

The workforce ageing phenomenon: statistics, policies and practices

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Abstract: The workforce ageing phenomenon is recently affecting most of the Organisation for Economic Co-operation and Development (OECD) member countries, due to a general ageing of their populations and a higher average retirement age of the workforce. The European population (referring to the 28 EU member countries) is projected to grow from 507.2 million in 2013 to 522.8 million in 2060, with the percentage of seniors (65 years or older) forecasted to grow by 10%. A similar trend is observed in both the USA and Japan. The importance of this issue has attracted a wide range of researchers and practitioners. Here, we aim to provide an overview of statistics regarding ageing population employment in OECD countries and compare the percentage of ageing workforce in each country. Furthermore, we aim to give an overview of governmental policies, actions and examples of companies’ perspectives and practices toward ageing workforce in the work environment. This study can help decision-makers and practitioners to better understand the ageing problems in the work environment and governmental policies point of view.

Keywords: ageing workforce, statistics, employers’ policies, well-being indexes

1. Introduction

People ageing is always more emerging as a key issue, since both the proportion and the absolute number of older people in populations around the world are increasing. Moreover, this increase is expected to grow in the next decades (Eurostat 2019), and, consequently, also the workforces in many European countries and some developed countries such as Japan, Canada and New Zealand are progressively ageing (OECD 2019). For this reason, it is important to consider the ageing workforce and its working conditions also in production research (Calzavara et al. 2020; Katirae et al. 2020). As also proposed by the ISO TC 314 on ageing society (2020), from one side, the study of ageing workers in production research can help the development of age-friendly workplaces and working environments, trying to involve aged workers as much as possible (Botti et al. 2017; Finco et al. 2019). On the other side, it could allow understanding the real employability of ageing workers, by comparing the costs of keeping them in the company with the ones related to their retirement (Bogataj et al. 2019).

Although there are some studies which have put emphasis on statistics (Conen et al. 2011), on ageing workers’ policies and age management practices (Foden & Jepsen 2002; Loretto & White 2006; Blomé et al. 2020) or have concerned about well-being indices (Silva et al. 2011; Anca 2017; Lima et al. 2018) an integrated analysis about the so-called workforce ageing phenomenon is still missing. In this paper, we provide an overview including statistics, policies and indices simultaneously, in order to better understand why ageing workers are important, how these are managed and considered both by governments’ and employers’ point of views and how their well-being and needs can be addressed by applying evaluation indices. For doing this, the remainder of the paper is structured as follows. Section 2 provides some statistics regarding ageing workforce among European countries and in particular the attention is focused on the countries

involved in the MAIA European project (MAIA-H2020-MSCA-RISE 2019). In section 3, some of the existing policies and the developed strategies are explained, to understand how ageing workforce problems are addressed by employers or governments. In the same section, some leading industrial cases, referring to company strategies are mentioned. Section 4 reports the most widespread well-being indexes, detailing their application to aged workers and specific industrial cases. Finally, Section 5 is for the conclusions and the proposal of future researches.

2. Statistical analysis

As stated in the introduction, the European population is progressively ageing. Declining fertility rates combined with increased life expectancy have reduced the natural increase in population. As a consequence, this issue also leads to a higher number of aged operators employed in several work environments. In this study, we consider the group of workers who are aged 55 years or more, which are usually referred to as “ageing workers” in a work environment. Employment rates are usually divided into three age groups: people aged 15 to 24 (those just entering the labor market following education); people aged 25 to 54 (those in their prime working lives); people aged 55 to 64 (those passing the peak of their career and approaching retirement).

According to the Eurostat “Ageing Europe”, statistics on working and moving into retirement (Eurostat 2019), the share of people aged 55 years or more in the total number of persons employed in the EU-28 constantly increased from 12.1% (sum of ageing persons in employment percentages for all aged categories) in 2003 to 19.7% in 2018. The number of employed people increased at its fastest pace among people aged 60-64 years, with the total number of employed people in this age group more than doubling (approximately from 3% to 6.2%); the number of employed people aged 65-69 years

and 55-59 also increased at a rapid pace, rising by 95% and 65%, respectively.

Figure 1 shows the percentage of employment rate for a given age group (55-64) in the same time framework (2003 to 2018) for 28 European countries and other developed OECD countries, chosen according to the origin of the partners involved in the MAIA project. The employment rate for a given age group is measured as the number of employed people of a given age as a percentage of the total number of people in that same age group. According to Figure 1, we have witnessed an upward trend in the rate of ageing employment from 2003 to 2018 which indicates the ageing workers involvement has increased over the last 15 years. Moreover, this figure demonstrates that in most OECD countries, more than 50% of the ageing people are hired, and this rate is very high in some countries such as New Zealand and Japan, with a rate of 77.93% and 75.27%, respectively. The employment of ageing workers has been stable during the years in some countries, such as in the United States, while in other countries like Germany, Italy and Slovenia the trend of ageing employment has increased gradually over the last 15 years. In any case, it can be concluded that a wide range of countries has faced the ageing workers problem over the last two decades, particularly in recent years.

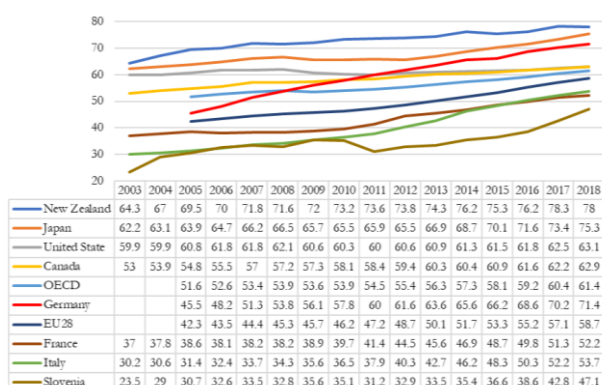


Figure 1: Employment rate by age group, 55-64 year-old (2003-2018). Source: OECD 2019.

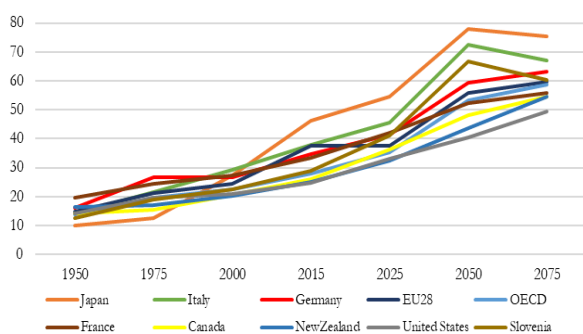


Figure 2: Demographic old-age dependency ratios: historical and projected values (1950-2075). Source: United Nations 2019

Figure 2 indicates how this trend will continue in the next years and helps us to compare it with the historical values. Here, the demographic old-age dependency ratio is defined as the number of individuals aged 65 and over per

100 people of working age, defined as those aged between 20 and 64 (OECD 2017). In 2015, the demographically oldest OECD country was Japan, with a dependency ratio equal to 47 (meaning 47 individuals aged 65 and over for 100 persons of working age). Finland, Greece, and Italy also had high dependency ratios, between 35 and 38. By 2075 the dependency ratio is expected to reach 76 in Japan, 75 in Portugal and 73 in Greece. Some main English-speaking OECD countries – Canada and the United States – have relatively low dependency ratios, between 22 and 26. This is partly due to the inward migration of workers. The United States, with large immigrant populations, have fertility rates currently just below replacement level. For the OECD as a whole, the increase in the dependency ratio is projected to continue. There is, however, an assumed convergence among OECD countries, with demographically younger countries ageing more rapidly. The pattern for the EU28 broadly follows the OECD average. European countries are already slightly older than the OECD average: a dependency ratio of 30 for the EU28 in 2015 compares with an OECD figure of 28. By 2075, the dependency ratio for the European Union is also projected to reach 58. According to the above figures, it can be concluded that the increase in the ageing population and, consequently, of the ageing workers will continue in a wide range of developed countries. For this reason, it is required for employers to develop practical strategies and implement related policies for ageing workers in workplaces. In section 3 some of the policies and strategies taken in this direction are explained.

3. Taken policies and strategies from governments and employers for active ageing

The impact of workforce ageing on employment and on the labor market is considered as a significant issue in the employment strategies in Europe since European societies are ageing. Not only the share of ageing workers in workplaces is growing rapidly, workers are also working until later. However, due to a variety of reasons, many ageing workers exit the labor market prematurely. For example, they are unable to combine work with illness, disability or care commitments, they have become unemployed, or they are not motivated to continue working – sometimes due to poor working conditions (Calzavara et al. 2020). Therefore, there is the need to develop proper policies that have to focus on the workplace, to involve partnerships between employers and workers, with support from governments, to ensure that age does not become a barrier to employment (Walker 2002). This requires an active approach, for example, in removing age barriers, changing employer behaviors and enabling flexible employment and retirement (Naegele & Walker 2006).

Some researches carried out in the United States and several European countries showed that many employers tend to be biased towards ageing workers and there is often a lack of corporate focus on ageing employees. It is reflected in the absence of programs to retain and retrain them (Barth et al., 1993; Guillemard et al. 1996; Taylor & Walker 1998; Chiu et al. 2001; Henkens 2005). Therefore, when economic prospects are weak, ageing workforce

find themselves in a vulnerable position since early retirement is often seen as a less painful way to downsize the workforce than large-scale layoffs. However, some articles examine the role played by employers in retaining and recruiting ageing workers. For example, Van Dalen et al. (2009) addressed employers' attitudes and actions regarding the position of ageing workers. They did a comparative survey among employers from four European countries: Greece, Spain, the Netherlands and the United Kingdom. The results indicated that despite the perceived challenges ahead (ageing workforce), employers take no significant measures to retain and recruit ageing workers or improve their productivity. Only employers in the United Kingdom seem to consider ageing workers as a valuable source of labor supply and act accordingly.

Furthermore, their results indicated that retaining or attracting ageing workers is generally not their first-best choice. This is in contrast with the rhetoric of Dutch policy makers, who want to promote the position of ageing employees. Indeed, compared to Greece and Spain where very little has been done to retain the ageing worker, the behavior of the Dutch employers regarding ageing workers is almost identical. According to the Van Dalen et al. (2009) survey, the British employers more set on using the capabilities of ageing workers, as 40% stated they would recruit additional ageing workers and 37% would encourage workers to continue working to the statutory retirement age of 65. In the United Kingdom, female workers, ageing workers and workers from ethnic minorities are equally popular among employers. The question is, therefore, how to encourage ageing persons to remain longer in the labor market if they are in good health and, at the same time, how to encourage companies to employ qualified ageing applicants. Here, we want to indicate some taken policies and strategies from different employers and governments in some countries, to understand which types of actions can be taken to facilitate ageing workers' condition in workplaces instead of forcing them to exit the market prematurely.

3.1 Reducing age discrimination in the labor market

It is desirable for governments to acknowledge that different age groups contribute positively with different skills to societal development. Therefore, it is necessary for governments to define mechanisms for making labor markets equally accessible to persons of all ages. Furthermore, improving the public perception of ageing workers can reduce age discrimination. Possible measures could be: promoting positive images of ageing, addressing age discrimination, promoting approaches for employing ageing persons. An employment policy without age discrimination would allow workers to be recruited according to their skills, not to their age. Regarding this policy, in 2004, the Italian Ministry of Labor, Health and Social Policy decided to develop a program that was aimed at the re-employment of disadvantaged workers, including workers aged 50 years and older. The *Programma d'Azione per il Re-Impiego di lavoratori svantaggiati (PARI)* was launched in 2005, and renewed in both 2007 and 2009. Up to December 2008 almost 14,900 workers had been re-

employed. Of the 6,000 ageing workers involved in the program, 1,900 were reported as already re-employed (UNECE 2011). Moreover, in Italy, *The L'Incontro Initiative* is a nonprofit, social cooperative that recruits ageing workers. It recruits ageing recently retired maintenance workers to work as instructors in protected job centers (Naegele & Walker 2006).

3.2 Enhancing age-friendly conditions in the workplaces

The development and implementation of age-friendly employment strategies bring advantages for ageing workers, employers, the economy and society as a whole. Therefore, it is beneficial to shape the working environment according to the needs of all ages to induce more people to remain in the labor market. Ageing workers may be eager to work for longer, if an age-friendly working environment and further financial incentives are guaranteed. The decision of ageing workforce to remain in the labor market depends on numerous items, such as the financial benefit of working longer, the interaction between individual's functional capacity, the nature of the work, workers' state of health, and the possibilities for work accommodation (Vodopivec & Dolenc 2008). Therefore, the creation of age-friendly working environments including age-adapted workplaces help ageing workers to promote their health and to contribute for longer in the labor market.

For example, *The UK Oil Company* is working to retain ageing workers despite the physical demands of its workplace. It offers workplace health assessments to resolve common issues among ageing workers such as back pain to review existing health problems and intervene when serious issues happen. It also offers annual medical exams for workers aged 50 and over (Naegele & Walker 2006). Moreover, *Gereng Hout en Beton*, a Dutch construction enterprise, has implemented age-aware human resources policies. Different worker capacities are taken into account in task planning, where ageing and more experienced workers are perhaps given more complex tasks, while younger workers might be given the more physically demanding tasks (Naegele & Walker 2006).

3.3 Creating incentives and legal frameworks

In order to prevent an early exit from labor markets of ageing employees who have not yet reached the retirement age, besides providing age-friendly workplaces, it is necessary to develop appropriate labor market policies. These policies shall be geared towards the establishment of incentives to stay in the labor market longer. Incentives can include implementing flexible work-time schedules such as part-time working/shift working, financial strategies, job satisfaction and life-long learning programs as part of the comprehensive education strategies. These actions are beneficial for improving the employability of all generations, particularly ageing workers.

For example, *CVS/Caremark* actively recruits ageing workers for entry-level positions and offers them part-time, flexible schedules (Piktialis 2007). *Baptist Health Systems* allows employees with at least 10 years with the

company who are 59.5 years or ageing to begin to draw on their pension and still work part-time. Ageing workers who decide to retire can return to the company within five years without losing their benefits (Piktialis 2007). UK-based *Firstgroup*, a surface transportation company, has a “Flexible Decade Program,” which aligns work arrangements with pension schemes, offering ageing workers a part-time work option while drawing a reduced pension or continuing to work full time or part-time while continuing pension contributions (Koc-Menard 2009). *Bon Secours Richmond Health System* has a policy allowing employees who are age 65+ to work up to 24 hours per week and receive the same benefits they would get if fully retired (Malone 2007). *Busch Entertainment* established a Legends Ambassador Program where teams of workers above 55 were selected each year and stationed at each park to ensure quality employment and job satisfaction among their ageing employees (Eyster et al. 2008). *Procter & Gamble*, *Siemens*, and *GE* offer reverse mentoring programs where younger employees teach managers and executives, who tend to be mid-career or ageing workers, about new technologies (Eyster et al. 2008).

In general, according to Foden & Jepsen (2002) study, active ageing workers is not given the same priority in all countries. Basically, four clusters of countries are identified by them. The Netherlands and Finland have increased efforts to change perceptions of the capacities of ageing workers and reduce their early retirement. In the Netherlands, the employment rates for the 55-59s and 60-64s have begun to rise. In countries like Denmark, Germany and Sweden, policymakers have also taken action to curb the early retirement trend. The fanatical incentives to retire early have been seriously restricted. The UK has taken some initiatives to make it more attractive for ageing workers to stay in employment. The last cluster of countries is France, Belgium, and Italy. In all three countries, the financial incentives to withdraw early have been restricted, but not much has been done to reintegrate ageing workers into the labor force.

4. Indexes for well-being assessment

Workers’ health and productivity are considered critical issues in the European context of an ageing population (Anca 2017). Managing an ageing workforce is a challenge for all businesses that must create and develop workplaces that allow operators to remain in work longer, maintaining their work-ability and health condition (Cebulla & Wilkinson 2019). As an example of a company that takes care of the health conditions of its employees, in order to reduce workforce physical issues and enhance welfare among its workers, we can cite BMW automotive company. In fact, it decided to re-design the assembly lines in order to alleviate ageing workforce musculoskeletal diseases by improving ergonomics and the consciousness of ageing workers in order to avoid physical disorders (De Pommereau 2012).

In the industrial environment, to evaluate workers’ well-being and health conditions related with the age of the single operator, different indexes based on the data which describe physical activities, are collected with self-reported retrospective assessments. In order to get a

precise and useful evaluation of the working conditions of the employees, either in a synchronous (on-line) way or also in an asynchronous one (after the progression of all the tasks that have been assigned to them), it would be useful to use a technology which supports the computation of ergonomics indexes. As an example of that kind of technology, in Battini et al. (2018) a motion capture system has been adopted to determine the ergonomic indexes to help practitioners and experts to define the right and acceptable posture and working conditions for an ageing workforce.

Two main categories of indexes, aiming to report workforce well-being and the maximum physical effort, exist in the literature, which can also be classified based on the data needed to obtain them: the qualitative indexes and the quantitative ones. The qualitative indexes, such as the Work Ability Index (WAI) and the Work Ability Score (WAS), require qualitative information to be calculated (e.g. self-assessment questionnaires). On the other hand, quantitative indexes are based on some real data obtained from the workforce characteristics, which can help to assure physical welfare and sustainable health conditions.

4.1 Qualitative indexes

One of the most useful indexes for determining operator’s well-being is the Work Ability Index (WAI), which is a diagnostic tool developed by Finnish authors (Ilmarinen 1991; Tuomi et al. 1998) that can help practitioners and professionals to evaluate operators’ health condition and welfare. It consists of a 7-items questionnaire that allows evaluating workers’ self-assessed work-ability in relation to work requirements, health status and worker resources. As reported in Table 1, for each point of the questionnaire, the worker gives a score. At the end, it is possible to calculate the WAI total score, which can vary from a minimum score of 9 to a maximum of 49, considering the sum of all single scores. Some of the subscales in the table present continuous range of possible scores, like the first two subscales, while others have categorical values among some predefined scores, linked to a certain category, like the fourth one, which can assume only the score of 1 or 6 (Yang et al. 2013). WAI is evaluated in a critical analysis made by Anca (2017) where three self-report tools have been compared: WAI, Health and Work Performance Questionnaire (HPQ) and Stanford Presenteeism Scale: Health Status and Employee Productivity SPS-6 (SPS-6). The comparison aimed to evaluate the three tools to find the most suitable one for evaluating and improving age management and operators’ health issues at the workplace. The results obtained in this research highlighted that the analysed tools could be appropriate instruments to undertake actions to maintain work-ability of ageing workers.

Several industrial cases have been carried out to evidence the suitability of well-being indexes developed in the literature. For instance, in Costa & Sartori (2007) the WAI has been used to monitor Italian workers’ health on a sample made by different working sectors (over 30% of the workers in the sample were light manual workers and heavy manual workers). Their results showed that WAI is affected by working conditions and personal health status,

but, in general, it suffers a decreasing trend over the years. In fact, WAI scores progressively declined over the age groups. Another case study is reported in Lima et al. (2018) in which data from workers of a meat processing industry were collected based on a survey including the Portuguese Version of the WAI (Silva et al. 2011). Some interesting results they obtain concern the distribution of

pain complaints. In fact, they stated that there was a prevalence of complaints in workers aged 44 or over and that a relationship exists between age and cervical and low back pain. Moreover, they highlighted that workers who did not report musculoskeletal symptoms showed a better WAI.

Table 1: Subscales, range and values to generate the total score of work ability index.

	Subscale	Response scale	Response values	Variable characteristics
1	Subjective estimation of current work ability compared with lifetime best	0 ÷ 10	0 = very poor 10 = very good	Continuous
2	Subjective work ability in relation to the demands of the job	2 ÷ 10	2 = very poor 10 = very good	Continuous
3	Number of current diseases	1 ÷ 5; 7	1 = 5 or more diseases 7 = no diseases	Categorical
4	Subjective estimation of work impairment due to diseases	1; 6	1 = fully impaired 6 = no impaired	Categorical
5	Sick leave during the past year	1 ÷ 5	1 = 100 days or more 5 = 0 days	Categorical
6	Prognosis of work ability 2 years from now	1, 4 or 7	1 = hardly able to work 4 = not sure 7 = fairly sure	Categorical
7	Mental resources (future work perception)	1, 4	1 = very poor 4 = very good	Categorical

Finally, another qualitative method that can be used to obtain operators' well-being assessment is the WAS. WAS is an assessment tool based only on the use of the first item of WAI. It consists of workers' self-assessment of their current work-ability in comparison to the best lifetime work-ability they have ever experienced during their career with a score between 0 to the maximum of 10, which represents the work-ability at its best.

In El Fassi et al. (2013) a comparative analysis to assess the work-ability has been made, aiming to compare the results obtained through WAI and WAS. Their outcomes stated that the single-item approach of WAS does not deteriorate the validity of the work-ability information collected. Moreover, they highlighted that both the indexes can report the increasing or the decreasing trend of work-ability. However, WAS is considered more user-friendly and easier to complete and to fill until its completion.

An interesting and recent qualitative tool, based on operators' self-assessment, which describes working condition of ageing employers in the workplace is provided by Wilckens et al. (2020) with their Later Life Workplace Index (LLWI). This new index can be useful also as a benchmark to compare different organizations, or among peers on industries, based on their best practices to help an ageing workforce to maintain work ability and health condition.

4.2 Quantitative indexes

Wolf & Ramsauer (2018) reported in their analysis that in literature several work evaluation tools already consider physical work stress but not many of them include in their parameters the age of the worker. Their research presents the main methods able to define worker's condition through quantitative measurements. All methods evaluate

also ageing by including for example the posture, the handled load or the force applied in executing tasks.

However, it is important to consider age discrimination in order to guarantee workforce welfare and stress balancing. For instance, the REFA-method generates a weighted factor to reduce the average maximum force based on operator's gender and age. Moreover, other newer methods exist, which consider worker's age. To take another example, “Age-differentiated Task analysis and Screening method” (ATS) (Keil & Spanner-Ulmer 2010) identifies through a particular approach the critical activities for ageing workforce in order to balance the stress and guarantee welfare among operators. This method can generate a request profile for each task, dependently from some pre-defined age profiles of production-relevant abilities. Another tool called “assembly specific force atlas” has been created to overcome the symmetric working postures problem evaluation, in ergonomic unfavourable conditions. It allows to identify the thrust forces trough different whole-body forces and finger-hand forces mapping, obtained from the collection of real data of force exertions in the automotive industry (Schaub et al. 2015). In order to take into account the age affecting the recommended force needed to execute a certain activity, gender and age are considered as corrective factors that can evaluate the heterogeneity of the workforce assuring the well-being of each operator. In addition to the other tools here presented, a German workplace screening approach called “Check-age” is used in the assembly industry to evaluate the risk level of a certain task whenever elder workers are involved in workplaces where maximum force or high speed movements are required (Börner et al. 2017). Its approach adds an age-differentiated assessment, consisting of increasing the risk

level of the operations considered by one whether elderly operators are involved in the workplace. Another method that considers workforce heterogeneity, especially for what concerns the age factor, has been developed specifically for the steel industry in Germany and is called “A-Flex” (Szymanski & Lange 2018). This method evaluates either body postures and load handling but also psychological and mental factors, to make a risk assessment analysis considering all the differences among the workforce. To conclude, Wolf & Ramsauer (2018) pointed out that among the indexes here presented and all the others which consider the age factor, most of them do a general age differentiation only between elder workers and younger ones. In fact, only few of them consider operators’ heterogeneity, especially for what concerns the link between individual age and operator’s abilities and skills.

5. Conclusion

This study aimed to provide an overview regarding ageing population of EU countries and some developed countries to understand the trend of the ageing workforce phenomenon and of the actions taken so far. As shown in Figure 1 and Figure 2, the employment rate of workers aged 55-64 has increased over the last years, and the rate of ageing workers is increasing in a wide range of countries. In order to keep ageing and expert workers as long as possible in the working system, some policies and strategies have been implemented so far, both from governments and single companies, such as: reducing age discrimination, enhancing age-friendly conditions and creating different types of incentives. Moreover, qualitative and quantitative well-being indexes have been explained, together with some related case studies. These show that they can be effectively used for better identifying workers’ needs in workplaces in terms of health and productivity. This paper represents a further acknowledgment to the ageing issue, showing that future research on this topic is absolutely useful. Besides introducing a ‘production research’ perspective (Calzavara et al. 2020; Sgarbossa et al. 2020), the following topics are becoming urgent:

1. Creation of an overall picture and comparison of all the applied policies of different countries toward ageing workforce. In particular, it would be important to investigate the implemented policies (and their outcomes) at country/government level, company level and individual level, in both EU and other developed countries, to help researchers and decision makers to compare their effectiveness.
2. Development of new indices and standards for the assessment of the well-being of aged workers and applying some self-assessment indices in order to integrate workers individually.
3. Development of new-age friendly design paradigms in order to permit the development of inclusive operation management strategies able to respond to the workers’ individual needs.

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References

- Anca, S. C. (2017). A Critical Analysis of Self-assessment Tools for Improving Workers’ Health and Work Performance. In *International Conference on Advancements of Medicine and Health Care through Technology; 12th-15th October 2016, Cluj-Napoca, Romania* (pp. 283-286). Springer, Cham.
- Barth, M.C., McNaught, W. and Rizzi, P. (1993) ‘Corporations and the Ageing Workforce’, in P.H. Mirvis (ed.) *Building the Competitive Workforce: Investing in Human Capital for Corporate Success*, pp. 156-200. New York: Wiley and Sons.
- Battini, D., Calzavara, M., Persona A., Sgarbossa, F., Visentin, V. & Zennaro, I. (2018). Integrating mocap system and immersive reality for efficient human-centred workstation design. *IFAC-PapersOnLine*, 51(11), 188-193.
- Blomé, M. W., Borell, J., Håkansson, C., & Nilsson, K. (2020). Attitudes toward elderly workers and perceptions of integrated age management practices. *International Journal of Occupational Safety and Ergonomics*, 26(1), 112-120.
- Bogataj, D., Battini, D., Calzavara, M., & Persona, A. (2019). The ageing workforce challenge: Investments in collaborative robots or contribution to pension schemes, from the multi-echelon perspective. *International Journal of Production Economics*, 210, 97-106.
- Börner, K., Löffler, T., & Bullinger-Hoffmann, A. C. (2017). CheckAge-Screening-Verfahren für die Bewertung alter (n) sgerechter Arbeitsplätze. *aw&I Report*, 2, 51-51.
- Botti, L., Mora, C., & Calzavara, M. (2017). Design of job rotation schedules managing the exposure to age-related risk factors. *IFAC-PapersOnLine*, 50(1), 13993-13997.
- Calzavara, M., Battini, D., Bogataj, D., Sgarbossa, F., & Zennaro, I. (2020). Ageing workforce management in manufacturing systems: state of the art and future research agenda. *International Journal of Production Research*, 58(3), 729-747.
- Cebulla, A., & Wilkinson, D. (2019). Responses to an Ageing Workforce: Germany, Spain, the United Kingdom. *Business Systems Research Journal*, 10(1), 120-137.
- Chiu, W.C.K., Chan, A.W., Snape, E. and Redman, T. (2001) ‘Age Stereotypes and Discriminatory Attitudes towards Older Workers: An East-West Comparison’, *Human Relations* 54: 629-661.
- Conen, W., Van Dalen, H., Henkens, K., & Schippers, J. (2011). Activating senior potential in ageing Europe: an employers’ perspective. *Netherlands Interdisciplinary Demographic Institute, The Hague*, 134, 135-136.
- Costa, G., & Sartori, S. (2007). Ageing, working hours and work ability. *Ergonomics*, 50(11), 1914-1930.
- De Pommereau, I. (2012). “How BMW reinvents the factory for older workers”. *The Christian Science Monitor*. <https://www.csmonitor.com/World/Europe/2012/0902/How-BMW-reinvents-the-factory-for-older-workers>.
- El Fassi, M., Bocquet, V., Majery, N., Lair, M. L., Couffignal, S., & Mairiaux, P. (2013). Work ability assessment in a worker population: comparison and

- determinants of Work Ability Index and Work Ability score. *BMC Public Health*, 13(1), 305.
- Eurostat (2019). Ageing Europe - statistics on working and moving into retirement. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Ageing_Europe_-_statistics_on_working_and_moving_into_retirement#Employment_patterns_among_older_people
- Eyster, L., Johnson, R., & Toder, E. (2008). Current strategies to employ and retain older workers. *Washington D.C.: The Urban Institute*. Retrieved from <http://www.urban.org/publications/411626.html>.
- Finco, S., Zennaro, I., Battini, D., Persona, A. (2019). Workers' availability definition through the energy expenditure evaluation. *25th ISSAT International Conference on Reliability and Quality in Design*, pp. 29-33.
- Foden, D., & Jepsen, M. (2002). Active strategies for older workers in the European Union: A comparative analysis of recent experiences. *Active strategies for older workers in the European Union*, 437-460.
- Guillemard, A., Taylor, P. and Walker, A. (1996) 'Managing an Ageing Workforce in Britain and France', *Geneva Paper on Risk and Insurance – Issues and Practice* 21: 478-501.
- Henkens, K. (2005) 'Stereotyping Older Workers and Retirement: The Managers' Point of View', *Canadian Journal on Aging* 24: 35-48.
- Ilmarinen, J. (Ed.). (1991) The aging worker, *Scandinavian Journal of Work Environmental Health*, 17, 1–141.
- ISO TC 314 Ageing Societies (2020). <https://committee.iso.org/home/tc314>
- Katirae, N., Battini, D., Battaia, O. & M. Calzavara. (2019) Human diversity factors in production system modelling and design: state of the art and future researches. *IFAC-PapersOnLine*, Volume 52, Issue 13, 2544-2549.
- Keil M, Spanner-Ulmer B (2010) Conception of a task analysis and screening-method for identifying age-critical fields of activity on the basis of the Chemnitz Age Model. *3rd international conference on applied human factors and ergonomics*, Boca Raton, USA, pp 393–400.
- Koc-Menard, S. (2009). Flexible work options for older workers. *Strategic HR Review*, 8(2), 31-36.
- Lima, I. A. X., Moro, A. R. P., & Cotrim, T. P. (2018, August). Capacity index for work, psychosocial risk of work and musculoskeletal symptomatology in workers of a meat processing industry in Portugal. *In Congress of the International Ergonomics Association* (pp. 289-295). Springer, Cham.
- Loretto, W., & White, P. (2006). Employers' attitudes, practices and policies towards older workers. *Human resource management journal*, 16(3), 313-330.
- Malone, D. (2007). How and why a culture of aging is good for business. *Presentation at the National Governors Association Policy Academy on Civic Engagement of Older Adults*, Annapolis, MD
- Naegele, G., & Walker, A. (2006). *A guide to good practice in age management*. Luxembourg: Office for Official Publications of the European Communities. Retrieved from <http://www.eurofound.europa.eu/publications/htmlfiles/ef05137.htm>.
- OECD (2017). “Old-age dependency ratio”, in *Pensions at a Glance 2017: OECD and G20 Indicators*, DOI: https://doi.org/10.1787/pension_glance-2017-22-en
- OECD (2019). Employment Outlook <https://data.oecd.org/emp/employment-rate-by-age-group.htm#indicator-chart>
- Piktialis, D. (2007). Adaptations to an aging workforce: Innovative responses by the corporate sector. *Generations*, 31(1), 76.
- Schaub, K., Wakula, J., Berg, K., Kaiser, B., Bruder, R., Glitsch, U., & Ellegast, R. P. (2015). The assembly specific force atlas. *Human Factors and Ergonomics in Manufacturing & Service Industries*, 25(3), 329-339.
- Sgarbossa, F., Grosse, E. H., Neumann, W. P., Battini, D., & Glock, C. H. (2020). Human factors in production and logistics systems of the future. *Annual Reviews in Control*.
- Silva CF, Amaral V, Pereira A, Bem-haja P, Rodrigues V, Pereira A, Alves A (2011). Índice de capacidade para o trabalho - Portugal e os Países Africanos de Língua Oficial Portuguesa.
- Szymanski H, & Lange A. (Accessed 30 May 2018). Den demografischen Wandel in der Eisen- und Stahlindustrie gestalten – eine Handlungshilfe zur alter(n)sgerechten Arbeitsgestaltung. www.ergo-stahl.de.
- Taylor, P. and Walker, A. (1998) 'Employers and Older Workers: Attitudes and Employment Practices', *Ageing and Society* 18: 641-658.
- Tuomi, K., Ilmarinen, J., Jankola, A., Katajarinne, L. and Tulkki, A. (1998), Work Ability Index. 2nd revised edition (*Helsinki: Finnish Institute of Occupational Health*).
- UNECE (January 2011) “Combating ageism in the world of work”. UNECE Policy Brief on Ageing No. 9. http://www.unece.org/pau/age/Policy_briefs/Good_Practices.html
- United Nations. (2019). World population prospects 2019. <https://population.un.org/wpp/>
- Van Dalen, H. P., Henkens, K., & Schippers, J. (2009). Dealing with older workers in Europe: a comparative survey of employers' attitudes and actions. *Journal of european social policy*, 19(1), 47-60.
- Vodopivec, M. and Dolenc, P. (2008). “Live Longer, Work Longer: Making It Happen in the Labor Market”, SP Discussion Paper No. 0803.
- Walker, A. (2002) ‘A strategy for active ageing’, *International Social Security Review*, Vol. 55. 1., p. 121–39.
- Wilckens, M. R., Wöhrmann, A. M., Adams, C., Deller, J., & Finkelstein, R. (2020). Integrating the German and US Perspective on Organizational Practices for Later Life Work: The Later Life Work Index. In *Current and Emerging Trends in Aging and Work* (pp. 59-79). Springer, Cham.
- Wolf, M. & Ramsauer, C. (2018). Towards an Age-Differentiated Assessment of Physical Work Strain. *In: Congress of the International Ergonomics Association*. Springer, Cham, p. 189-205.
- Yang, D. J., Kang, D., Kim, Y. K., Kim, Y. H., Yang, Y. A., Cha, S. M., ... & Kim, J. E. (2013). Reliability of self-administered Work Ability Index questionnaire among Korean workers. *Ergonomics*, 56(11), 1652-1657.