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Inclusion of Workers with Disabilities in Production 4.0: Legal Foundations in Europe and Potentials Through Worker Assistance Systems

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Received: 21 September 2019; Accepted: 21 October 2019; Published: 28 October 2019

Abstract: The inclusion of employees with disabilities in production is an issue that has rarely been addressed by scientists from the manufacturing sector. In this article, we examine to what extent the trend towards Industry 4.0 offers potential for the inclusion of people with disabilities in Production 4.0. First, we examine relevant legal foundations and restrictions in Europe and in more detail in Austria, Italy, and Norway. Next, based on a literature review, we examine which technological aids in the form of worker assistance systems derived from Industry 4.0 can make jobs in the manufacturing sector accessible for people with disabilities. Three types of assistance systems have been examined: sensorial aid systems, physical aid systems, and cognitive aid systems. In a concluding discussion of the results, we finally summarize the implications on management and policies as well as the potential and limitations of identified worker assistance technologies. On the one hand, the study is intended to draw the attention of researchers and industrial companies to new technological possibilities for the inclusion of people with disabilities in production. On the other hand, difficulties and grievances due to the legal foundations are pointed out to stimulate a critical discussion here as well.

Keywords: workers with disabilities; inclusion; sustainable production; Industry 4.0; assistance systems; social sustainability; reasonable accommodation

1. Introduction

Over the last few years, the industrial environment has been changing radically due to the introduction of concepts and technologies based on the fourth industrial revolution, also known as "Industry 4.0" [1]. This term is inferred from a high-tech strategy project of the German government and was introduced at the Hannover Fair in 2011 [2]. Industry 4.0 aims to implement digitalized, flexible, highly efficient, and automated manufacturing processes [3], usually known from mass production, also in an industrial environment, where individual and customer-specific products are fabricated according to mass customization strategies [4,5]. Despite many fears that Industry 4.0 will lead to machines gradually replacing employees, Industry 4.0 aims much more at a human-centered production in which humans will continue to play an important role in the future [6]. Furthermore, the development of Industry 4.0 provides a contribution to also tackle other challenges—like sustainability, resource, and energy efficiency—and strengthens global competitiveness [2]. Though technological progress

might be predictable to a certain extent, its effect on social impacts and related regulations on an international and national basis is not [7].

In this context, it could be possible that these systems may denote big differences on labor content and work organization in the short term and modify the manner in which the human is taking part and contributing value in industrial value chains [8]. In addition, the current demographic development will inevitably lead to a shortcoming of workers/employees in the industrial sector, which means that many countries and companies are more specifically concerned with new potential sources of labor such as the integration of older employees, a better reconciliation of family and career [9] or the integration of potential skilled workers with a migration background [10].

By looking at the socio-technical system concept, it is not about 'either technology or humans', but more about a coordinated design, which comprises a total socio-technical system. The criterion for definition should always be to use to the fullest capacity the potentialities of the human-oriented design features. In this case the goal is an intersection design whereat the human operator is facilitated by intelligent assistive systems [11]. Such assistance systems do not only offer the possibility to increase the capabilities of workers in the production, but also to create job opportunities for those groups of people, to whom such jobs were not accessible or only with difficulties. In many respects, assistance systems can also be described as systems that can compensate a deficit or shortage of the employee with technological aids. People with disabilities often have difficulties accessing jobs in the production sector, as they cannot carry out work processes due to such deficits, or only with difficulty.

Therefore, the research question we present in this article is: "Can we also use modern assistance systems to enable the inclusion of people with disabilities in the production sector?" The ambitious goal of such a research question would therefore be to find or develop assistance systems through which people with disabilities can become full-fledged operators in production. In the past, there were many preconceptions against people with disabilities in industrial production which are still shared in the modern world. Due to diverse handicaps, people with disabilities could not be fully deployed, although many of them would like to be involved in the daily work routine and could be employed as motivated workers.

The aforementioned research question would lead to the following three positive effects. On the one hand, (1) the satisfaction of people with disabilities could be increased by making them equal employees and this could positively influence their self-esteem and well-being. On the other hand, (2) it would encourage entrepreneurs to create more jobs for people with disabilities in the future, as the hurdle to inclusion decreases and the employee would be able to create a nearly equal contribution to the operating result as his colleagues without disabilities. The third aspect, (3) lies in the current shortcoming of infrastructures for the assisted employment of people with disabilities. The current structures would be less crowded and could take care of people who are currently on the waiting list or who cannot be included in the labor market due to more serious deficits. Overall, this results in an optimized situation for all stakeholders (people with disabilities, employer, government, and society in general).

Based on this research question and the above described assumptions, we want to examine this in more detail in this article. After an introduction into the topic and the problem formulation, in Section 2 we review the theoretical background of Industry 4.0 and its impact on more human-centered production as well as the current situation regarding the inclusion of people with disabilities into the workforce and if new Industry 4.0 technologies may be a problem solver. After the statement of the research question in Section 3, Section 4 summarizes the legal foundations for the inclusion of persons with disabilities in European companies giving a deeper insight into the examples of Norway, Italy, and Austria. Section 5 describes the technological possibilities of worker assistance systems categorizing them into (i) sensorial, (ii) physical, and (iii) cognitive aid systems and examines which assistance systems are suitable to better include disadvantaged persons in production. In Section 6, we critically discuss the potentials and limitations of such technical assistance systems and the implications on management and policies before concluding and giving an outlook for the need of further research in Section 7.

2. Theoretical Background

2.1. Industry 4.0 and Human-Centered Production 4.0

The fourth industrial revolution indicates an increase in quality of industrial production by combining machines, products, and people. This is done by forming a new production system, which enables a more targeted and faster information exchange. By doing so, it moves towards a future, in which a collaboration of robots and people takes place together with the support of intelligent assistive systems and web technology during the performance of the work activities [12]. The anxiety regarding upcoming systems and the related new working conditions are the result of a mistakable comprehension of the human's role in the future manufacturing processes. This does raise the question of how and in which way the role of the worker in Industry 4.0 will change in human-centered Production 4.0 [6]. The term Production 4.0 is based on the phrase Industry 4.0 and represents the production within a manufacturing company which is oriented in the direction of Industry 4.0 relevant topics. Such a human-centered, or also anthropocentric, view on production within Industry 4.0 refers to generally valid concepts already known since the 1980s, where the social presentation of work and technology has been defined as an important way to increase firm performance and on top of that the work and life quality of the operators [13]. In the context of workplace relations, the anthropocentrism angle of view indicates the focus on the human, in our case the worker, as an individual being and not as a random segment of the production [14]. Companies realize that not only economical aspects affect the productivity within the production environment but also the human centered ones [5]. The research linked to human workers within Industry 4.0 goes towards the application of digital information [15] and assistive systems [16] as solutions for the worker in order to better handle the increasing complexity that goes together with the production systems of the future [17]. Worker assistance systems have been classified as one out of five main branches of research related to Industry 4.0 [18].

The anthropocentric approach of production and manufacturing systems describes the social interaction between machine and human in the physical as well as the digital world. This mentioned interaction is subject to a permanently ongoing interpretation and re-interpretation process in terms of the availability of technical standards and current technologies. In each period, its own concepts of the human-machine-relation have been developed, which has led to several own visions of human-centered production. [5]. Today, the technological possibilities (machine/devices) are understood as a 'partner' that improves and supports the capabilities, knowledge, and competences of the human. In Industry 4.0, anthropocentric production is built around an operator, who receives support by assistive systems or machines. According to Romero et al. [19], such worker assistance systems are able to enhance humans' physical, sensorial, and cognitive capabilities. The authors introduce the term 'Operator 4.0' as a skilled and smart operator who performs on the one hand cooperative work together with the robots, but also work aided by machines [20]. The Operator 4.0 is hence the worker of the future. In Romero et al. [20], a proposal for a human-centered architecture is given in order to structure and guide the future, next generation, production systems with the goal to support disabled and aging operators during their performance in a comfortable and efficient way. In this case, the workers get assisted by using supporting systems in an adaptive, intelligent, and dynamic way. The importance of working with persons with disabilities and elderly people was also discussed by Korn et al. in 2014 [21]. According to the authors context-aware assistance systems have become omnipresent in smartphones or cars. This is not the case for industrial working contexts. Context-specific support during the process is rarely offered while there are systems that control work results. As a consequence, operators working in production still have to trust in their expertise and skills. While persons without disabilities may manage this situation, people with disabilities or elderly people need context-sensitive support in production facilities [21].

As mentioned above, Industry 4.0 and the development of new and advanced assistance systems also offer new possibilities and potentials for a better inclusion of employees with disabilities, which will be examined in more detail in this article.

2.2. Inclusion of People With Disabilities Into the Workforce

When talking about inclusion of persons with disabilities in employment there are two main aspects we need to look at: what do we understand by inclusion and what is employment?

Employment refers to paid work, a trade or profession and therefore a specific form of work and doing [22]. Its importance in the life of people is however about more than just payment. The International Labor Organization (ILO) has identified three main motivations for being employed: (i) the need to earn a livelihood, (ii) the enjoyment of social contacts, and (iii) a strengthened self-esteem generated by contributing to society [23]. Realizing the right to employment for persons with disabilities can therefore be seen as one of the core human rights. It is a precondition to ensure their full participation in society, safeguard their equal opportunities in life, and their dignity [24].

While the details of what such a human right to work for persons with disabilities entails, will be discussed in a later part of this article, we need to take a closer look at the concepts of equality and inclusion to understand how to frame the following discussion from a theoretical perspective.

Throughout the history of labor, persons with disabilities were seen as an exception to the rule of having to earn one's living by working. Priestley describes how what he refers to as "administrative segregation" dates back to industrialization and urbanization, when laws dictated that only persons with disabilities were allowed to beg and subsequently were the first recipients of welfare [25]. This stage of exclusion was followed by the establishment of so-called sheltered workshops, where persons with disabilities were offered some structure for their lives and occupation in a segregated setting [26]. The concept of normalization then aimed at making persons with disabilities fit into the norm of the labor market in order to make it possible to integrate them into the existing system. By asking them to adjust instead of looking for how to accommodate their diversity, this approach was highly assimilationist. Only the concept of inclusion looks at the individual and their accommodation needs as part of human diversity and asks the question what is needed so that both the person with a disability and the work environment are catered for [26].

The understanding of equality has developed largely in parallel to the concept of inclusion. Its beginnings can be traced back all the way to Aristotle who set out the principle of treating likes alike and unalike differently in proportion to their unlikeness [27,28]. Accordingly, if a person with a disability could show that they were alike in regard to the relevant criteria, in our case the job requirements, then it would amount to discrimination to exclude them because of their disability. We can see however, how this criterion is again following the logic of the having to fit into the dominant norm, thereby being assimilationist. Therefore, the concept of substantive equality was subsequently developed to address systematic, historical inequalities, thereby introducing a group approach instead of looking only at the individual. It accepts that we need to move beyond the idea of identical treatment and allow for preferential treatment to overcome the barriers society had created so far [29]. One specific version of substantive equality is that of equality of opportunity, which is concerned with ensuring that everybody can compete on an equal basis, from an equal starting point. This understanding led to the introduction of positive measures. Once this equal starting point has been reached, decisions can be made fairly, based on merit [30]. In the context of employment, such measures are often quotas, which will be discussed in Section 4 of this article.

The need for such equality of opportunity measures can be seen when looking at the numbers of persons with disabilities in employment and the situation of those who are not. European Union (EU) wide the last census showed that only 45 percent of persons with disabilities were in employment. As a reaction the EU's Disability Strategy 2010–2020 set employment as one of its priority areas with the goal of increasing the level of participation in employment [31]. A closer look at the legislation and reality of some of the EU's member states is required to gain a better picture of the challenges we face in implementing this goal.

3. Research Question

After examining the scientific literature on new opportunities offered by Industry 4.0 and the inclusion of people with disabilities in the world of work, it can be said that there is a real need for research in this area. In this article, we want to draw attention to this new field of research and also answer the following research questions that are derived from the findings in the previous section:

RQ1: What are the legal foundations and restrictions for including persons with disabilities in European manufacturing companies?

RQ2: What kind of new technologies can support the inclusion of persons with disabilities in production?

RQ3: What are the most promising technologies to achieve this goal?

4. Legal Foundations for the Inclusion of Persons with Disabilities in European Companies

4.1. General Overview in Europe

While the focus of this article is on the European situation in regard to inclusive employment and how it can be facilitated by technology, it is nevertheless important to first look at international law, more specifically the Convention on the Rights of Persons with Disabilities (CRPD). The CRPD has been ratified not only by all member states of the European Union (and Norway) but also by the European Union itself [32]. It therefore binds the policy makers and guides the legal development of the region in terms of the rights of persons with disabilities, whose progress is monitored by the United Nations (UN) via periodic reviews [33].

For the purposes of this research, three articles are of particular importance: Article 5 on equality, Article 9 on accessibility, and Article 27 on employment. The CRPD Committee clarifies in its General Comment on Article 5 that equality—to be understood as substantive equality, as described in Section 1 of this article, even though the General Comment introduces the terminology of 'inclusive equality' —is to be understood as both a right and a principle that guides the interpretation of the entire Convention. The goal of equality is described as having four contents of "(a) a fair redistributive dimension to address socioeconomic disadvantages; (b) a recognition dimension to combat stigma, stereotyping, prejudice and violence and to recognize the dignity of human beings and their intersectionality; (c) a participative dimension to reaffirm the social nature of people as members of social groups and the full recognition of humanity through inclusion in society; and (d) an accommodating dimension to make space for difference as a matter of human dignity" [33] (para. 11). Accessibility in this context is then understood as "a precondition and a means to achieve de facto equality for all persons with disabilities" [34]. (para. 40). It can therefore be seen as part of the tools to achieve the overall goals of equality of opportunities and the recognition of full human dignity of persons with disabilities.

Article 9 on accessibility has to be understood, as outlined by the CRPD Committee, in its entirety as applying to both private and public actors, in regard to the physical environment, transportation, information and communication technologies (ICT), and any services offered to the public [34]. The principle of universal design specifically describes the obligation to ensure that two approaches are abided at the design stage of a product: (1) User-Aware Design: pushing the boundaries of 'mainstream' products, services, and environments to include as many people as possible; (2) Customisable Design: design to minimize the difficulties of adaptation to particular users [35]. Already existing products and services have to be adapted gradually, depending on the country's resources, to ensure they can be accessed by persons with disabilities on an equal basis with others. This approach is therefore to be to understood as an ex ante group approach, making everything as accessible as possible from the outset, without anyone having to request it or having to show a need for it [36].

Even when the standards of universal design are followed, it will still not be possible to foresee and cater for every eventuality. It will therefore always be necessary to have the complementary tool of reasonable accommodation. Reasonable accommodation has been defined as the "necessary and

appropriate modification and adjustments not imposing a disproportionate or undue burden, where needed in a particular case, to ensure to persons with disabilities the enjoyment or exercise on an equal basis with others of all human rights and fundamental freedoms" [33] (Article 2). It is the corresponding individual ex nunc duty to accessibility. It means that—in the context of this article— the employer has to consider the effectiveness of the measure in the specific individual case, while considering the burden it imposes on their specific business, such as the financial costs or disruptions of the work arrangements which have to be measured against the overall benefits of the arrangement, such as broadening the customer base because the increased overall accessibility. The exact accommodation arrangements have to be decided in consultation with the employee in question [37].

Finally, Article 27 of the CRPD sets out the duties of the state parties regarding the right to employment. It clarifies that the right to equal, freely chosen employment opportunities covers every aspect of employment, starting from the recruitment process, covering labor rights, career advancement, and training amongst other things. It reaffirms the duty to provide reasonable accommodation and clarifies that the state parties duty goes beyond a mere anti-discrimination approach and explicitly allows for affirmative action [33] (Article 27).

At the European Union level two acts are of especial importance: The Council Directive 2000/78/EC of 27 November 2000 establishing a general framework for equal treatment in employment and occupation and the Directive (EU) 2019/882 of the European Parliament and of the Council of 17 April 2019 on the accessibility requirements for products and services.

The Framework Directive forbids both direct and indirect discrimination, meaning that not only is it forbidden to give less favourable treatment because of the disability itself (direct discrimination) but also to use a seemingly neutral criterion which negatively affects persons with disabilities disproportionally. It also implements the duty to provide reasonable accommodation into EU law [38].

The Accessibility Act finally entered into force in 2019 after years of drafting and negotiations. It sets out compulsory accessibility requirements for producers, which are also mandatory for member states to abide to in procurement processes. Its focus is however primarily on technology, such as self-service machines or e-commerce to name just two examples. Important other fields, such as the built environment are not regulated by the act, which is considered as one of its main shortcomings, as it can therefore not promote full accessibility of public services [39]. The act focuses on making products of general use accessible, it does not focus on assistive technology specifically for persons with disabilities. Member states have until 2022 to implement the directive in their national law, otherwise it will be directly applicable [30]. As part of the EU's Disability Strategy it aims to target the fragmentation of the market for assistive technology and their high costs for consumers. It however also clarifies that in this field its role is to support and supplement national efforts, in other words a subsidiary competency [40].

4.2. Case Norway

Norway ratified the CRPD in 2013 and received its first Concluding Observations in 2019 [41]. It is not a member state of the European Union but as a member of the European Economic Area bound by the four freedoms of the EU and harmonizes its laws to a large extent with EU legislation, including a voluntary commitment to bring its laws in line with the Employment Equality Directive, amongst others [42].

The main acts relating to employment of persons with disabilities are the Anti-Discrimination and Accessibility Act and the Work Environment Act. The Anti-Discrimination and Accessibility Act states that both a denial of reasonable accommodation and universal design are to be understood as discrimination. It furthermore requires employers to set active steps to promote equality [35]. The Work Environment Act on the other hand regulates health and safety duties of the employer, both in terms of general obligations towards their employees and in terms of reasonable accommodation for individuals. The act covers both permanent and temporary employment. When determining appropriate solutions,

the employer has to consult with the employee, who has a corresponding duty to take part in the process; the local welfare service; and the occupational health service [43]. Finally, the "A More Inclusive Working Life Agreement" (IA Agreement) is a voluntary, tripartite agreement, to which companies can sign up. It aims at achieving three main goals namely to promote the employment of persons with reduced functional abilities, keeping older people in employment, and reducing sick leave and providing reasonable accommodation for the company's employees with a disability [44].

The Norwegian Labor and Welfare Administration is responsible of implementing and overseeing schemes in support of inclusive employment of persons with disabilities [45]. It offers services both for workers and employers, such as the Inclusive Workplace Support Centers which function as a one-stop-shop for work-place related questions by the employer, or a mentoring scheme [46]. Job seekers with disabilities can access both mainstreamed labor market services and disability-specific services, whereby Norway is following the twin-track approach of mainstreaming disability [42,47]. In doing so, Norway is focusing specifically on the group of under 30-year olds, which are a priority when places in programmes are allocated [44]. While this approach is apparently successful in facilitating transition from education into the labor force, it risks leaving those behind that face the intersectional barrier of disability and age.

The Concluding Observations of the CRPD Committee point in a similar direction when noting that the efforts of including persons with disabilities in the open labor market show only limited impact and especially mentions that intersectional inequality remains. It furthermore notices that—despite the aforementioned efforts of the Anti-Discrimination and Accessibility Act—discriminations, including denial of reasonable accommodation, remain [41].

4.3. Case Study: Austria

Austria has ratified the CRPD and received its first Concluding Observations in 2013 [48,49]. When looking at the employment legislation affecting persons with disabilities it is important to note that while employment falls under federal responsibility, social welfare, which covers many aspects of disability, such as personal assistance or workshops for those considered unfit to work, falls under state responsibility, resulting in varying legislations and funding options. The main actors are the Ministry for Social Affairs, the Labor Market Service (federal), and the relevant state agency in charge of disability matters, each providing different funding options and supports [50].

The Disability Recruitment Act sets out a quota of one "disadvantaged employee" per every 25 employees. A fine per person the company fails to employ has to be paid, which then is used for the fund supporting inclusive apprenticeships or reasonable accommodation measures. However, it has been criticized that the quota system does not cover small enterprises, which make up for about 97 percent of the market [50].

Another problem is that certain supports, such as access to the Labor Market Service or access to a certificate as advantaged disabled rely on certain degrees of disability. To get the certificate, a person—which then grants certain rights relating to protection from dismissal amongst others—must have a medical report stating a disability of at least 50 percent. Access to the Labor Market Service—and therefore access to training and unemployment benefits amongst other things—again requires that a person is still medically considered fit to work [51].

Discrimination of persons with disabilities is forbidden by Article 7 of the Austrian Constitution, a rule which is substantiated by the Disability Recruitment Act, which outlines the different types of discrimination and sets out rules for compensation but does not provide for a right to be employed if the recruitment decision was discriminatory [52]. The right to reasonable accommodation is codified in Article 6 of the Disability Recruitment Act. It is the employer's duty to provide reasonable accommodation both when he knows or should know about an employee's disability. The larger the number of employees, the more adjustments can be expected from an employer, without them constituting an undue burden. Jurisdiction has however specified that the employer cannot be

expected to create an entirely new post in the company, tailored to the exact needs of the employee in question [43].

While all three of the aforementioned actors provide certain subsidies, it is mostly the Ministry for Social Affairs that offers funding for making workplaces accessible [52].It offers a subsidy of up to 100 percent for technical work aids and contribution to the costs or provision of goods when new workplaces are created for persons with disabilities or existing workplaces adjusted to make them accessible [53]. However, there is no general right to receive assistive technologies in Austria [54]. It depends on the specific context, in our case employment, where it can be claimed under the right and within the boundaries of reasonable accommodation.

4.4. Case Study: Italy

Italy has ratified the CRPD and received its first Concluding Observations in 2016 [55]. Its anti-discrimination law is mainly based on the EU's equality directives, which were almost directly transformed into national law and not fully harmonized with the wider legal system [56]. The prohibition of discrimination in the workplace on the grounds of disability can be found in Legislative Decree 216/2003. The other law of particular interest in the context of inclusive employment for persons with disabilities is Law 68/1999 on the right to work of persons with disabilities. It sets out several specific measures to promote employment but does not apply to every person with a disability, but only specific groups as listed in the act itself, for instance requiring a specific percentage of disability for certain impairments [57].

Italy has a quota system, introduced by Law 68/1999, of 7% for enterprises with more than 50 employees and one employee with a disability for enterprises with more than 15 but less than 50 employees. It has been reported that this quota is generally complied with and that specific exemptions have to be granted for enterprises who cannot comply with the quota for legitimate reasons [54]. This quota system does not change the situation of smaller enterprises however, which are about 95 percent of the Italian economy [57].

Act 68/1999 offers some incentives for employers, such as tax reductions and subsidies if they employ persons with disabilities. Job seekers with disabilities can be added to a specific job placement list and have an assessment of their abilities done and get some training offered. This approach led to an increase in registrations at the job centers and employment of persons with disabilities [56].

Funding for additional costs of employing persons with disabilities is mostly available on a regional basis, coming from the Regional Fund for the Employment of Persons with Disability, which was set up in accordance with Article 14 of the Act 68/1999. It covers, amongst other things the costs of some cases of reasonable accommodation [56]. Regional Laws can also regulate a claim to assistive technology at the workplace. The Southern Tirolian Law on Participation and Inclusion of Persons with Disabilities for instance sets out that the region subsidises the extra costs of buying necessary work equipment for employees with disabilities [58].

Reasonable accommodation in general is a topic of ongoing debates in Italy. The CRPD Committee noted in its Concluding Observations "The Committee is concerned that national legislation lacks a definition of reasonable accommodation and does not include an explicit recognition that the denial of reasonable accommodation constitutes disability-based discrimination" [55]. This statement is all the more relevant as case law has shown that employers rarely agree to carry the costs of reasonable accommodation. The existing regulation of the duty to provide reasonable accommodation states furthermore that "public employers shall apply this provision without any additional burden and with the human, financial and technical resources already available" [59]. Thereby emitting the word 'undue', which apparently lowers the threshold of what constitutes a burden too high for the employer to be expected to carry [55].

4.5. Summary

This section has outlined the international and European legal obligations in terms of employment and specifically accommodating persons with disabilities in the workplace, followed by a brief overview of the legislative situation in the three research countries of this study. What can be learnt from the CRPD is that the right to inclusive employment has to be seen from a holistic perspective. It entails more than just having the means to gain a living but is also about participation in society and leading a dignified life. Furthermore, in order to ensure this right, state parties have to look at the entire convention and how the different articles interact. It is of utmost importance to ensure full accessibility of the (potential) workplace from the outset, for instance in terms of built environment and to consider reasonable accommodation measures where needed, including assistive technology. This has to be seen in the context of reaching full equality of opportunity and also with the knowledge that a denial of reasonable accommodation amounts to discrimination.

The European Union follows this approach of anti-discrimination and equality in employment and provides legislation on accessibility alongside funding options. It does however not yet provide a holistic legislation in this field, for instance does the Accessibility Act does not apply to the built environment.

The three country studies show, despite their different welfare systems and histories, similar approaches to promoting inclusive employment. They offer specific employment supports for persons with disabilities, subsidies for the employers who provide reasonable accommodation, and have anti-discrimination legislation in place. Nevertheless, they all have higher unemployment rates for persons with disabilities than in the general population. Their support services seem not to target all persons with disabilities, amounting to discrimination within the group. Studies have also shown that reasonable accommodation is not as common in companies as it should be. All three countries show progress on the path to providing workers with support but still have to broaden access to funding and increase the awareness of the employment rights of persons with disabilities.

In relation to access to assistive technologies for employees with disabilities, it has been shown that while efforts are being made to regulate and unify the production of these devices, that, despite there being funding frameworks, there is no overall right to receive assistive technology free of charge or subsidized. In the context of employment, a stronger case can be made however under the right to reasonable accommodation at the workplace, which can in many cases may take the form of technological devices.

5. Worker Assistance Systems to Support the Inclusion of People with Disabilities in Production

5.1. Overview of Worker Assistance Systems

Autonomous and fully automated production systems are getting more and more attention, though this does not mean that the human can be excluded from production [60]. Despite the advances that were made in technology in the last years, it is still the human, which is considered the most flexible element in the production process [12]. Nonetheless, the human operator still has certain limitations, mainly connected to their cognitive abilities and physical strengths. The mentioned limitations increase in the modern, complex working environment, which makes the need of assistance systems essential to support the operator in their daily work [17]. With regard to the inclusion of people with disabilities, the limitations resulting from the respective impairment of the person are added here.

According to Romero et al., the goal of the Operator 4.0 vision is to create interaction-based relations between the machines and the humans, which is described in form of eight different future workers. Figure 1 shows a typology classification of those.

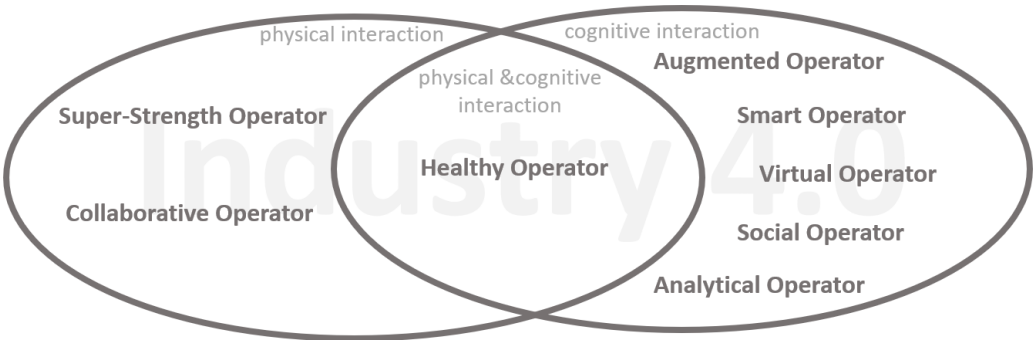

Figure 1. Terminology of the Operator 4.0 [20].

On the left side of Figure 1 operators with physical interactions are shown. The 'Super-Strength Operator' is described as an operator wearing an exoskeleton as supporting system, which is flexible in terms of working area. The so-called 'Collaborative Operator' characterizes the other type of physical interaction, where the operator is working together with a collaborative robot (cobot). On the right side of Figure 1 operators with cognitive interactions are shown. The 'Augmented Operator' is a worker equipped with augmented reality (AR) devices in order to enrich the factory environment seen by the operator with additional digital information and augmented artefacts. In such cases, the information can be directly overlaid in the worker's field of view with specific AR headsets. A similar approach is used for the 'Virtual Operator', in which the worker immerses with virtual reality (VR) headsets in a computer-simulated and interactive multimedia reality that digitally replicates a design or a manufacturing environment. The 'Smart Operator' is equipped with an intelligent personal assistant (IPA) in form of artificial intelligence or a software agent that helps the operator to interface better with computers, machines, and databases. The 'Social Operator' uses social and mobile collaborative methods to be connected with the resources within the smart factory at the shop floor. This can empower the workforce in order to contribute their know-how across the assembly-line and directly to the shop floor. The 'Analytical Operator' is defined as the worker equipped with big data analytic tools, which describes the process of organizing, collecting, and analyzing a large amount of data with the goal to observe useful information and predict events. At the intersection of physical and cognitive interaction the 'Healthy Operator' is located. It is an operator, who is equipped with wearable trackers aimed to measure stress, heart rate, GPS location, exercise activity, and other personal data [20].

In Figure 1, the eight different types of future workers shown do not exclude the Operator 4.0 to be an operator with disabilities. The presence of assistance systems would enhance the working environment and the well-being of a worker as shown in Figure 2.

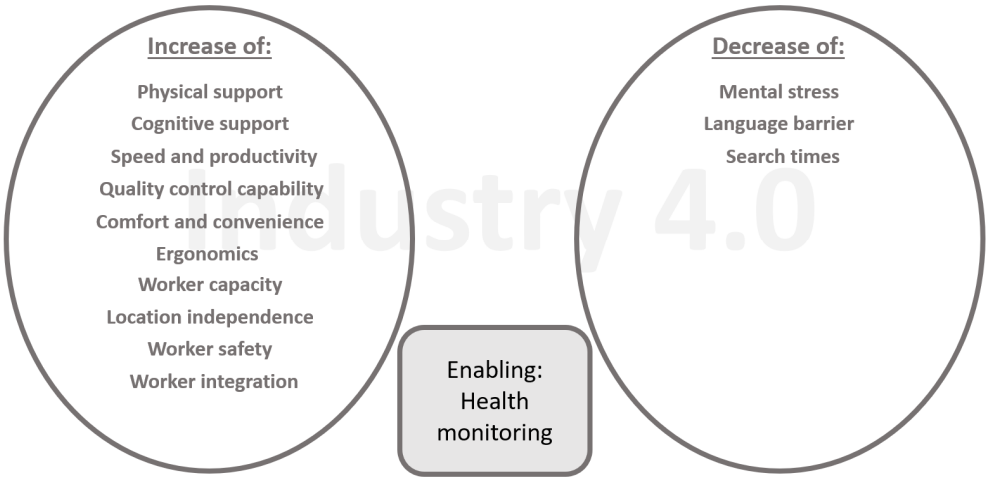

Figure 2. Advantages and functionalities of worker assistance systems.

Mark et al. [61]. introduce the concept of subdividing users into different user groups for worker assistance systems in the modern Production 4.0. One of these user groups are workers with impairments, who are subdivided into (i) physically impaired and (ii) mentally impaired workers. In Figure 3, a proposal for assigned supporting aid systems is given.

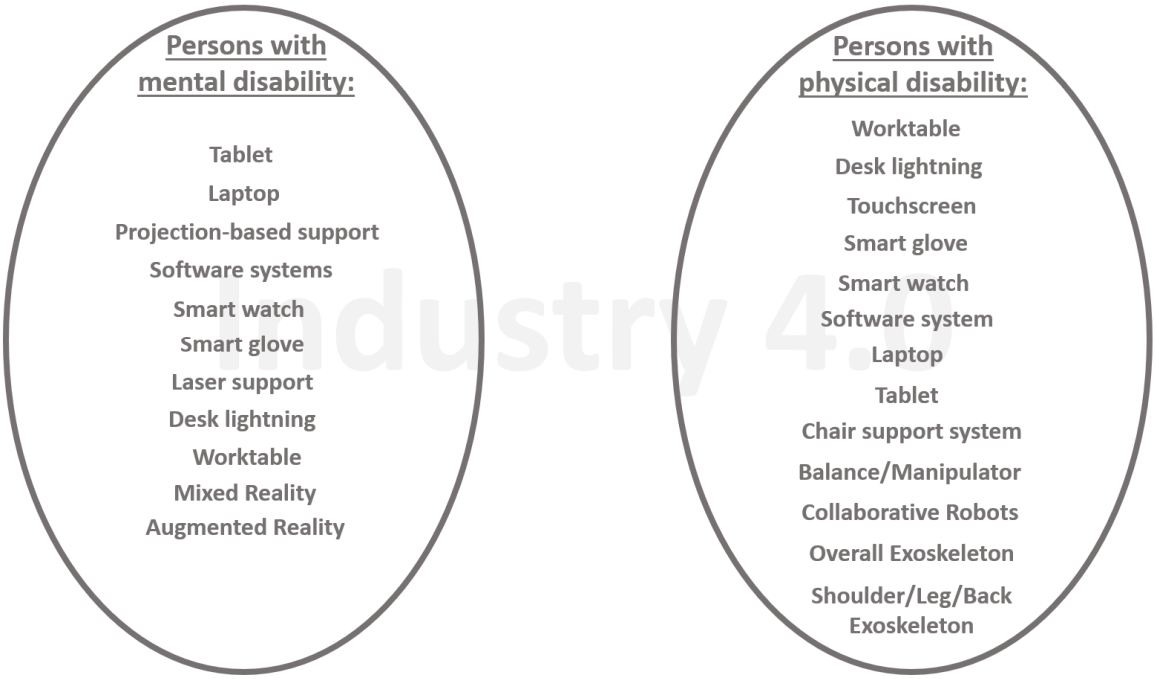

Figure 3. Overview of assistance systems for persons with mental or with physical disability.

In the following subsections, the three different categories of assistance systems, as previously defined by Romero et al. [19], are described in detail and hands-on examples of suitable aid systems for persons with disabilities are shown and explained.

5.2. Sensorial Assistance Systems

A sensorial capability is defined as the ability and capability of the worker to acquire information from the environment. This helps to create knowledge necessary for decision-making and for the orientation of the operator during his working day [62]. Romero et al. defines two different components of sensing: (i) the physical ability to gather information from the environment using the senses (by smell, sound, vibration, touch, etc.); and (ii) the ability to perceive it in a selective way. This is based on the background that very little data generated by the physical sense of a person are made available for further processing after they entered the short-term memory of the human [19].

Sensorial assistance systems are already being implemented in many factories in order to enable support for persons with disabilities in a modern industrial production. Warning lights mounted on top of doors or technical machines to show the manufacturing plants' status are already state of the art and help persons with hearing problems to recognize dangerous areas early enough to react in an appropriate manner. A combination with audible signals can warn also visually impaired persons. Pictographs are used to replace written information, especially about hazards, when this information must be communicated quickly with its viewer and when the law prescribes to inform operators for their safety. They must increase risk awareness, capture attention, and their meaning must be easily understood from a distance [63]. Pictographs can consequently support the understanding and risk awareness of persons with reading difficulties and provide additional safety. For communicating with visually impaired and deaf people, braille was invented. It is the writing system for the blind anywhere in the world and is used to send and obtain information [64]. Ramteke et al. converts

information from CAD files into voice or braille to make engineering drawings accessible to visually impaired operators [65]. This shows an application, in which the impairment can be compensated with the appropriate assistance system to include the worker with a disability in the daily work in production. To monitor the operators' health and consequently act adequately, smart watches can be used in production environments. Generally, they are wrist-worn devices with integrated sensors (e.g., gyroscopes, barometers, light sensors, and heart rate sensors) [66]. Through the use of these sensors operators with certain problems can check and evaluate their current health status on their own, without consulting a doctor or specialist. A further possible application of sensorial aid in situations where people collaborate with a cobot has been commercialized by Alumotion srl. A ring (YouRing—see Figure 4) is installed between gripper and robot as a plug-and-play device. The ring can be flexiblely programmed with programmable LEDs indicating in which direction the robot is moving next or if a certain assembly task has been finished correctly by choosing between a wide range of different colours of the LED lights. In addition, it is possible to program acoustic sounds for certain situations in order to warn the operator or to signal a certain task to be fulfilled by the operator to proceed with the assembly process.

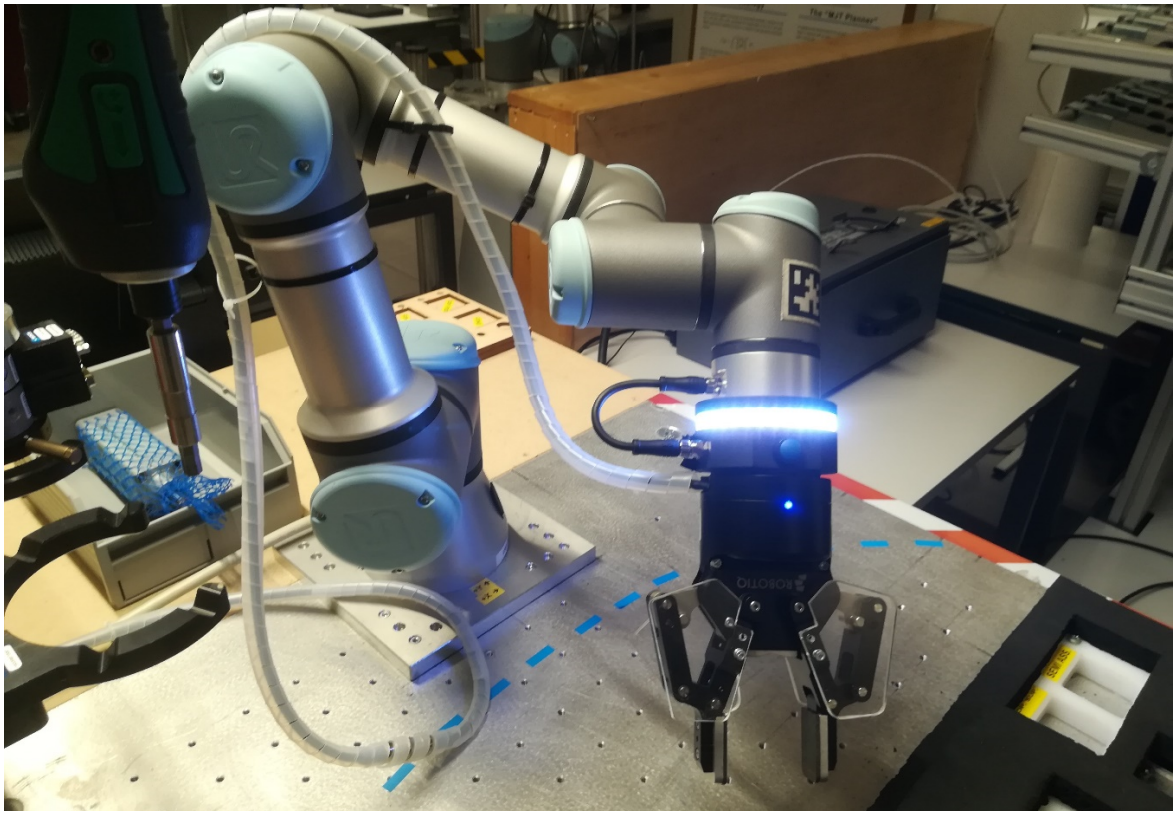

Figure 4. Sensorial assistance system in form of a ring (Alumotion YOUring) with LED lights and signal/warning sounds mounted on a cobot (picture taken in Smart Mini Factory—Laboratory for Industry 4.0, Free University of Bozen-Bolzano).

5.3. Physical Assistance Systems

A physical activity can be defined as any movement by the body created by skeletal muscles that need expenditure of energy. It is the operator's ability and capacity to perform physical activities required for daily work and can be characterized by physical functions—such as the ability to assemble, manipulate, and lift—together with their non-functional properties, e.g., precision, dexterity, speed, and strength [19].

To support persons with disabilities, several physical supporting systems are available on the market. Intensified research is done on the development and improvement of exoskeleton to increase

the mobility and force of the user. This support can be limited to particular body parts, such as upper extremities and hands [67], or can also assist the whole body [68]. The exoskeleton's motion is checked by the movement of the user which can be realized by implemented sensors [67]. New devices are also coming onto the market which assist workers who lost the use of their finger, hand, or arm. According to Perkins, around half of the 500,000 people who end up in a wheelchair each year suffer injuries to their hand—and this number does not include the population who sustain just hand injuries [69]. To deal with this, gloves made with a rubberlike, flexible material are designed, which can be moved with a small motor [69]. Hand impairments can be counterbalanced using a robotic glove created to detect user intent provided by EMG signals in the forearm [70]. In addition, highly mobile wheelchairs got developed to overcome the stair climbing problem [69].

Also, collaborative robots can be used to compensate physical disabilities of workers (see Figure 5). They are robots that allow working together with the operator within a shared workspace [71]. They can be integrated in a standard manual workstation as an additional and individual aid component to give lifting support or to hold parts while the operator is executing, e.g., assembly tasks. With such a collaborative robot the operator can receive an individually ergonomic working environment in addition to the aligned table height [72].

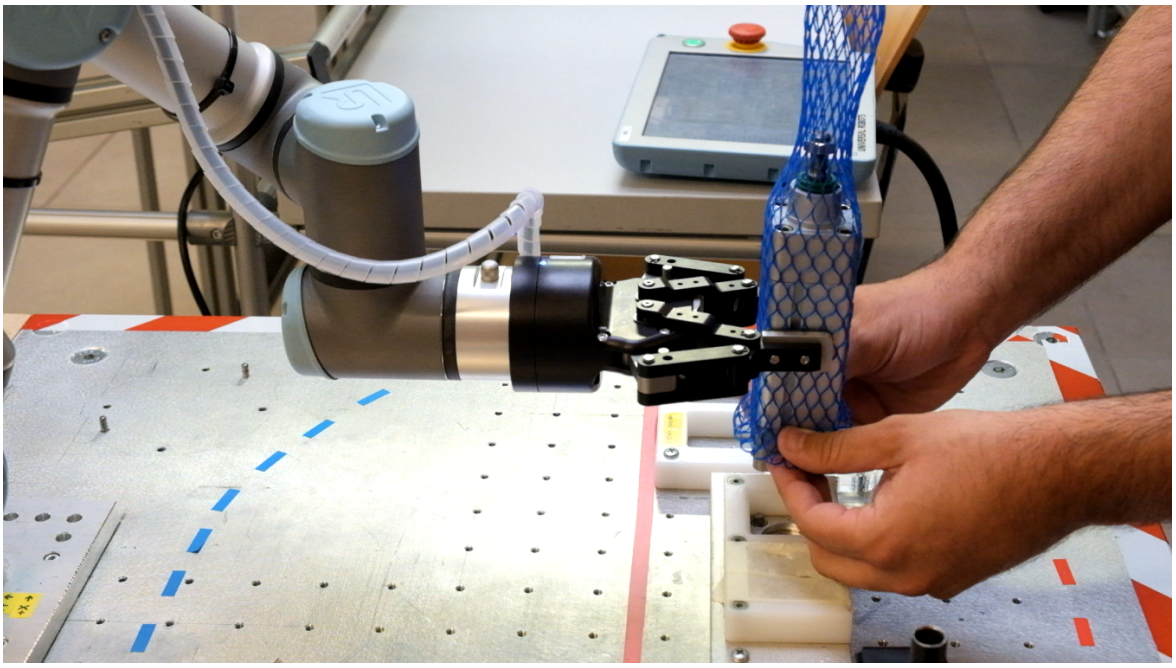

Figure 5. Physical assistance systems in form of a collaborative robot (Universal Robot UR3) to hold or lift heavy parts for people with disabilities (picture taken in Smart Mini Factory—Laboratory for Industry 4.0, Free University of Bozen-Bolzano).

5.4. Cognitive Assistance Systems

A cognitive capability is defined as the ability and capacity of the worker to undertake mental tasks that are needed to properly perform the work task. In the OODA model (Observe, Orient, Decide, Act), the cognitive tasks are the parts of to 'orient' and to 'decide', amounting to human–computer interaction, dealing with work stress and reliability in performance and a mental workload [19]. Since the factories in times of Industry 4.0 are becoming more dynamic working environments due to the need for flexibility, there is the necessity for cognitive supporting systems to help the worker to perform the mental tasks.

Also, for persons with disabilities, such cognitive assistance systems can be helpful for a better inclusion in industrial jobs. Laser projections can indicate the assembly tasks to provide assistance to the operator with a mental disability (see Figure 6). An adapted inspection system can use diverse

methods, such as the thermography, to check the quality of the work [73]. Mueller et al. show that assistance systems provide useful information to the operator by considering the level of education [73]. Teaching assembly instructions at assembly workplaces can nowadays be done by digital automatic supporting systems. They can be adapted to the user needs and provide dynamic support [74]. Such assistance systems are especially useful for persons with disabilities, since they can decrease the cognitive workload of operators, as they have to memorize the specific assembly instructions for every change of the product line. Kosch et al. present the impact of projected in-situ instructions on experienced workers, workers with cognitive disabilities, and freshman workers [74] While for operators with cognitive disabilities continuous support is useful, for others an additional support in form of information is necessary only during the learning phase [74]. Funk et al. determine common visualizations which are used by supporting systems for people with disabilities and present a simple contour visualisation. The results show that the contour visualisation is notably better in perceived performance and mental load of the participants. Moreover, participants were faster and made fewer errors while assembling [75]. In order to see the effects of in-situ instructions, Funk et al. did a comparison between in-situ instructions and state of the art pictorial guidances with people with cognitive disabilities. The results showed that the workers were able to assemble products with higher complexity with up to 50 percent less errors and up to 3 times faster using in-situ instructions. In addition, the workers with disabilities liked the in-situ instructions [76].

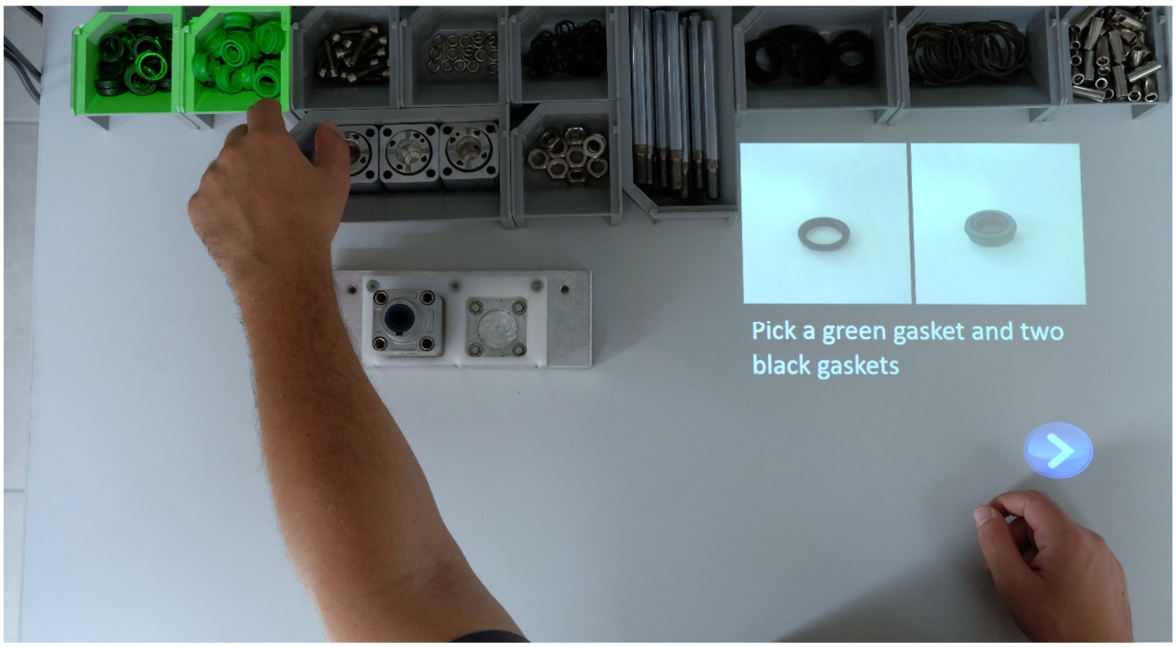

Figure 6. Projection-based assistance systems (Ulixes "Der Assistent") to guide people with disabilities through a complex assembly cycle (picture taken in Smart Mini Factory – Laboratory for Industry 4.0, Free University of Bozen-Bolzano).

6. Discussion

6.1. Critical Remarks and Limitations of Assistance Systems

Summarizing Section 5, there are many starting points and technologies which offer great potential for supporting people with disabilities in production and thus for inclusion in the industrial labor market. The practical examples given also show that some of the technologies can already be applied directly to people with disabilities. Despite the high potential for assistance systems in terms of inclusion of people with disabilities, there are some limitations that must be taken into account and that require further research:

1. Missing attention of people with disabilities as a 'user group' of assistance systems (result of market research);
2. Acceptance of technical aid systems by people with disabilities (result of interviews with disabled people, caregiver and stakeholder);
3. Lack of practical use cases for people with disabilities (result of literature review);
4. Missing allocation of assistance systems in production to different types and levels of disabilities (result of literature review and market research);
5. High prices for investing in such new technologies (result of market research combined with questions in interviews with stakeholder);
6. Lack of incentives for industry to invest in assistance systems for people with disabilities (result of interviews with stakeholder).

Regarding the first point there is actually not enough attention in research and on the market of assistance systems for production related to developing systems for people with disabilities. Although this seems to be a niche topic in the area of assistance systems, it should be addressed in future research. Furthermore, it opens new possibilities for new business opportunities specializing on assistance systems for people with disabilities in production, known also from other non-industrial sectors, where specialized firms develop, commercialize, and implement special devices for office workplaces.

An important aspect in the introduction and installation of such assistance systems in production is also to include the interested person from the beginning in order to increase the acceptance of such aid systems. The expenditure and the investments are not useful, if the worker does not accept the measure and/or the aid system and thereby company owners lose interest in a financial contribution to the design of disabled-friendly workplaces and jobs.

The third point describes the lack of practical implementation in industry. So far, assistance systems have mainly been used to enhance an employee's skills, but not to compensate employee deficits. There is therefore still a need for action to test and further optimise the existing technologies in workplaces with people with disabilities. Practical success stories normally also contribute to encouraging companies to invest in assistance systems.

As described in the fourth point, research should also deal with the allocation of assistance systems to different types of impairments (vision, motoric skills, mental impairments) and their manifestations (e.g., blind employees or employees with visual impairment). There is currently no complete categorization of user cases with the characteristics of the deficits and an allocation of the currently available technologies. On the one hand, this could define which aids would be particularly suitable for which employees and, on the other hand, whether there are currently inadequate solutions on the market for certain impairments, which would necessitate further development work.

Technologies such as augmented reality, laser projections, or cobots are very expensive as they are not yet established technologies. Although price reductions can be expected in the coming years due to progressive developments and rising sales figures, there is still a risk that some of the technologies mentioned above will be difficult to finance, especially for small- and medium-sized companies.

This also leads to the last item in the list regarding incentives for companies to invest in these technologies. In particular, there is a need for direct support programs for this type of assistance system or indirect incentives in the form of tax reductions for companies employing people with disabilities in production or investing in a corresponding assistance system.

6.2. Implications on Management and Policies

As the previous sections of this research have highlighted, assistance systems can and do play a big role in promoting inclusion in the workplace for persons with disabilities. It is however a growing and developing field of research, which is yet to be fully captured by policies and comprehensive funding opportunities.

Assistance systems can be captured both under universal design and reasonable accommodation aspects. The aforementioned use of pictographs instead of written information, is a good example of a universal design measure, which does not involve high costs and can potentially benefit not just people with disabilities but also other persons which are not familiar with technical terms. These measures should therefore be part of the design from the outset and not later adaptations. Many businesses might however not be aware of such a need and option. It is therefore the job of the government, in cooperation with the trade union and persons with disabilities, as part of a participatory tripartite approach, to develop and implement an awareness-strategy on universal design for assistance systems. Furthermore, design regulations and policies should include a duty to incorporate universal design into the development of new products from the outset, including being tested by persons with disabilities. Finally, to increase knowledge of universal design, its implications, and technical requirements, university curricula need to incorporate aspects of universal design into their courses.

Other systems, such as collaborative robots for instance, are however not designed to be of use to the general population and fall under the category of reasonable accommodation. As has been discussed beforehand, costs are a factor to be considered under what is reasonable to expect from an employer. The country studies have however also outlined different financial supports that are available for employers aiming to make workplaces more accessible. It is the duty of the states to ensure that such financial supports cover the entire labor market, that their criteria are not too restrictive, and that information is distributed to businesses and unions to ensure that employers are aware of these options. Financial supports can be granted in the form of subsidies and grants, both to self-employed persons with disabilities directly and their employers. Additionally, reducing taxes on assistance system products would help make the products themselves more affordable in the first place.

Summarizing, assistive systems have to be covered in policies in two contexts: firstly, in the context of employment for persons with disabilities, discussing duties of employers and (financial) supports and secondly from a regulatory perspective of assistive systems themselves. In the spirit of the CRPD and disability mainstreaming, persons with disabilities need to be involved as experts in a truly participatory manner. In doing so, the sector can also fulfil its obligations and act as a good example as an equal opportunity employer.

7. Conclusions and Outlook

This article examines the potential of assistive systems in promoting not only employment of persons with disabilities but also an understanding of how every human has a unique set of capabilities, which can be supported by responsive assistive systems at the workplace. By involving persons with disabilities from the initial planning stage, this potential can be maximized while also making the industrial sector a best practice example of a truly participatory, inclusive field of business.

In answer of the first research question—"What are the legal foundations and restrictions for including persons with disabilities in European manufacturing companies?"—the article has shown that including persons with disabilities in manufacturing companies has to be understood as a part of employers respecting the human right to employment of persons with disabilities as enshrined in the CRPD. Legally, there are no obstacles in employing a person with a disability. On the contrary, it is the employer's duty and the employee's right to receive accommodation measures for their impairment, as far as the efforts do not amount to an unreasonable burden for the employer. States offer (financial) supports to help relief such a barrier. Furthermore, in doing so, manufacturing companies can involve persons with disabilities in the development of products from the outset and ensure they are accessible for users with disabilities and position themselves as a best practice employer, attracting socially conscious customers and potentially government contracts under a social clause in calls for tender.

As for the second research question—"What kind of new technologies can support the inclusion of persons with disabilities in production?"—diverse assistance systems identified in the scientific literature and through a market research could be shown in Section 5. The terminology of the Operator 4.0 together with advantages and functionalities of worker assistance systems in the vision of smart

factories of the future was explained. The subdivision of aid systems into sensorial, physical, and cognitive systems helps to categorize such systems according to the needs of workers with disabilities.

Regarding the third research question—"What are the most promising technologies to achieve this goal?"—we identified especially projection- and laser-based assistance systems as promising approaches to face mentally impaired persons. The possibility of using cobots or exoskeletons shows an important opportunity in order to face physically impaired persons. Most of the sensorial assistance systems are rather easy to include in production and therefore a good start for companies to adjust their facilities according to the needs of their employees with disabilities. However, it must be mentioned that, overall, very few assistance systems have been developed specifically for people with disabilities. Therefore, we have also found that further specific research can introduce other helpful assistance systems in the future.

With the research project Assist4Work at the Free University of Bozen-Bolzano a cornerstone in the direction of the modern Production 4.0 including also the needs of persons with disabilities is set. By the time of finishing this article, the project was at the first phase, in which the state of the art and already existing systems on the market were the focus of this research initiative where we collaborated with trade associations and organizations for the care and inclusion of people with disabilities in the workplace. Over the next two years, we want to identify the specific requirements for assistance systems, which are necessary to compensate physical or mental deficits. Based on this analysis, we then want to develop assistance systems for different types and levels of disabilities in a pilot industrial workplace and test their suitability and acceptance.

Author Contributions: Introduction, D.T.M.; Literature review, E.R., S.H., and B.G.M.; Legal foundations, S.H.; Assistance Systems, B.G.M.; Discussion, S.H., B.G.M., and E.R.; Conclusion, B.G.M. and S.H.

Funding: This research was funded by the Free University of Bolzano; project title: Assist4Work: Social sustainability in production through age-appropriate and disability-friendly workplace design using assistance systems, grant number TN200J.

Conflicts of Interest: The authors declare no conflict of interest.

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