The occupational health and safety risks of ongoing digital transformation. A knowledge management software powered literature review

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Abstract: The fast technical-organizational transformation undergoing, promoted by Industry 4.0 as well as other similar initiatives, partly sped up due to the Covid-19 pandemic, is radically changing actors, modes, and environments of human work. Although part of these innovations is directed at occupational health and safety (OHS), some scholars raise reasonable doubts, arguing that the same innovations even if they solve some problems, could create new ones. The 4th industrial revolution is likely introducing entirely new categories of worker risks. This review explores the evidence base that supports the latter hypothesis. Besides, it proposes an innovative and potentially useful combination of methods and computer applications. By applying the Prisma methodology, tagging one-by-one activity, and hyperlinks, the paper proposes a knowledge graph explorable in terms of semantic, logical and chronological links as well as argumentative. In the final phase, the paper synthesizes in a meta-annotation ten recurring themes and clusters that emerged in this bottom-up process of knowledge elicitation.

Keywords: Cyber Physical Systems, Work 4.0, Enabling technologies, Occupational Health and Safety

1.Introduction

The so-called 4th Industrial Revolution, often referred as *digitalization*, subsumes different uses of technology and several distinct connotations of transformation (Polat and Erkollar, 2021). The glimpsed future is that of environmental and economics savings, of tasks and procedures simplification and, finally, of ubiquitous and persistent real-time information sharing (Hagberg, Sundstrom and Egels-Zandén, 2016). In a speed up feedback loop, technology modifies society and is modified by society (Stephan et al., 2012). In addition, the ongoing Covid-19 pandemic is acting as true catalysts, accelerating more the digitalization process (Sarfraz et al., 2021). Regardless of its pace, by changing modes and places of human work, digitalization seems to affect performance and safety favorably as confirmed by several researchers (Romero et al., 2018). However, other researchers scale back this expectation because of potential new categories of hazards that the 4.0 worker will face (Pietrafesa et al., 2019). Undoubtedly the technological revolution requires new perspectives: industry 4.0 needs a worker 4.0, a Safety 4.0, hence, a Safety Science 4.0. Actually, the Safety Science has already undertaken an autonomous critical journey of content reworking, as Resilience Engineering (RE) acknowledges the complexity of socio-technical systems and the consequent need for a different perspective (e.g., Safety-II) (Patriarca, Bergström, et al., 2018). Safety-II and Safety 4.0 seem to follow separate trajectories, yet, although from different perspectives, there is no shortage of commonalities, such as, e.g., the recognized interdependence of technological and social factors characterizing contemporary complexity. Therefore, the currently underway Safety reworking is making converge concepts that previously seemed distant (e.g. within cyber-security, safety and security are progressively losing their distinction), as is making reconsider relative importance of other concepts. The phenomenon is paroxysmal, given the speed with which both revolutions are proceeding. Scholars are demanded to redefine old ideas and to come up with new ones to cope with the challenges yield by contemporary sociotechnical systems (Patriarca et al., 2021). Academics risk to make useless effort with little or no benefit since a large amount of the scholarly process takes place tacitly, therefore making explicit some of that tacit knowledge would be extremely advantageous. For these reasons, this article shows how to integrate a systematic review method (i.e PRISMA) with a knowledge management tool with the aim of internalizing even discarded documents during the necessary literature review process. The following section details the method by implementing it to newer trends in Occupational Health and Safety (O.H.S. 4.0); section 3 reports major findings; section 4 concludes the article with general considerations on the results.

2.Methodology

The proposed approach follows the PRISMA framework (Moher et al., 2009), currently used for systematic reviews in many field (Patriarca et al., 2017; Cantelmi, Di Gravio and Patriarca, 2021). For first, review's rationale and objectives were defined which, in our case, are to identify peer-reviewed articles concerning occupational hazards related to digitalization. Scopus database has been chosen as primary source to meet the requirement over peer-reviewed documents. The survey was limited to journal articles and conference proceedings, in Italian and English, over a time span from 2012 to now. The documents were looked for at the intersection of two semantic domains corresponding to “Digital transformation” and “Occupational Health & Safety”(cfr. figure1).

Figure 1: The area investigated by the review is at the intersection between “digital transformation” and “occupational health and safety” concepts.

The search query returned 379 documents that will be evaluated in the next screening phase. In the screening phase, a researcher, by reading the abstracts, classified the documents into three categories of relevance: *Yes* (definitely relevant – 41 documents), *No* (definitely not relevant – 299 documents), *Maybe* (relevance not assessable from just reading the abstract – 39 documents). In detail, off-topic articles, those concerning patient safety and those directly related to cyber-security have been considered irrelevant, due to the conceptual difference between safety and security. In the next phase, a researcher provided in-depth reading of 80 articles (i.e., *Yes* + *Maybe*), jointly with the usage of Obsidian knowledge management software (Obsidian, 2020) (for approximately 50 man-hours). The complete list of documents is available at https://tinyurl.com/obs-results. The implemented use of Obsidian roughly traces the approach adopted and described by sociologist Luhman for his *Zettelkasten* (Faatz, Zimmermann and Godehardt, 2009). During this stage the researcher created two possible types of notes: literature notes and topic notes.

2.1 Literature notes

Literature notes were created concurrently to reading and follow a standard format: note title – bibliographic information – tag section – note body. The note title is built as a unique alphanumeric identifier, while bibliographic information section lists article title, authors, journal name, publication date, doi. However, any other relevant information may be indicated, e.g., references and citing documents. The tag section is reserved for tags freely assigned by the researcher during the reading stage. Tags are semantic marks established by the reader of the article and they are generally different from the its keywords. However, Obsidian has built-in powerful search capabilities, therefore a keyword search is easy. More notably, the tool suggests tags already in use to avoid redundancy given by semantically overlapping tags (e.g., #cobot, #cobots, #collaborative_robots).

The note's body contains researcher’s thoughts annotated during the reading stage. Obsidian allows quite complex text formatting (e.g., bold, italic, bulleted and numbered lists, hierarchy of headings, tables, graphics) which increases the expressiveness of the annotation. In addition, external files, images, audio and uniform resource locators (URLs) can be embedded in the notes. However, the most important feature is that of embedding another type of hyperlink in the note (known as direct link) achievable by enclosing a string of text between a double pair of square brackets. Whenever a text string is enclosed in square brackets, Obsidian creates a direct link from the current note to another note identified by that same text string. (e.g., **[[*Other Note*]]** is a direct link to a note called *Other Note*). By clicking on the direct link, the corresponding note is open if it exists, or it is created if it does not. It follows that the knowledge graph created with Obsidian is made up of elements (notes) and ties between them: weak and undirected when made up of tags, or strong and directed when made up of links embedded in square brackets. Even the draft knowledge graph created after the completion of articles' reading stage shows some infantile semantic clusters generated by the tags.

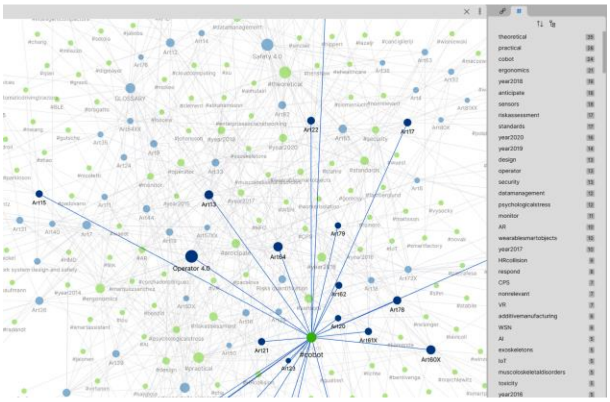

Figure 2: The knowledge graph. Blue dots are notes (both literature and topic ones); green dots are tags involving certain notes. A specific side pane shows used tags

2.2 Topic notes

Exploring the graph (and therefore re-reading the notes), another researcher (or possibly the same one) may insert direct links between notes or, as an alternative, create a new type of note: the topic note. From a topological stand view, topic notes are hubs (i.e., nodes from which it is possible to reach many other nodes), while from a knowledge one are notes borrowing general considerations. In this review, two more experienced researchers than the one who had created the literature notes worked at topic notes (approximately 30 man-hours each).

2.3 A note on tagging

It is worth pointing out that the process described above separates the activity of creating literature notes from that of creating topic ones, exactly with the aim of tagging the documents out of the specific context of the research. The idea is to obtain a basin of information that can be everlastingly explored and enriched, even and above all, after the writing of a single article. Moreover, the process can be described as a bottom-up meaning making: from tags to topics. Because of this, the categories emerge – especially in the first instance – as not rock-hard distinct, but somehow fluid. Indeed some macro-themes repeat due to the fact that the same articles can clearly be part of multiple topics (See Figure 3). This makes it easier to identify potential common narratives rather than separate arguments.

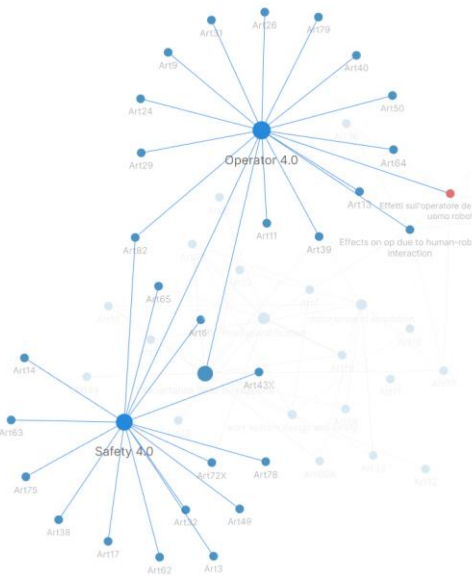

Figure 3: Two themes identified by Topic nodes share some common articles; the presence of direct links enforces the cluster formation.

3.Findings

The corpus of articles deals entirely with OHS, consequently the specific tag (and those semantically related) was excluded during the topic attribution phase. The resulting themes express discourses within academic research. Figure 4 shows the frequency distribution for the top 20 most recurring from the identified 266 tags. Moreover, 10 topic notes were created (6 from one researcher and 4 from the other) corresponding to the following research macro-themes:

3.1 Anticipating the effects of new technologies

Predictably, a number of articles strive to anticipate possible future developments of new technologies, e.g., about the actual impact on OHS, following the obvious principle that identifying preventive actions is more relevant than prioritizing mitigation actions (Hauke, Flaspöler and Reinert, 2020). Several articles are concerned with envisioning psychological risks (e.g., anxiety, burnout, depression, perceived isolation, fatigue) for operators. Among the causes identified, the phenomenon of continuous connection 24 hours a day (*always-on*) and that of the *Problematic Internet Usage* (Mohammed Abubakar and Al-zyoud, 2020). It follows that the 4.0 operator will need to possess particular characteristics to cope with prolonged daily exposure to new technologies (Siemieniuch, Sinclair and Henshaw, 2015; Lööw, Abrahamsson and Johansson, 2019). The main tool of the anticipation is the simulation of the working environment in ergonomic terms (Hovanec *et al.*, 2014). Predictive models can be used to anticipate the effects of applying a specific design theory (Gualtieri *et al.*, 2018) or the early implementation of new technologies (Nickel *et al.*, 2020).

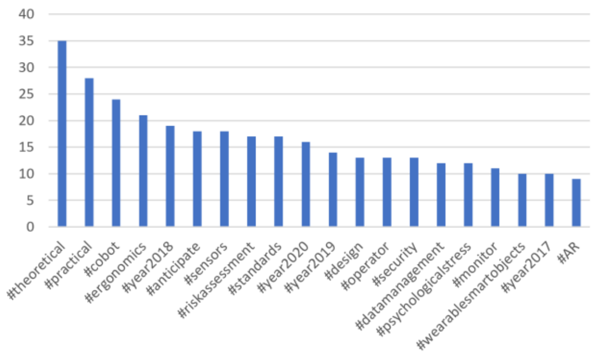

Figure 4: top 20 recurring tags

3.2 Ergonomics

The aforementioned rapidity at which new technologies are introduced is of concern to some researchers. As such, it becomes critical to investigate the proactivity aspects of ergonomics (Hovanec *et al.*, 2014), in order to anticipate any risks associated with the ergonomic solutions undertaken (Askarpour *et al.*, 2019). In part, this proactivity takes the form of an effort to identify risks specific to certain new production sectors (Digmayer and Jakobs, 2018) or simply to classify some new emerging issues of interest to top management (Hauke, Flaspöler and Reinert, 2020).

Proactivity in ergonomics is expressed in assisting the design processes in human work to achieve an optimal balance of systemic performance as well as the psycho-physical well-being of the operators (Nickel *et al.*, 2020).

In this sense, an interesting tool has been developed for evaluating the extent of collaboration achieved in automated environments using Cobots (Gualtieri *et al.*, 2019). Other ergonomic assessments are made purely in relation to individual 4.0 technologies, such as: cobot (Rojas, Wehrle and Vidoni, 2020); autonomous guided vehicles (AGV) (Manfreda, Ljubi and Groznik, 2019); virtual and augmented reality (VR and AR) (Gutsche and Droll, 2020).

3.3 Adequacy of standards and standardization

A portion of the articles are about standardization processes and standards that currently are present in Industry 4.0, for example in terms of streamlining labor (Bretschneider-Hagemes, Korfmacher and von Rymon Lipinski, 2018) as well as certain categories of machinery (Faria et al., 2020). Many of these standards are defined following ergonomic principles concerning work environment (Nickel *et al.*, 2020) especially whenever are heavily digitalized (Lee and Cha, 2019). A widely recognized problem about the lack of standardization relates to inadequate standards for intellectual property, additive manufacturing, and human-robot collaborative activities (Ferraro *et al.*, 2020).

3.4 Data management

The digitalization process freed big data and the consequent appearing of information overload phenomenon which, along with lack of standards and procedures, justify the fear that this large amount of data will not be analyzed properly (McKee *et al.*, 2017). The problem is particularly relevant whenever data leakage may represent a potential issue as in healthcare, railways and energy (Digmayer and Jakobs, 2018; Svendsen *et al.*, 2018).

3.5 Intellectual Property Protection

Managing intellectual property in collaborative interconnected systems presents entirely new challenges (Digmayer and Jakobs, 2018). For example, a lot of concern regards additive manufacturing and 3D printing, where there is a real risk of dumping, counterfeit products and inappropriate use of initial designs (Engelmann *et al.*, 2018). The lack of appropriate laws exacerbates the unprotection of CAD files and their poor traceability. Such legislative deficiency is echoed by standards one, especially in some countries (Nwabueze, 2017) and for some technologies, as Cobots and A.I. (Khalid *et al.*, 2018). Blockchain-based solutions have been proposed by some authors (Holland, Nigischer and Stjepandic, 2017).

3.6 Workplace design

Design of workplaces is crucial to safety. Particularly important in this regard are the human-robot collaborative environments, where the operator is likely to suffer stress from interaction (Rojas, Wehrle and Vidoni, 2020). The digitalization enables machines remote control and therefore the operator direct risks removal. This chance is widely used in agriculture. (Pirozzi *et al.*, 2020). Among enabling technologies, virtual reality could be used in design evaluation (Lee and Cha, 2019).

3.7 Potential effects of new technologies on operators

Coexistence with new technologies will expose operators to new kinds of risks. Progressive dematerialization of activities, a more frequent human-robot interaction, the loss of distinction between physical spaces and times related to work and personal life, are all factors of the so-called techno-stress, characterized by an excessive cognitive workload (Pietrafesa *et al.*, 2019). As pointed out above, the ergonomic design of environments is essential for risk mitigation (Hovanec *et al.*, 2014). For cobots mitigation efforts result in improving robots' trajectories and behaviors (Rojas, Wehrle and Vidoni, 2020) as well as their appearance (Müller et al., 2017). In 3D printing and additive manufacturing risk mitigation works toward reduction of eye and respiratory irritation, and metal poisoning (Franco *et al.*, 2020). For exoskeletons, attention is focused on unbalanced loads on the spine and reduced mobility (Polak-Sopinska *et al.*, 2019)

3.8 Worker 4.0

The worker 4.0 must be smart and skilled, aware and proactive as well as technological literate (Pardo-Ferreira *et al.*, 2020), especially in smart wereables and robotics (Lundberg, Nylin and Josefsson, 2016; Pirozzi *et al.*, 2020). The worker will become a decision maker, assuming more and more the role of "human in the loop" described so often in Cybernetics and RE (Vysocky and Novak, 2016). The required competencies of work will be progressively dematerialized (Lööw, Abrahamsson and Johansson, 2019), and the workers shall participate actively to the changing process (Digmayer and Jakobs, 2018), therefore, the role of training will be fundamental (Sànchez and Manuel, 2020).

3.9 Technologies 4.0

Not surprisingly, part of the collected articles concern technologies 4.0. Noteworthy is the integration between smart wearables and smart devices with personal protective equipment, both for reporting risky conditions and for monitoring/analysis of accident (Gnoni *et al.*, 2020).

3.10 Risk management methodologies

A large group of these articles relate to the quantification of risk. Risk quantification in digital manufacturing often refers to the inherent variability of information flows, human interaction with the system which is reflected in ergonomic requirements (Nickel et al., 2020). Some authors have quantified risk and potential damage, classifying the results into different levels of performance (Schiemann, Hodapp and Berger, 2018). Others, have assigned a risk coefficient by using the hazard rating number method (Hippertt et al., 2019), succeed in estimating the feasibility of human-robot collaboration. In general, the way risk analysis is carried out is domain-specific, therefore often interviewing experts is necessary (Digmayer and Jakobs, 2018). Finally, starting from axiomatic design some authors have proposed necessary functional requirements and have identified sources of danger in accordance with current standards (Gualtieri et al., 2018).

4. Discussion and conclusions

4.1 Analysis of results

The review confirms some authors' partial concern about the risks associated with digital transformation, as well as the trending alignment between Safety-II and Safety 4.0 issues. The need for a proactive attitude, a security culture shared at the organization level and embodied in a role, the 4.0 operator, that is capable of managing the information overload resulting from the ongoing digital transformation. Enabling technologies bring, therefore, a new list of aspects to consider. The articles analyzed show a certain propensity to look to the future: similarly to what RE assumes, anticipation is a crucial ability for drawing general lessons, therefore for finding solutions to undertake. The worker is seen as a resource, no longer as a source of error, and must therefore kept distant from danger. If production requirements demand human presence, the work of the machines must be adapted. At the same time workers must be able to evolve and change in symbiosis with the environment in which they operate. Human work is undergoing dematerialization, losing characteristics of mere manual strength and dexterity, and becoming a repository of embodied knowledge to be transferred to other entities (including machines). The work environment must be rethought to materially accommodate this knowledge transfer and encourage the sharing of a safety culture. Everything must be defined during the design phase that implies also setting suitable standards. The speed whereby ideas are changing as result of digitalization is reflected also in the articles investigated, from whose RE seems to be the most promising candidate to accompany OHS in its digitalization process (Patriarca, Bergström, *et al.*, 2018). In our opinion, already deployed assessment tools such as the Resilience Analysis Grid (Falegnami *et al.*, 2018; Patriarca, Di Gravio, *et al.*, 2018) could just as successfully be used as tools to analyze the risks associated with Industry 4.0. Moreover, another transferable concept is that of simple presentation and management of complexity, i.e. *simplexity* (Patriarca, Falegnami and Bilotta, 2019).

4.2 Advantages and limitations of the methodology

In line with simplexity, the methodology here proposed allows for coping with the kind of information overload afflicting researchers. In contrast with the traditional top-down method, the proposed bottom-up construction meaning does not need prior knowledge on the topics under investigation. Eventual lack of deep knowledge of the topics is not a limitation per se, yet it offers a fresh perspective potentially not influenced by habitual reading of that kind of articles, and this means that in a team, even less experienced researchers in a certain field can contribute significantly to the outcome. The following meaning-making phase (i.e., realization of topic notes) can be instead delegated to team members of greater experience and speculative depth. The results of the present work could be conditioned by being limited to one database (Scopus); moreover, a poor distinction between macro-themes is evident, which obviously implies a difficulty in interpretation. However, the information artifact resulting from the review activity is not solidified only in the article, but it constitutes a potentially continuously explorable, expandable, and transferable information object. For example, some articles that took part in the review were discarded (7 articles were tagged as #nonrelevant), though they may gain more weight in future research. Moreover, the notes (which in Obsidian are files with .md extension) are simple text files, open to further analysis (e.g., statistical, network analysis, etc.).

Using a proprietary software like Obsidian is not a limitation per se, since an open-source counterpart called Zettlr already exists (*A Markdown Editor for the 21st Century | Zettlr*, 2020), and possibly the process is easily replicable with other knowledge management tools.

4.3 Future steps

We believe that the proposed methodological solution can help research to face the challenges proposed by the ongoing digital transformation. This research has shown how digitalization, beyond the positive expectations, also raises potential related criticalities. With this concern, we believe it is timely to reconstruct the correlation between potential new classes of hazards and enabling technologies of the 4th industrial revolution. Finally, according to our opinion, the scholarly efforts should be aimed to new proactive instruments for health and safety of worker 4.0 possibly akin to those developed for RE.

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References

A Markdown Editor for the 21st Century | Zettlr (2020). Available at: https://www.zettlr.com/ (Accessed: 9 March 2021).

Askarpour, M. et al. (2019) 'Formal model of human erroneous behavior for safety analysis in collaborative robotics', Robotics and Computer-Integrated Manufacturing, 57, pp. 465–476. doi: 10.1016/j.rcim.2019.01.001.

Bretschneider-Hagemes, M., Korfmacher, S. and von Rymon Lipinski, K. (2018) The Role of Standardization for Occupational Safety and Health (OSH) and the Design of Safe and Healthy Human-Computer Interaction (HCI), Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). doi: 10.1007/978-3-319-91397-1_2.

Cantelmi, R., Di Gravio, G. and Patriarca, R. (2021) 'Reviewing qualitative research approaches in the context of critical infrastructure resilience', Environment Systems and Decisions. doi: 10.1007/s10669-020-09795-8.

Digmayer, C. and Jakobs, E. M. (2018) 'Employee empowerment in the context of domain-specific risks in industry 4.0', IEEE International Professional Communication Conference, 2018-July, pp. 125–133. doi: 10.1109/ProComm.2018.00034.

Engelmann, F. et al. (2018) 'Intellectual property protection and licensing of 3d print with blockchain technology', in Advances in Transdisciplinary Engineering. IOS Press BV, pp. 103–112. doi: 10.3233/978-1-61499-898-3-103.

Faatz, A., Zimmermann, B. and Godehardt, E. (2009) 'Luhmann's slip box - What can we learn from the device for knowledge representation in requirements engineering?', in 2009 2nd International Workshop on Managing Requirements Knowledge, MARK 2009, pp. 22–26. doi: 10.1109/MARK.2009.6.

Falegnami, A. et al. (2018) 'A multicountry comparative survey about organizational resilience in anaesthesia', Journal of Evaluation in Clinical Practice, 24(6). doi: 10.1111/jep.13054.

Faria, C. et al. (2020) 'Safety Requirements for the Design of Collaborative Robotic Workstations in Europe – A Review', in Advances in Intelligent Systems and Computing. Springer, pp. 225–232. doi: 10.1007/978-3-030-50946-0_31.

Ferraro, A. et al. (2020) Powder bed fusion/sintering machines: Safety at workplaces, Procedia Manufacturing. Elsevier B.V. doi: 10.1016/j.promfg.2020.02.061.

Franco, D. et al. (2020) 'Consolidated and inconclusive effects of additive manufacturing adoption: A systematic literature review', Computers and Industrial Engineering, 148. doi: 10.1016/j.cie.2020.106713.

Gnoni, M. G. et al. (2020) 'Integrating IoT technologies for an "intelligent" safety management in the process industry', in Procedia Manufacturing. Elsevier B.V., pp. 511–515. doi: 10.1016/j.promfg.2020.02.040.

Gualtieri, L. et al. (2018) 'Application of Axiomatic Design for the Design of a Safe Collaborative Human-Robot Assembly Workplace', in MATEC Web of Conferences. EDP Sciences. doi: 10.1051/matecconf/201822301003.

Gualtieri, L. et al. (2019) 'An evaluation methodology for the conversion of manual assembly systems into human-robot collaborative workcells', in Procedia Manufacturing. Elsevier B.V., pp. 358–366. doi: 10.1016/j.promfg.2020.01.046.

Gutsche, K. and Droll, C. (2020) 'Enabling or stressing? – Smart information use within industrial service operation', in Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer, pp. 119–129. doi: 10.1007/978-3-030-49907-5_9.

Hagberg, J., Sundstrom, M. and Egels-Zandén, N. (2016) 'The digitalization of retailing: an exploratory framework', International Journal of Retail and Distribution Management, 44(7), pp. 694–712. doi: 10.1108/IJRDM-09-2015-0140.

Hauke, A., Flaspöler, E. and Reinert, D. (2020) 'Proactive prevention in occupational safety and health: how to identify tomorrow's prevention priorities and preventive measures', International Journal of Occupational Safety and Ergonomics, 26(1), pp. 181–193. doi: 10.1080/10803548.2018.1465677.

Hippertt, M. P. et al. (2019) 'Towards safety level definition based on the HRN approach for industrial robots in collaborative activities', in Procedia Manufacturing. Elsevier B.V., pp. 1481–1490. doi: 10.1016/j.promfg.2020.01.139.

Holland, M., Nigischer, C. and Stjepandic, J. (2017) 'Copyright protection in additive manufacturing with blockchain approach', Advances in Transdisciplinary Engineering, 5(October), pp. 914–921. doi: 10.3233/978-1-61499-779-5-914.

Hovanec, M. et al. (2014) 'Proactive ergonomics based on digitalization using 3D scanning and workplace modeling in texnomatix jack with augmented reality', Nase More, 61(1–2), pp. 22–26.

Khalid, A. et al. (2018) 'Security framework for industrial collaborative robotic cyber-physical systems', Computers in Industry, 97, pp. 132–145. doi: 10.1016/j.compind.2018.02.009.

Lee, H. and Cha, W. C. (2019) 'Virtual reality-based ergonomic modeling and evaluation framework for nuclear power plant operation and control', Sustainability (Switzerland), 11(9). doi: 10.3390/su11092630.

Lööw, J., Abrahamsson, L. and Johansson, J. (2019) 'Mining 4.0 - The impact of new technology from a workplace perspective', Mining Engineering, 71(12), pp. 47–48. doi: 10.1007/s42461-019-00104-9.

Lundberg, J., Nylin, M. and Josefsson, B. (2016) 'Challenges for research and innovation in design of digital ATM controller environments: An episode analysis of six simulated traffic situations at Arlanda airport', AIAA/IEEE Digital Avionics Systems Conference - Proceedings, 2016-Decem, pp. 1–9. doi: 10.1109/DASC.2016.7777949.

Manfreda, A., Ljubi, K. and Groznik, A. (2019) 'Autonomous vehicles in the smart city era: An empirical study of adoption factors important for millennials', International Journal of Information Management, p. 102050. doi: 10.1016/j.ijinfomgt.2019.102050.

McKee, D. W. et al. (2017) 'Massive-Scale Automation in Cyber-Physical Systems: Vision & Challenges', in Proceedings - 2017 IEEE 13th International Symposium on Autonomous Decentralized Systems, ISADS 2017. Institute of Electrical and Electronics Engineers Inc., pp. 5–11. doi: 10.1109/ISADS.2017.56.

Mohammed Abubakar, A. and Al-zyoud, M. F. (2020) 'Problematic Internet usage and safety behavior: Does time autonomy matter?', Telematics and Informatics, (March), p. 101501. doi: 10.1016/j.tele.2020.101501.

Moher, D. et al. (2009) 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement', PLoS Medicine, 6(7), p. e1000097. doi: 10.1371/journal.pmed.1000097.

Nickel, P. et al. (2020) Human-system interaction design requirements to improve machinery and systems safety, Advances in Intelligent Systems and Computing. doi: 10.1007/978-3-030-20497-6_1.

Nwabueze, C. J. (2017) 'Copyright and data authenticity in the digital preservation of heritage: The case of OAPI', International Journal of Intangible Heritage, 12(12), pp. 93–110. doi: 10.35638/ijih.2017..12.010.

Obsidian (2020). Available at: https://obsidian.md/ (Accessed: 9 March 2021).

Pardo-Ferreira, M. D. C. et al. (2020) 'Using functional resonance analysis method to understand construction activities for concrete structures', Safety Science, 128. doi: 10.1016/j.ssci.2020.104771.

Patriarca, R. et al. (2017) 'A paradigm shift to enhance patient safety in healthcare, a resilience engineering approach: Scoping review of available evidence', International Journal of Healthcare Technology and Management, 16(3–4), pp. 319–343. doi: 10.1504/IJHTM.2017.088872.

Patriarca, R., Di Gravio, G., et al. (2018) 'An Analytic Framework to Assess Organizational Resilience', Safety and Health at Work, 9(3). doi: 10.1016/j.shaw.2017.10.005.

Patriarca, R., Bergström, J., et al. (2018) 'Resilience engineering: Current status of the research and future challenges', Safety Science, 102, pp. 79–100. doi: 10.1016/j.ssci.2017.10.005.

Patriarca, R. et al. (2021) 'WAx: An integrated conceptual framework for the analysis of cyber-socio-technical systems', Safety Science, 136. doi: 10.1016/j.ssci.2020.105142.

Patriarca, R., Falegnami, A. and Bilotta, F. (2019) 'Embracing simplexity: the role of artificial intelligence in peri-procedural medical safety', Expert Review of Medical Devices, 16(2). doi: 10.1080/17434440.2019.1561269.

Pietrafesa, E. et al. (2019) 'Digital transformation in organizations: The impact on working life quality and new risk factors', in Multi Conference on Computer Science and Information Systems, MCCSIS 2019 - Proceedings of the International Conferences on ICT, Society and Human Beings 2019, Connected Smart Cities 2019 and Web Based Communities and Social Media 2019, pp. 433–436.

Pirozzi, M. et al. (2020) 'Possible innovative technical measures for risk prevention during the use of mobile machines with remote guide/control', in Procedia Manufacturing. Elsevier B.V., pp. 457–461. doi: 10.1016/j.promfg.2020.02.049.

Polak-Sopinska, A. et al. (2019) Impact of industry 4.0 on occupational health and safety, Advances in Intelligent Systems and Computing. doi: 10.1007/978-3-030-20494-5_4.

Polat, L. and Erkollar, A. (2021) Industry 4.0 vs. Society 5.0, Lecture Notes in Mechanical Engineering. doi: 10.1007/978-3-030-62784-3_28.

Rojas, R. A., Wehrle, E. and Vidoni, R. (2020) 'A multicriteria motion planning approach for combining smoothness and speed in collaborative assembly systems', Applied Sciences (Switzerland), 10(15). doi: 10.3390/app10155086.

Romero, D. et al. (2018) Digitalizing occupational health, safety and productivity for the operator 4.0, IFIP Advances in Information and Communication Technology. Springer New York LLC. doi: 10.1007/978-3-319-99707-0_59.

Sànchez, S. M. and Manuel, C. R. J. (2020) 'Smart protective protection equipment for an accessible work environment and occupational hazard prevention', Proceedings of the Confluence 2020 - 10th International Conference on Cloud Computing, Data Science and Engineering, 548, pp. 581–585. doi: 10.1109/Confluence47617.2020.9058188.

Sarfraz, Z. et al. (2021) 'Is covid-19 pushing us to the fifth industrial revolution (Society 5.0)?', Pakistan Journal of Medical Sciences, 37(2), pp. 1–4. doi: 10.12669/pjms.37.2.3387.

Schiemann, M., Hodapp, J. and Berger, U. (2018) 'Collaboration-gap: A bus-modular architecture for human-robot-collaboration systems in production environments', 50th International Symposium on Robotics, ISR 2018, pp. 450–454.

Siemieniuch, C. E., Sinclair, M. A. and Henshaw, M. J. C. (2015) 'Global drivers, sustainable manufacturing and systems ergonomics', Applied Ergonomics, 51, pp. 104–119. doi: 10.1016/j.apergo.2015.04.018.

Stephan, K. D. et al. (2012) 'Social implications of technology: The past, the present, and the future', Proceedings of the IEEE, 100(SPL CONTEN), pp. 1752–1781. doi: 10.1109/JPROC.2012.2189919.

Svendsen, A. B. et al. (2018) 'Digitalization of the power business: How to make this work?', in Safety and Reliability - Safe Societies in a Changing World - Proceedings of the 28th International European Safety and Reliability Conference, ESREL 2018. CRC Press/Balkema, pp. 2513–2520. doi: 10.1201/9781351174664-316.

Tra.d.a.r.s. (2021). Available at: https://www.tradars.it/home (Accessed: 9 March 2021).

Vysocky, A. and Novak, P. (2016) 'Human - Robot collaboration in industry', MM Science Journal, 2016-June(December 2017), pp. 903–906. doi: 10.17973/MMSJ.2016_06_201611.