Article

A Theoretical Framework for Industry 4.0 and Its Implementation with Selected Practical Schedules

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Abstract: In recent years, there has been dynamic changes in the industrial environment as a result of further innovations called Industry 4.0 (I.4.0), especially in the field of digital technology and manufacturing. Despite numerous examples of the implementation of Industry 4.0 in enterprises, there is no general framework for the implementation of Industry 4.0 with a detailed schedule. Researching the ways of implementing Industry 4.0 is still a current and unexplored area of research. The main aim of the paper is to present the concept of the theoretical framework for Industry 4.0 implementation based on selected schedules of the Industry 4.0 implementation. The paper was based on information from literature review and analysis of pilot enterprise projects to Industry 4.0 (case study) that were conducted in selected enterprises. The paper presents the key components of the framework of Industry 4.0 and the basic stage of implementing the concept in the enterprises, paying attention to their sequence and time frames. The proposed approach is dedicated to researchers and practitioners who implement the concept of Industry 4.0 in enterprises.

Keywords: Industry 4.0; framework for Industry 4.0; schedule of implementation I 4.0

1. Introduction

In the last few years, the global industrial environment has changed deeply due to successive technological developments and innovations in manufacturing processes. The new concept is called Industry 4.0 (abbreviation: I 4.0) [1]. Industry 4.0 is a strong combination of operational technology (OT) and information technology (IT) in production. The Industry 4.0 concept is the result of the technological progress of the Fourth Industrial Revolution [2]. The term "Industry 4.0" was introduced in 2011 by Henning Kagermann, professor of physics and former president of the SAP board, and evolved into a strategy for the development of German industry [3]. Industry 4.0 uses the technical achievements of the Third Industrial Revolution, in the area of the degree of automation and digitization of production already achieved [4].

Industry 4.0 is a technological system with many innovations called Technology 4.0: robotics and automation, 3D printing, collaborative robots (cobots), cloud computing and Internet of Things to be implemented on a large scale in smart factories in the future [5]. Industry 4.0 is based on cyber physical systems with the Internet of Things—IoT and Internet of Services—IoS [6], and Big and Mining Data [7]. The intensive development of CPPS is heading towards the development of artificial intelligence, i.e., self-improving devices and objects, on an increasing scale [8]. Technology 4.0 builds intelligent production processes that are able to independently exchange information, trigger actions and control each other [9]. Industry 4.0 is the path to greater competitive advantage for businesses [10], also SMEs [11].

The Industry 4.0 concept is gradually implemented in enterprises through investment projects implemented in segments in selected areas of activity [12]. The ways of implementing Industry 4.0 in enterprises have not yet been described in detail in a comprehensive and compact manner in the literature [13]. There are no publications describing ready-made scenarios and instructions) regarding the implementation of individual investment projects related to the Industry 4.0 concept [14]. The selectivity of implementing technological solutions typical for Industry 4.0 occurs both in manufacturing companies and in individual industries [15–17]. There are industries where technological progress is realized faster and easier, as well as industries that are more difficult to implement new solutions (studies PwC, Deloitte, London, UK) [18,19]. The first group includes light industry, e.g., food, clothing, production of household appliances, and the second group includes heavy industry, e.g., metallurgy, mining, or process industry, e.g., fuel and energy industry [20]. The effects of the changes introduced in enterprises are also different, e.g., in production where the end product is e.g., electricity, chemicals or fuels, greater control over processes and increased energy efficiency are achieved [21]. In the case of discrete and hybrid production, such as e.g., the production of vehicles in automotive companies or production in the food & beverage sector, the changes allow for a better adaptation of products to individual customer needs (personalization) and shortening the delivery time, thanks to the flexible adjustment of the production scale in factories located in various countries [22].

Therefore, the research aims at presenting the general path of enterprises to Industry 4.0 and building the stages of work carried out by the surveyed enterprises to achieve the level of Industry 4.0. The paper was based on the analysis of investment projects of selected enterprises, considered as benchmarks in a given industry. The content of the work consists of variants of the stages of reaching the next levels I 4.0 by enterprises. The mentioned variants of business development are the authors' scientific contribution to building knowledge about the way of enterprises, aimed at transforming their enterprises into Smart Factory. The practical element of the work is to present the planned period of implementation of individual stages of work in enterprises (case study) [23]. The presented companies do not constitute a representative sample of all companies in a given industry. Their choice was determined by the availability of information about the duration of projects in the area of Industry 4.0. The activities presented in the manuscript of implementation of Industry 4.0 together with the schedule of projects carried out in companies help to understand the concept of Industry 4.0 from a practical perspective.

Requirements for manufacturers are currently undergoing significant changes. It is desirable to have a shorter reaction time with an increasing number of variants and decreasing batch size, up to individualization of products. These requirements are difficult to meet in companies without innovative technology. Technology 4.0 creates new, intelligent factories that produce customized products [24,25]. The key technical innovations, treated as technology 4.0, create, e.g., [26–32]:

- a new system of communication in which both the digital world and the real world are connected with each other, thanks to which machines, products in different processing phases, systems and people—having an individual IP address—exchange digital information via the Internet protocol; direct communication between devices; advanced human-machine interfaces;
- intelligent sensors with built-in systems of individual identification, data processing and communication; incremental manufacturing technologies, e.g., 3-D printing—both for prototyping and for the implementation of individual orders are carried out in stages in stages, and breakthrough changes are and will be triggered by the scale of their application, synergy, integration and development dynamics;
- data processing in the cloud or fog, with response dynamics at the level of milliseconds; analytics of large data sets on all aspects of product development and production; simulation techniques for the operation of real objects in their virtual representations, based on data provided and processed in real time, allowing to test and optimize the configuration of production processes before introducing physical changes;

- a new generation of robots, characterized by active interaction with the environment and with other robots and adaptation to changing conditions and requirements; augmented reality systems, supporting the design and servicing of devices;
- cybersecurity solutions ensuring secure, reliable communication and identification as well as management access to systems and devices.

Enterprises of particular industry sectors are currently at various levels of advancement of their work in the reorganization of production to a level of I 4.0. The development of enterprises towards Industry 4.0 requires rethinking the methods, processes, IT solutions and organizational forms used. Research on the ways of leading enterprises to implement Industry 4.0 is carried out in industry sectors, in-market segments, in clusters (e.g., OWL), in capital groups, and other formal structures [33]. The research is most often carried out by consulting companies commissioned by public institutions or organizations. In addition, individual commercial (trade) companies in the IT area promote their solutions for intelligent technical systems in the industry. Commercial applications are various from production automation, through productive maintenance, to self-optimization of processes carried out by "intelligent" robots. Digital models are designed for selected processes or production, taking into account the specifics of the industry, up to full digital planning of entire factories [34].

The new paradigm of Industry is already available for production companies, but its complete implementation is still under development. However, the question arises: what is the path (way) or maybe instruction of companies to implement Industry 4.0? Unfortunately, this question cannot be answered in a clear and simple manner. Because it is impossible to develop a universal and useful for every enterprise step-by-step instruction, due to the variety of investment projects being carried out and a wide range of differences in the functioning of enterprises in particular branches of industry. However, it is possible to present the general components of Industry 4.0 [35].

The review of scientific literature was a source of secondary data on the framework of Industry 4.0. However, the analysis of planned and implemented activities of enterprises in reaching Industry 4.0 led the authors to develop the selected practical schedules.

2. Materials and Methods

The Materials and Methods should be described with sufficient details to allow others to replicate and build on the published results. Please note that the publication of your manuscript implicates that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

In order to obtain knowledge about the ways of implementing Industry 4.0 in enterprises, a review of scientific papers was carried out using the main databases of Web of Science—WoS and Scopus and other publications by using the web browser: google.com.

The research was carried out in two stages:

Scientific papers in key scientific databases: WoS and Scopus
Overview of public publications: reports, case studies, commercial offers, reviews, news etc. by using google.com.

The research question was formulated: How do enterprises implement investment projects towards Industry 4.0—step by step, i.e., the way of enterprises to Industry 4.0 and how long each projects take—search for schedules?

The final results of the research were:

(1)   The general framework for the implementation of Industry 4.0.
(2)   The basic path (way) of enterprises to Industry 4.0.
(3)   The schedule of activities of enterprises leading to Industry 4.0.

The used method by the authors from planning and results was presented in that publication in Figure 1. The authors used a bibliometric analysis and selection analysis, i.e., searching for information available to the public using a web browser. The performed analyses provided information used to develop a general framework for implementation of Industry 4.0, enterprises' way to Industry 4.0 (step-by-step) and schedules of enterprises' projects. The presented information is the scientific contribution of the authors in building knowledge about Industry 4.0.
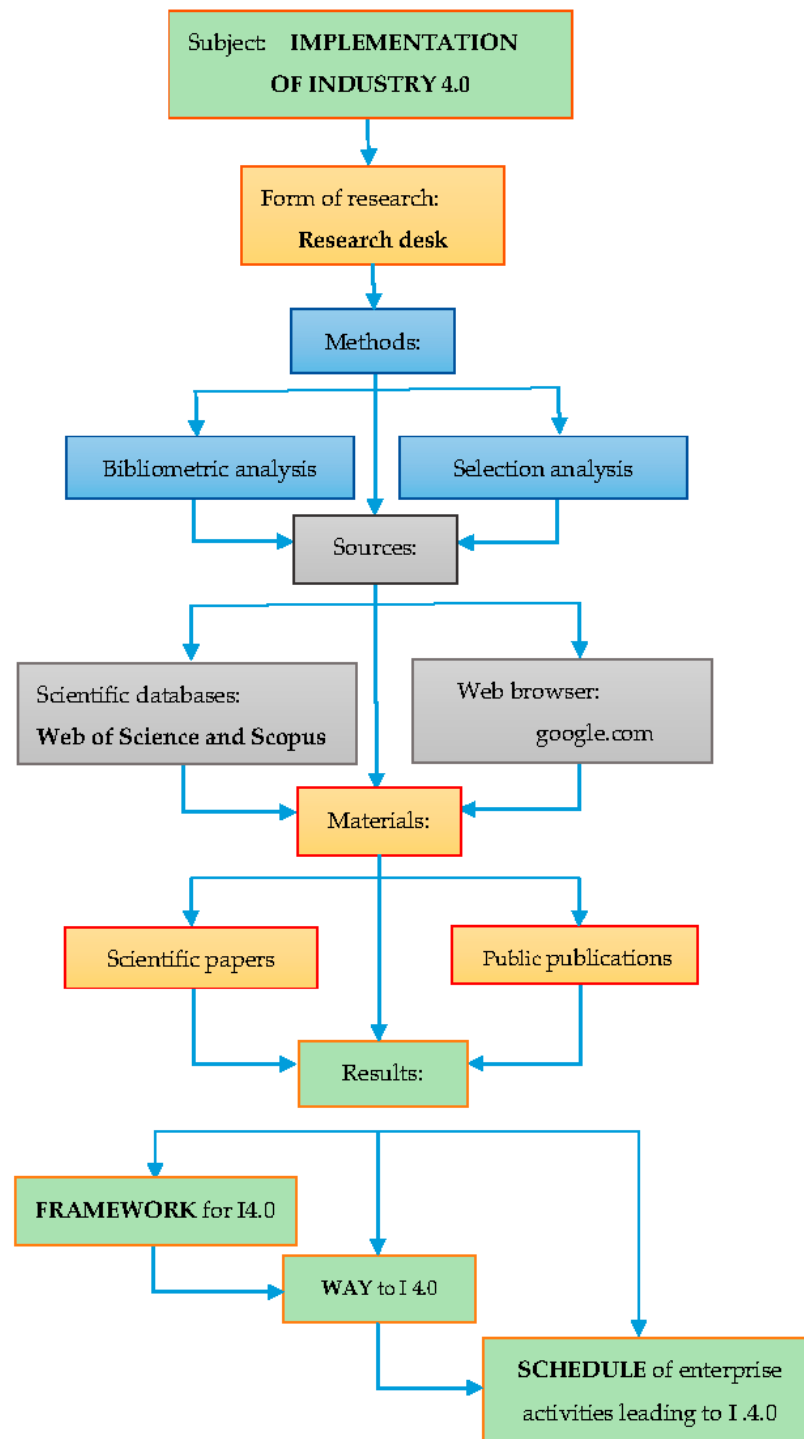
Figure 1. Diagram of the research being carried out. Source: Own study.

3. Results

3.1. Lietrature Review

The first step of literature review was used the bibliometric analysis [36]. The following keywords were selected in the bibliometric analysis: "way to Industry 4.0", "implementation of Industry 4.0", "application of Industry 4.0", "roadmap (for) to Industry 4.0" and "framework for Industry 4.0". The selection of keywords was consistent with the adopted research objective, which was to search for an answer to the question: How to implement Industry 4.0, step by step?

The period of analysis was 2011–2020. From 2011 on, the popularisation of industry 4.0 begins and continues for years to come. On the basis of the review of scientific publications (databases: WoS, Scopus) by using mentioned keywords, few publications (single-topic) were obtained. When analyzing the results of the review of scientific databases according to the adopted keywords, it was found that most publications were in the databases for the keyword: "implementation of Industry 4.0", and the least for "way to Industry 4.0", which may mean that general information on the implementation of solutions in the scientific databases, there are more technological, organizational and managerial ones leading to Industry 4.0 in the form of "instructions" leading to the goal, in this case, Industry 4.0. Results of these analyses are presented in Tables 1–9.

Table 1. Results of own literature review in the field: number of publication.

Keywords/Number of Publications	WoS	Scopus
"implementation of Industry 4.0"	112	177
"application of Industry 4.0"	29	68
"framework for Industry 4.0"	24	28
"way to Industry 4.0"	8	13
"roadmap for Industry 4.0"	1	1

Table 2. Results of own literature review in the field: access type.

Keywords/Access Type	WoS		Scopus	
	Open Access	Other	Open Access	Other
"implementation of Industry 4.0"	50	62	57	120
"application of Industry 4.0"	9	20	16	52
"framework for Industry 4.0"	15	9	10	18
„way to Industry 4.0"	3	5	3	10
"roadmap for Industry 4.0"	0	1	0	1

Table 3. Results of own literature review in the field year.

Keywords/Year	WoS	Scopus
"implementation of Industry 4.0"	2016 (8); 2017 (14); 2018 (17); 2019 (38); 2020 (31)	2014 (2); 2015 (4); 2016 (9); 2017 (18); 2018 (25); 2019 (61); 2020 (53); 2021 (5)
"application of Industry 4.0"	2016 (3); 2017 (8); 2018 (3); 2019 (8); 2020 (7)	2016 (2); 2017 (15); 2018 (5); 2019 (25); 2020 (21)
"framework for Industry 4.0"	2016 (2); 2017 (2); 2018 (6); 2019 (9); 2020 (5)	2016 (1); 2017 (4); 2018 (6); 2019 (11); 2020 (6)
"way to Industry 4.0"	2016 (1); 2017 (1); 2018 (3); 2019 (3)	2014 (1); 2015 (2); 2016 (4); 2017 (1); 2018 (3); 2019 (2)
"roadmap for Industry 4.0"	2020 (1)	2018 (1)

Table 4. Results of own literature review in the field: author of publication.

Keywords/Author	WoS	Scopus
"implementation of Industry 4.0" *	Sony, M. (4); Wan, J.F. (4); Li, D. (3); Tang, S. L. (3); Chromjakova F. (3)	Sony, M.(5); Lanza, G. (4); Karabegović, I.(3); Liebrecht, C.(3); Majstorovic, V.(3); Telukdarie, A.(3); Chromjakova, F.(2); Constantinescu, C.L.(2); Contreras, J.D.(2); Delsing, J(2)
"application of Industry 4.0" *	Basl, J. (2); Munsamy, M. (2); Telukdarie, A. (2); Aguayo-Gonzalez, F. (1); Alexandre, B. (1)	Basl, J. (2), Dallasega, P. (2), Lanza, G. (2), Liebrecht, C. (2); Munsamy, M. (2); Telukdarie, A. (2); Vidanagamachchi, K. (2); Adsbøll Wickstrøm, K. (1); Aguayo-Gonzalez, F. (1); Aguayo-Gonzalez, F. (1)
"framework for Industry 4.0" *	Bratan, S. (1); Chova L.G. (1); Gorbatyuk S. (1), Leonov S. (1), Martinez A.L. (1)	Agrawal, R. (1); Antony, J. (1), Ariansyah, D. (1), Azimov, P (1), Babkin, A. (1) (Additional information: the list was prepared alphabetically in the databases, each author had only one documents, so there was not the Top 5 list)
"way to Industry 4.0" **	Ageyeva, T. (1); Dold, L. (1), Gepp, M. (1); Horvath, S (1); Kireeva, A.A. (1); Kovacs, J.G. (1); Maier, R. (1); Mussabalina D.S. (1); Tarassov V.B. (1); Tauchnitz T. (1); Tolysbaev, B.S. (1); Tsoi, A.A. (1); Unverdorben, S. (1), Urbas, L. (1)	Schulz, J. (2); Brozzi, R. (1); Dumitrescu, R. (1); D'Amico, R.D. (1); Gausemeier, J. (1); Isenberg, F. (1); Jasperneite, J. (1); Jurke, B.(1); Kletti, J.(1); Kühn, A.(1); Lantzke, K.(1); Marcher, C.(1); Matt, D.(1); Pasetti Monizza, G.(1); Pruschek, P.(1); Ratzek, U.(1); Rehage, G.(1); Reisch, R.(1); Riedl, M.(1); Schoppe, D.(1); Sheremetov, L.(1); Smirnov, A.(1); Strassmann, B.(1); Tarassov, V.B.(1); Teslya, N.(1); Trsek, H. (1); Weber, J. (1)
"roadmap for Industry 4.0" **	Jain, R. (1); Rathore A.P.S. (1); Wagire A. A. (1)	Ghobakhloo, M. (1)

* top 5 lis or 10 top list; ** finished list.

Table 5. Results of own literature review in the field: subject area or web of science category.

Keywords/Subject Area	WoS	Scopus
"implementation of Industry 4.0"	Engineering Industrial (31); Engineering Manufacturing (27); Operations Research Management Science (19); Management (15); Engineering Electrical Electronics (12)	Engineering (111); Computer Science (71); Business, Management and Accounting (51); Decision Sciences (37); Social Science (19)
"application of Industry 4.0"	Engineering Industrial (7); Engineering Manufacturing (7); Operations Research Management Science (5); Environmental Sciences (4); Automation Control Sciences (4)	Engineering (39); Business, Management and Accounting (24); Computer Science (24); Decision Sciences (16); Environmental Sciences (8)
"framework for Industry 4.0"	Computer Science Information Systems (4); Engineering Manufacturing (4); Engineering Industrial (3); Computer Science Artificial Intelligence (3); Operations Research Management Science (3)	Engineering (13); Computer Science (10); Business, Management and Accounting (6); Materials Science (6); Decision Sciences (5)
"way to Industry 4.0"	Automation Control Systems (4); Engineering (2); Area Studies (1); Business Economics (1), Chemistry (1)	Engineering (10); Decision Sciences (5); Business, Management and Accounting (4); Computer Science (3); Materials Science (3): Chemical Engineering (2)
"roadmap for Industry 4.0"	Engineering Industrial (1); Engineering Manufacturing (1), Management (1)	Business, management and accounting (1), Computer Science (1); Engineering (1)

Table 6. Results of own literature review in the field: document type.

Keywords/Document Type (Top 5)	WoS	Scopus
"implementation of Industry 4.0"	Article (54); Proceedings papers (47); Early Access (12), Review (11); Book Chapter (1)	Article (82); Conference Paper (76); Review (8); Book Chapter (4), Conference Review (3)
"application of Industry 4.0"	Article (15); Proceedings papers (14); Early Access (2), Book Chapter (1)	Article (34); Conference Paper (30); Book Chapter (3), Book (1)
"framework for Industry 4.0"	Article (14); Proceedings papers (9); Early Access (1), Review (1)	Article (17); Conference papers (6); Book Chapter (2); Review (2), Conference Review (1)
"way to Industry 4.0"	Editorial Material (3); Article (2); Proceedings Paper (2); Review (1)	Article (10); Conference Paper (3)
"roadmap for Industry 4.0"	Article (1)	Article (1)

Table 7. Results of own literature review in the field source title.

Keywords/Source Title	WoS	Scopus
"implementation of Industry 4.0"	Procedia CIRP (8); Production Planning Control (5); Sustainability (5), International Conference of Industrial Engineering and Engineering Management IEEM (3), International Journal of Production Research (3)	Advances In Intelligent Systems And Computing (8); Procedia CIRP (8); ZWF Zeitschrift Fuer Wirtschaftlichen Fabrikbetrieb (7); IFIP Advances In Information And Communication Technology (6); Procedia Manufacturing (6); Production Planning And Control (5); Science And Engineering (4); Sustainability Switzerland (4); IEEE International Conference On Industrial Engineering And Engineering Management (3); IEEE International Conference On Industrial Engineering And Engineering Management (3); International Journal Of Production Research (3)
"application of Industry 4.0"	27th International Conference on Flexible Automation and Intelligent Manufacturing Faim2017 (2); International Conference of Industrial Engineering and Engineering Management IEEM (2); Production Planning Control (2); Procedia Manufacturing (2); International Journal of Environmental Research and Public Health (2)	ZWF Zeitschrift Fuer Wirtschaftlichen Fabrikbetrieb (3); Advances In Intelligent Systems And Computing (2); IEEE Engineering Management Review (2); IEEE International Conference On Industrial Engineering And Engineering Management (2); International Journal Of Environmental Research And Public Health (2); Lecture Notes In Mechanical Engineering (2); Procedia Manufacturing (2); Proceedings Of The International Conference On Industrial Engineering And Operations Management (2); Proceedings Of The Summer School Francesco Turco (2)
"framework for Industry 4.0"	IFAC Papersonline (3), 13th International Symposium in Management (1), 2017 IEEE International Conference on Systems Man and Cybernetics SMC (1); 51 st CIRP Conference on Manufacturing Systems (1), Cluster Computing The Journal of Networks Software Tools and Applications (1)	Chernye Metally (4); IFAC Papersonline (2); Idimt 2019 Innovation And Transformation In A Digital World 27th Interdisciplinary Information Management Talks (2); Academy Of Strategic Management Journal (2); 2017 IEEE International Conference On Systems Man And Cybernetics Smc 2017 (1)

Table 7. *Cont.*

Keywords/Source Title	WoS	Scopus
"way to Industry 4.0"	ATP Edition (3); 2018 IEEE 14th International Conference On Automation Science And Engineering Case (1); Advances In Intelligent Systems And Computing (1); Economic And Social Changes Facts Trends Forecast (1); Ekonomika Regiona Economy Of Region (1); IEEE InternationaL Conference On Automation Science And Engineering (1); Proceedings Of The Third International Scientific Conference Inlligent Information Technologies For Industry IITI 18 Vol 1 (1); Sensors (1)	ZWF Zeitschrift Fuer Wirtschaftlichen Fabrikbetrieb (3); IFIP Advances In Information And Communication Technology (2); Advances In Intelligent Systems And Computing (1); Chernye Metally (1), Mechatronik (1); Productivity Management (1); Professional Papermaking(1); Thyssenkrupp Techforum (1); Wochenblatt Fuer Papierfabrikation (1); Wt Werkstattstechnik (1)
"roadmap for Industry 4.0"	Journal Of Manufacturing Technology Management (1)	Journal Of Manufacturing Technology Management (1)

Table 8. Results of own literature review in the field: country.

Keywords/Country	WoS	Scopus
"implementation of Industry 4.0"	India (12); Czech Republic (11), Poland (9); Italy (8)	Germany (26), Italy (14), India (11), Unit. States (10, Czech Republic (9), Poland (9), Russia (9), UK (9), Brazil (7); Austria (7)
"application of Industry 4.0"	Germany (5); Italy (4), Czech Republic (3), Indonesia (92), China (2)	Italy (12), Germany (10); UK (6); India (4), Poland (4), Spain (4), China (3), Czech Republic (3), Indonesia (3); Brazil (2)
"framework for Industry 4.0"	Russia (6); Germany (4), Italy (4), China (3), Spain (3)	Germany (9); Russian (6), China (3), Italy (3), France (2)
"way to Industry 4.0"	Germany (3); Kazakhstan (2); Hungary (1); The Netherlands (1); Russia (1)	Germany (8); Russian Federation (2), Italy (1); Mexico (1); Switzerland (1)
"roadmap for Industry 4.0"	India (1)	Iran (1)

Table 9. Results of own literature review in the field: language of publication.

Keywords/Country	WoS	Scopus
"implementation of Industry 4.0"	English (109), German (1), Slovak (1), Spanish (1)	English (167), German (1)
"application of Industry 4.0"	English (27), German (1), Spanish (1)	English (64), German (3), Spanish (1)
"framework for Industry 4.0"	English (22), Russian (1), Spanish (1)	English (21), Russian (5), German (1)
"way to Industry 4.0"	English (5), German (3)	German (7); English (6), Russian (1)
"roadmap for Industry 4.0"	English (1)	English (1)

Source: own study.

The problem was access to publications because in the form of open access, assuming that we are looking for publications that show companies the way to Industry 4.0 in the form of simple instruction, only 3 publications were available. The available publications concerned the paths towards Industry 4.0 in two fields: the first field: in-mould sensors for injection moulding [37] and the second field: creating the clusters in regions [38,39].

Individual documents (results of database searches in the adopted topic) were published in the years 2014–2021. No time limits were introduced during the database searches. Databases were searched in the period from 6 September to 14 October 2020 (the indication

for the year 2021 in Table 3) resulted from the dating of the journal). Analyzing the results of the searches according to the author of the publication, it can be observed (Table 4) that the author of Sony, M. [40] with co-author and their documents: Critical factors for the successful implementation of Industry 4.0: a review and future research direction appears most often; on the basis of bibliometric analysis it was also found that other authors have from 1 to 4 results. The basic categories in the field: "subject area" (Table 5) were: manufacturing, engineering, management, computer science. Analyzed documents in the databases had such forms as: editorial materials, articles, reviews and proceedings papers and conference papers (Table 6) and were published in scientific journals and materials (Table 7). In the country of publication category, Germany was the most frequently indicated country (Table 8), and English and German were the main languages of publication (Table 9).

To ensure that key scientific publications were reviewed, additional keywords were also introduced: "applying Industry 4.0", "doing Industry 4.0", "path to Industry 4.0" and "towards Industry 4.0". The results of database searches did not increase the number of publications obtained, and individual publications in the lists were repeated (they were the results of searches of documents using the entries listed in Table 1).

The second step of literature review was created a semantic map as a visualisation of the basic components of Industry 4.0. The semantic map was generated from various text sources, based on individual words extracted from scientific papers, descriptive terms or descriptors assigned by the publisher provided by the database provider [41–43]. "Industry 4.0" was used to build the map as the most widely described subject of analysis. The visualisation is to provide a more information about the framework for implementation of Industry 4.0. The key area of analysis was the framework of change leading enterprises to Industry 4.0, which were indicated in publications. In the analyzed period (from 2011 to 2020), 2 conceptual clusters (Figure 2) were identified from WoS. On the semantic map, the coexistence of keywords is clearly visible. The basic clusters built around the word industrial revolution and its performance. On the basis of created semantic maps, one can observe the nonlinear development of concepts and abrupt changes in thinking and conducting scientific research. Figure 2 shows the intensity of the results of the analysis in the studied subject.

Figure 2. The semantic map for analysis of Industry 4.0. Source: own study.

After the literature review with the use of scientific databases: Scopus, WoS, a search was started for publicly available studies on the ways of implementing Industry 4.0 projects in enterprises. The information was provided, among others, by reports from consulting

companies and other publications. PwC's report [19] lists six stages for digital success: (1) Map out your Industry 4.0 strategy, (2) Create initial pilot projects, (3) Define the capabilities you need, (4) Become a virtuoso in data analytics, (5) Transform into a digital enterprise, (6) Actively plan an ecosystem approach. The process of implementing Industry 4.0 in enterprises starts at the strategic level and ends at the operational level. Enterprises start with pilot change projects for selected areas of their business, and over time the projects are more and more and the final result of the changes will be smart factory. Changes within the enterprise are shifting to changes in the network of cooperating companies. Results of the changes are two ways of development: (1) a system with plants with large specialized technology and advanced process control using thousands of sensors providing online data processed by highly sophisticated decision-making tools. Such plants can be located in large industrial basins outside of cities and strongly interconnected with their industrial neighbors. Plants in those industrial parks or basins require a large infrastructure and perfect logistics to deliver final goods to remote places with both personalization of products and mass products (2) a system with mini and micro stand-alone plants embedded into the dense urban tissue, flexible and able to provide products for consumers nearby (Philippe Queille, Group R&D VP, Asia at Air Liquide in McKinsey report, 2015, [44] p. 30). On the basis of the abovementioned information, a general path to Industry 4.0 was proposed (Figure 3).
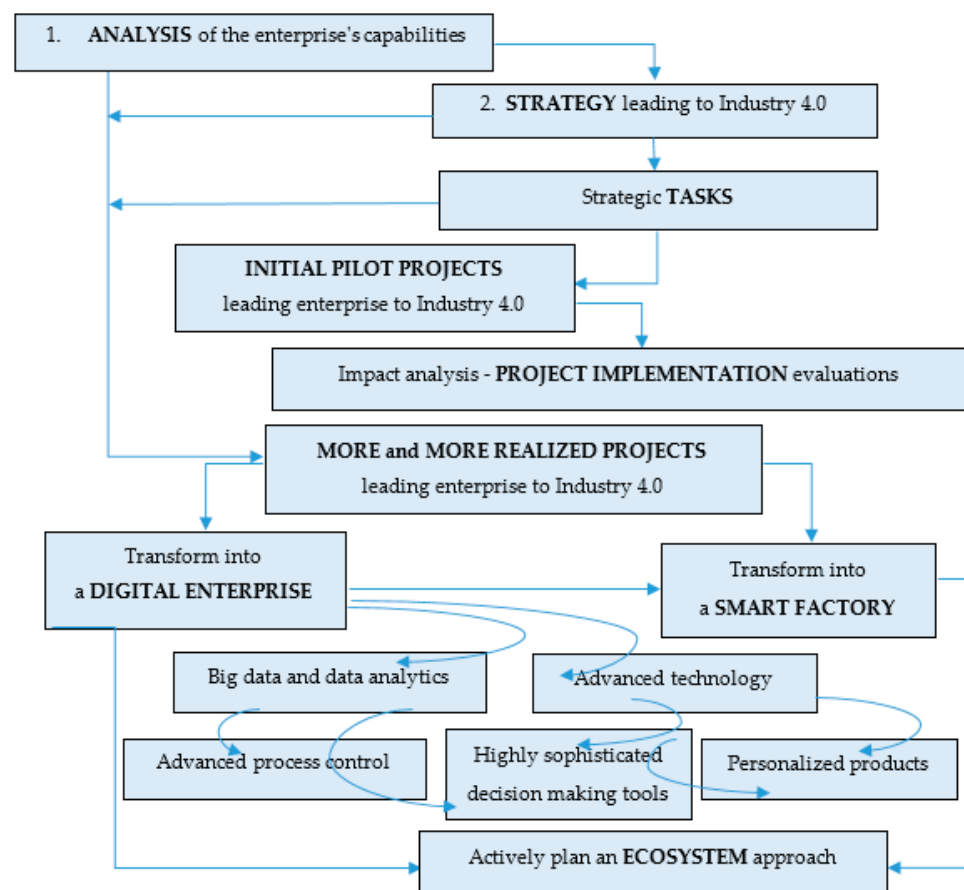
Figure 3. The way to Industry 4.0—key steps. Source: own study.

3.2. Analysis of Cases of the Industry 4.0 Implementation

Looking for instructions for implementing activities leading enterprises to Industry 4.0, going beyond the scientific bases, the authors found examples of investment plans and pilot projects of enterprises. Three examples are presented in this section of the publication. The case studies were investment projects carried out in three companies. The publication intentionally did not mention the names of the companies to avoid promoting

their corporate images. The purpose of the analysis of investment projects was to develop a collective time schedule for the implementation of individual projects.

The first company has created a platform with which production data are processed and visualized of its products. The company uses IoT and Cloud Computing technologies. The platform operates in real time. Data collected by the company concern both entire plants and production lines as well as individual machines and individual products and give an insight into all performance indicators, allowing for analysis and optimization of production. Work on Industry 4.0 began with entering the goal into the development strategy in 2013. In 2016, the first cyber physical production line was created. The preparatory work (design) began in 2011. The length of the cycle is 3 years from 2013, when it was included in the Industry 4.0 strategy, until 2016, when the cyber physical production line was launched or 5 years, counting until 2011—the beginning of design works. The projects implemented in the company covered both production and all logistics of company products. The logistics area includes factory logistics and external logistics. The system: internal logistics together with external logistics is to ensure efficient operation of the company necessary to achieve high efficiency. Investments realized in internal logistics include the use of RFID gates, automatically recording transported elements and intermediating in the exchange of information between production and warehouse, also using advanced solutions of Industry 4.0—automation and robotization of warehouse and transport activities. External logistics is among others information exchange in products (cars) that have already left the factory. This enables, for example, permanent delivery of the latest software updates to them—without having to wait until the final producer does. The modules installed in cars have the latest available version of the software that controls it. Industry 4.0 solutions in individual plants cover all aspects of both the production itself and its tools—materials, production, products, factory, energy management, fleet, security technologies, including the evacuation process and even the factory canteen, in which the automated ordering process has been applied meals. The most important advantage of the solutions is the possibility of rapid transfer of solutions or processes developed in this model plant to other factories located around the world (based on portal: Industry 4.0) [45].

In the second case study, a company creates the factory about type "speed". The first speed factory (naming adopted by the company) was opened on the domestic market (in 2015), the second on the foreign market (2019). The factory is completely automated and designed to be able to quickly produce a limited series of products or to supplement the range with a product that sells quickly in a given season. The company implements two production strategies:

- a traditional production line with mass production with a diverse range of products produced by machines operated by people,
- smart lines in speed factories with production in short series (cycles) of products according to the needs of a specific customer (closer to the customer) using robots and 3D printers.

Production in speed factories is faster than traditional. Robots have the ability to create a specific and non-standard product in short series of production. Production in speed factories is complementary to traditional (its share in total production is small) but of strategic importance (by 2020 the company intends to develop the production of non-standard products). The sale of products is carried out through e-commerce and retail trade. Improving distribution—the company wants to deliver the product in the future within one day. Production in speed factories is still being tested and refined. After 2020, the transfer of the technologies to the Asian market is planned. The idea of speed factories appeared in Germany in the beginning XXI century. In the analyzed company, the new strategy is realized in production (smart/sped factory) and distribution (warehouses with robots and system of fast product distribution) (based on descriptions on speed factory) [46].

In 2018, the third analyzed company entered into its strategy for 2019–2023 the goal of implementing solutions in the field of Industry 4.0. The work carried out (before the development of the new company strategy 4.0) is a multidimensional data analysis (the

beginning of activities—before the advent of the Industry era 4.0). Until 2018, database management in individual branches of the company. From 2018, the implementation of the project: Centralization of knowledge (knowledge was dispersed)—knowledge is systematized, and the relationship between new technologies in the area of extraction and IT solutions is becoming more and more strict. Works carried out in 2019—creation of dedicated IT systems for production management—(every decision regarding the optimal use of resources is to be based on reliable data provided in real time)—IT supports the development of multidimensional data analysis from production processes. Currently, the company implements approx. 50 projects in various areas of its activity. The basic level of implementation of the Industry 4.0 assumptions will reach in 2023 with a private cloud used by the company's customers (contractors) and access to data outside the company's systems (Big Data and analytics, that is analysis and drawing conclusions from data, including the Internet of Things). The company is at the beginning of its path to Industry 4.0, plans to take action in many areas at the same time: data governance, Analytic and Big Data, cybersecurity, optimization of product, services, cooperation etc. [47]. The key components of Industry 4.0 used during the implementation in each company in Table 10 are presented.

Table 10. Summarizes the areas and technology that was implemented through the transformation of the case studies studied.

No. Case Study	Area/Goal of Change	Industry 4.0 Technologies Used
Case study 1	Increase productivity, flexibility and efficiency of processes, increase product quality, improve cooperation with customers	process digitalization, Big Data, sensors, autonomous production line, virtual data processing platform, product visualization, IoT, Cloud Computing, continuous monitoring of productivity indicators, RFID gates, warehouse automation and robotization, additive manufacturing.
Case study 2	personalization of production, improvement of cooperation and contacts with the customer	Fully automated factory, 3D printing,
Case study 3	increasing work safety during raw material extraction, improving the flow of information within the company	Knowledge centralization, Cloud Computing, data analytics, IoT, robots at resource extraction sites, autonomous transport.

Each of the companies which implemented the components of the Industry 4.0 concept made it intuitively. The analyzed implementations significantly differed in terms of components and implementation method. It is necessary to propose a general approach which can support companies that intend to implement the Industry 4.0 concept. The authors aimed to standardize the approach and create a framework for implementation on an aggregated, fairly general level. The companies have to be aware that the implementation of Industry 4.0 has the individual nature of each implementation in terms of scope (components) and duration.

In this part of the work, the schedules of measures/implementations of the Industry 4.0 tools (schedules made on the basis of implemented projects in companies used as case studies) were summarized. The individual schedules set out: basic and auxiliary activities (additional), which are carried out in parallel with the basic (key) activities. The variety of industries, the specifics of business, the scope of the market served and the size of capital are the basic criteria differentiating the presented projects for the Industry 4.0 implementation (Figure 4).
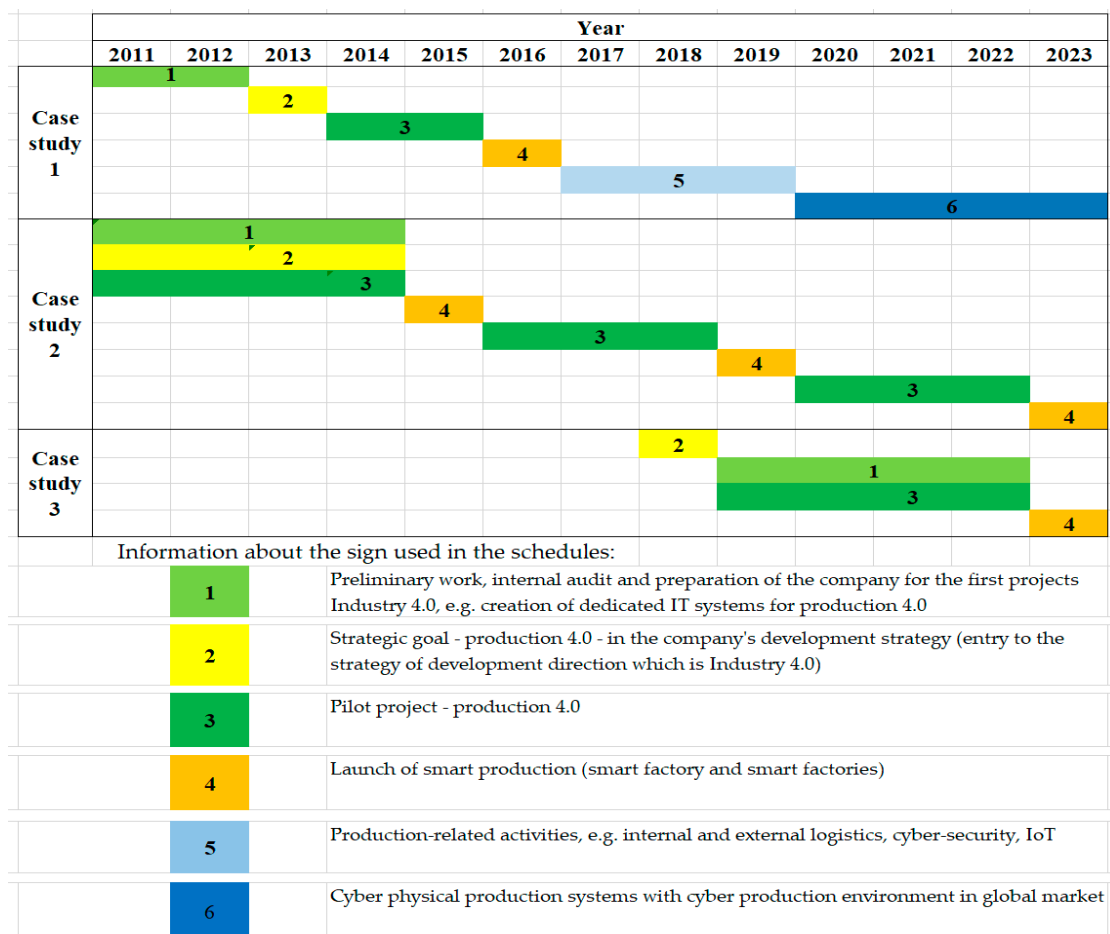
	Year												
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023

Figure 4. Schedule of work carried out in the enterprises (case studies 1–3). Source: own study.

In the companies surveyed, decision makers show an increased willingness to invest in their company's digital transformation, lacking knowledge of their current status in Industry 4.0 and strategic guidance for its implementation. What is characteristic of many other companies implementing the concept of Industry 4.0 [48]. This knowledge enables you to take more targeted and sustainable strategic steps along the path of transformation [49].

Based on the analyzed cases, the adoption of strategic objectives and the establishment of Key Performance Indicators (KPI) is considered to be the beginning of the path to Industry 4.0. Once a strategic objective has been defined, it is worthwhile to determine which business processes are key to achieving it and choose those that will be developed or improved. Implementation of changes in the company towards Industry 4.0 is a process and not a group of correlated individual tasks.

It means that all works related to the implementation of strategy I 4.0 come under a continuous verification of the adopted assumptions and its adjustment to the current situation in enterprises. The strategies of Industry 4.0 cause changes in the organizational structures of enterprises. Industry 4.0 leads to the flattening of structures, decentralization of decisions, teamwork and less formalization.

4. Discussion

The technological projects of enterprises leading to Industry 4.0 on the operation level are surrounded by knowledge management and new organization culture based on cooperation people and machines [50]. The structure of the key fields is presented in Figure 5.
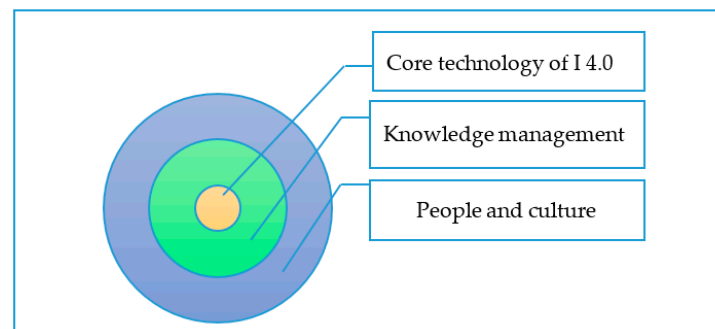
Figure 5. General fields on the way to Industry 4.0. Source: own study.

The starting point for introducing changes in the company is the appropriate entry in the development strategy. Enterprises should include in their strategies the following statement: "our company is moving towards Industry 4.0". The process of building a roadmap for Industry 4.0 initiatives should start with a situation analysis and audit. It is worth answering the question: Where is the company located on the way to Industry 4.0? [51]. At this stage, companies can perform benchmarking to get answers to the questions: What 4.0 technologies have been used in the industry? What business benefits have other companies achieved? Can the benchmark approach be applied to the organization and will the organization achieve similar benefits? [52]. The process of analyzing the situation in the company and the sector should be supported by collecting information about new technologies related to Industry 4.0 and existing megatrends, e.g., energy efficiency, sharing things, online communication, new materials, energy return, staff rotation. Industry 4.0 has great potential and provides a set of economic and social opportunities through changes in work organization, production technology, product forms, type of service, product design, distribution, etc. [3].

The accession of companies to the implementation of changes in their aspirations to operate in Industry 4.0 is associated with the appointment of an organizational unit responsible for planning and implementation of projects together with the coordinator of implemented activities. The implementation of individual projects is the responsibility of interdepartmental units, and the duties of the coordinator of activities related to the implementation of the Industry 4.0 strategy are performed by the Chief Digital Officer (CDO) or Chief Digital Information Officer (CDIO) or Chief Industry 4.0 Officer. His responsibilities include the implementation of Industry 4.0 technology and the management of related processes. He or she is usually a manager with extensive authority. The person in this position is also often a member of the board [53]. In case of a decision to implement a project, investments start with pilot projects because they allow to gain knowledge about the usefulness of given technologies for the company, but also to gain application experience for subsequent projects. Technology projects in the area of Industry 4.0 are focused on combining operational technology (OT) with information technology (IT). Individual investment projects are usually carried out in one core business process. The changes are not yet broad enough to be called comprehensive. Enterprises from various industry sectors implement pilot projects that do not include all their processes at the same time (e.g., production with logistics [54], energy management, management of security technologies). The implemented investment projects prepare enterprises for long-term changes in the implementation of the new development strategy for Industry 4.0 [55,56]. After the initial pilot projects, next projects are realized and new advanced technology enlarges and creates cyber-physical systems.

Technology is an important area of change, i.e., replacing the current technology with technology 4.0. At this stage, it is worth considering which of the Industry 4.0 technologies can significantly help you achieve your goals. Brainstorming to identify key Industry 4.0 initiatives in the enterprise can be helpful. Projects should not only concern technology but also processes or employee (team) development. In addition, it should be noted that

companies investing in technology 4.0 are largely collaborative, e.g., through technology platforms. Commencing cooperation is easy at the level of capital-related enterprises e.g., big capital international group in steel industry [57]. It is also worth considering alliances with partners, clients, research centers and universities, and even with some competition within coopetition [58]. New Industry 4.0 investments are cost-intensive and very often at the stage of their planning and IRR calculation, a decision is made not to implement them. The rate of return is spread over time (there are 5-year and longer periods), which is unprofitable for companies and institutions co-financing the project (banks).

The creation of a virtual production line requires the company to obtain a high degree of automation of production work, and individual devices should be equipped with sensors to generate data on the parameters of devices and create a cloud. At this stage of the work, the companies commission a specialized IT company to configure the data so that the information provided to the manufacturer is up-to-date and complete. Information and computer systems that are already in enterprises must be compatible so that there is no duplication of data and, what is worse, the transmission of incoherent (contradictory) data [58]. The decision-maker receiving data cannot be exposed to losses due to outdated data (data is provided in real-time) [59]. The aim of this stage of work is called: Audit of Systems and Data is to monitor the operation of the production line in real-time and to fix a new investment. At this stage, the producers are benefiting from, for example, the knowledge gained about processes in their companies [60]. In order to be able to process data—environment for data processing, this data should be somehow obtained [61]. For this purpose, devices are created whose task is to obtain process data from various types of PLCs from leading brands as well as from industrial robots. In the era of ubiquitous Internet, enterprises can use open communication protocols of the REST/SOAP type, transferring data to the cloud computing, while implementing available solutions, enabling the acquisition of data directly from the machines.

The choice of the way companies develop depends on their resource capabilities. Core technology: predictive analytics, big data, cloud computing, advanced automation of machines, advanced scheduling, robotized palletizing, smart robots and machines, intelligent sensors, autonomous vehicles additive manufacturing (e.g., 3D printing) for components, process traceability, advanced materials, advanced manufacturing systems (CPS, full interconnected automation) etc. is essential to create an enterprise 4.0 [15,62,63]. Another aspect is business intelligence (BI) systems that enable access to information and its analysis in order to improve—optimize decision-making processes both in terms of efficiency and productivity [64], in the case of Industry 4.0 it is the management of huge amounts of data coming from big data environments [65]. This development is associated with the need to implement the digitization of process safety and risk management [66]. In transformation to Industry 4.0 organizations can focus not only on building out the strong foundation of technologies, but also include truly innovative new approaches and priorities. Links between leading technologies and Industry 4.0 are research facilities of scientists and practitioners. According to Di Nardo paper [50] the cyber-physical systems with the Design Anywhere, Manufacture Anywhere (DAMA) function in a push automation environment where the human operator's role is not marginal (with the exception of oversight and problem solving) create the framework model of Industry 4.0 for industrial management. According to Kagermann (2013) [67], the greatest challenges connected with implementing Industry 4.0 are: standardization, process/work organization, product (means technology) availability, new business models, security/cybersecurity, a specialist staff, research, training and CPD (continuing professional development). Enterprises can use: asset performance management, lean manufacturing, real-time enterprise, world class manufacturing, etc. In each of these areas we can look for an application to Industry 4.0. As an example, the principles of lean production are related to Industry 4.0, such as: integration of human activity with the entire production chain [68], a continuous improvement with "kaizen" [50] and lean automation [53]. A collection of big data from the machines involved in the production and study of a trend of their sensitive parameters

(such as quality of the finish, processing time, consumption of wear parts of the tool) in conjunction with human skills build a lean structure in Industry 4.0. In the future, great importance will be given to the study of human error and how it can be reduced in lean cyber-production systems [50].

Producers in network systems, when implementing investment projects, must connect them with partners throughout the supply chain. Mini and micro-producers should focus on building a competitive advantage in the immediate environment through quality, originality, energy-efficient, safe, clean, esthetical, or invisible, with minimal environmental impact. According to the systems three forms of the plant are proposed in the McKinsey report ([44], p. 30):

(1)　"Smart automated plants (producers) address the need for mass products at low cost and are fully automated, digitized, and highly cost efficient. These plants produce large volumes and commodities.

(2)　Customer-centric plants address trend markets. These are ultra-responsive plants producing highly customized products at scale and affordable cost to address the trend towards mass personalization.

(3)　E-plant in a box addresses niche and remote markets. This small-scale, low-capex, mobile plant is able to produce a limited range of products at a new location and can be set up quickly to address subscale niche markets".

According to the project management methodology, the activities of companies towards Industry 4.0 should be divided into organizational and technological [55]. The changes introduced in enterprises are carried out according to the Deming cycle: PDCA, and the management of individual projects is carried out according to the principles of the system functioning [56]. In order to achieve the effectiveness of the project, it is necessary to use optimal techniques, in which the selection of rules is helpful in terms of the manner of performing a given job or the procedure, called management methodologies. The steps on the way to the implementation of Industry 4.0 projects always include planning, preceded by analysis and audit, execution, checking and adjustment. Project management requires a feedback loop, i.e., verification of the assumptions made in the strategy of action and changes implemented on an ongoing basis (project cycle management) [57].

It is also important to properly prepare the whole organization for the implementation of Industry 4.0 projects by building the awareness of employees about the importance of Industry 4.0 solutions for the development of the company [58] and the new working culture (culture Industry 4.0) [62]. The basic question when building a new organizational culture is: what extent the organizational culture is able to absorb modern manufacturing technologies. It is analyzed organizational culture openness to innovation, in this: technology/technical competences of employees, employee empowerment level, employee satisfaction level, level of technical culture, ability to use modern technologies, and engineer development systems [51,54].

The implementation of the Industry 4.0 strategy requires new competences from employees. One of them is data collection and analysis, which includes knowledge in the areas of big data and machine learning. New competences and new specialists will also be needed in the areas related to data security, access control and information management. The changes affect many employee skills. New skills are a widely discussed topic in discussions among business practitioners, politicians and academia [69–73].

Computer environments and cloud systems creates a backup for further changes.

Digitization is the basis for Industry 4.0 projects (Figure 6). On the basis of the web pages of IT companies, steps (stages) have been established for companies to initiate Industry 4.0. The basis for digitalization is data. The data are included in the communication system. The step consists in creating production lines—machines—which exchange data, hence the need for digitization in enterprises implementing the Industry 4.0 development strategy). Digitalization helps an enterprise be smart [74]. Machines provide a large amount of data and records, which is why enterprises must have adequate large systems to store them. Most often enterprises create many databases, e.g., accounting (financial),

CRM, MRP or ERP, on the website, etc. It all depends on the type of data and how to use them (so-called relational and non-relational databases). The communication system is the way in which machines communicate with each other, how they exchange data. Enterprises create (program) a communication interface (Programming Interface) that can communicate with different types of databases, and devices/applications. Such programs function as links between various databases and devices that generate data (they are in the middle and do not generate data themselves, meaning they do not have their own data). These are programs for searching data from databases or other connected devices. The next stage is defining the scope of activities performed by machines and by people (machine operators of equipment owners). According to Industry 4.0, you have to assign new tasks to the machines. Implementation projects—based on determining -what machines are doing are very important, because machines get new roles in Industry 4.0 (they can replace people), e.g., data analyst, performance evaluation of other machines and people's work [69]. In cyber-physical systems outside machines there is still a man—an operator. In models focused on human importance in industry 4.0, the function of operators is exhibited. Operators with technical skills, methodological skills, attitudes to teamwork and individual attitudes at the start to full industry 4.0 are very active participants in the created cyber-physical systems [50]. The structure constructed from the fields is presented in Figure 6.
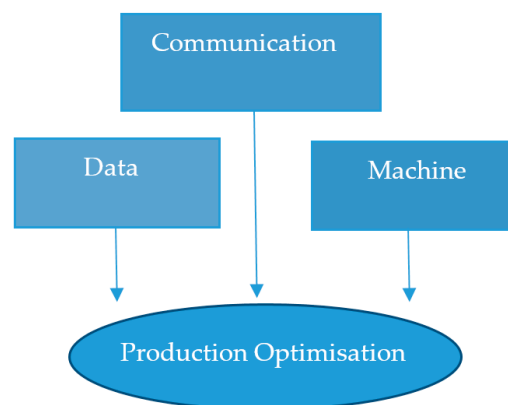

Figure 6. Key components of the project: Digitalization of enterprise. Source: own study.

Proposals for innovativeness in the scope of work carried out by machines are implemented non-stop. The machine learning project (carried out at the start-up phase) involves the start-up of machine learning elements and the use of current data processing algorithms to enable production machines to learn. The scope of machine learning concerns the optimization of production.

Works on the learning of devices are realized in stages and are conditioned by the degree of robotization of work and work on building algorithms of device learning and creating models of optimal work. Works at this stage require significant investment expenditures (purchase of industrial robots, devices for additive manufacturing) and time, because the device learning models are created on the basis of the experience of equipment work (learning from mistakes, work anomalies). Two forms of machine learning can be distinguished:

(1) Learning machines with a teacher—the operator of the device "prompts" the machine, controls data, participates in the decisions of machines. Traditional information and computer systems use averaged statistical data to predict when corrections should be made to system operation or corrective or preventive actions should be taken.

(2) Learning machines without a teacher—algorithms of this type work on datasets without human help, and their result is a set of automatically found patterns, based on collected data that can be applied to existing faults, problems, anomalies in production. If we want machines and production cells to adapt their configuration to individual

workpieces, we should be able to add or reorganize machine modules dynamically. The final result of the activities is full openness and decentralized production [9]. New production systems are based on artificial intelligence and use various technologies such as machine learning, deep learning and cognitive computing algorithms, complementary learning [7,74,75]. Moreover, no supplier is able to provide an optimal solution for all needs in learning machines. Therefore, it is absolutely necessary to create solid foundations for compatibility with existing systems and the pursuit of open technologies (cooperation with external systems).

As part of this area, production machines learn to perform their tasks optimally while simultaneously calibrating their adjustable parameters. Machine learning, cloud computing and feedback in the form of robot calibration based on experience (i.e., historical data also understood as Big Data) are the basic elements of implemented projects [76–78]. It is a cyclical process of all work at the start up stage in Industry 4.0 (Figure 7).
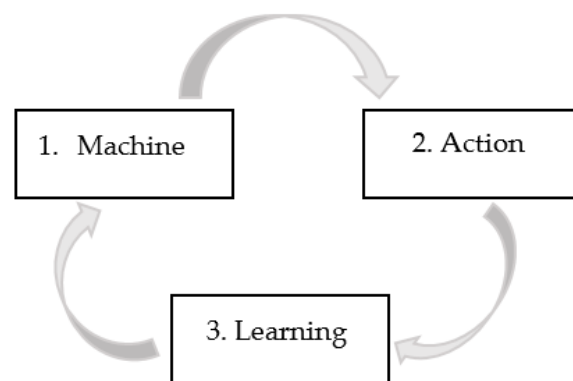
Figure 7. Key components of the project: Learning machines. Source: own study.

Enterprises can consist in investing in the automation of production—selected production lines—and improvement of internal and cooperative IT and computer systems along with the provision of data of selected devices and products on the network (outside the enterprise) or they can decide on creation of cyber-physical production system (CPS) for all enterprise [12,79–81]. Learning machines cooperate with external systems.

When analyzing Industry 4.0 projects from the client's side, i.e., the degree of product personalization, the following stage of enterprises' evolution can be assumed:

(1) Manufacturers produce mass products but with variants of products designed on the basis of their modular architecture by using flexible manufacturing systems. Flexible automation of production lines, thanks to the introduction of programmable controllers and computers for industrial devices, enabled the extension of the range of products to the family of predefined modules, with production costs comparable to mass production. By choosing a specific product configuration from the catalog of available options, the desired level of his customization is achieved, thus satisfying the needs of more customers than in the case of non-personalization of the offer [8,23,24,82–84].

(2) Producers use additive devices (e.g., 3D printers) and a customer becomes an active participant in product design. The customer now creates his own configuration, usually with the use of specialized tools supporting design, and only after this stage the product is manufactured. The means enabling the effective implementation of this concept are reconfigurable manufacturing systems based on the assumption: "efficiency and functionality precisely adapted to the needs and their changes over time" [7,12,28,29,70,73,79,85–89].

Industry 4.0 projects are implemented in enterprises gradually (in stages) over a long period of time and there is no universal instruction for implementing changes. The implemented projects begin from the implementation of individual machines and ends

with entire production lines. In the future, these modern production lines will create smart factories. On the way of enterprises to Industry 4.0, production is being reevaluated, from traditional production to smart factories. On the one hand there are enterprises that use selected forms of changes because a traditional form of production is a priority for them e.g., steel industry [90,91] and on the other hand there are enterprises that use more and more new forms of changes—typical for Industry 4.0 e.g., automotive sector, production of home appliances, production of clothes and shoes etc. [18,19,44,92–94]. On the base of literature review the following stages can be implemented on thaw of enterprises to Industry 4.0:

(1)   Traditional production is a priority in relation to intelligent production,
(2)   Both types of production are almost equally important,
(3)   Intelligent production is more important and more developed than traditional production.

The discussion is summarized in the general framework of implementation of Industry 4.0 presented in the form of a diagram in Figure 8. This framework shows the main areas of change, which will result in a smart factory. Smart factories create new values for economies and markets. Personalized products replace the mass products. Moreover, clients can obtain products faster, easier, more comfortable etc. Economies receive new businesses that are flexible (smart) and therefore more "resilient" to market situations (downturn).
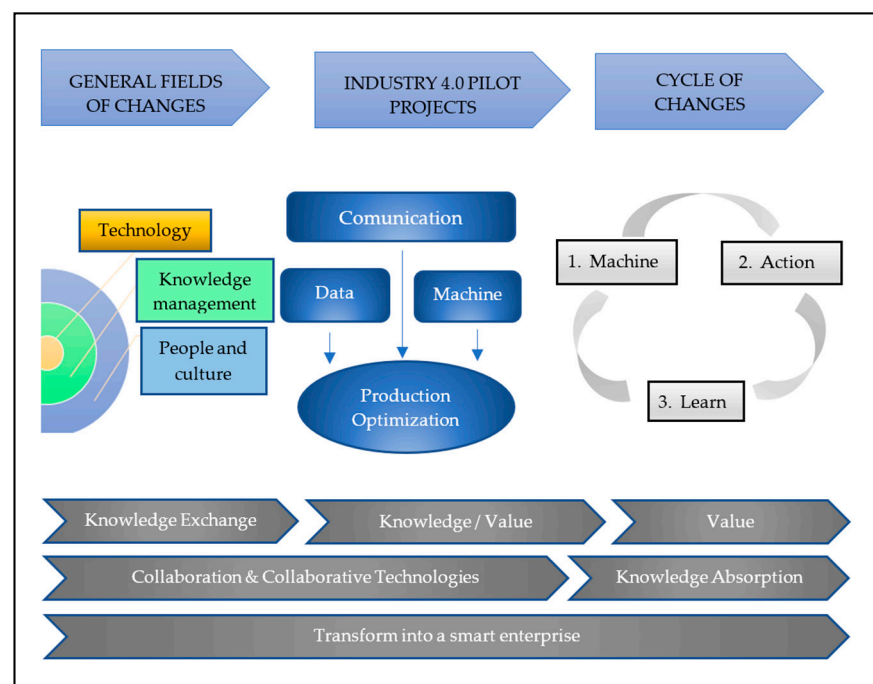

Figure 8. Industry 4.0 implementation framework. Source: own study.

5. Conclusions

The article presents stages on the way of enterprises to transform factories for the needs of the fourth industrial revolution. The following projects for the implementation of Industry 4.0 were identified in the surveyed companies: auditing and organizing existing databases, investing in devices for data transfer from devices, creating dedicated programs for production management, digitalization of processes, robotization of work, analytics and Big Data, and the use of IoT. The level of sophistication varies across companies. However, all companies are working intuitively, as the market still lacks concrete benchmarks. The road to Industry 4.0 is one of trial and error, and it is important to remember that it is fraught with a high risk of failure. As practice shows, not every company is successful in implementing Industry 4.0 components. For each company, Industry 4.0 means something

different, each company has to choose appropriate technologies for its needs. In the global market, there are factories that have cyber-physical production systems, and there are manufacturers who are just beginning or are planning to move to Industry 4.0. However, it can already be seen that the adopted objectives in the development strategies of companies for the coming years is to invest in CPPS as an alternative to manual (traditional) production. The stages described in the publication on the way of enterprises to Industry 4.0 contain many simplifications. It can be assumed that this is general information about the way of enterprises on their way to Industry 4.0. The presented case studies provide an overview of the duration of individual activities in projects. For each different company, the schedule will be modified to suit its needs, it may include all the described stages or only selected ones. The work schedule included in this publication gives an idea that the initiation and implementation of the process of transformation to Industry 4.0 is a process spread in time, and its course depends on the type of implemented project.

The study was two-part, consisting of a literature part and a case study. On the basis of the literature part, both the general framework for building Industry 4.0 (Figures 2 and 8) and the path to Industry 4.0 (Figure 3) were determined, which seems obvious to Industry 4.0 experts, but may prove to be useful information for other recipients of knowledge. The part—case studies—on the basis of which the schedule was created (Figure 4), showed that the stages of implementing Industry 4.0 in enterprises are implemented gradually, are spread over time and are different for each company.

The juxtaposition of background information (general framework for implementing Industry 4.0) with the timeline allows comparing the paths leading to Industry 4.0. Based on this comparison, it was found that:

- Leading technologies: cyber-physical systems (CPS), cloud manufacturing, IoT, etc. form the base for Industry 4.0;
- this base is being overbuilt with further management systems, e.g., knowledge and human-machine relations;
- the cycle of changes: machine—action—learning creates new value for the economy, which is the possibilities offered by an intelligent factory: better, faster, more comfortable, personalized products, etc.
- A company's path to Industry 4.0 is gradual, but involves two levels: strategic and operational;
- enterprises in different industries choose which technology projects will be implemented first (industries where Industry 4.0 solutions are more easily implemented are considered to be clothing, footwear, automotive);
- the implementation time of enterprises' projects towards Industry 4.0 depends on the size of individual projects, their complexity and the resource capabilities of enterprises (large enterprises have more opportunities to change towards Industry 4.0).

The proposed approach provides a general framework for the implementation of the concept of Industry 4.0. It allows you to design your own path to transform your enterprise into a smart factory and indicates potential areas of investment for effective implementation of the concept of Industry 4.0. The article provides a basis for further in-depth research on how to implement the concept in industrial enterprises of different industries. Moreover, it requires additional research in identifying key investment areas in enterprises interested in effective implementation of the Industry 4.0 concept.

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