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A literature review of contemporary industrial revolutions as decision support resources

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A B S T R A C T

Today's industrial revolutions radically transform our understanding of technological possibilities and the importance of human creativity. All these contribute to changes in the process and tools of decision support. In this literature review, I will discuss the technological opportunities that can be applied in Industry 4.0 and Industry 5.0 and the related role of human resources. Industry 4.0 is not just about an explosion in the industry, but about the digitalization of the entire economy. Digitalisation solutions include CPS systems that integrate computing, networking and physical processes. CPS systems are based on the networking of the machines that make up the system, with the ultimate goal of developing a learning algorithm that can autonomously perform optimization tasks. In the centre of Industry 5.0 is people-centredness, sustainability and resilience. Along with Industry 5.0, human-machine interfaces have developed. Its aim is to help the employee to work in a way that takes into account his or her abilites. Harnessing the potential of the human-robot interface to improve economic and social processes will be a crucial factor in the coming years. Moreover, supporting the technological lagging is also a priority in the modern industrial revolutions. In additional to financial incentives, availability of technical support can be a critical factor during the implementation procedure and the use of these new technologies. This can have a big impact on the daily lives of businesses and households.

1. Introduction

The constant battle for competitiveness between companies has opened up a new dimension of industrial development: Industry 4.0. The modern industrial revolution is no longer just a technological change in the life of companies but also has a direct impact on human resources. The sharp difference between the modern industrial revolution and the previous ones is that the changes that have taken place so far have primarily affected the manufacturing technology of the time. The first industrial revolution brought the dramatic development of the textile industry, the second the advent of mass production, electricity and the internal combustion engine, and the third the advent of computers (Nagy 2019). The fourth and fifth industrial revolutions are linked to the technological developments of the last ten years. The two industrial revolutions (Industry 4.0 and Industry 5.0) are closely related. The former aims at technological innovation and renewal at companies and households, while the latter focuses on human creativity by applying new technologies based on new foundations. The article aims to present the current industrial revolutions as decision-support resources and evaluate the different opportunities.

2. Industry 4.0

The causes of the Fourth Industrial Revolution include environmental pressures from production systems, scarcity of resources and the gradual shortage of labour in ageing societies. The ageing of the population is a feature of European society, which is perhaps why Germany can be seen as the starting point of the fourth industrial revolution. The concept of Industry 4.0 was born due to a German government project in 2011. The concept and its underlying content were presented to the public at the Hannover Business Fair in 2012. The objective of the German Industry 4.0 strategy was to develop a

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production system that uses self-learning optimisation prediction and helps to manage the associated human resources (Jasperneite, Niggemann 2012). With IoT (Internet of Things) technology, production planning, production scheduling, product management and related logistics systems are undergoing a drastic transformation. The tools of Industry 4.0 are the production scheduling, warehousing and other IT systems and interfaces that exchange data from which information can be generated without human intervention.

Erboz (2017) identified nine areas based on a literature review that could be the future domain of Industry 4.0. All areas offer software-based solutions to existing problems. That confirms Jasperneite-Niggemann's prediction from 2012 that Industry 4.0 will see the rise of software solutions to support production.

Industry 4.0 is not just about an explosion in the industry but about the digitalisation of the entire economy, which will encompass the whole of society. Deloitte (2015) analyses the expected impact of Industry 4.0 at the level of companies and households. Industry 4.0 technologies are based on the internet and the connections between things, data, people and services. IoT (Internet of Things) technologies refer to networked smart devices that can communicate with each other to collect and transmit data (Sisinni et al. 2018). Common applications include smart homes wearable devices. IoD (Internet of Data) enables big data analytics, and its technology is Big Data analytics. The main difference between IoT and IoD is that while an IoT device can only collect and display data, IoD can analyse and make predictions.

The IoP (Internet of People) is a segment of Industry 4.0 that makes technology more human-centric to use and understand. IoP was a concept used before, but these were applications and technologies only used by humans. Industry 4.0 technologies require M2M (Machine to Machine), i.e. direct communication between machines without human interaction. Technologies such as Alexa, developed by Amazon and Siri created by Apple, bring digitalisation benefits and tools closer and more understandable to people (Miranda et al. 2015).

IoS (Internet of Services) is the standard interface between the IoT and IoP segments. IoS refers to services that connect IoT devices (hardware) to serve consumer needs appropriately (IoP). IoS aims at realising a full-fledged digital enterprise that functionally fully digitises the processes, assets and products of an existing service company (Simmers, Anandarajan 2018).

Deloitte's (2015) industry analysis highlights four areas of opportunity for Industry 4.0 that could bring future-defining changes to businesses: vertical linkages between smaller manufacturing systems, horizontal linkages between value chains driven by globalisation, lifecycle analytics, the exponential acceleration of the pace of development. The development of vertical links between production systems refers to the IT systems linking machines and the indispensable sensors on production equipment. Data collected by sensors are collected in a dedicated network in a storage area. A cloud-based, decentralised location for data storage and analysis is proposed. The advantage is that the information can be made available at one site and between members of the value chain. By efficiently processing and analysing the data collected by sensors and transmitted from the machines, it is possible to make fast and efficient business decisions that can help to ensure the safety, security, workflow, services and sustainability of the company's operations.

Changes in the horizontal relationships of value chains can create new business models. Industry 4.0 requires a new way of thinking and a new attitude from corporate decision-makers. New skills may need to be acquired at both employee and organisational levels. Consumer needs will become more central, leading to new cooperation models between stakeholders in the value chain. Research and development, procurement, sales and production processes are undergoing a digital evolution, changing platforms. Successful companies will use the value-added information generated by Industry 4.0 to improve and streamline communication with suppliers and customers to serve the needs of the value chain. Solutions and businesses that ensure cyber security will enter the value chain. Digitalisation increases the need for adequate protection of data and information stored locally or in the cloud against unauthorised access or external attack.

In their analysis, Oláh, Popp and Erdei (2019) divided Industry 4.0 systems into three major areas from a technological point of view: cloud-based systems, cyber-physical systems (CPS) and smart factories. Cloud-based systems are characterised by the fact that they are usually thin-client based software with the database side hosted on external storage. Cloud-based systems include data-driven solutions based on Big Data, such as comparing and analysing manufacturing fact data and design data in the ERP system to optimise production.

CPS systems are defined as integrating computing, networking and physical processes (Baheti - Gill, 2011). CPS systems must meet five requirements to be considered Industry 4.0 compliant (Lee, Bagheri & Kao 2015).

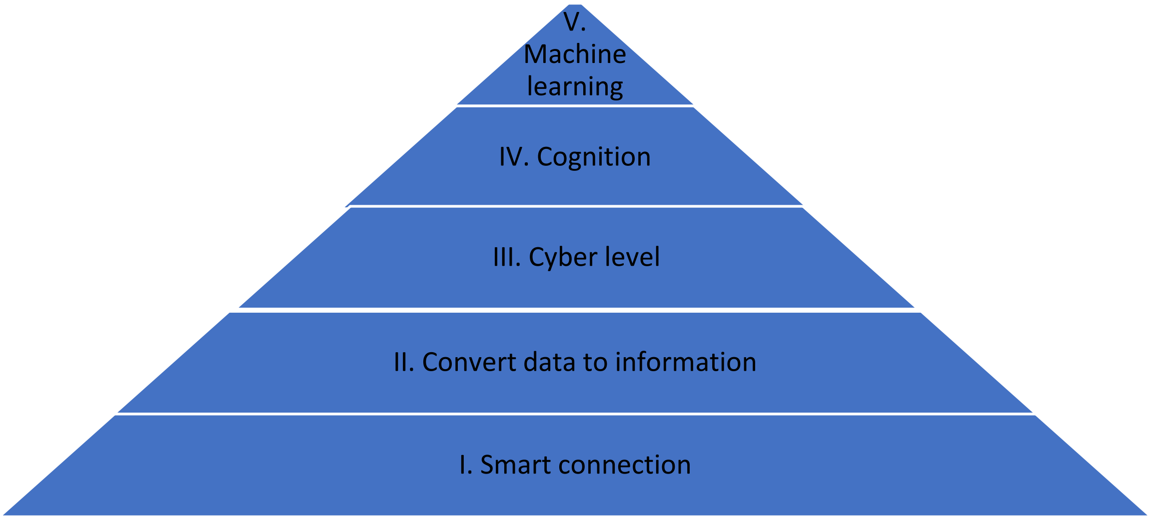

Figure 1. Levels of a CPS system

The first level of CPS systems (Figure 1.) is the implementation of data extraction from production machines. For Industry 4.0 compliant devices, this can be easily achieved through pre-installed interfaces, but additional sensors may need to be installed for older types of devices. The second level is to convert the extracted data into information. This step helps, among other things, to optimise production planning to determine the optimum remaining cycle time until maintenance of the production machines. The third "cyber" level serves to process and collect the information generated centrally. At the cyber level, primary decision support is provided through complex interpretation of the incoming data, usually using big data-based data analytics. Predictive data analysis helps to predict a future event based on past data. The fourth requirement is the possibility of insight. The level of process optimisation is where a worker with the proper knowledge can make a task priority decision based on comparative information and live data from machines. For cognition to be effective, it is essential to have a decision support system that can present the information generated from the data with appropriate infographics. The final requirement is the self-learning of the developed CPS system. The design of a feedback system acts directly on the production machines in a self-learning manner from cyberspace (machine learning). In Industry 4.0, these instructions are usually interventions to preserve the physical state of the equipment.

Smart factory is a production-related solution that can flexibly adapt to production processes and their changes to solve production challenges. This requires the existence of an automated system, often combined with several software solutions, and it also implies collaboration, even between companies from different industries (Hozdic 2015).

Lifecycle design should consider that innovative solutions are not only available in the classical design phase of product manufacturing. Innovation can affect the company's organisational structure, processes, business planning, distribution channels, which may individually or even collectively impact the saleable goods. The analyses produced by Industry 4.0 technologies help to calculate a return on investment and indicate internal or external threats that require the intervention of the company's management. In product development, information technologies can accelerate and control R&D processes.

The emergence of disruptive technologies will increasingly become part of our everyday lives. Examples include 3D printing, drones, artificial intelligence, and augmented reality (Büchi, Cugno & Castagnoli 2020). What these technologies have in common is that they have been part of our world for years or decades, but that they have now reached a stage where they can be placed on the market at a price/value ratio that allows businesses to integrate them into their business processes or households to buy them. Previously available only to the military, drones are now available directly to consumers with the financial ability to pay. The use of drones could rejuvenate many industries, such as parcel delivery. The exponential emergence of technological innovations also opens new opportunities for venture investors. As an incubator of new trends and technologies, it can become commercially interested in innovation's development and long-term success.

With the changes brought about by the emergence and application of Industry 4.0, companies need to transform themselves into perpetual learners. The use of information that becomes available as a result of the introduction of new technologies can be a decisive factor in a company's success. The introduction and integration of Industry 4.0-related technologies into an organisation must be gradual and permanent. Continuous learning is the key to organisational development. Too rapid change can be counterproductive and may encounter resistance within the organisation (Filep 2020).

The introduction of Industry 4.0 and related technologies in the life of a business is critical because knowing the correct information can save resources. These changes come with the rise of digital enterprise. Digital enterprise and entrepreneur can be expressed from the digital and entrepreneurial ecosystems. A business cannot be called digital because it is connected to the internet. It requires a supportive business environment that also provides the institutional framework to take advantage of digitalisation (Szerb et al. 2020). According to the research of Szerb et al. (2020), all elements of the entrepreneurial ecosystem need to be improved, highlighting the areas of human capital and education, regulatory environment, financing and support.

The analysis of the areas of funding and support did not include a more detailed examination of the availability of external financial resources. Respondents rated the availability of financial resources (European Union) as above average. However, the authors conclude that the attitude of the Hungarian government towards financial incentives has changed, while the European Structural and Investment Funds is the central financier.

The experts interviewed in the research (Szerb et al. 2020) clearly stated that rural areas lack the socio-economic potential to support the emergence of Industry 4.0 businesses.

In the light of the above findings, it is also worth examining the distribution of EU funds allocated for the implementation of Industry 4.0 projects in the regions of Hungary. In the 2014-2020 funding period, Industry 4.0 or digitalisation funding at the floor level was available under GINOP-1.2.8-17 and GINOP 3.2.6-8-2-4-17.

The emergence of Industry 4.0 has implications for existing integrated business management systems. In his research, Ternai (2020) analysed the opportunities and challenges for ERP systems from several angles. In his opinion, ERP systems are most affected by the changes brought about by Industry 4.0 in transport, logistics, manufacturing and maintenance, and the functionalities covering these areas. The related software developments are being driven by the major suppliers (e.g. SAP, Infor) with standardised, centralised solutions. Local partner companies implement customisation needs.

3. Industry 5.0

Industry 5.0, in contrast to the digitisation of Industry 4.0 production, focuses on the collaboration between man and machine. Industry 5.0 is a set of technologies designed to make business processes respond as quickly and efficiently as possible to the changing business environment. Industry solutions based on predictive data analytics and machine learning will become more prevalent and accessible among management decision support tools (Bharati 2021).

The fifth industrial revolution is built on three corresponding values: people-centricity, sustainability and resilience. The ongoing Covid-19 epidemic has reinforced the importance of these values. The shift from an employee-cost approach to a worker-as-investment approach should be emphasised in the people-centred approach. Technology exists to serve people and society.

Sustainability criteria respect the finite natural resources provided by the environment. The criterion aims to use technologies that reduce waste and ecological footprint, while the primary objective is to use resources efficiently to achieve a business goal. Industry 5.0 technology resilience refers to responding to external environmental (economic, political, natural) changes. It supports and equips business infrastructure and makes it more resilient to environmental changes. Industry 5.0 aims to support value-creating processes with people at the value-creating centre (Xu et al. 2021).

Villani et al. (2021) investigated the acceptance criteria of a human-machine interface (HMI) that helps workers perform their tasks in an automated industrial environment. The HMI device should monitor the user's health status (blood pressure, body temperature, pupil reactions). The user of the HMI device must trust the device, and the user's data must be securely transmitted to the data centre, stored and processed there. The worker must feel that the monitoring is in its best interest and does not cause discomfort at work. The software solution behind the HMI tool should be customisable according to the task to be performed, the worker's skills and abilities, and the employee's preferences. Based on the above, the solution should monitor the user's physical condition in real-time and make suggestions for improving the worker and enhancing its performance. As a result, it should improve the employee's well-being while reducing stress during work. In this way, the employee will become more confident in using the HMI and make fewer mistakes. In order to achieve these goals, it is essential to train employees, including through augmented reality learning solutions.

Employing people with the right digital skills is essential for implementing Industry 5.0 processes. Human-machine interaction involves a reallocation of tasks. Human tasks will remain the creative and imaginative ones, while mechanised work processes will mainly mean the implementation of the former in mass production (Oláh, Popp & Erdei 2019).

In its Future of Jobs Report 2020 (WEF 2020), the World Economic Forum has listed the top 15 skills identified as the most important for 2025. The fifteen most essential skills include those that meet and contribute to the human-centredness criteria of Industry 5.0:

- Analytical and innovative thinking,
- creativity, originality
- the ability to master new technologies,
- flexibility, stress tolerance,
- emotional intelligence,
- critical thinking.

These skills will be essential in implementing solutions that meet the criteria of Industry 5.0 and, ultimately, in supporting managerial decision support.

4. Summary

Today's industrial revolutions bring changes in the way products are created and how a company's management treats employees. Industry 4.0 has brought a technological shift (production and warehouse logistics) on the corporate side. In contrast, Industry 5.0 is centred on value-creating processes and the human being's creative source of value creation.

Industry 4.0 is a resource with many opportunities for businesses and households. These technologies are not only exclusively for manufacturing companies; they can also mean innovations in a distribution channel or a product or service that creates value for the end consumer. The application of Industry 4.0 as a resource requires adopting an approach that focuses on the collection and processing of data from our environment to generate information for value creation. The 4th Industrial Revolution, generated by the technologies and tools associated with Industry 4.0, will bring businesses and households digital transformation.

Supporting the technologically backward is an important issue to avoid widening the gap between technologically advanced and less advanced companies. Financial incentives alone are not enough to support the laggards. The use of workshops organised by professional organistaions and a close, professionally based follow-up may be necessary to enable lagging companies to effectively introduce Industry 4.0 technologies into their daily processes.

Industry 5.0 seeks to build on technological advances to link physical and cyberspace. The means to do this is to integrate production machines into a network. At the same time, the worker is given suggestions for priorities based on data from the machines, helping him or her to make task-related decisions. The introduction of digital solutions should consider the worker's skills and support those who are lagging with development.

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