# Key socio-economic megatrends and trends in the context of the Industry 4.0 framework

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## Abstract

With the development of Industry 4.0, modern companies are forced to adapt quickly and flexibly to changing competitive conditions. This has an impact on the strategic management of the enterprise and is reflected in the creation of new strategic models, such as those that allow the introduction of innovations, the rapid reorganisation of processes and the highly flexible adaptation of business operations to new conditions. The aim of the article was to identify trends and megatrends and to assess their impact in the context of the implementation of the Industry 4.0 framework in enterprises. The research used bibliometric analysis, force-field analysis and the results of a survey conducted on a group of small and medium-sized enterprises. The matrix for assessing the impact of megatrends and socio-economic trends in the context of the implementation of Industry 4.0 technologies was established using the expert method. The article presents key trends in the development of enterprises implementing Industry 4.0 technologies. The results may provide useful guidelines when formulating new strategies for enterprises.



## Key words

Industry 4.0, megatrends, strategic management



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## Introduction

The development of automation, robotisation and digitalisation significantly affects the permanent process of change in industrial enterprises. A global tendency in the development of industry is its movement towards the 'Industry 4.0' level and the penetration of information technologies into all fields and aspects of human activity (Krykavskyy et al., 2019; Hofbauer and Sangl, 2019; Grabowska, 2020; Gajdzik, 2021). The concept of Industry 4.0 is a new reality of the modern economy, because innovation and technological development play an important role in each organisation. Industry 4.0 significantly changes products and production systems concerning

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design, processes, operations and services (Ślusarczyk, 2018). Currently, the industry is subject to the pressure of development associated with the implementation of the fourth industrial revolution. After 2011, the direction of change in industry is referred to as Industry 4.0. Companies are influenced by the strong impact of competition as well as rising consumer expectations. The environment forces companies to make changes, sometimes very radical ones, which enable them to operate in global markets and compete in terms of flexibility, quality and low production costs. Today's buyers' markets are very demanding, which concerns not only the issue of the quality and variety of products, but also the personalisation of products. Changes were and are a constant element of business, but now their course is highly dynamic. Rapid technological progress forces the process of change and affects the decline of stability in the functioning of enterprises. The company must be oriented to changes and the strategic management of a company does not offer manufacturers "certainty" in predicting the future. In a turbulent environment, with a high degree of dynamism and high intensity of change, confidence in long-term strategies, which usually do not work, has decreased. Therefore, long-term strategies have increasingly begun to be replaced by scenarios. Foresight studies and trend analysis, including megatrends, have become increasingly popular. Companies are attempting to be flexible and are striking a balance between reactive and proactive actions. Adaptability is a requirement of doing business. The business models used are rapidly aging and new solutions are replacing previous ones. As a result of fierce competition, companies are constantly making operational changes to be more customer-oriented.

Since 2011, opportunities for the development of companies have been seen in the concept of Industry 4.0, and in the current decade in the concept of Industry 5.0 as well. The term "Industrie 4.0" was first used at the Hanover Fair in 2011 (Industrie 4.0, 2011). In October 2012, a working group led by Siegfried Dais of Robert Bosch GmbH presented a set of recommended industrial changes to the German government. The final report entitled "Industrie 4.0" was developed on 8 April 2013 (Hermann et al., 2005, based on "Platform Industrie 4.0", 2014). Industry 4.0 is the general concept of technological change of the fourth industrial revolution. The current industrial revolution focuses on building cyber-physical systems and business overcoming spatial and temporal barriers (DAMA – Design Anywhere, Manufacture Anywhere) (Nardo, 2020). Industry 4.0 is characterised by the strong interaction between virtuality and reality supported by big data, the Internet of Things (IoT)[1] and cloud computing (Schwab, 2016). Governments in many countries see this concept as increasing productivity and reducing production costs. Industry 4.0 is a major challenge for manufacturers in key industries because of the radical changes not only within companies but also in supply chains. Industry 4.0 is changing manufacturing processes by integrating them into cyber-physical systems and flexible supply chains. Information technology (IT) and information and communication technologies (ICT) are applied in the processes of technical preparation of production, manufacturing and distribution, transforming factories into smart factories (Kagermann et al., 2013; Hermann et al., 2015; Schwab, 2016).

The directions of development of Industry 4.0 are determined by changes, the implementation of which takes place over a long period of time. The currents of change, in relation to contemporary business, must appear much earlier, or if they are initiated now, they will last for several

1 The term Industrial Internet of Things (IIoT) is used to refer to the industrial environment.

more years. Megatrends are characterised by profound changes, the implementation of which has an impact on social, economic and ecological development. Megatrends influence all areas of life for a significant period of time (Naisbitt, 1982).

Megatrends create the "environment" in which other trends develop. Megatrends are the true boundary conditions for trends, and are made up of sets of trends. Megatrends transform the environment globally and create new conditions for many industries (Kee 2012, p. 12). Nowadays, changes are affecting many aspects of organisations simultaneously, and the importance of the environment in their activities is constantly increasing.

The article presents considerations on the essence of megatrends from the perspective of the future development of Industry 4.0. The authors also attempted to detail the key trends of change. The added value of the publication is a matrix of the impact of megatrends on the development of Industry 4.0. The publication was based on secondary sources of information (desk research). The authors used scientific literature published in the Web of Science and Scopus databases. While reviewing the literature, the authors assumed that modern manufacturing companies are headed towards Industry 4.0. The authors are aware of the existence of the next level of industry development, referred to as Industry 5.0, but at the current stage of company development it has not been the subject of research. The aim of the article was to identify trends and megatrends and to assess their impact in the context of the implementation of the Industry 4.0 framework in enterprises.

## 1. Industry 4.0 frameworks as a megatrend – Literature review

Companies embrace technological progress as a determinant of competitiveness but with a balance between business, ecology and society. Sustainability continues because it "protects the environment for us and for future generations". The strength of business in the near future is cyber-physical manufacturing technology, which is promoted by the concept of Industry 4.0. At the heart of smart factories are cyber-physical manufacturing systems (CPPS) with technology controlling physical processes, creating virtual (digital) copies of the real world. Decision-making is decentralised. Access to data is in real time, and with the Internet of Things (IoT) and cloud computing, companies benefit from multiple intra- and inter-operational services. Machines, automations, and robots work together and take over activities performed by humans. The framework of Industry 4.0 is a set of technologies used in the following processes: manufacturing, communication, IT, logistics, and many others. The BCG (Rüßmann et al., 2015) introduces nine pillars of Industry 4.0 technological advancement: big data and analytics, autonomous robots, simulation, horizontal and vertical integration, the Industrial Internet of Things (IIoT), cybersecurity, cloud computing and manufacturing, additive manufacturing, and augmented and virtual reality. These technology pillars make up the megatrend that is Industry 4.0. The individual pillars consist of sub-pillars, which are the tools, forms of technology or applications used. Examples of pillars and sub-pillars of Industry 4.0 are included in Table 1.

**Table 1.** Pillars and sub-pillars of Industry 4.0

| Pillar | Sub-pillars: Tools/forms/applications |
|---|---|
| Cloud computing | Cloud services, cloud products, cloud manufacturing |
| Internet of Things | Internet of People; Internet of Everything; Internet of Data; System of Systems (SoS); Web-based organisation |
| Embedded systems | Cyber-Physical (Production) System (CPPS); wireless sensing (Nodes/Network); RFID; smart sensing and actuators |
| Smart factory | Ecosystem of smart factories |
| Inter-connection | Networking; interoperability; vertical integration of production systems; horizontal integration of partners in value chains (via value creation networks); simultaneous planning of products and production processors; cross-functional activities |
| Servitisation | Product service ecosystems |
| Virtual and Augmented Reality | Augmented reality (AR), Virtual Reality (VR), Mixed Reality (MR), Extended Reality (XR) |
| Value chain | Added value, supply chain flexibility and visibility, SCM and logistics |
| Mass customisation | Individualisation, personal/product experience, personalised production, personalised product |
| Digitalisation | Digitalisation of physical processes, virtualisation, virtual assistance, digital transformation end-end digital integration, simulation and virtualisation |
| Adaptability | Adaptive manufacturing |
| Agent theory | Multi-agent systems |
| Intelligent and autonomous | Intelligent and autonomous shop-floor/processes, tailored products, connected/smart products and machines, self-organised |
| Decentralisation and distributed | Decentralised decisions, Decision Support Systems (DSS), networked and distributed data diffusion |
| Data analysis | Big Data, information provision, information transparency, real time data, promptly analysing data stream, open data |
| Cybersecurity | Safety, privacy, knowledge protection |
| Additive manufacturing | 3D printing |
| Collaboration | Collaboration network, co-innovation, human-machine-system communication and collaboration, synchronous operations, information sharing |

**Source:** Santos, C., Mehrsai, A., Barros, A. C., Araújo, M., Ares, E., "Towards Industry 4.0: an overview of European strategic roadmaps", paper prepared for the Manufacturing Engineering Society International Conference 2017, MESIC 2017, 28-30 June 2017, Vigo (Pontevedra), Spain.

Klaus Schwab (2016) organises the various technological trends of Industry 4.0 into three clusters: physical, digital and biological. Included in the first group are production automation systems, industrial robotics, machines equipped with sensors, data processing systems, autonomous vehicles, 3D printing, and new materials such as ceramics that exchange pressure for energy. The second group – the digital cluster – is defined by the Internet and high computing power information and computer systems, as well as data collection and processing systems and production control systems. The key technologies that make up this group are the Internet of Things (IoT) and the Internet of Services (IoS). The third group includes technological solutions that interact with humans and facilitate the operation of machines, such as controlling machines using voice, movement, gestures, the eye, facial expressions, and others.

Industry 4.0 is built on the basis of many trends that had already been available on the market previously. Łapuńka and Kołodziej (2017) list the following among the most important determinants of business functioning: the globalisation of economic activity; strategic alliances and the emergence of strong capital groups; the spread of information technology and digitalisation; the formation of post-industrial society; the increase in the importance of knowledge and qualifications; functioning under conditions of constant change; the increase in aspirations of society (employees, customers, contractors); and the influence of the state on the economy. Currently, people live in an open society where the source of change is the freedom (liberty) to transfer everything. A global picture of the world has been formed, in which everyone has access to everything. Globalisation is accompanied by the development of information technology. The Internet, computers and mobile devices have built cyberspace (a term introduced 50 years ago). The productivity and competitiveness of companies is determined by access to data and information. A network of information flows creates a network of knowledge. Easy access to information and knowledge is a feature of the information society – a term coined in 1963 by Tadao Umesamo. An information society has the ability to process and use information. With the development of information technology, information societies are transforming into digital societies and in time into post-digital societies, also referred to as Society 5.0. The new image of society is built on the basis of industrial society, or rather on its evolution towards a post-industrial society. The concept of the post-industrial society was born in the late 1960s and early 1970s, and its creators were the Frenchman Alain Touraine and the American Daniel Bell (Bell, 1967; Bell, 1973). At some point, humans became participants in full automation and robotisation and cyber-physical systems.

A strong trend is digitisation, which converts analogue information into digital form using suitable electronic devices. This allows data to be processed, stored and transmitted through digital circuits, hardware and networks (OED). This is the simplest definition of digitalisation, because with the advancement of technology, digitalisation has created many digital products and services, improving the quality of life (Stolterman and Fors, 2004). According to Bloomberg (2018), digitalisation enables the combination of communication and business functions. The use of digital technologies enables the implementation of new processes throughout the value chain, from sourcing to production, sales, and services. Digitalisation covers all areas and functions of a company. Information technology and computers have built the digital economy (Tapscott, 1999). Its characteristic feature is the strong digitalisation of the functioning of society. With the development of digitisation, the producer-consumer relationship is changing. The consumer becomes a key player in the market, and digital technologies help to simplify the interaction between consumer and producer (Natalya et al., 2020).

Technological trends are changing people, who are becoming more confident, more flexible and open to change, characterised by creativity and emotional intelligence. "Greyness" has been replaced by "colourfulness" in which everything is possible. Drucker (2003) stated that management is first and foremost about people, management is deeply embedded in culture, management requires simple and understandable values, action goals and objectives that unite organisational participants, management should lead the organisation to be able to learn, management requires communication, management requires an elaborate system of indicators, and management must be explicitly oriented towards the primary and most important outcome, which is a satisfied customer.

In these new conditions for the functioning of people and organisations, the state, which sets the basic directions of development, promoting technologies considered suitable for their implementation, acquires significant importance (Pisar and Bilkova, 2019). In the description of trends preceding the emergence of Industry 4.0, one cannot forget about ecological innovations and the concept of sustainability. The second half of the last century was primarily about initiating the development of ecological innovation, also referred to as green innovation, environmental innovation or sustainable innovation. Although they are defined differently, their common feature is the reduction of the negative impact on the environment. These innovations are related to best technology (BAT), resource and energy savings, diversification and the circulation of resources. Highly developed countries are characterised by the circular economy, in which products, materials and raw materials should remain in the economy as long as possible and waste generation should be minimised as much as possible. This idea takes all stages of a product's life cycle into account, from its design to production, consumption, waste collection and management. This refers to a departure from a linear economy, based on the "take – produce – consume – throw away" principle, in which waste is often treated as the last stage of the life cycle. In a closed-circuit economy, it is important that waste, once created, is treated as secondary raw materials. This is the purpose of all activities preceding the creation of waste. At the same time, the closed loop economy approach, e.g. in product design or manufacturing processes, is aimed at increasing the innovativeness of European entrepreneurs and making them more competitive in relation to entities from other parts of the world.

In the new business environment, the employee is the expert and teacher for the robots. Concepts that place workers at the centre of new technology are popularised (Wittenberg, 2016). Employees are characterised by disruptive thinking. The employee thinks originally, strategically, unconventionally, and differently than before. Industry 4.0 is driven by the openness of innovative solutions. At the centre of this thinking is the customer, who demands personalisation. Personalised products are produced in short series according to customer needs. The production of the product is often carried out with customer participation in design, modification and manufacturing. Customers are participants in the company's processes. The customer designs the product, follows its manufacture, and also determines the form of payment and distribution, and makes the choice of after-sales services. Modern IT technology is based on digital modelling, which allows the production system to take the differing wishes of customers into account at each stage of production. The success of personalisation can evolve into mass personalised production, or the affordable personalisation of products similar to mass production. Affordability is determined by production costs and demand (Aheleroff et al., 2017). Industry 4.0 technologies identify customers and offer them customised products. This is possible by combining information from multiple sources and configuring technologies flexibly. Machines in line layouts or production cells are computer-controlled. The speed at which they are ready to meet customer orders is a key determinant of their flexibility and productivity. Manufacturing flexibility is made possible by process orientation, which for many years has been a trend in manufacturing (a trend for manufacturing companies in a market economy) (Willaert et al., 2007). Manufacturers function in network structures within cyber-physical systems. The network world creates many networks, e.g. knowledge, work, communication, services. Collaborative networks are efficient, which is convenient because it is possible for chains to adapt to constant change and easy to implement cyber-physical systems into other plants (Weck and Reed, 2014). Networking as a trend is different than previously. Individual network participants are "neurons" on "paths" of connections. The network is flexible and changes depending on e.g. customer needs, the availability of raw material suppliers, the availability of technology, etc. Each company in the network can be (for a moment) a power centre due to the adopted network optimisation criterion. "Neural" network structures are an alternative to hierarchical solutions. In Industry 4.0 smart factories, virtual organisations are predominant. Rigid links are giving way to fuzzy, smart links, and individual companies are characterised by responsible autonomy (Fairtlough, 2005; Ogilvy, 2002; Stephenson, 2006). Learning technologies, cloud computing, and feedback in calibrating robots based on experience (i.e. historical data, also understood as big data) are opportunities for a company to build a competitive advantage (Weck and Reed, 2014). The investments made require financial resources. As an example, the German industry assumed a level of investment of a total of 40 billion euros in Industry 4.0 every year until 2020. Applying the same investment level to the European industrial sector, the annual investments were to be as high as 140 billion euros (Geissbauer et al., 2016). The promoted Industry 4.0 technologies are implemented in manufacturing, commerce, services and other businesses. Examples include tracking the flow of products in the supply chain on mobile devices – using database networks (blockchain), impersonal forms of sales and customer service (customer service by chatbots) supported by mobile marketing, Internet marketing, artificial intelligence, omnipresence etc. (Ungerman, Dedková, 2019).

## 2. Material and methods

The research methodology has been divided into three parts. The research is the result of reviewing secondary sources of information in the form of bibliometric analysis and gathering primary information on the basis of direct research conducted in the SME sector and expert opinions. The individual stages of the research are presented in Fig. 1. The choice of research methods was conditioned by the adopted detailed objectives of the research, which resulted from the key objective. The key aim of the research was to identify trends influencing Industry 4.0. The specific objectives were as follows:

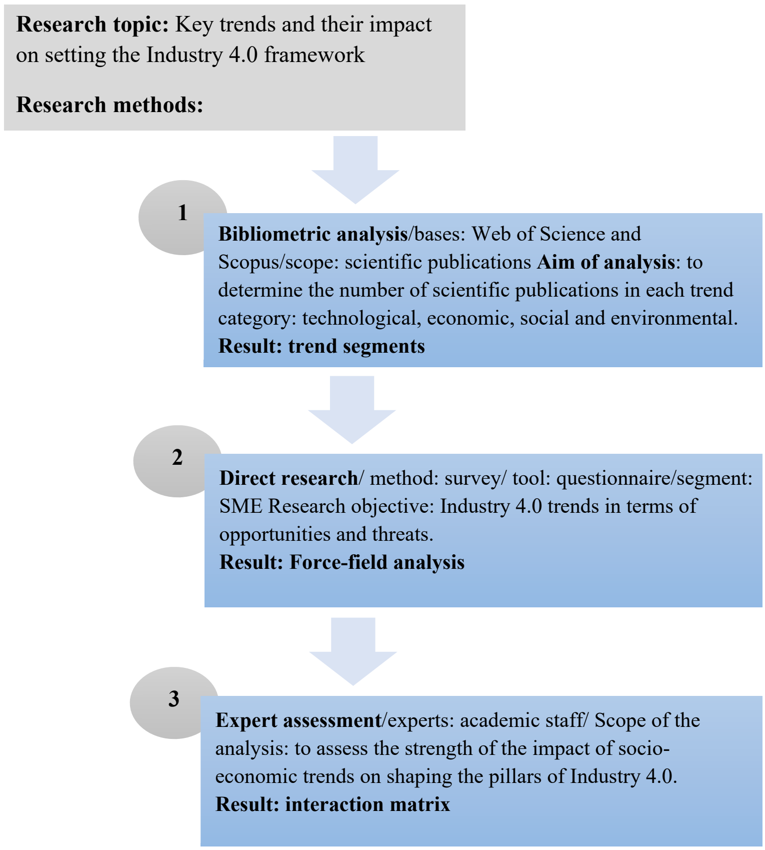
**A1:** to determine the interest of scientists in the topic of trends / to determine the distribution of scientific productivity / progress in the number of publications / authors publishing works on trends. For the purpose of the research, trends were organised by category/type into technological trends, social trends, economic trends, and environmental trends. Bibliometric analysis was applied at this stage of the research. Bibliometrics can be considered a form of organising and categorising knowledge. It provides a reference to those of its resources that allow for the codification of given knowledge with a given reference among other possible references (Wouters, 1999). According to A. Prichard (1969), bibliometrics is a set of research techniques that can be used to analyse publications. A distinction is made between evaluative bibliometrics concerning the assessment of scientific centres or researchers, which is based mainly on citation indexes of articles (Solla Price, 1976; Bornmann and Daniel, 2008), and descriptive bibliometrics, which is used in analyses of trends in scientific research, the identification of relevant researchers or research centres. A descriptive approach was used for the planned analyses.

**A2:** the arrangement of key determinants of Industry 4.0 in terms of opportunities for and threats to enterprises. On the basis of direct research, opportunities and threats to the implementation of the pillars of Industry 4.0 in enterprises were identified. The results of the research were published (Saniuk et al., 2020). In order not to duplicate the research results, the authors applied force-field analysis based on the primary information collected during the survey research. The study was conducted using the CAWI method (a standardised computer-based internet interview). The research tool was a questionnaire consisting of 25 questions (closed, complex, filtering, conditional and tabular). The survey questionnaire consisted of three parts and specifications. The first part contained questions in the field of customisation; the second part concerned issues pertaining to the implementation of the concept of Industry 4.0 in Poland; while the third part was related to the benefits of Industry 4.0. The questionnaire was validated, and a pilot study was conducted among 15 experts with knowledge of Industry 4.0. The questionnaire was corrected for their comments. The respondents were potential customers representing the Silesian, Lower Silesia, Greater Poland and Lubuskie voivodships; as such, the assumption that it is an infinite population may be made. Assuming a confidence level of 0.99 and an error of 10%, it was determined that the minimum size of the general population should be 166 customers. Therefore, the information contained in the surveys received can be treated as representative, as a total of 504 opinions were obtained.

Force-field analysis uses the assumption of Kurt Lewin (1951) that every change is the resultant of two types of forces: driving and inhibiting. Force-field analysis is a tool that helps to identify and analyse the forces (factors) that support or hinder change. This analysis is used by companies, among others, to determine the strategy of action in the area which is the subject of study (Thomas, 1985; Maslen and Platts, 1994). In the adopted research topic, the aim was to determine the strength of the positive or negative impact (in the opinion of respondents of the surveyed segment) of Industry 4.0 technology. The results of the analysis can be used to determine the strategy of companies in their transformation to Industry 4.0.

**A3:** determining the strength of the impact of trends on the pillars of Industry 4.0. The goal was achieved on the basis of expert opinions. The experts comprised six scientists studying Industry 4.0 (in terms of its impact on management) and six representatives of companies that have already implemented at least five pillars of Industry 4.0. The knowledge of experts was used in the construction of the interaction matrix of trends and key technologies of Industry 4.0. The method was implemented in accordance with the Delphi method of research (Sudol, 2016).

**Figure 1.** Methodology for researching the impact of socio-economic trends on shaping the Industry 4.0 framework




**Source:** own elaboration

# 3. Results

## 3.1. Bibliometric analysis

Based on the bibliometric analysis, the authors presented a schema for the relationship between Industry 4.0 technologies and the discussed trends. Although the diagram demonstrates a high level of generality, it presents a key trend framework for the promoted changes. This framework is to be found in ecological, sociological and economic trends. Individual trends were identified from publications in the WoS and Scopus databases. The number and areas of research were systematised into four streams: ecological, social, technological and economic. The time span of the analysis was set for the period of 2000-2020. The analysis period being longer than the duration of Industry 4.0 was due to the nature of the trends (it is assumed that the trend lasts for several decades). The analysis was performed in the following fields: titles, keywords and abstracts. Identical criteria were used in searching the research areas in each trend segment. The number of publications is summarised in Table 2.

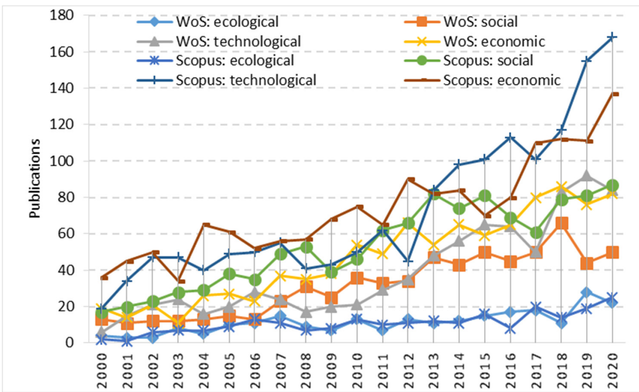
**Table 2.** Number of publications by trend segment

| Database | Trends | | | |
|---|---|---|---|---|
| | Ecological | Social | Technological | Economic |
| WoS | 239 | 667 | 818 | 987 |
| Scopus | 230 | 1119 | 1519 | 1540 |

Source: own analysis based on the WoS and Scopus databases.

The three trend areas, namely social, technological and economic, show that the number of publications in the Scopus database clearly outweigh the number of publications in the WoS database. In the period from 2000 to 2020, the number of publications has grown more rapidly in recent years, especially concerning technological, economic and social trends. After 2011, the number of publications in the technology trends segment increased sharply in the Scopus database. The results of the analysis are summarised in Figure 2.

**Figure 2.** Number of publications in trend segments




**Source:** own analysis based on the WoS and Scopus databases

Based on the review of publications, a list of the five research areas with the most publications was compiled by trend as shown in Table 3.

**Table 3.** Trend segment research areas

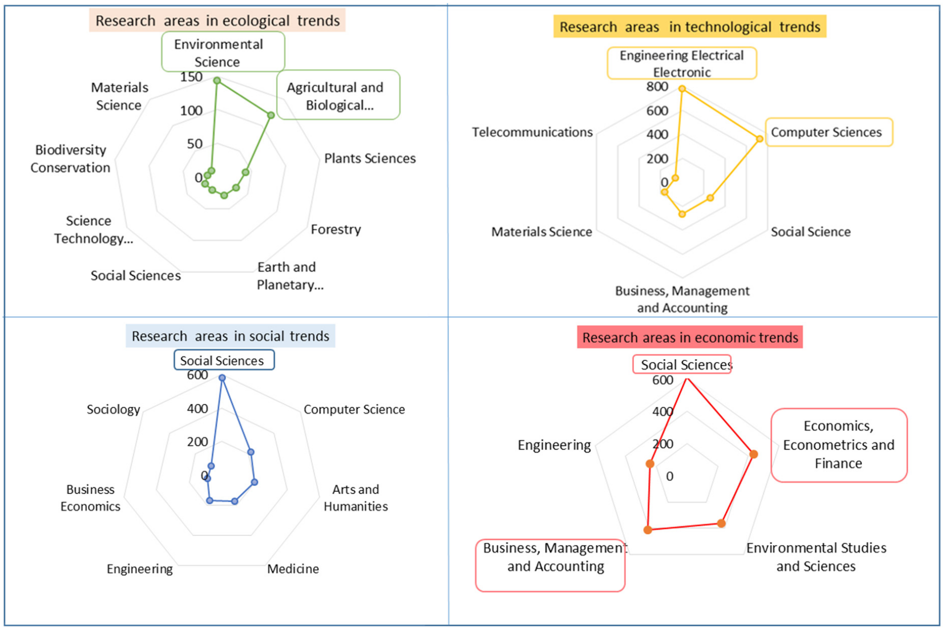
| Database | Trends | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Ecological** | | **Social** | | **Technological** | | **Economic** | |
| WoS | Environmental Sciences Ecology | 65 | Business Economics | 86 | Engineering Electrical Electronic | 138 | Economics, Econometrics and Finance | 182 |
| | Plants Sciences | 42 | Sociology | 84 | Computer Science information systems | 89 | Environmental Studies | 75 |
| | Forestry | 31 | Social Sciences | 65 | Computer Science Theory Methods | 83 | Environmental Sciences | 68 |
| | Science Technology Other Topics | 20 | Computer Science | 63 | Telecommunications | 67 | Business | 57 |
| | Biodiversity Conservation | 14 | Engineering | 56 | Management | 56 | Management | 57 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scopus | Agricultural and Biological Science | 120 | Social sciences | 517 | Engineering | 643 | Social Sciences | 614 |
| | Environmental Science | 78 | Arts and Humanities | 199 | Computer Science | 551 | Business, Management and Accounting | 300 |
| | Earth and Planetary Science | 29 | Medicine | 175 | Social Science | 263 | Economics, Econometrics and Finance | 254 |
| | Social Sciences | 20 | Computer Science | 159 | Business, Management and Accounting | 207 | Engineering | 239 |
| | Materials Science | 13 | Engineering | 114 | Materials Science | 163 | Environmental Science | 217 |

**Source:** own analysis based on the WoS and Scopus databases

Repeated study areas (comparing the two databases) were summed and resulted in a common study area matrix for the four trends as shown in Figure 3.

**Figure 3.** Research areas in particular segments of trends




**Source:** own analysis based on the WoS and Scopus databases

## 3.2. Force-Field Analysis

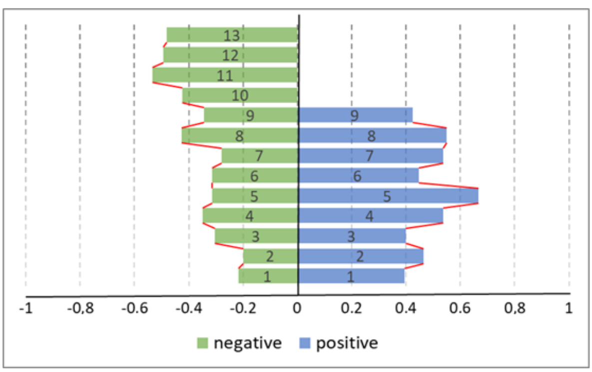
It should be noted that there are operational gaps in the process of implementation of new technologies of Industry 4.0, for example, in the issue of personal data protection, the degree of information disclosure, the extent of human control over robots, cooperation of cyber-physical systems, information technology security, and the personalisation of products (Saniuk et al., 2020). Table 4 summarises the lists of negative and positive factors. The list was created on the basis of direct surveys. There are 13 negative factors and nine positive factors. The strength of influence of each factor was determined by the number of respondents' indications. Individual factors may be trends for Industry 4.0 if the strength of their impact is maintained over a long period of time. Figure 4 shows, in the form of force-field analysis, the range of gaps emerging in Industry 4.0.

**Table 4.** The list of negative and positive forces

| Negative Forces | Positive Forces |
|---|---|
| 1. The danger of theft of "intellectual capital" in the case of own designs of personalised products.<br>2. Dependence on the purchase of personalised products.<br>3. Difficulties with the service of personalised products (e.g. lack of availability of spare parts).<br>4. Problems with returning personalised products to the point of sale (return logistics).<br>5. The decrease in the number of stationary sales points and an increase in electronic sales (e-commerce).<br>6. Ecological problems, e.g. the need to withdraw products from the market more often.<br>7. An increase in the level of stress caused by the desire to have new, personalised products.<br>8. Changes in the social structure, especially due to the exclusion of people with low professional qualifications.<br>9. Excessive increase in the level of consumption for personalised products and thus the risk of increased demand for energy and environmental pollution.<br>10. Interest in foreign products produced by companies that will implement the Industry 4.0 concept faster and will offer highly personalised products;<br>11. A decline in competitiveness, especially of small and medium-sized manufacturing enterprises, which cannot afford to invest in new technologies;<br>12. Change in the employment structure including higher requirements (required qualifications) in relation to employees employed in industry;<br>13. Technological unemployment, which will affect the decline in consumer demand. | 1. Industry 4.0 can solve the problem of the lack of employees with basic qualifications.<br>2. Reducing the number of elements of the supply chain.<br>3. Production of highly personalised products at a low purchase price.<br>4. Higher level of on-time delivery of orders (orders).<br>5. Higher level of adjustment of the production offer to the current client's needs.<br>6. Increasing the availability of a wide range of products.<br>7. Increase in the quality of life through the opportunity to purchase personalised products.<br>8. The possibility of active involvement in the design of new products.<br>9. The possibility of developing new business models based on the products of one's own design produced by enterprises of Industry 4.0. |

**Source:** Saniuk, S.; Grabowska, S.; Gajdzik, B. Social expectations and market changes in the context of developing the Industry 4.0 concept. Sustainability 2020, 12, 1362

**Figure 4.** Power Force Analysis for Industry 4.0




**Source:** Own elaboration

Respondents were able to select from a list of five responses that they felt most accurately described their subjective concerns. The biggest negative factor for the megatrend – Industry 4.0 – is the risk of high investment costs in new technologies (53.3%) and employees' fear for their current jobs (49.3%). The risk of technological unemployment and falling consumer demand is also a strong factor (48.1%). In the segment of weaker negative impacts are changes in the social structure, especially due to the exclusion of people with low professional skills (42.5%) and consumption – the increased interest in highly personalised foreign products (42.3%). Niche factors are the trend of customers' dependence on personalised products (19.8%). In terms of positive factors, respondents also selected five answers, the strongest being the trend of increasing the level of adjustment of the production offer to the current needs of the customer (66.6%). The direction of shortening supply chains (55%) and increasing the availability of diversified and personalised products (53.8%) are also firmly positive. The ability to actively participate in the design of new products is also a positive trend for customers (46.4%).

## 3.3. Expert evaluation

Nine pillars of Industry 4.0 (Table 5) and nine technology trends were evaluated by experts. The following technologies/pillars of Industry 4.0 were included in the matrix:

1. Big data and analytics (I.4.0/1);
2. Autonomous robots (I 4.0/2);
3. Simulation (I 4.0/3);
4. Horizontal and vertical integration (I 4.0/4);
5. Industrial Internet of Things (I 4.0/5);
6. Cloud computing and manufacturing;
7. Additive manufacturing;
8. Virtual and augmented reality;
9. Cybersecurity.

List of key megatrends/trends (T):

1. Globalisation (T1);
2. Digitalisation of the economy and development of ICT (T2);
3. Informatisation of society/computerisation (T3);
4. Sustainability (T5);
5. Knowledge economy (T5);
6. Mobility of society (T6);
7. Smart business/virtualisation of organisations (T7);
8. Personalisation/customer orientation (T8);
9. Process approach/process optimisation/productivity (T9).

The strength of influence of trends on the development of pillars was determined by an expert method using a five-point Likert scale. The answer variants used were as follows: definitely no impact strength, no impact strength, no opinion, visible impact strength, definitely visible impact strength. A total of 10 experts participated in the survey; the answers obtained were aggregated on a point scale, and the results obtained – in the form of averaged numbers – were presented by colour intensity from red to green. An example of the interaction of trends on the pillars of Industry 4.0:

Where: red – no interaction, green – strong interaction

Based on the experts' answers to the question about the strength of the impact of trends on the development of technologies (pillars) of Industry 4.0, Table 5 was developed. Based on the analysis performed, the information obtained is that four trends can be considered key (due to their impact on building the Industry 4.0 framework). They are as follows: T2: Digitalisation of the economy and development of ICT technologies (predominance of green intensity adopted for the strong impact of the trend on the pillars of Industry 4.0); T5. Knowledge economy (also a strong green intensity); T7: Virtualisation of organisations and smart business, as well as T8: Customer orientation and personalisation of products.

**Table 5.** Matrix evaluation of the impact of megatrends and socio-economic trends on the development of Industry 4.0 technologies

| Trends/Pillars Industry 4.0 | I 4.0/1 | I 4.0/2 | I 4.0/3 | I 4.0/4 | I 4.0/5 | I 4.0/6 | I 4.0/7 | I 4.0/8 | I 4.0/9 |
|---|---|---|---|---|---|---|---|---|---|
| T.1 | | | | | | | | | |
| T.2 | | | | | | | | | |
| T.3 | | | | | | | | | |
| T.4 | | | | | | | | | |
| T.5 | | | | | | | | | |
| T.6 | | | | | | | | | |
| T.7 | | | | | | | | | |
| T.8 | | | | | | | | | |
| T.9 | | | | | | | | | |

**Source:** Own elaboration

## 4. Discussion

Industry 4.0 refers to the fourth industrial revolution, in which it is assumed to be a vision of smart factories built with intelligent cyber-physical systems. Under the proposed concept of Industry 4.0, there is a close connection between physical objects and information networks. Sophisticated networks of enterprises, connected by intelligent resources, communicating via the Internet, are emerging. The effectiveness and efficiency of the new functioning requires that enterprises create new innovative solutions and formulate new strategies. Based on the literature analysis, the dominance of technological trends over the others in the research areas of the researchers was asserted. The key research area in the technology trends segment is the engineering, electronics, electrical and computer sub-segments. Such research areas confirm the popularity of Industry 4.0. However, there is still little attention paid to managerial aspects. Companies need to set new strategies for operating with digital solutions and advanced robots for product manufacturing, as Fasth-Berglund and Stahre (2013) also point out.

It is important to note that there are operational gaps in the implementation of the new technologies of Industry 4.0, e.g. in the protection of personal data, the degree of information disclosure, the extent of human control over robots, the cooperation of cyber-physical systems, IT security or product personalisation.

The globalisation of brands, the growing availability of products, and the ability to make purchases on the other side of the world without leaving home are just some of the opportunities provided by the modern consumer market. Its increasingly dynamic development also means that gaining competitive advantage goes beyond the classic norms of competing on price, availability and quality. However, the competitiveness of companies that have based their strategy solely on production is currently decreasing, which to some extent is the result of market pressure from consumers who wish to participate in the product design process. As confirmed by the research, modern customers are already accustomed to a large selection and privileged position in which they find themselves; they expect more than just the best quality product at the lowest price. Customers expect to be able to personalise products, and this phenomenon is already quite evident in many industries, especially in the clothing and footwear, consumer electronics and automotive sectors.

## Conclusions

The research results and considerations presented in the article confirm that Industry 4.0 is a megatrend that requires radical changes at the strategic and operational levels of business operations. It has been shown that the most important trends are: the digitalisation of economy and development of ICT, the knowledge economy, virtuality of organisations and smart business, as well as customer orientation and the personalisation of products. In the current research, it is possible to identify the dominance of technological trends over the others in the research areas of scientists. The key areas of research in the technology trend segment are engineering, electronics, electrical and computers. A still under-recognised area relates to social changes resulting from the implementation of Industry 4.0.

Industry 4.0 is a megatrend not only for business environments, where the technologies of the fourth industrial revolution set new trends, but also for society. Technological changes influence societies, economy and ecology. A new quality of life is being created in societies, social structures and households are changing, and consumption models are changing with them. For economies, industry is the production of added value characterised by economic growth measured by GDP per capita. Society expects Industry 4.0 to reduce the negative impact on the environment and to use the environment rationally. These four trend streams are interrelated, with technological trends building Industry 4.0 at their centre.

The research presented in this paper has the following limitations: the literature analysis was conducted using only two databases – WoS and Scopus, and the force-field analysis presented does not take into account the relationship or force between these fields.

The discussion presented in the article opens further opportunities for research in the field of adjustment of enterprise development strategies to implementation of Industry 4.0 technologies, the development of the Society 5.0 model and the principles of operation of Economy 4.0.

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