The Role of Knowledge Management in Transition to Industry 5.0

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***Abstract* - Fifth industrial revolution, or Industry 5.0 is gaining a momentum in last several years, additionally enhanced with many disruptive events in global economy. Its main keywords are sustainable, human-centric and resilient, and it should bring these benefits to industry and society. Knowledge management enables the cycle of knowledge through organization and is a human oriented dicipline that continually embraces new technologies, helping organizations to achieve their goals. This paper explains that sustainability, human-centricity and resilience are naturally supported by knowledge management. Investigation of connection of elements of Industry 5.0 action plan with knowledge management processes and technologies shows that knowledge management has an important role in achieving Industry 5.0, especially through processes of knowledge creation/acquisition and storing and supporting artificial intelligence technologies.**

Keywords – knowledge management; Industry 5.0; technology

I. Introduction

The society is continually and inevitably changing, rushing forward (some would say backward) with big strides. The advancement of technology is ever faster, with new possibilites it offers causing both thrill and fear. Of course, it is inevitable to mention large language model ChatGPT [1], that is causing a lot of controversy and polemics, also about its impact on future of certain professions.

Humans have embraced almost every new technology for personal and business benefits. Organizations carefully consider positive and negative impacts that new technology can bring them for competitive advantage and profit. Many information systems that help organization in everyday business, including knowledge management systems (KMS), already rely on a wide range of latest technology, including artificial intelligence (AI).

Recent disruptions in various forms have shown that businesses and society in general lack resilience, despite all available technology. Covid-19 pandemic and, recently war in Ukraine are most warning examples on global level. Brexit also caused disruptions, and more localy, earthquakes in Croatia and Turkey. A single container ship that was blocking the Suez Canal for six days in 2021 caused global logistic problems.

Negative impact of humans on climate change and biodiversity collapse is making headlines for a long time, with grim warnings for future generations. Technology use and production are seen very negative in this context, with urge for lower energy consumption, waste reduction, recycling and re-using natural resources. For that reason, the concept of sustainability requires of current generation not to compromise the needs of future generations with satisfying their own needs.

All those issues caused the move of current industry trends to Industry 5.0, that tries to take into account needs of humans without geopardizing the planet, and to the consideration of means how to achieve it . This paper is organized as follows. In Section II the concept of Industry 5.0 and its goals are explained. Section III gives review of knowledge management and Section IV discusses how knowledge management can help in realization of Industry 5.0 concepts and action plan. Conclusion remarks are given in Section V.

II. Industry 5.0

Industry 4.0 (coined in 2011) was, or is, considering how technology advancements can help economy, and is focused to a great extent on interconnection of physical and virtual world, humans and devices, concentrating on Internet of Things (IoT) and cyber-physical objects, although it also considers ecological aspects [2,3]. It fosters enhanced efficiency through the technology for the purpose of minimisation of costs and maximisation of profit and, since it is concentrated more on AI-driven technologies and digitalisation than on sustainability and social fairness, it is not sufficient to tackle climate, environmental or social issues [3, 4].

Raised concerns about future human and planet well-being caused deliberations of how the abundance of technology that are developed and used every day can be used to avoid those issues, hence leading to the idea and the concept of Industry 5.0. European Union (EU) puts much effort into Industry 5.0 in the scope of its support to research and innovation. Fig 3. [5] depicts three core elements of the concept [3,5]:

- Human-centricity – Human needs and interests should be put first with ensuring that technology is used to serve people and adapt production process to workers, enabling them to develop new skills and roles and ensuring that their rights are respected. Workers are investment (not cost) and must have opportunity to continually learn to advance their careers. Technology should be adaptive to make workplaces safer and more inclusive, including remote work, thus increasing job satisfaction and taking care of physical and mental health and well-being. General Data Protection Regulation, White Paper on Artificial Inteligence and Digital Education Action Plan (2021-2027) are examples of steps towards human-centricity in EU.

- Sustainability – Processes should be circular and re-use natural resources, as well as reduce waste and energy consumption, in order to minimize environmental impact, respect the boundaries of the planet and consequently enable safe future for living beings. Circular economy should ensure efficient and effective resource use. Reflection paper Towards Sustainable Europe by 2030 and European Green Deal show EU determination to achieve climate-neutrality.

- Resilience – Production should be more robust and resilient to disruptions, including resilient value chains, flexible business processes and support to critical infrastructure. Resilient industry should cope with various vulnerabilities on global and local level, caused by various sources, such as political or natural. As a key instrument to help in achieving more resilient economy and society, EU statrted Recovery and Resilience Facility.

Industry 5.0 implementation requires new approach to business, as well as new design for business models and decentralisation, meaning that organizations must change, ensuring that sustainability is part of the strategy and that progress can be measured [4]. The concept can also be connected with the concept of Society 5.0 that is characterized by balance between economic development and environmental and societal issues and is a society where technology is used for the benefit of all people [3].

There are many technologes that should enable Industry 5.0, as identified at a virtual workshop with Europe's technology leaders [2]:

- Human-centric solutions and human-machine interaction (robotics, augmented reality, enhancement of physical or cognitive human capabilites…)

- Bio-inspired technologies and smart materials (self-repairing, recyclable, biosensors, adaptive ergonomics…)

- Real time based digital twins and simulation (digital twins of products, processes or systems, simulation of environmental impact…)

- Cyber safe data transmision, storage, and analysis technologies (networked sensors, big data management, edge computing…)

- Artificial intelligence (brain-machine interfaces, energy-efficient AI, causality-based AI…)

- Technoloiges for energy efficiency and trustworthy autonomy (smart dust, low energy data transmission…)

Both chalenges and enablers of Industry 5.0 are social, economic, governmental and political dimension, as well

Figure 1. Industry 5.0 [5]

as scalability, interdisciplinarity and transdisciplinarity [2]. Therefore, the success of the new industry paradigm depends also on government support in the form of creating new policies and active participation in the transformation [4].

III. Knowledge Management

A. *Development of Knowledge Management*

Interest in knowledge management, as well as a number of research papers about the discipline started to grow in 1990s [6], especially after the first knowledge management related scientific conference in 1993 [7]. Development of the field was driven by widespread use of information and communication technologies (ICT) and Internet [8]. Of course, research in topics of knowledge management started even earlier than book „The Practice of Management“ by Peter L. Drucker, the most prominent figure in the field, was published in 1954 [9].

Since then, a large number of defintions of knowledge management were created, in general or from various prespectives. According to one research [10], there are over one hundred definitions, from which authors, regarding most used terms, created two similar definitions, one of them being: „Knowledge Management is the process of creating, sharing, using and managing the knowledge and information of an organization“ [10, p. 14].

Researchers usually divide knowledge management processes into three to six or more [11], but all proposals reflect the flow (or cycle) of knowledge through organization, from its creation or acquisition, to storage, sharing and using. It is obvious that knowledge creation and acquisition are very important processes in knowledge management strategy [12], but knowledge sharing is usually considered to be a critical process within an organization for achieving better performance, competitive advantage and innovativeness [13,14,15,16]. Final goal is, of course, the use of knowledge for achieving organizational goals and strategy.

Stages of knowledge management development identified by McInerney and Koenig [8] show that, although largely impacted with information technology at the beginning, knowledge management over time added important elements needed for a long-term success and positive impact on organization:

- Stage 1: Information technology – The initial driver of knowledge management was information technology that could enable faster and more effective knowledge sharing with the use of both Internet and intranet. Knowledge management became new product to preserve intellectual capital and enable storage of valuable experience (in the form of „lessons learned“).
- Stage 2: Human and cultural dimension – This stage marks the realization that knowledge management system has little value if people don't use it, or, better to say, participate in it. The purpose of the knowledge management is to help people in making decisions and achieving organizational goals. On the other side, the system also needs employees' knowledge, especially tact expert knowledge. To ensure this, knowledge management needs to be part of organizational culture that foster the learning organization. In this stage communities of practice became important.
- Stage 3: Content and retrievability – With large ammount of information available (today known as big data), it was important for it to be structured and described, so that specific information can be easily retrieved when needed. Enterprise content management became important, as well as structuring knowledge in taxonomies that evolved into ontologies as a form of a knowledge bases.
- Stage 4: External knowledge and information – External knowledge was allways important to organizations, but it is a two way process. Organizations need external knowedge, and they are also providing information to to their customers or suppliers. Opening communities of practice to a wider group of participants can enable more knowledge flow into organization, but it also has some risks of knowledge leak. Usability of the available knowledge depends on its context and relation to other knowledge and informaiton.

McInerney and Koenig [8] marked the start of stage four in the beginning of 2010s, but also noticed that this may be merely the maturing of knowledge management.

B. Knowledge Management Processes

Knowledge management processes are supported with various mechanisms and technologies. Mechanisms are structural organizational means that foster knowledge processes, such as meetings, conferences, tutoring, presentations, projects, models, prototypes, lessons learned, organizational policies or standards [17]. All those mechanisms don't have to but can be supported with various technologies [11, 17, 18]:

- Knowledge creation/acquisition – data and text mining, big data analytics, natural language processing (NLP), machine learning (ML), Internet of Things, augmented reality (AR), content management systems, business intelligence, videoconferences, social media, communites of practice…
- Knowledge storing – databases, knowledge bases, warehouses, blockchain, document management systems, repositories…
- Knowedge sharing – visualisation tools, simulations, webinars, videoconferences, socal media, communities of practice, blogs, wikis, NLP, chatbots, virtual assistants…
- Knowledge use – knowledge-based systems, enterprise resource planning systems, management information systems, cognitive computing, robotics…

One technology and/or mechanism can support several processes. For example, at a videoconference one person shares knowledge and the other acquires it. All processes are connected and successful knowledge management system depends on their smooth performance, ensuring uninterrupted flow of knowledge through organization, although it can be developed to support all of some of them.

C. Artificial Intelligence Supported Knowledge Management Systems

Knowledge management systems can include various information technologies mentioned in previous subsection and many more, depending on the needs of the organization. They can also incorporate AI technologies, also listed in previous subsection, to support some or all knowledge management processes. Most of the systems on the market that include AI technologies are aimed at improving employee decision making and customer service [19,20,21,22,23] with supporting processes of knowledge creation/acquisition, storing an sharing, and consequently knowledge using. Therefore, examples of those systems will be presented.

Document360 [19] is an AI supported knowledge base platform that uses natural language processing, AI algorithms and text analytics to foster knowledge creation, knowledge storing in public or private knowledge base and knowledge sharing. AI algorithms improve content creation and collaboration and enable employees to quickly find and use relevant knowledge. They also enable performance analytics of documents and thus help creators to improve the knowledge base content. Document360 also has various extensions and allows integration with other tools, such as Zendesk or Google Analytics.

Lucy [20] is an AI-powered enterprise knowledge management system and answer engine (chatbot) that also supports knowledge creation, storing, sharing and use. Information in knowledge base can be received in various formats (documents, audio, video) and Lucy uses NLP and machine learning to give relevant answers and knowledge for better decision making.

eGain Knowledge Hub knowledge management software [21] provides content and workflow management, search and knowledge analytics, giving support to all knowledge processes. With the use of NLP, machine learning and case-based reasoning, it enables knowledge access through virtual assistant and supports decision making. New eGain 21 [22] is organised as three hubs: Knowledge Hub, Conversation Hub and Analytics Hub. eGain enables integration with call tracking systems

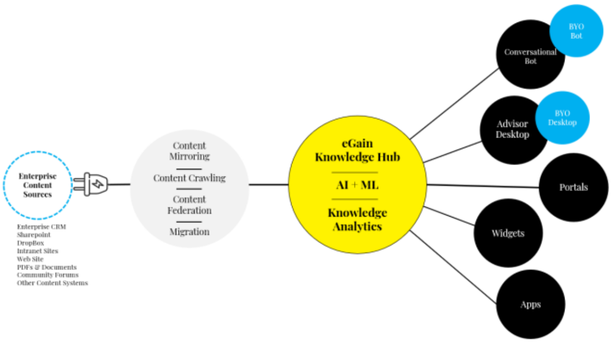

Figure 2. eGain Knowledge Hub with connections [23]

and third party tools, such as Lotus Notes or Microsoft Share Point [21]. Fig. 2 [23] shows eGain Knowledge Hub and connection to various third party information sources as well as with eGain developed tools.

IV. Knowledge Management Support to Industry 5.0

A. *Industry 5.0 Core Elements and Knowledge Management*

During last ten years in the focus of research came various issues related to the rising concerns or possibilites for future workers because of advancement of the technology: from low-skill tasks workers displacement and less work for information technology specialists due to outosurcing, over possibility for creativity and new human capacities, and lastly to human-computer collaboration with emergence of Industry 5.0, titled Employment 5.0 [24].

Knowledge management benefited from many Industry 4.0 technologies, such as Internet of Things, cloud computing, Blockchain, simulation and modelling, visualisation or automation, especially for knowledge sharing, but also for other processes [25]. These technologies comprise also Industry 5.0 and continue to support knowledge management. On the other hand, knowledge management recognizes the importance of people from its second development stage [8] and acknowledges that all technology that is used to help knowledge management processes is actually used for the purpose of ensuring that workers have the knowledge they need when they need it to make decisions and develop new products and services, thus enabling innovation and progress. Therefore, knowledge management naturally suports humans as the important element of Industry 5.0 and Employment 5.0, where technology is used to serve people.

Sustainability issues are already considered by many organizations [26,27,28], where knowledge management plays an important role in providing critical knowledge for making the organization and subsequently its processes and products more sustainable, especially through innovation [29,30,31]. It also fosters resilience - many organizations that possesed required knowledge and technology at the beginning of Covid-19 pandemic made easy transition to making products needed to overcome this crisis [32,33]. Another example is a supply chain – suply chain risks lead to more focus on all knowledge management processes in organizations, which improves risk management culture and consequently supply chain resilience [34].

B. *Industry 5.0 Action Plan and Knowledge Management Processes*

ESIR, expert group on the economic and societal impact of research and innovation that advises European Commission, has proposed action plan [4] that should lead to Industry 5.0 implementation. This plan is in large part oriented towards sustainability, meaning that other two aspects, human-centricity and resilience should follow from required transformations of business. To achieve sustainability through technology and production, knowledge of new technologies and knowledge how to implement and use them to achieve it is necessary, as well as knowledge that can lead to innovations in sustainable technologies, processes and products.

The role of knowledge management and its processes in supporting Industry 5.0 can be discussed through support in achieving specific six elements of the Industry 5.0 action plan [4]. Active participants in implementation of the plan are government, industry, financial sector, as well as civil society and NGOs. The role of knowledge management in this paper is observed from the industry side and knowledge management processes are connected to four of action plan six elements, which is supported with literature. Last two elements are dependent on the government support.

First element, „The triple Imperative and the role of industry“ [4] requires from industry transformation of business models towards sustainablity, changing the mind-set and redesign of value chains to include new technologies, circular economy and well-being, as well as to adopt metrics that will measure the progress. For all major changes in organizations, such as change of business model and value chain, knowledge needed for making optimal decisions must be available. Innovation of green processes and green technology is important for the transition to sustainability, where knowledge management plays a major role [29,30,31]. Although all processes can impact green innovation [29], knowledge creation and acquisition process is crucial in gaining knowledge that can result in innovation.

„New Economic Orientation and New Approaches to Industry Performance“ [4], as a second element, asks industry to observe return on investment with the purpose to optimise a return on invested energy or natural assets, to support „resource efficiency first“ principle and to review all value chains that result in products on EU market. It is well known that innovations in energy and resource efficiency require knowledge acquisition from various stakeholders and other sources [35] and that knowledge sharing and transfer is critical for decision making and their succesful implementation [36]. This emphasizes knowledge storing after acquisition and before sharing as important process that enables formating and representing gathered knowledge for transfer and use.

Reshoring (backshoring) of economic activities to lessen carbon and material footprint is required from industry in third element, „New Design for Business

Models, Value Chains and Supply Chains“ [4]. When returning production to Europe or any home country, it is important that all relevant knowledge is also transfered and reintegrated [37,38], and therefore process of knowledge sharing is the one that plays important role in achieving this element. With the change of employee base, part of tacit knowledge can be lost [37], which emphaiszes knowledge creation and acquisition process during and after reshoring for continuation of business with less disruption.

According to fourth element, „New Purpose for Digital Transformation, Achieve Life within Planetary Boundaries“ [4], digital technologies should be used in industry to make positive impact on climate. This again stresses connection of knowledge management and sustainability [29,30,31], and need for green innovations in technology with the help of knowledge creation process. If environmental aspects are included in knowledge management, all its processes positively impact on green technology innovation [29], especially knowledge acquisition that includes big data analytics [39].

Fifth element of Industry 5.0, „New Approaches to Policy-Making“ [4], includes development of green and social industrial strategy and policies and interaction with public sector during transformation (where the role of public sector in transition to Industry 5.0 should be revised). Final, sixth element, „New Capabilites and Approaches to Research and Innovation“ [4] requires the change of regulations and research and innovation policies, as well as increase of funding connected to sustainable solutions. Both elements are dependent on the goverment, which should interact with and consult other stakeholders. Therefore it is clear that industry role in those two elements is only to share its knowledge to provide input for new strategies and policies for easier implementation of sustainability in business.

C. Industry 5.0 Action Plan and Knowledge Management Technologies

Industry 5.0 action plan calls for sustainability with new business models, redesigned value chains, circular economy, resource efficiency, reshoring and green digital technologies supported with new government strategy, policies and regulations. Various knowledge management technologies mentioned in Section III B and many of them in the scope of Industry 4.0 and belonging to AI are used to achieve these specific goals.

Circular economy itself implies changes in business model and value chains, and demands resource efficiency through reuse of materials and products or their parts or through products durability [40]. The smart circular economy framework, shown in Fig. 3 [41] explains connection of AI technologies with data transformation into knowledge and how they can help in resource optimization. These technologies, that are listed on the right side of the Fig. 3 [41], support processes of knowledge creation/acquisition as well as knowledge storing in desired forms and subsequently its use - for example, various sensors can acquire data about product condition in phases of production and use, and analysis of these data can result in knowledge that can be applied for improvements in product quality and durability.

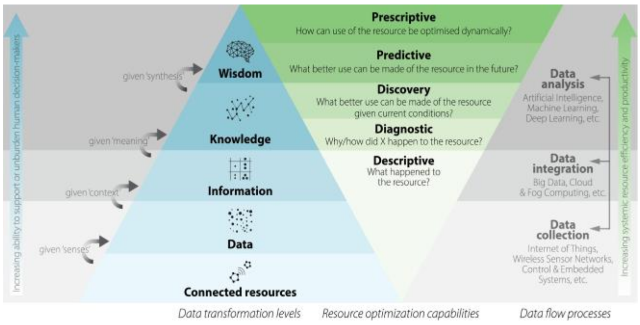

Figure 3. The smart circular economy framework [41]

Internet of Things in general supports knowledge creation from data embedded into objects, and augmented reality also creates, stores and transforms vast ammounts of data into knowledge that can be shared to enable easier learning and then the use of learned knowledge [42]. Machine learning can be used to design and test new sustainable materials [43] through knowledge acquisition and storage (and analysis) processes. This can lower the need for raw natural materials, ensure material reuse and durability, thus enabling resource efficiency. New digital technologies, such as IoT, sensors for real-time data collection or data analytics, can be of support to reshoring [44], and they foster knowledge creation and acquisition process that is important, as already mentioned, because of need for recovery and reintegration of relevant and tacit knowledge [37,38].

Need for technology support, especially for knowledge creation/acquisition and then storing (for subsequent sharing and use) to achieve elements of action plan is obvious. All AI supported KMS solutions in subsection III C and similar systems can therefore help in achieving Industry 5.0 goals. Action plan asks for those digital technologies to have positive impact on climate [4]. From technologies mentioned in this subsection and examples of AI supported KMS in subsection III C it is clear that many AI technologies for support to knowledge management processes in the scope of Industry 5.0 are related to data collection and analysis. However, there is currently a lot of discussion about large ammounts of energy that large ammounts of data, information and knowledge consume [45]. Controversial topic is also a large energy consumption that an AI model training requires [46], thus making a large carbon footprint.

The shift to renewable energy resources is invitable, where many AI technologies have an important role, for example smart grids or virtual power plants, making knowledge sharing process also important to enable succesful technology implementation [47]. For instance, Google claims that it operates their data centres on carbon-free and renewable energy, continually lowers power consumption, uses wastewater for cooling and new solutions to lower water consumption (including ML), and that companies moving to their cloud solutions from local servers also add to energy efficiency [48,49,50]. 2023 Best Practice Guidelines for the EU Code of Conduct on Data Centre Energy Efficiency [51] list many factors that can make data centres more sustainable, such as proportion of energy used from renewable sources, optimal extended operating temeperature and humidity range, air flow and liquid management for cooling, equipment containing high efficiency AC/DC power converters, deployment of virtualisation technologies, selection and/or development of energy efficient software, or data management policy (to lower energy consumption with deleting unnecessary data), to name a few. Carbon footprint of machine learning models can be evaluated by tracking electric energy consumption allowing for energy efficiency improvement with different training methods [52]. Selection of efficient ML model architectures, processors optimized for ML training and cloud computing using carbon neutral cloud can significantly lower the energy consumption [53]. In this way digital transformation can get closer to support Industry 5.0 action plan.

V. Conclusion

Industry 5.0 in a way represents new hope for the future of human society, trying to overcome issues that are concerning it for a long time. It represents the idea to divert the technological advancement into more greener track, because it can not be stoped. And it also requires more technological innovations that can enable climate-neutral production based in large part on recycling and reuse (and other R's of circular economy), with less energy and resources consumption. Besides this, they must also support the well-being of workers, of those that will create them and of those that will use them.

It is obvius that those goals first require new perspective, and then research that will lead to creation of new knowledge that will then lead to innovations – known as knowledge and innovation cycle, which is part of knowledge management. Investigation of connection of KM processes and technologies with Industry 5.0 action plan clearly shows the role that knowledge creation/acquisition and storing, and associated supporting AI technologies have in achieving Industry 5.0 action plan. Therefore knowledge management should be considered as an important part of transition to Industry 5.0.

Besides the problem of AI technology sustainability, which is addressed in previous section, an important issue is also AI ethics, especially conisdering human element of Industry 5.0. This problem is already tackled, for example with EU Ethics Guidelines for Trustworthy AI [54], but is still gaining momentum because of ChatGPT [1] and other large language models. Government support with new regulations is crucial for dealing with this issue, as is in acheiving elements of Industry 5.0 action plan.

To successfuly implement action plan, technologies that support knowledge management processes must themselves be aligned with principles of Industry 5.0. Only continual access to needed knowledge and carefull implementation of innovative technologies, taking into account specific needs of organizations can foster more human-centric, sustainable and resilient industry and consequently society.

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