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From Digitization to Digital Collaborative Service Designs: A Systematic Literature Review on the Categories, Concepts and Constructs of Industry 5.0

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Abstract. In the last decade, business and industry put major emphasis on the digitization of its infrastructures, resources, processes and business models. In doing so, managers and organizational decision makers experienced support and guidance from the so-called Industry 4.0 paradigm. At the beginning of the year 2021, the European Commission launched the Industry 5.0 paradigm, an approach, that in comparison to Industry 4.0, puts human-centricity, sustainability, and resilience at the heart of the ongoing digital transition. However, the concept of Industry 5.0 still remains vague. This systematic literature review at hand builds upon this lack of knowledge and inductively investigates into the categories, concepts, and constructs of Industry 5.0. By the use of the Grounded Theory Methodology, a representative sample size of scholarly papers has been analyzed and coded. This process resulted in the emergence of the five categories Governance, Humanness, Technology, Intelligence & proficiency, and Environment. These categories as well as its related concepts and constructs are recognized as the main fields of action in Industry 5.0.

Keywords: Industry 5.0, Technology, Governance, Humanness, Intelligence & proficiency, Environment

1 Introduction

The digitization of business and industry, especially the digitization of small and medium-sized enterprises, is of major interest to the European Commission and its member states. Digitized enterprises maintain competitive advantages and can provide more efficient, effective, and value-added processes and services to their customers and supply chain stakeholders. However, the speed of digitization has surprised many enterprises. Many businesses and industries are stuck in traditional service provision mechanisms, business models, and processes.

The last decade was highly influenced by the Industry 4.0 paradigm (*Advanced Manufacturing program in the United States*). Industry 4.0 is about the fourth industrial revolution and the transition of traditional processes to digitally supported processes.

At the centre of Industry 4.0 is the digitization of enterprises, including its infrastructure, shopfloor, assembly lines, services, processes, business models, etc. Less emphasis is on humans, their creativity and innovativeness as well as the environment. This shall be corrected through the Industry 5.0 paradigm. According to the European Commission [1], [2], which launched their approach towards Industry 5.0 at the beginning of 2021, Industry 5.0 focuses on human-centricity, sustainability and resilience in digitized businesses and industry. Nevertheless, the European Commission as well as other (*scholarly*) sources remain vague in their statement about Industry 5.0. This circumstance motivates us to investigate the paradigm of Industry 5.0. The objective of this systematic literature review at hand is to explore the fields of action of the Industry 5.0 paradigm in more detail. In doing so, the aim is to categorize the fields of action and explore the concepts and constructs which the Industry 5.0 approach is built upon. This systematic literature review is based on the research question “**What are the categories in Industry 5.0, and what are the concepts and constructs?**”.

Following Cooper's (1985) taxonomy of literature reviews [3], the focus of this systematic literature review is on practices and applications and the research goal is to identify the central issues of the Industry 5.0 approach. By the application of the Grounded Theory Methodology, the organization of the systematic literature review is conceptual and presents the categories, concepts, and constructs of the Industry 5.0 approach. A representative sample of scholarly papers has been coded and the emerged categories, concepts, and constructs are presented from a neutral perspective. Due to the novelty of the Industry 5.0 approach, the audience of the paper at hand are specialized and general scholars as well as practitioners, policymakers, and the general public.

The paper is organized in four chapters. While chapter 1 introduces the paper and presents the research motivation and the research question, chapter 2 presents the applied research methodology. Chapter 3 introduces the findings of the systematic literature review at hand. It is divided into five sections that present the findings of the identified categories of Industry 5.0: Governance, Humanness, Technology, Intelligence & proficiency, and Environment. Chapter 4 concludes the paper and provides future directions.

2 Research Methodology

The research methodology used in this paper is the Grounded Theory Methodology. The Grounded Theory Methodology (GTM) is a research paradigm for discovery [4]. It is an inductive research methodology [5] and is used in many scientific disciplines, such as Information Systems, Software Engineering, Sociology/Social Sciences, Management [6], as well as for different purposes [7], such as qualitative research, literature reviews [8], etc. The objective of GTM is to build theory from empiricism [7], thus, a theory that is empirically grounded in data (e.g. [4], [9]). The research products of a GTM research are, for example, new core categories [10], models [11], reports, articles, books, etc. that contribute to and extend the ongoing substantive and theoretical conversations from different methodological perspectives [12].

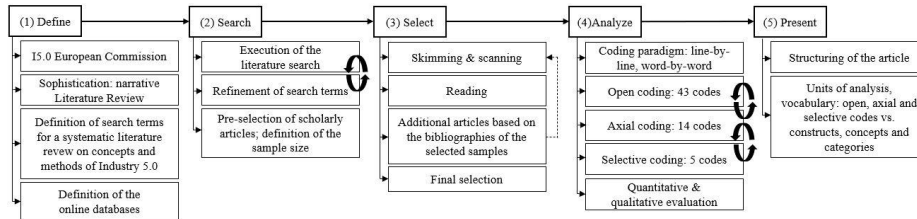


Fig. 1. Research design (based on: [8])

As depicted in figure 1, Wolfswinkel's et al. (2013) [8] five-stage grounded-theory method framework has been applied. This framework is composed of the stages: (1) define, (2) search, (3) select, (4) analyze, and (5) present. After a narrative literature review and the reading of introductory articles on Industry 5.0 and its emergence from Industry 4.0, published, for example, by the European Commission, the search terms and the online databases have been defined. It was an iterative process and the search terms experienced continuous tailoring, developing from the existing Industry 5.0 understanding. Thereby the conception of the European Commission [1], [2] acted as a basis, determining 3 out of the 4 search terms "Industry 5.0 AND human centricity", "Industry 5.0 AND sustainability" and "Industry 5.0 AND resilience". The fourth research term "Industry 5.0 concepts" was developed to represent the research question. The final literature search was performed from November 2021 to January 2022 and the search terms were applied in Google Scholar and ScienceDirect.

The literature search resulted in the pre-selection of 254 scholarly articles. Following Hart (2003) [13], as next, the pre-selected scholarly articles experienced rigorous skimming and scanning. In doing so, the title, abstract, and conclusion have been read and their appropriateness has been evaluated towards the set research motivation and research question. 27 scholarly articles passed this process and have been chosen for the literature review. Additionally, six papers from the bibliographies of the selected papers have been included. In total 33 papers were selected for the systematic literature review.

The analysis of the selected scholarly articles is based upon the GTM approach of Strauss [14] and applies open coding, axial coding, and selective coding. Open coding is about the close reading of a set of single studies and the early abstracting and categorizing of the hidden aspects of the research topic under exploration and is about the coding of, as important rated, passages (quotes), incl. text, figures, tables, etc. [15]. The objective of open coding is to produce useable and useful abstractions [15]. The applied coding paradigms are line-by-line and word-by-word coding (e.g. [16], [17]). As next, axial coding has been applied. Axial coding is about an intense analysis of the open codes and their further development as well as their alignment to sub-categories. Selective coding is about the identification and development of categories, and the relations between the categories.

3 Findings

The literature analysis resulted in the emergence of five categories of Industry 5.0 that are: Governance, Humanness, Technology, Intelligence & proficiency, and Environment. Each category describes a selective code that emerged through the application of the Grounded Theory Methodology.

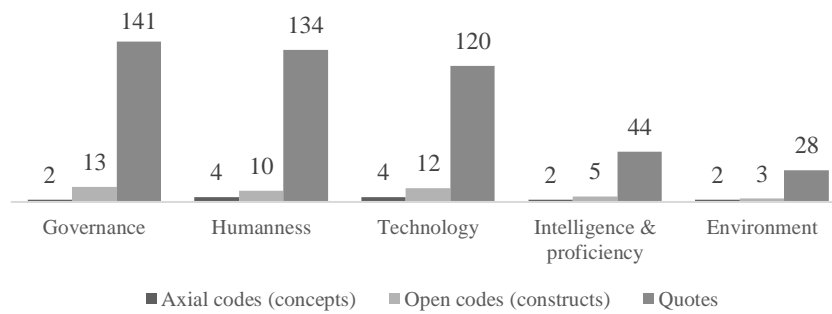


Fig. 2. Code system categories

As presented in figure 2, the category “Governance” gained the most quotes and open codes. It is composed of 141 quotes, captured in 13 open codes and 2 axial codes. The following categories are Humanness (4 axial codes, 10 open codes, 134 quotes), Technology (4 axial codes, 12 open codes, 120 quotes), Intelligence & proficiency (2 axial codes, 5 open codes, 44 quotes), and Environment (2 axial codes, 3 open codes, 28 quotes).

The categories are presented in more detail in the following sections. To enable smooth reading and to provide better understanding, in the below paragraphs, the selective codes are called categories, composed of concepts (axial codes) and constructs (open codes).

3.1 Governance

The category “Governance” focuses on the non-technological sides of Industry 5.0, such as management practices, policies, or security, and is composed of two axial codes, formed by 13 open codes and 141 quotes.

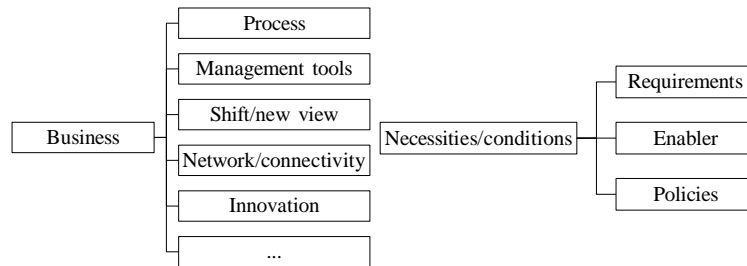


Fig. 3. Category “Governance”, its two concepts and most frequently quoted constructs

As depicted in figure 3, the concepts (axial codes) are business, and necessities/conditions. The concept business consists of ten constructs (open codes) that cover processes, management tools, methods as well as innovation, and the shift of procedures and a new view on business approaches. The two most frequently mentioned constructs in business are management tools (12 quotes) and processes (13 quotes). While management tools describe different designs, frameworks, or models that support and structure the management (process) in Industry 5.0, processes direct the focus on typical, necessary, or arising types of processes in Industry 5.0. Thereby examples are digitization, continuous improvement process (CIP), or change processes [18]–[21]. Concerning these two constructs, the constructs methods, standards/rules, and business models are very similar, summarizing requirements and strategies for Industry 5.0 operations. A separately mentioned requirement however is security, which forms a construct covering different types of security such as cybersecurity, access control security, as well as the significance of security in Industry 5.0. The constructs innovation and shift/new view, underline the creative and cutting-edge part of the concept business. This field of interest reflects not only the continuous demand for innovative environments but also a visible transition of (industrial/business) approaches, perspectives, and/or society in the context of Industry 5.0. The centre of attention of the construct network/connectivity is on cooperation and communication rather than on technology. The interaction between employees, stakeholders, machines, and devices is of key importance for Industry 5.0. A prevalently mentioned way of doing this is through a social business network [22].

The concept necessities/conditions includes the constructs policies, requirements, and enabler. The construct enabler examines different enablers for Industry 5.0 from a business viewpoint. This combines various technologies as well as research fields. The business dimension of technologies includes for example organizational impact, process optimization, or change management [23], [24]. Defined business-related research fields are among others bionics, techniques and designs like green computing, or financial systems like fin-tech [23], [25]. The construct requirements consists of 41 quotes, making it one of the biggest and at the same time one of the most varying construct. The only true similarity between the indicated requirements is their necessity. Authors, such as [19], [24], [26], [27] agree on a variety of requirements that need to be fulfilled for Industry 5.0 to evolve. These include, for example, the collection of (big) data, the implementation of strategies, the involvement of external actors, a digital infrastructure,

or an increased focus on resilience. A more agreed-upon necessity however is the change or adaption of policies including laws, regulations, and political aspects. Therefore, the third construct is called policies.

3.2 Humanness

The category “Humanness” puts the human and all characteristics that constitute humanity at the centre of attention.

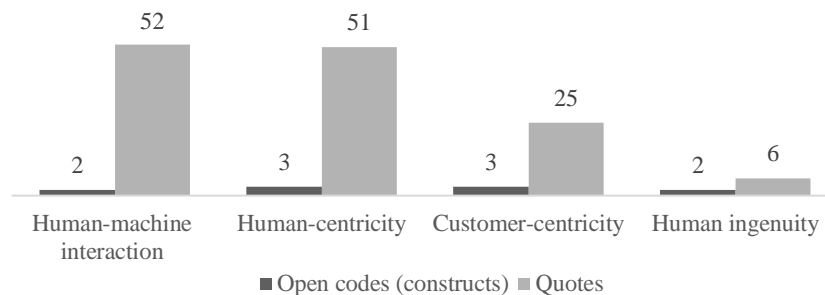


Fig. 4. Category “Humanness” and its code system

As illustrated in figure 4, humanness is developed from four axial codes, ten open codes, and 134 quotes, with a focus on human-machine interaction, customer-centricity, human-centricity, and human ingenuity. Thereby human-machine interaction with 52 quotes and human-centricity with 51 quotes, are by far the largest axial codes.

The three constructs (open codes) socio-technical, values, and human-centricity form the concept (axial code) human-centricity and focus on the increased human-centric approach in production/manufacturing. Values, within this concept, include a variety of ethical considerations as well as the creation of values towards internal employees and also external stakeholders like customers. The socio-technical approach supports the social and human side of technologization and directs focus on an increased synergistic relationship between systems and people. Human-centricity not only places the human back on the shopfloor but also shapes all activities around the human. This includes a human-centric design of cyber-physical systems, adaptable technology to the needs of humans, and an increase in human resilience [18], [28]–[30].

The concept human-machine interaction consists of two constructs, augmentation, and human-machine interaction. Augmentation is mostly about the extension of human abilities through (a human-friendly) technology. The focus lies on enhancement, whereas in human-machine interaction the most important factor is the cooperation between a human and a machine. Thereby the importance of the synergy between humans and machines gets emphasized. It is suggested repeatedly to assign boring or dangerous work to machines and robots and let people unfold their creativity and ingenuity [19], [20], [24], [27], [31]–[34]. But human-machine interaction even goes one step further and targets the direct cooperation between humans and machines for example a robot acting as a third hand or an exoskeleton enhancing the human’s strength.

The concept customer-centricity captures the customers and their demands and preferences. This gets reflected through the three constructs customer, personalization, and customization. The terms personalization and customization describe the Industry 5.0 trend to create products and services that are highly adjusted to a customer's demand. Authors, such as [19], [20], [23], [27], [30], [33], [35], point also in the direction of mass customization/personalization, picturing Industry 5.0 as a way to increase the production, keeping overall costs at a minimum and at the same time including every customer's wish. A few authors, such as [32] consider personalization as an advancement of customization where products and services get adjusted to people's personal needs through the so-called human touch. It is argued that, through human workers on the shopfloor, increased creativity, and human ingenuity incorporated in a product, personalization can be achieved. The construct customer points towards the inclusion of the customer in the design and production process and therefore increasing not only the production of personalized products but also active customer engagement.

The concept human ingenuity emphasizes the human touch as well as creativity and design as two separate constructs. Thereby the possibility for people to engage in creativity, design, innovative ideas, and problem-solving activities is pointed out and described as a crucial difference to the Industry 4.0 paradigm.

3.3 Technology

The category "Technology" describes the technological side of the fifth industrial revolution and is made upon four axial codes named technologies, network and interoperability, robotics, and technologies for energy.

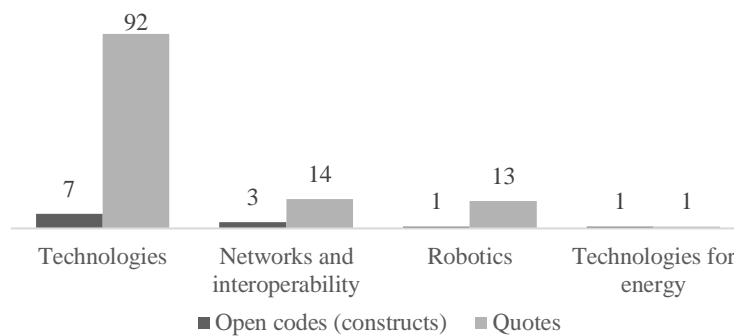


Fig. 5. Category "Technology" and its code system

As depicted in figure 5, the most quoted concept (axial code) is technologies, consisting of seven constructs (open codes) and 92 quotes. These constructs however do not describe different types of technology but rather show the current status of technology, for example, future technology, enabling technology, or bio-inspired technology. Thereby the most frequently mentioned technologies are artificial intelligence (AI; 17 quotes), the (Industrial) Internet of Things ((I)IoT; 12 quotes), augmented reality (AR; 5 quotes), cyber-physical systems (CPS; 4 quotes) and robots (13 quotes). A certain

consistency can be identified within this data, since a majority of authors [19], [20], [22], [24], [28], [31], [34], [36], [37] mention the same kind of technologies as crucial factors of Industry 5.0 be it as a future necessity or already existing base from the previous industrial revolution, Industry 4.0. It needs to be pointed out that in many journals the term technology is used for a yet unknown development and hence cannot be classified.

The concept robotics was developed separately from the concept technology. The key difference lies in the type of robot described in the selected samples. Whenever the term robot is used in the I5.0 context there is talk of collaborative robots, the cobots. Cobots are robots that work in tandem with and assist humans on the shopfloor by for example taking over dangerous or boring work [33].

Another focus of technological development in Industry 5.0 lies in networks and the interoperability and connectivity of systems and devices. This concept consists of three constructs of which two describe the smart environment and smart manufacturing, representing the established connection between information, technology, and human ingenuity. The construct network/connectivity includes technological developments like (multiple) networks, platforms, or advanced interconnectivity.

Besides the huge ICT focus of the category “Technology”, the fourth concept technologies for energy addresses developments around the energy sector, focusing more on energy efficiency or possibilities to accumulate energy.

3.4 Intelligence & Proficiency

The category “Intelligence & proficiency” captures the work environment including physical and psychological aspects as well as the educational sector. This category is represented through the axial codes work and knowledge/skill.

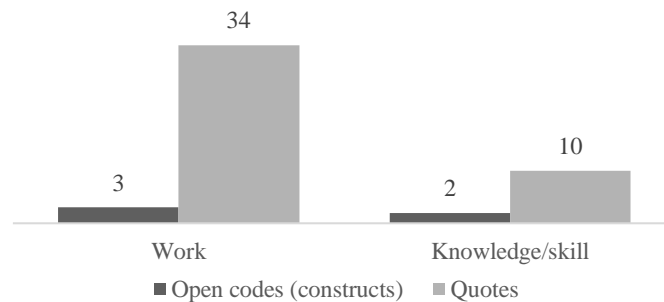


Fig. 6. Category “Intelligence & proficiency” and its code system

As shown in figure 6, the concept (axial code) work consists of three constructs (open codes), formed by 34 quotes. The construct new work system/tasks address the question how future work will look like. The focus, on the one hand, is on the transition of the workplace which includes a change of infrastructure on the factory floor (e.g., shared workspaces), as well as a change of established work systems. Due to increased automation, the integration of cobots, and further importance of the wellbeing of workers, work systems and manufacturing processes get rearranged and often become more

effective and efficient. On the other hand, the structure of existing jobs changes, and new jobs arise. Especially through new technological achievements, certain jobs become unnecessary whereas new positions are required to use, manage, or design the new technology. A frequently mentioned new position is the Chief Robotics Officer [19], [24], [33], [38] in which the human develops skills in the field of robotics especially cobots, and therefore the interaction between humans and machines. The focus of the construct characteristics of workforce/future work lies in the transformation of the workforce. This includes making the workforce more resilient and skilled. Increased resilience can be achieved through physical, cognitive, and psychological enhancements (e.g. exoskeletons, digital assistance systems, VR) [29]. The Industry 5.0 workforce is also required to upskill which includes being more creative, critically thinking and reasoning, since these are abilities, robots cannot acquire. The construct wellbeing underlines the human-centric approach of Industry 5.0. To operate from a human-centric viewpoint, increase efficiency, creativity, and also resilience, the well-being of the workforce is of crucial importance. Developments to achieve this are people-aware designs of devices [27], inclusive work environments, or work-life balance [28].

The concept knowledge/skill is composed of the two constructs education and research. Education combines all action steps to educate, train or upskill the employees. Having appropriately educated and trained personnel is frequently mentioned as an important factor and advantage to keeping up with the fast pacing digitized and technologized industrial environment [19], [26], [38]. In addition to well-known teaching methods, innovative solutions and new ideas to train employees are for example, modelling and simulation where educational contents are imparted in virtual reality. Besides education, research also plays an important role in Industry 5.0. Fields of application such as agriculture, biology, innovation, economy, etc. are examined, to support and advance the fifth industrial revolution. Additionally, research on Industry 5.0 is conducted to increase the understanding of the fifth industrial revolution.

3.5 Environment

The category “Environment” captures environment-related topics as well as environmental sustainability. This category focuses on ways to operate more sustainably in business and industry, including the scarcity and limitation of resources. The category is composed of two axial codes that are sustainability (1 open code, 15 quotes) and biologizing (2 open codes, 13 quotes).

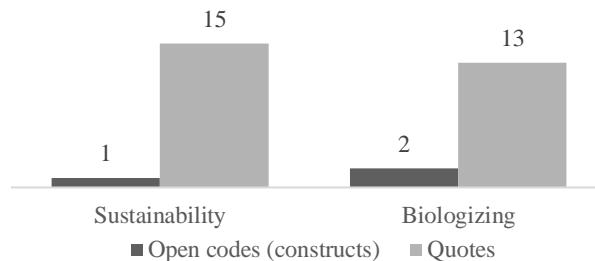


Fig. 7. Category “Environment” and its code system

Sustainability describes several different practices, methods, and ideas to create a more environmentally friendly Industry 5.0. Frequently mentioned are establishing or enhancing a circular economy, waste reduction, better resource efficiency and effectiveness, and production and usage of clean energy [19], [23], [25], [28], [36], [38].

The concept biologizing consists of two constructs bioeconomy (7 quotes) and biology (6 quotes). The construct biology describes the biological direction of research in the Industry 5.0 context. Included are topics that support a more technical approach to finding technical solutions through the help of biology. Tools and methods are, for example, bionics, synthetic biology, biotechnology, or phenomics. Furthermore, bioeconomy investigates the field of biology and economics. The centre of attention hereby is the smart use of biological resources and their transformation into value-added products such as food, bioenergy, or bio-related products.

4 Discussion, conclusion and future directions

This paper at hand presents a systematic literature review of the categories, concepts, and constructs of the Industry 5.0 approach. It responds to the research question about **“What are the categories in Industry 5.0 and what are the concepts and constructs?”** and presents five categories. The first category “Governance” represents the business dimension of Industry 5.0, including processes, management tools, business models, methods but also innovation, and security. The second category “Humanness” directs the focus on human-centricity, resulting in concepts such as human-machine interaction, customer-centricity, human-centricity, and human ingenuity. “Technology” forms the third category, emphasizing the role of different technologies, networks and interoperability, and robotics in Industry 5.0. The fourth category “Intelligence & proficiency” points out the importance of knowledge, skill, and education and also captures the change (needed) in the future of work. The fifth category “Environment” outlines the concepts of sustainability and biologizing, focusing on ways to operate more sustainably in business and industry.

Comparing the findings of this systematic literature review with the Industry 5.0 approach of the European Commission, differences in scope and focus could be identified. The European Commission defined three pillars, human-centricity, sustainability, and resilience [1], [2]. According to the findings of this literature review, the pillar of human-centricity correlates with the category “Humanness”. The pillar of sustainability is comparable with the category “Environment” and is additionally represent in other categories and concepts. For the pillar resilience, no equivalent category could be singled out. Following the approach of Maurer (2020) [39], resilience is a capability of a system (e.g. an enterprise, value/supply chain, etc.) and aims to design, develop, and (*re-*) engineer of VRIN-resources, responsiveness capabilities, cognitive capabilities, and dynamic capabilities for system adaption, renewal, innovation, and evolution. Resilience needs continuous attention and refinement and is best reflected in concepts such as business, human-machine interaction, network and interoperability, and work. The

remaining three categories “Governance”, “Intelligence & Proficiency”, and “Technology” can be seen as extensions of the existing Industry 5.0 definition.

Based on the findings and its discussion, the conclusion is that the Industry 5.0 approach extends the Industry 4.0 approach. It not only incorporates the technological dimension but also takes the human, social, governmental and environmental dimensions of business and industry into account. Additionally, Industry 5.0 focuses on the workers' education, wellbeing, and creativity by leveraging and continuously expanding their knowledge, skills, capabilities, and innovativeness. Industry 5.0, thus, is a more symbiotic approach between technology, environment, humans, and society, while considering the scarcity and limitation of (economic) resources and developing a higher degree of robustness and resilience.

This systematic literature review presents a detailed picture of the status quo of the Industry 5.0 approach. Due to the novelty of the Industry 5.0 paradigm, future research is needed in several directions – vertically and horizontally. For example, each category, concept, and/or construct could be examined in more detail by exploring arising artifacts, such as technologies, management frameworks, models, tools, etc. Additionally, further systematic literature reviews and empirical research need to be carried out repeatedly since research and development thus technologies and innovation emerge continuously in both academia and practice.

Acknowledgment

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