickable appearance and large clickable areas. Do not invent your own versions of standard icons. Use the appearance that the user has a chance of recognising from previous use.

User can invert the screen contrast (dark text on a light background, and vice versa).

Provide a setting for invert colors or contrast.

User can change font type and size, and zoom in or out on the interface.

a) Provide a setting for change font type and size within a minimum text size.

b) Make sure user can zoom the interface up to 200%.

8. **Assistive technology and web interfaces**

User can use assistive technology to interact with the robot, such as screen reader, braille keyboards, etc.

For web interfaces:

a) Design accessible patterns and widgets based on WAI-ARIA, by defining roles, properties and states of the widgets in the code. For example: in the code, mark-up is used to describe the type of the widgets, such as "button" or "tree item". Moreover, the developer can describe the state of the widgets using properties, such as "checked" for check boxes.

b) Identify the organization and structure of a web page by using ARIA landmark roles in the code, such as headings and regions.

c) Provide keyboard navigation in the code based on WIA-ARIA for UI objects and events. For example: when the focus is on a closed node in a tree view widget, then the Right arrow opens the node without moving the focus.

For hardware:

d) Provide industry standard ports for alternate input and output device, e.g., assistive tools.

Operable

9. **Hardware controls and physical operation**

   User can operate all hardware and physical controls with one hand and minimum dexterity

   Design the input devices, such as, keyboards, remote controls (including the joysticks, buttons, etc.) so the user can operate them with one hand and minimum dexterity. For example: provide extra-large buttons which are easy to press, with non-slip texture.

10. **Keys, Keyboards and Keypads**

    User can verify the status of locking or toggle keys visually, through touch or sound, or tactically.

    Provide visual, auditory or tactile feedback to verify the status of locking or toggle keys. For example: use a small light for visual feedback, e.g., Caps Lock. A binary position, e.g., depressed, not depressed for the tactile feedback.

11. **Navigating on displays**

    Facilitate navigation process while interacting with robot's display.

    Provide methods that help the user to navigate, find content and determine where s/he is in a structure. For example: enable the user to bypass the repeated content viewed on robots' display, and provide descriptive titles, headings and labels for any content on the page.

12. **Time**

    Time does not affect users' ability to finish any interactive task with the robot, s/he has started.

    Allow user to control the time limits, turn off, adjust or extend the time limit, except when time is an essential part of activity or real-time event.

Understandable

13. **Predictable interaction**

    Interaction with the robot is consistent and predictable.

    a) Use a simple and familiar interaction and navigation mechanism.

    b) A change in operation of the robot should preferably be initiated by the user.

14. **Errors, help and feedback**

    User can review and correct interaction information before submitting, this can avoid errors. User can at all times query what the robot the doing or processing.

    a) Provide a clear mechanism controlling the robot and reviewing commands before execution. For example: give the user options to fill the required field (checkboxes, radioboxes, etc.), and provide a mechanism, a button control for example, where the user can press it after filling the required fields.

    b) Design robot's system to detect and explain errors to the user, and where possible explain how to correct them. For example: if the user makes an error during the interaction with the robot, provide the user with error messages that can be expressed through the multichannel output and considering the user-selected interaction model, and allow him/ her to check and reconfirm the submitted interaction information.

c) Inform the user about progress status during their interacting with the robot.

15. Natural voice

Robot's voice should be clear and natural, user can choose robot's voice s/he prefers, and adjust/ set the voice volume.

a) Provide the robot with a set of different clear and appropriate voices and allow user to choose the voice that matches his/her hearing abilities or preferences.

b) Where possible, allow the user to select a preferred voice accent.

c) Provide a mechanism to allow user to adjust the robots' voice volume.

16. Displays

Predictable UI components and functionality.

Use familiar user interface components and widgets. For example: use the integrated objects that is contained in the operating system instead of implementing new components with the same functionality. For example, use the PLAY ▶ symbol instead of designed a new symbol.

(Readability) Text on the robot's display should be legible for user.

a) Provide additional information for unusual words or phrases, avoid the use of abbreviations.

b) Make sure the line length does not exceed 70 characters.

c) If necessary, identify a specific pronunciation of words to give them the correct meaning.

d) Ensure the readability of all text

General

17. Adopting user's interaction preferences

User adjusts/sets the interaction settings of the robot, preferences are stored.

Design the robot to adopt to and store the users' interaction abilities, preferences and settings. For example: adapting the mode of interaction or the robot's voice volume and font size to the user's preference.

18. Reachable Human support

User can easily ask for human help or support.

Design the robot with a mechanism for calling human support or help. For example: a robot is used as a medical assistant in a hospital, at any time while interacting with the robot, patients can call the doctor/nurse by pressing a button on the robot's display.

7.2 ETHICS

In 2020 the European Parliament proposed a framework of ethical aspects of artificial intelligence, robotics and related technologies where they describe the particular aspects related to different sectors and they define a process to apply the ethical principles to different areas.

The world's first explicit standard in robotics is BS8611 *Guide to the Ethical Design and Application of Robots and Robotic Systems*, wich was published in April 2016. BS8611 guides on how designers can undertake an ethical risk assessment of their robot or system, and mitigate any ethical risks so identified. At its heart is a set of 20 distinct ethical hazards and risks, grouped under four categories: societal, application, commercial & financial, and environmental. Advice on measures to mitigate the impact of each risk is a powerful new addition to the ethical roboticist's toolkit.

In this section, firstly, an example of ethical risk assessment is presented. Secondly, the particular aspects related to the sector of employment, workers' rights, digital skills and the workplace are summarized. After that, the explanation of the main ethical principles is provided and the articles 6 to 14 of the proposed regulation are explained.

DEFINITION

BS8611 defines an ethical risk as the "probability of ethical harm occurring from the frequency and severity of exposure to a hazard"; an ethical hazard as "a potential source of ethical harm", and an ethical harm as "anything likely to compromise psychological and/or societal and environmental well-being".

EXAMPLE

RoboTED: a case study in Ethical Risk Assessment

The tables below summarise the ERA of RoboTED for (1) psychological, (2) privacy & transparency and (3) environmental risks. Each table has 4 columns, for the hazard, risk, level of risk (H=high, M=medium or L=low) and actions to mitigate the risk.

Table 8: Ethical Risk Assessment (Winfield and Winkle, 2020)

Hazard	Risk		Mitigation
Addiction	Child plays with RoboTed obsessively and neglects family	M	Explore "RoboTed needs to sleep" function
Deception (of child)	Child believes that RoboTed has feelings (for her)	M	Design chatbot to avoid language that suggests feelings
Over trusting (by parents)	Parents come to rely on the child minder function	H	Remove the child minder function
The Uncanny Valley	Child becomes fearful of robot	L	Use "cartoon" voice; engage children in early user trials
Weak security	Malicious hackers gain access to RoboTed's sensors & control functions.	H	Implement strong encryption together with best practice password protection.
Privacy	Personal data, including images and voice recordings of child are stolen.	M	Put in place auditable measures to ensure personal data is deleted immediately.
Lack of transparency	Lack of data logs makes it hard or impossible to investigate accidents.	H	Build a secure local data logger into RoboTed.
Sustainability (of materials)	Robot uses unsustainable or high carbon cost materials.	M	Use materials (e.g. RoboTed's fur) from sustainable sources, avoiding plastics.
Unrepairability	Robot's lifetime is limited because faults cannot be repaired or parts replaced.	M	Design for ease of repair with replaceable parts – especially battery.
Unrecyclability	End of life robots are dumped in land fill.	M	Design for ease of recycling parts and materials.

6.2.1. Ethical aspects related to the sector of employment, workers' rights, digital skills and the workplace

The most interesting points described by the European Parliament in the framework of ethical aspects of artificial intelligence, robotics and related technologies are listed below. The sentences directly related to the scope of EARASHI project are highlighted in bold characters.

109. Notes that the application of artificial intelligence, robotics and related technologies in the workplace can contribute to inclusive labour markets and impact occupational health and safety, while it can also be used to monitor, evaluate, predict and guide the performance of workers with direct and indirect consequences for their careers; whereas AI should have a positive impact on working conditions and be guided by respect for human rights as well as the fundamental rights and values of the Union; whereas **AI should be human centric, enhance the well-being of people and society and contribute to a fair and just transition; such technologies should therefore have a positive impact on working conditions guided by respect for human rights as well as the fundamental rights and values of the Union;**

110. Highlights the need for competence development through training and education for workers and their representatives with regard to AI in the workplace to better understand the implications of AI solutions; stresses that **applicants and workers should be duly informed in writing when AI is used in the course of recruitment procedures and other human resource decisions and how in this case a human review can be requested in order to have an automated decision reversed**;

111. Stresses the need to ensure that productivity gains due to the development and use of AI and robotics do not only benefit company owners and shareholders, but also profit companies and the workforce, through better working and employment conditions, including wages, economic growth and development, and also serve society at large, especially where such gains come at the expense of jobs; calls on the Member States to carefully study the potential impact of AI on the labour market and social security systems and to develop strategies as to how to ensure long-term stability by reforming taxes and contributions as well as other measures in the event of smaller public revenues;

112. Underlines the importance of corporate investment in **formal and informal training and life-long learning in order to support the just transition towards the digital economy**; stresses in this context that companies deploying AI have the responsibility of **providing adequate re-skilling and up-skilling for all employees concerned, in order for them to learn how to use digital tools and to work with co-bots and other new technologies,** thereby adapting to changing needs of the labour market and staying in employment;

113. Considers that **special attention should be paid to new forms of work, such as gig and platform work, resulting from the application of new technologies** in this context; stresses that regulating telework conditions across the Union and ensuring decent working and employment conditions in the digital economy must likewise take the impact of AI into account; calls on the Commission to consult with social partners, AI-developers, researchers and other stakeholders in this regard;

114. Underlines that artificial intelligence, robotics and related technologies must not in any way affect the exercise of fundamental rights as recognised in the Member States and at Union level, including the right or freedom to strike or to take other action covered by the specific industrial relations systems in Member States, in accordance with national law and/or practice, or affect the right to negotiate, to conclude and enforce collective agreements, or to take collective action in accordance with national law and/or practice;

115. Reiterates the importance of **education and continuous learning to develop the qualifications necessary in the digital age and to tackle digital exclusion**; **calls on the Member States to invest in high quality, responsive and inclusive education, vocational training and life-long learning systems as well as re-skilling and up-skilling policies for workers in sectors that are potentially severely affected by AI**; highlights the need to provide the current and future workforce **with the necessary literacy, numeracy and digital skills as well as competences in science, technology, engineering and mathematics (STEM) and cross-cutting soft skills, such as critical thinking, creativity and entrepreneurship**; underlines that **special attention must be paid to the inclusion of disadvantaged groups** in this regard;

116. **Recalls that artificial intelligence, robotics and related technologies used at the workplace must be accessible for all, based on the design for all principle**;

6.2.2. Ethical principles of artificial intelligence, robotics and related technologies

1. Any artificial intelligence, robotics and related technologies, including software, algorithms and data used or produced by such technologies, **shall be developed, deployed and used** in the Union in accordance with Union law and **in full respect of human dignity, autonomy and safety and other fundamental rights** set out in the Charter.

2. **Any processing of personal data** carried out in the development, deployment and use of artificial intelligence, robotics and related technologies, including personal data derived from non-personal data and biometric data, **shall be carried out in accordance with Regulation** (EU) 2016/679 and Directive 2002/58/EC.

3. The Union and its Member States shall **encourage research projects** intended to provide solutions, based on artificial intelligence, robotics and related technologies, **that seek to promote social inclusion, democracy, plurality, solidarity, fairness, equality and cooperation.**

Human-centric and human-made artificial intelligence

1. Any artificial high-risk technologies, including software, algorithms and data used or produced by such technologies, shall be developed, deployed and used in a manner that **guarantees full human oversight at any time.**

2. The technologies referred to paragraph 1 shall be developed, deployed and used in a manner that **allows full human control to be regained when needed**, including through the altering or halting of those technologies.

Safety, transparency and accountability

1. Any high-risk artificial intelligence, robotics and related technologies, including software, algorithms and data used or produced by such technologies, **shall be developed, deployed and used in a manner that ensures:**

(a) **an adequate level of security** by adhering to minimum cybersecurity baselines proportionate to identified risk, and one that prevents any technical vulnerabilities from being exploited for malicious or unlawful purposes;

(b) there are safeguards that **include a fall-back plan and action in case of a safety or security risk**;

(c) **a reliable performance as reasonably expected by the user** regarding reaching the aims and carrying out the activities they have been conceived for, including by ensuring that all operations are reproducible;

(d) that the performance of the aims and activities of the particular technologies **is accurate**; if occasional inaccuracies cannot be avoided, the system **shall indicate**, to the extent possible, **the likeliness of errors and inaccuracies to deployers and users** through appropriate means;

(e) an easily explainable manner so as to **ensure that there can be a review of the technical processes of the technologies**;

(f) that **they inform users that they are interacting with artificial intelligence systems**, duly and comprehensively disclosing their capabilities, accuracy and limitations to artificial intelligence developers, deployers and users;

(g) that makes it possible, in the event of non-compliance with the safety features set out in subparagraphs (a) to (g), for the functionalities concerned **to be temporarily disabled and to revert to a previous state restoring safe functionalities.**

2. In accordance with Article 6(1), the technologies mentioned in paragraph 1 of this Article, including software, algorithms and data used or produced by such technologies, **shall be developed, deployed and used in transparent and traceable manner so that their elements, processes and phases are documented** to the highest possible and applicable standards, and that it is possible for the national supervisory authorities referred to in Article 18 **to assess the compliance of such technologies with the obligations** laid down in this Regulation. In particular, the developer, deployer or user of those technologies shall be responsible for, and be able to demonstrate, compliance with the safety features set out in paragraph 1.

3. The developer, deployer or user of the technologies mentioned in paragraph 1 shall **ensure that the measures taken to ensure compliance with the safety features** set out in paragraph 1 **can be audited by the national supervisory authorities** referred to in Article 18 or, where applicable, other national or European sectorial supervisory bodies.

Non-bias and non-discrimination

1. Any software, algorithm or data used or produced by high-risk artificial intelligence, robotics and related technologies developed, deployed or used in the Union **shall be unbiased** and, without prejudice to paragraph 2, shall **not discriminate on grounds such as race, gender, sexual orientation, pregnancy, disability, physical or genetic features, age, national minority, ethnicity or social origin, language, religion or belief, political views or civic participation, citizenship, civil or economic status, education, or criminal record.**

2. By way of derogation from paragraph 1, and without prejudice to Union law governing unlawful discrimination, **any differential treatment between persons or groups of persons may be justified only where there is an objective, reasonable and legitimate aim that is both proportionate and necessary** insofar as no alternative exists which would cause less interference with the principle of equal treatment.

Social responsibility and gender equality

Any high-risk artificial intelligence, robotics and related technologies, including software, algorithms and data used or produced by such technologies, developed, deployed and used in the Union shall be developed, deployed and used in compliance with relevant Union law, principles and values, in a manner that **does not**

interfere in elections or contribute to the dissemination of disinformation, respects worker's rights, promotes quality education and digital literacy, does not increase the gender gap by preventing equal opportunities for all and does not disrespect intellectual property rights and any limitations or exceptions thereto.

Environmental sustainability

Any high-risk artificial intelligence, robotics and related technologies, including software, algorithms and data used or produced by such technologies, **shall be assessed as to their environmental sustainability by the national supervisory authorities** referred to in Article 18 or, where applicable, other national or European sectorial supervisory bodies, **ensuring that measures are put in place to mitigate and remedy their general impact as regards natural resources, energy consumption, waste production, the carbon footprint, climate change emergency and environmental degradation** in order to ensure compliance with the applicable Union or national law, as well as any other international environmental commitments the Union has undertaken.

Respect for privacy and protection of personal data

The use and gathering of biometric data for remote identification purposes in public areas, as biometric or facial recognition, carries specific risks for fundamental rights and shall be deployed or used only by Member States' public authorities for substantial public interest purposes. Those authorities shall **ensure that such deployment or use is disclosed to the public, proportionate, targeted and limited to specific objectives and location and restricted in time**, in accordance with Union and national law, in particular Regulation (EU) 2016/679 and Directive 2002/58/EC, **and with due regard for human dignity and autonomy and the fundamental rights** set out in the Charter, namely the rights **to respect for privacy and protection of personal data.**

Right to redress

Any natural or legal person shall have the right to seek redress for injury or harm caused by the development, deployment and use of high-risk artificial intelligence, robotics and related technologies, including software, algorithms and data used or produced by such technologies, in breach of Union law and the obligations set out in this Regulation.

8. BIBLIOGRAPHY

Afacan, Y. (2015). Older Workers and a Sustainable Office Environment. The Design Journal, 18(1), 57–82. https://doi.org/10.2752/175630615X14135446523260

British Standard Institution. (2005). British Standard BS 7000-6:2005 Design Management Systems: Managing inclusive design. Guide, Parte 6. BS 7000-6:2005 Design Management Systems: Managing Inclusive Design. Guide, Parte 6.

British Standard Institution (2016). Guide to the Ethical Design and Application of Robots and Robotic Systems https://standardsdevelopment.bsigroup.com/projects/9021-05777#/section

Bühler, C. (2009). Ambient intelligence in working environments. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 5615 LNCS(PART 2), 143–149. https://doi.org/10.1007/978-3-642-02710-9_17/COVER

Cambridge University. (2010). Inclusive Design Toolkit. http://www.inclusivedesigntoolkit.com/

Case, K., Hussain, A., Marshall, R., Summerskill, S., & Gyi, D. (2015). Digital Human Modelling and the Ageing Workforce. Procedia Manufacturing, 3, 3694–3701. https://doi.org/10.1016/J.PROMFG.2015.07.794

Checklist for Web Content Accessibility Guidelines 2.0. https://www.w3.org/TR/2006/WDWCAG20-20060427/appendixB.html. Accessed 24 Mar 2019

da Silva, A. G., Gomes, M. V. M., & Winkler, I. (2022). Virtual Reality and Digital Human Modeling for Ergonomic Assessment in Industrial Product Development: A Patent and Literature Review. In Applied Sciences (Switzerland) (Vol. 12, Issue 3). MDPI. https://doi.org/10.3390/app12031084

de la Rica, S., Gorjón, L., Martínez de Lafuente, D., Romero, G., & Camper, A. (2022). LIBRO BLANCO DEL EMPLEO EN EUSKADI. https://www.euskadi.eus/contenidos/noticia/libro_blanco_empleo_2013/es_def/adjuntos/Libro-Blanco-del-Empleo-en-Euskadi-ISEAK.pdf

European Commission. (2021). Industry 5.0 - Towards a sustainable, human-centric and resilient European industry. https://doi.org/https://data.europa.eu/doi/10.2777/308407

European Commission (2023). European accessibility act. https://ec.europa.eu/social/main.jsp?catId=1202#:~:text=The%20European%20accessibility%20act%20is,EU%20leading%20to%20costs%20reduction

European Parliament (2020). Framework of ethical aspects of artificial intelligence, robotics and related technologies. https://www.europarl.europa.eu/doceo/document/TA-9-2020-0275_EN.html

Fundación ADECCO. (2022). Tu edad es un tesoro 2022. https://fundacionadecco.org/wp-content/uploads/2022/06/TuEdadEsUnTesoro-2022.pdf

Future Media Standards & Guidelines - Accessibility Guidelines v2.0. http://www.bbc.co.uk/guidelines/futuremedia/accessibility/html/. Accessed 24 Mar 2019

Gonzalez, I., & Morer, • P. (2016a). Developing a workstation design assistance tool for older knowledge workforce inclusion. Universal Access in the Information Society, 16. https://doi.org/10.1007/s10209-016-0507-7

Gonzalez, I., & Morer, P. (2016b). Ergonomics for the inclusion of older workers in the knowledge workforce and a guidance tool for designers. Applied Ergonomics, 53, 131–142. https://doi.org/10.1016/J.APERGO.2015.09.002

Hussain, A., Case, K., Marshall, R., & Summerskill, S. (2016). Using Ergonomic Risk Assessment Methods for Designing Inclusive Work Practices. Human Factors in Ergonomics & Manufacturing, 26(3), 337–355. https://doi.org/10.1002/HFM.20650

IBM Human Ability and Accessibility Center | Developer Guidelines | Hardware Checklist. https://www.ibm.com/able/guidelines/hardware/accesshardware.html. Accessed 24 Mar 2019

INE. (2008). Encuesta sobre Discapacidad EDAD 2008, 1989, 1–52. Retrieved from http://www.ine.es/daco/daco42/discapa/edad_dis.pdf

INE. (2022). Encuesta de Población Activa (EPA) y Estadística de Flujos de la Población Activa (EFPA).

Instituto Nacional de Estadística. (2022a). Encuesta sobre Equipamiento y Uso de Tecnologías de Información y Comunicación (TIC) en los Hogares. In INE.

Instituto Nacional de Estadística. (2022b). Encuesta sobre Discapacidad, Autonomía y situaciones de Dependencia EDAD 2020. https://www.ine.es/prensa/edad_2020_p.pdf

Jones, H., Schiebinger, L., Grimes, A., & Small, A. (2021). Intersectional Design Cards – Explore, analyze and invent inclusive design solutions. https://intersectionaldesign.com/

Marshall, R., Brolin, E., Summerskill, S., & Högberg, D. (2022). Digital Human Modelling: Inclusive Design and the Ageing Population. In Studies in Computational Intelligence (Vol. 1011, pp. 73–96). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-981-16-8488-3_5

Maurya, C. M., Karmakar, S., & Das, A. K. (2019). Digital human modeling (DHM) for improving work environment for specially-abled and elderly. In SN Applied Sciences (Vol. 1, Issue 11). Springer Nature. https://doi.org/10.1007/s42452-019-1399-y

Microsoft. (2021). Microsoft Design. Retrieved February 5, 2022, from https://www.microsoft.com/design/inclusive/

Mobile guidelines. https://www.funka.com/en/our-assignments/research-and-innovation/ archive—research-projects/mobile-guidelines/. Accessed 16 Mar 2019

PUX Recommendations and Lessons Learned. https://gpii.eu/pux/guidelines/PUX-Recommendations.V1.pdf. Accessed 24 Mar 2019

SEGG. (2017). Últimas notas de prensa y comunicaciones noviembre de 2017 publicadas por la SEGG. Retrieved January 25, 2022, from https://www.segg.es/actualidad-segg/notas-de-prensa/todo/noviembre/2017/0

Stanford University. (2009). Gendered Innovations | Stanford University. https://genderedinnovations.stanford.edu/

The Center for Universal Design. (2002). Universal Design: Product Evaluation Countdown. Raleigh. https://doi.org/800-647-6777

UNESCO. (2022). Recomendación sobre la ética de la inteligencia artificial. https://unesdoc.unesco.org/ark:/48223/pf0000381137_spa

United Nations. (2017). World population prospects: Data booklet 2017 Revision. Population Division. Retrieved from https://population.un.org/wpp/Publications/Files/WPP2017_DataBooklet.pdf

WAI-ARIA Authoring Practices 1.1. https://www.w3.org/TR/wai-aria-practices-1.1/#kbd_generalnav. Accessed 16 Mar 2019

Washington Group on Disability Statistics. (2011). Washington Group - Extended Question Set on Functioning (Version 9 November 2011), (November), 1–11. Retrieved from http://www.cdc.gov/nchs/washington_group.htm.

WHO. (2015). WHO | World report on ageing and health 2015. World Health Organisation. World Health Organization. Retrieved from http://www.who.int/ageing/events/world-report-2015-launch/en/

Winfield et al. (2022). Ethical Risk Assessment for Social Robots: Case Studies in Smart Robot Toys. Intelligent Systems, Control and Automation: Science and Engineering. Volume 102

World Health Organization (WHO). (2003). International Classification of Funcitoning, Disability and Health. Retrieved December 1, 2017, from http://www.who.int/classifications/icf/icfchecklist.pdf?ua=1

World Health Organization. (2015). WHO | World report on ageing and health 2015. World Health Organisation. WHO, Geneva. https://doi.org/10.1016/j.jmgm.2016.10.012

World Health Organization. (2021). Ageing and health. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

World Health Organization. (2021). Decade of healthy ageing: baseline report. (WHO, Ed.). Retrieved from https://www.who.int/publications/i/item/9789240017900

Yanguas Lezaun, J. J. (2021). Pasos hacia una nueva vejez : los grandes retos sociales y emocionales de la madurez. Retrieved from https://www.planetadelibros.com/libro-pasos-hacia-una-nueva-vejez/335774