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# Human-centred work design in times of digital change – work conditions, level of digitization and recent trends for object-related tasks

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**Abstract**

New technologies are influencing today's work and change social attitudes towards the organization and design of work. Against this background, the question arises as to how human-centred work design has to be in the digital age. In order to derive indications for work design, first it is necessary to find out which work conditions actually are present for different tasks and what their level of digitization is. This article focuses on the working conditions and the level of digitization of object-related tasks. These tasks are characterized by the fact that objects are processed or handled. In particular, it includes the task groups manufacturing, transporting and cleaning.
For these three groups, current working conditions of N = 6.435 employees with object-related tasks were analyzed based on the BIBB/BAuA Employment Survey. Furthermore, the current state of digitization of N = 411 employees with object-related tasks was analyzed based on the survey Digitization and Change in Employment (DiWaBe). The results show, that a high proportion of physical work requirements and physical-chemical environmental conditions have an impact on object-related tasks. Furthermore, the results indicate tendencies towards monotonous work processes. Object-related tasks show a rather low degree of digitization. However, especially in manufacturing and transport, detailed instructions are often given by means of various technologies.
Based on the data analysis, a structured literature analysis was conducted about the current state of research on new technologies in object-related tasks. It was found, that research and practice is concerned with technologies that meet the high physical demands of object-related tasks in particular (e.g. HRC, exoskeletons). In addition, there are many approaches to support employees cognitively with digital assistance systems. This article present the results of the data and literature analysis.



*Keywords:* OSH; new technologies; work conditions

## 1. Introduction

Innovative technologies are influencing social attitudes surrounding the organizations as well as the design of work. Bundled in a focus programme called “occupational safety & health in the digital world of work” the Federal Institute for Occupational Safety and Health (BAuA) conducts research on human-centered work design in the digital age. For this purpose, one programme component analyzes the effects of digital change and the development of human-centered design principles within four different activity clusters: leadership and management, person-related tasks, information-based tasks and object-related tasks, on which this article focusses.

Object-related tasks are characterized by the fact that material goods, which are fed into the work system as input, are transformed into a different state against the background of value creation [1]. This transformation of the objects condition can be spatial or temporal as well as qualitative or quantitative [2]. The spatial and temporal transformation of objects is particularly about transport and storage activities. Quantitative state transformation is found, among other things, in sorting and picking activities, while qualitative state transformation is particularly evident in the manufacturing, processing, treatment or cleaning of goods [3]. To investigate the possibilities of new technologies for supporting employed persons in object-related tasks, different steps were carried out.


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First, we identified manufacturing, transporting and cleaning as subclusters representing object-related tasks. The analysis then included a data based study about current working conditions as well as about the level of digitization within the three subclusters. Furthermore, we collected and analyzed the current state of research on the use of new technologies in object-related tasks. The following sections describe the study design and report the results of the three analyses.

## 2. Study design

In the focus programme mentioned before the responsible researchers followed a common methodical approach for their analysis about knowledge-based, object-related, and person-oriented work tasks as well as leadership and management. This mainly was done to ensure the highest possible comparability and quality assurance. The study design for object-related tasks thus corresponds to the other subclusters.

### *2.1. Current working conditions*

The analyses of the current working conditions base on the BIBB/BAuA Employment Survey. This is a cross-sectional telephone survey of approximately 20,000 employed persons aged 15 and older who are in paid employment for at least 10 hours per week. For the analyses, dependent employees between the ages of 15 and 65 were taken into account, if the data sets are completely valid. The survey focuses on questions about working conditions and the health situation of employees in the workplace. In addition, employees are asked about 16 separated work activities and how often they perform each of these tasks [4]. By means of these activities, an identification of the three subclusters manufacturing, transporting and cleaning as object-related tasks was possible in the data sets. The exact detailed identification process is described in [5]. By this, n = 6,435 employees with object-related tasks were identified from a total of n = 17,500 respondents in the Employment Survey of 2018. The employees with object-related tasks can be clearly distinguished from the comparison group of all other respondents (n = 11,127).

### *2.2. Level of digitization*

The survey "Digitalization and Change in Employment" (DiWaBe) is a telephone survey on the effects of the digital transformation, which was conducted in 2019. The focus is on the spread of the use of digital technologies as well as on their social, work organization and health-related consequences. Approximately 7,500 employees from around 2,000 German manufacturing and service companies were surveyed. Randomly selected employees up to and including the age of 65 were taken into account for the analyses, insofar as they provided valid information on the questions [5].

For the analysis of the level of digitization, we identified anchor occupational groups in the KldB 2010 [6], which represent the three subclusters by means of their task profile. The exact derivation of the sample can be found in [5]. In the DiWaBe n = 411 employees with object-related tasks were identified for the analysis from a total of n = 6,333 respondents.

### *2.3. Current state of research*

Together, the responsible researchers developed parallelized review protocols before this review was done. In addition to defining the research questions, these contained a description of the individual search steps and basic inclusion and exclusion criteria for the selection of publications. We conducted a systematic search using an extended version of the PICO (population, intervention, control and outcomes) format to identify literature on the digital transformation. The following inclusion and exclusion criteria for articles were used:

- **Population**: Workers or workplaces with manufacturing, transportation or cleaning tasks, aged 18-65 years.
- **Intervention**: Research studies about the use of digital technologies for object-related tasks or changes of these work tasks associated with digital transformation. Laboratory studies about simulated object-related tasks in a work context.
- **Comparator**: Any comparator including no intervention.
- **Outcomes**: Physical/psychological outcomes related to OSH. Studies that only aimed to measure performance or productivity were excluded.
- **Study Design**: All empirical research designs with both qualitative and quantitative findings. Non-empirical publications such as discussion articles, articles introducing concepts, models or applications, unsystematic reviews and non-research-related publications were excluded. Systematic Reviews and Meta-Analysis were included.
- **Period**: Only journal articles published between January 2007 and December 2020, in order to portrait contemporary effects of digital transformation on object-related tasks.
- **Language**: Only articles written in English or German.
- **Databases**: Web of Science, PubMed, and EbscoHost as well as hand search.
- **Other**: No proceedings, reference lists or grey literature.

To identify potentially relevant papers we used variants and combinations of search terms relating to 1) object-related tasks, 2) information and communication technologies or digitization and 3) OSH related outcomes. The terms within these string categories were combined using a Boolean OR operator. The string categories itself were then combined using a Boolean AND operator. In addition, we performed an opportunistic backward and forward citation analysis.

For publication selection within the identified references, initially all duplicates were removed. Studies were then first screened based on title and abstract, then by reading the full text to identify whether it met the following criteria: (1) Directly related to object-related tasks, (2) Reference to digitization, (3) Participants in employable age.

Based on the full-text, we excluded studies as well based on the following criteria: technology only as measurement instruments; only technology development with usability tests; development of measurement instruments; prevalence of technology use only; modelling or simulation only; methodological contributions; only performance or productivity as outcomes. The lead reviewer screened the studies for inclusion, with a subsample done by a second reviewer.

## 3. Results

This section describes the results of the three performed studies. For the analysis of the working conditions and the level of digitization, interference statistical methods were used. Primarily conspicuous differences between the subclusters and the respective comparison group are reported descriptively by means of rounded percentage values. The current state of research on the use of new technologies in object-related tasks was collected as described above and will be reported as qualitative results.

### *3.1. Current working conditions*

Based on the analyses of the BIBB/BAuA Employment Survey of 2018, object-related tasks show high physical working conditions as well as strongly pronounced environmental influences compared to other employees. Fig. 1 shows the characteristics of physical working conditions in the three subclusters compared to the comparison group. We can see that working in standing position and working with the hands occur significantly more frequently than in other tasks. In the case of transportation, there is also a high level of stress due to handling heavy loads, while work in forced postures notably is pronounced in the case of cleaning.

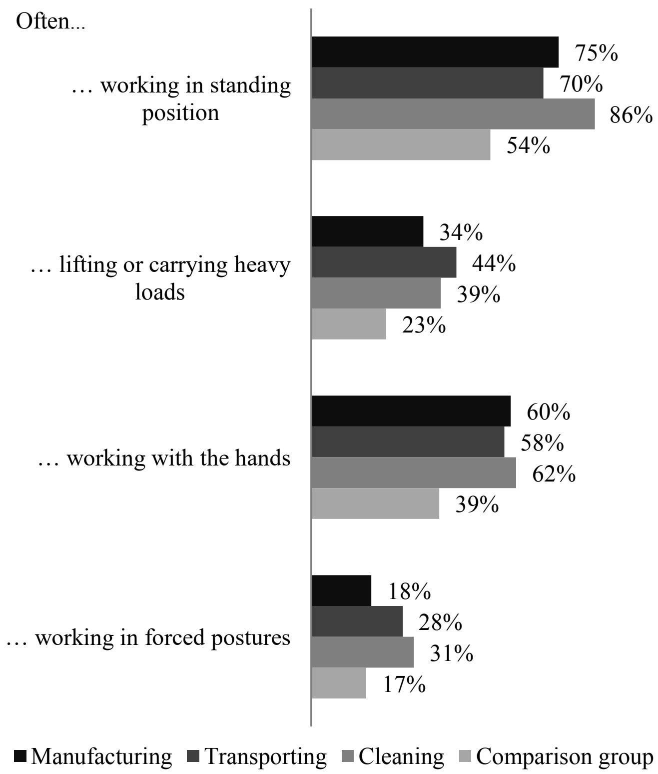


Fig. 1. Physical requirements of workers with object-related tasks

With regard to environmental influences, working under loud noise is more frequent in manufacturing and cleaning tasks than in the comparison group (56 %; 40 % vs. 27 %). In addition, handling oil, grease, dirt or grime (38 %; 37 % vs. 18 %) as well as working under the influence of smoke, gases, dust or vapors (32 %; 24 % vs. 13 %) is stronger pronounced these two subclusters. Transporting and cleaning tasks are more frequently performing under difficult climatic conditions than other activities (39 %; 35 % vs. 21 %).

Consistently, employees with object-related tasks in manufacturing, transporting and cleaning report a higher average value of musculoskeletal complaints than employees in the comparison group (2.1; 2.6; 2.5 vs. 1.9; scale: 1 to 5). Higher physical fatigue (37 %; 45 %; 42 % vs. 33 %) is also mentioned.

In the case of object-related tasks, the factors influencing monotony are more pronounced overall than in the case of other employees. Against the comparison group, in object related tasks the working process is more frequently prescribed in all details. Furthermore, we can see a predetermination of work performance parameters and the majority of employees regularly repeat the same work operation (see Fig. 2).

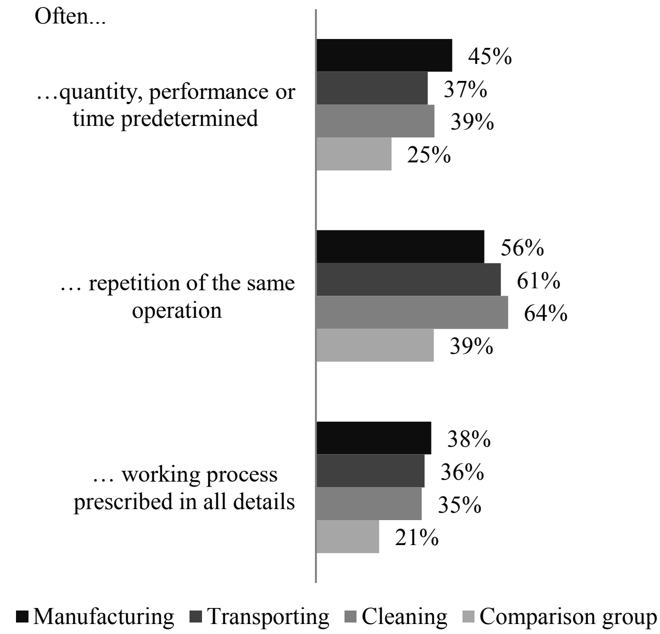


Fig. 2. Factors of monotony in object-related tasks

With regard to the employees' scope of action, 47 % of the employees in the manufacturing sector are able to plan and schedule their work themselves, which is lower than in the comparison group (66 %). Employees in the transport sector are confronted with new tasks less often than other employees (31 % vs. 42 %). In cleaning tasks, learning and problem-solving requirements are less frequent. Only 24 % of respondents frequently are confronted with new tasks at work.

### *3.2. Level of digitization*

Based on the DiWaBe, the majority of employees considered in manufacturing tasks (57 %) state that they frequently use information and communication technologies (ICT) at work. This is a significantly lower proportion than in the comparison group (84 %). The smartphone in particular they use less frequently than other employees do. The use of other technologies such as desktop PCs, laptops and tablet PCs is roughly the same as in the comparison group. For 42 % of respondents, it is common that technology provide them with instructions in their work. In manufacturing tasks, 68 % of the respondents report a frequent use of tools, machines, devices or equipment. The focus here is on stationary machines and equipment (66 %). The employees in the manufacturing subcluster also use modern trending technologies at work. For example, there is a partial use of technologies such as virtual/augmented reality, artificial intelligence or 3D printing.

In transportation, only 57 % of respondents frequently use ICT at work. The focus here is on the use of smartphones. Other technologies such as desktop PCs or laptops are used less frequently. In contrast, employees use vehicles at work significantly more frequently (88 %) than people in the comparison group (25 %). In particular, the frequent use of trucks (84 %) significantly exceeds the corresponding value in the comparison group (11 %). For the majority of employees in transportation tasks, it happens that the technologies within the vehicles provide them with work instructions.

In the cleaning subcluster, the use of technology is minimal. Respondents very rarely use information and communication technologies at work. A breakdown of the individual technologies is not possible due to this low proportion.

### *3.3. Current state of research on new technologies in object-related tasks*

Research into manufacturing tasks is based broadly. In the course of digitization, we see the investigation on possible applications of future technologies. An overview is provided by an online benchmark study on the importance of various technologies for companies in the industry [7]. They surveyed 91 participants from industries related to manufacturing tasks. Participants provided an assessment, if specific technologies are important for future manufacturing or if they are already in use. Table 1 shows excerpts from the results for the automotive industry and other industrial manufacturing.

Table 1. Assessment of various future technologies [7]

| Technology | Automotive industry | |
|---|---|---|
| | Important | In use |
| Collaborative robotics | 74 % | 23 % |
| Self-learning systems | 45 % | 16 % |
| Driverless transport systems | 48 % | 32 % |
| Augmented Reality | 58 % | 10 % |
| Exoskeletons | 26 % | 32 % |
| Technology | Industrial manufacturing | |
| | Important | In use |
| Collaborative robotics | 71 % | 27 % |
| Self-learning systems | 49 % | 27 % |
| Driverless transport systems | 42 % | 24 % |
| Augmented Reality | 33 % | 18 % |
| Exoskeletons | 24 % | 20 % |

The fact that company representatives classify collaborative robots as the most important technology is consistent with the amount of research activity in this topic area within the literature. One author [8] addresses the concern that an increasing use of robotics and automation can lead to a substitution of humans in industrial routine work. The author also makes clear that a machine cannot replace humans so easily due to their characteristics in terms of flexibility and adaptability. The mutual support of humans and machines with their respective strengths also results in economic potentials [8]. The use of personally assisting service robots in manufacturing [9] represents still a small research area. A much broader topic is the physical support of humans by robotics. For example, in a case study of human-robot collaboration (HRC) in wire harness assembly, the authors report that the use of HRC offers potentials to improve the physical load as well as the posture of workers in their jobs [10]. Other research also concludes that the use of HRC can mitigate various musculoskeletal risk factors, such as bad postures and large physical load handling during repetitive movements [11].

An alternative technology to robotics for the physical assist of workers load handling are exoskeletons. However, this technology, and especially its potential for spinal relief, is more in focus of current research than in real implementation [12].

By means of stakeholder interviews, one study elaborate user requirements for human-robot collaboration in industrial manufacturing [7]. The authors report about the relevance that robotic systems are able to adapt to workers in terms of their parameters (safety level, speed etc.). Among other things, the employees' experience with robots, their preferred working methods, skills and physical characteristics must be taken into account. Furthermore, it is important that the robots can be controlled via mobile device, voice or gesture control and provide at least visual and auditory feedback [7].

A second major topic in research on manufacturing tasks is cognitive work assistance including the implementation of augmented reality (AR). In many cases, the use of digital, information-based assistance systems is investigated either for the provision of work instructions or for learning processes. In the first case, studies predominantly compare work instructions via digital information systems, e.g. smartphone or projectors to paper-based systems with regard to various factors such as usability, stress and performance [13]. One laboratory study state that a projection-based AR assistance system leads to increased user acceptance, improved performance, and reduced task complexity compared to paper-based instructions [14]. Other authors compare six different human-machine interfaces (e. g. data glasses, headset, and smartphone) as part of a field study in the automotive industry with a total number of 67 quality assurance workers [15]. The results indicate that the implementation on a smartphone achieves the highest user acceptance. Furthermore, from the participants' point of view, smartphone and data glasses show the most potential. This potential of digital information provision during task execution can be supported by multimedia content [7]. Among other things, so-called serious gaming, implemented e.g. by using augmented or virtual reality, can increase the effectiveness of learning complex assembly activities [16]. Finally, it can be crucial to adapt the information provision and the level of support to the experience knowledge of the employees [7].

Self-controlling systems and artificial intelligence (AI) also play a central role in manufacturing research. There is an increasing number of general or prototype feasibility studies, which focus more on functionality, efficiency and cost-effectiveness than on relevance for employees. This includes driverless transport systems, which have been successfully developed and tested in the field of intralogistics [17]. However, some authors also address opportunities for cognitive support of employees in the execution of tasks as well as in learning processes [18]. One study present and investigate a context-sensitive assistance technology that supports employees with cognitive disabilities in an assembly task via a sensor and AI-based prompting system [19]. The authors report positive results in the task performance, so that this type of technology have possibilities for inclusion support.

For tasks in the area of postal and parcel services, various research foci can be found, especially based on an increasing online trade and climate change factors [20]. There is an enormous increase in the number of packages delivered to organizations and individuals. On-time delivery and customer satisfaction are top priorities due to strong competition between different service providers [20, 21]. For employees, this means time and performance pressure at work. However, they are not always able to meet this for various reasons. Especially in inner cities, a large amount of vehicles result in crowded streets, traffic-related delays, and lack of stopping facilities [22]. Another reason is the frequency of incorrect deliveries. This results in increased time as well as handling costs due to redundancies in delivery [21]. Although the number of parcel stations and pick-up points is increasing, customer acceptance in this regard is lower in comparison to front door delivery [22]. If the amount of work remains the same, the time-bound stress for employees is very high.

The digitization of many business processes at service providers is a great challenge. Many digital services have been implemented for customers, such as online payments or track & trace, which have an impact on employees [21]. Through live tracking systems, the work performance of the person delivering becomes transparent. In addition, employees need digital skills for these new digital tasks. The large volume of parcels generated by online retailing results in a large number of handling operations during working hours. These occur during loading and unloading of the vehicles as well as during manual transport between the vehicle and customer. One study is about using motion capturing for an ergonomic assessment of risks to the musculoskeletal system of postal workers [23]. The results indicate an increased risk of musculoskeletal disorders, particularly in the shoulders, cervical and lumbar spine for employees. Increased attention to OSH for postal workers is called for. Innovations in this topic may include physical assistance systems, such as exoskeletons [12].

In response to the relevance of customer satisfaction in terms of on-time delivery or minimal delivery times, research is also looking at the potential of drones for parcel delivery. The increase in efficiency in delivery times would also be associated in part with personnel cost savings for the companies and thus substitution effects on side of employees [20]. According to [24], however, the use of drones in this industry is still discussed very critically despite advanced technological developments. Beside the fact that the legal framework is not yet given in many countries, the author points out various reasons that currently speak against an introduction. High acquisition costs and restrictions on parcel delivery in terms of transport volume (only individual parcels), transport weight and battery life are mentioned. In addition, there is a limited range of the drones as well as a scattering in the landing accuracy. The use of drones results in a need for restructuring with regard to warehouses and transshipment points as well as the creation of a charging infrastructure. Further, there are existing safety risks as barriers [24]. These can arise due to fluctuating weather conditions, vandalism, and the interception or hacking of drones, resulting in crashing into people or colliding with other flying objects. One study also investigated the acceptance of drone use for parcel deliveries, in which 832 telephone interviews were made with randomly selected participants in Germany [25]. The results show a critical attitude of the participants towards the use of drones. 59 % of the respondents reject drone deliveries. 71 % of the respondents cannot imagine using drones for their own purposes. Traffic safety, noise, privacy and animal protection were cited as reasons for the predominantly negative attitude.

For cleaning, there is a small number of research activities in current literature. Studies mainly deal with the development of cleaning robots and its functionality. Because there is no clear reference to OSH, we do not report any results here.

## 4. Conclusion

For the described results, the data of two quantitative studies about work conditions and level of digitization were combined with a structured literature search. A common methodical approach within four different subclusters of work tasks was followed to ensure a high level of comparability. Here, the researchers are aware that the exclusion of proceedings, especially for manufacturing, is also associated with a loss of knowledge across the complete range of research.

In the case of object-related tasks, there are two main areas of focus for the human-centered design of work by means of digital assistance systems: The physical support of employees on the one hand and the reduction of monotony and dequalification on the other. For object-related tasks, overall higher physical requirements can be identified compared to other employees. Work in standing position and handling of heavy loads frequently happen. Consistently, there are more musculoskeletal complaints and higher physical exhaustion. In addition, work under unpleasant environmental conditions occurs. In manufacturing, work under loud noise is pronounced. Employees with cleaning and transporting tasks, on the other hand, often work in unfavorable climatic conditions. Thus, the selection of digital assistance systems and its interaction design must take into account the respective physical requirements and environmental conditions for object-related tasks. With a view to the current state of research, all three subclusters accordingly have in common the examination of the physical support of employees by digital assistance systems. Predominantly, the use of robots is investigated and many possible use cases are shown. The literature increasingly also deals with exoskeletons to support manual load handling. A human-centered use of physically supporting assistance systems can offer the chance to reduce risks for the musculoskeletal system of the employees. However, it is important to adapt the respective systems and the associated interaction to the abilities and skills of the employee.

In addition to the physical requirements, lower learning and interaction requirements are evident in object-related tasks. Employees are faced with new tasks less frequently. There is a high repletion of same operation steps during work in all subclusters, with employees often get predefined work performance parameters. It results in a tendency toward monotonous work processes in object-related tasks. In particular, employees in the manufacturing and transportation subclusters are often prescribed work instructions in all details. Within the two subclusters, this correspond to the results of the DiWaBe. The prescribed work method matches with the frequent reception of work instructions by ICT in manufacturing tasks and by technologies in vehicles in case of transporting tasks. The need for cognitive support in manufacturing tasks arises from the increasingly complex, varying assembly and products. In this area, mobile devices and augmented reality offer great potential for mental relief. Both during task execution and for learning processes, these can enable targeted, individually adaptable information provision. Here, it is important to design assistance systems that are favorable for learning and to adapt them to the respective knowledge of employees. For transportation tasks, the focus is on the digital competence development of employees. This is necessary in order to avoid a high level of stress for employees when dealing with the high amount of digital services. However, digital assistance systems can also downsize processes, save time and support necessary decisions through intelligent information exchange. This can lead to an additional support for employees, provided that the amount of work does not increase at the same time. At this point, a high degree of system transparency is required, as well as consideration of the scope of action and the knowledge of the employees.

Overall, in object-related tasks there is currently only a small use of digital assistance systems. By the increasing use of modern intelligent ICT, however, there is enormous potential for supporting employees. In this context, existing work requirements must be taken into account. By means of suitable technologies, currently existing physical as well as mental stress factors can be reduced. Environmental influences can function as criteria for the selection of technology.

## References


[1] Ulich E. Arbeitspsychologie. Stuttgart: Schäffer-Poeschel, 2005.

[2] Dangelmeier W. Theorie der Produktionsplanung und -steuerung. Berlin Heidelberg: Springer, 2009.

[3] Dyckhoff H. Produktionstheorie. Grundzüge industrieller Produktionswirtschaft. Berlin Heidelberg: Springer, 2006.

[4] Wittig P, Nöllenheidt C, Brenscheidt S. Grundauswertung der BIBB/BAuA-Erwerbstätigenbefragung 2012. Dortmund/Berlin/Dresden: BAuA, 2013.

[5] Terhoeven J. Objektbezogene Tätigkeiten im digitalen Wandel. Arbeitsmerkmale und Technologieeinsatz. 1st ed. Dortmund: BAuA, 2021.

[6] Bundesagentur für Arbeit. Klassifikation der Berufe 2010. Band 2: Definitorischer und beschreibender Teil (KldB 2010). Nürnberg: Bundesagentur für Arbeit, 2011.

[7] Fletcher S, Johnson T, Adlon T, Larreina J, Casla P, Parigot L, Alfaro P, Otero M. Adaptive automation assembly: Identify-ing system requirements for technical efficiency and worker satis-faction. Computers & Industrial Engineering. 2020; 139:105772.

[8] Pfeiffer S. Robots, Industry 4.0 and Humans, or Why Assembly Work Is More than Routine Work. Societies. 2016; 6(2):16.

[9] Brandl C, Mertens A, Schlick CM. Human-Robot Interaction in Assisted Personal Services: Factors Influencing Distances That Humans Will Accept between Themselves and an Approaching Service Robot. Human Factors and Ergonomics in Manufacturing & Service Industries. 2016; 26(6):713-727.

[10] Gualtieri L, Palomba I, Merati FA, Rauch E, Vidoni R. Design of Human-Centered Collaborative Assembly Workstations for the Improvement of Operators' Physical Ergonomics and Production Efficiency: A Case Study. Sustainability. 2020: 12:3606.

[11] Realyvasquez-Vargas A, Arredondo-Soto K, García-Alcaráz JL, Márquez-Lobato, BY, Cruz-García J. Introduction and configuration of a collaborative robot in an assembly task as a means to decrease occupational risks and increase efficiency in a manufacturing company. Robotics and Computer-integrated Manufacturing. 2019; 57:315-328.

[12] Madinei S, Alemi MM, Kim S, Srinivasan D, Nussbaum MA. Biomechanical evaluation of passive back-support exoskeletons in a precision manual assembly task: 'expected' effects on trunk muscle activity, perceived exertion, and task performance. Human Factors. 2020; 62(3):441-457.

[13] Minow A, Böckelmann I. Beanspruchung, objektive Leistung und Gebrauchstauglichkeit bei simulierten Montageprozessen mit digitalen Arbeitsanweisungen. Zentralblatt für Arbeitsmedizin, Arbeitsschutz und Ergonomie. 2020; 70:47-56.

[14] Uva AE, Gattullo M, Manghisi VM, Spagnulo D, Cascella GL, Fiorentino, M. Evaluating the effectiveness of spatial augmented reality in smart manufacturing: a solution for manual working stations. The International Journal of Advanced Manufacturing Technology. 2018; 94(1-4):509-521.

[15] Borisov N, Weyers B, Kluge A. Designing a Human Machine Interface for Quality Assurance in Car Manufacturing: An Attempt to Address the "Functionality versus User Experience Contradiction" in Professional Production Environments. Advances in Human-Computer Interaction. 2018; 9502692.

[16] Li K, Hall M, Bermell-Garcia P, Alcock J, Tiwari A, Gonzalez-Franco M. Measuring the Learning Effectiveness of Serious Gaming for Training of Complex Manufacturing Tasks. Simulation & Gaming. 2017; 48:770-790.

[17] Karabegović I, Karabegović E, Mahmić M, Husak E. The application of service robots for logistics in manufacturing processes. Advances in Production Engineering & Management. 2015; 10(4):185-194.

[18] Fahle S, Prinz C, Kuhlenkötter B. Systematic review on machine learning methods for manufacturing processes – Identifying artificial intelligence methods for field application. Procedia CIRP. 2020; 93(1):413-418.

[19] Mihailidis A, Melonis M, Keyfitz R, Lanning M, van Vuuren S, Bodine C. A nonlinear contextually aware prompting system (N-CAPS) to assist workers with intellectual and developmental disabilities to perform factory assembly tasks: system overview and pilot testing. Disability and Rehabilitation: Assistive Technology. 2015; 11(7):604-612.

[20] Bosona T. Urban Freight Last Mile Logistics – Challenges and Opportunities to Improve Sustainability: A Literature Review. Sustainability. 2020; 12:8769.

[21] Otsetova A. Digital Transformation of Postal Operators – Challenges and Perspectives. Transport and Communications. 2019; 7(2):15-20.

[22] Visser J, Nemoto T, Browne M. Home Delivery and the Impacts on Urban Freight Transport: A Review. Procedia - Social and Behavioral Sciences. 2013; 125:15-27.

[23] Silva L, Rosa C, Paulo I, Mattos N, Giracca C, Merino G, Merino, E. Ergonomic Assessment of Musculoskeletal Risks in Postal Workers Through Motion Capture, a Case Study. In: Arezes, P, Baptista, JS, Barroso, MP, Carneiro, P, Cordeiro, P, Costa, N, Melo, R, Miguel, AS, Perestrelo, G., editors. International Symposium on Occupational Safety and Hygiene: Proceedings Book of the SHO2020. 2020; 85-88.

[24] McKinnon AC. The Possible Impact of 3D Printing and Drones on Last-mile Logistics: An Exploratory Study. Built Environment. 2016; 42(4):617-629.

[25] Eißfeldt H, Vogelpohl V, End A. Investigating attitudes towards drone delivery. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2020; 64(1):169-173.