Industry 4.0 Concept Introduction into Construction SMEs

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Abstract. The article presents a general idea of Industry 4.0 concept with the introduction presenting descriptions of the most important aspects in terms of production and construction industry development. The importance of the SME sector is stressed showing that this group of companies plays significant role in the European economy. The main objective of the article is to define and show possible research areas connected with the introduction of Industry 4.0 concept into SMEs with the main focus on the construction sector. For this purpose, an analysis was made, based on the most recent literature, to point out actual needs in the SMEs sector in terms of its evolution into 4.0 level. What is more, the analysis was performed based on the most popular articles published in journals available in Thomson Reuters Web of Science Core Collection database regarding Industry 4.0 concept in the last decade showing the actual change of interest in this filed, taking into account possibility of usage of this concept in the construction and production sector. Authors tried to describe current knowledge regarding Industry 4.0 introduction for SMEs. Performed analysis showed that there is a wide spectrum of disciplines that are affected by the Industry 4.0 that needs to be examined considering introduction into SMEs. Study also showed that multidiscipline approach was not investigated so far to create special rules, procedures and methods and know-how designed for introduction of main principles of Industry 4.0 in the SME sector. Authors came to the conclusions that there should be more stress put into research in this field especially taking into account the huge potential which lies in SME sector in terms of global economic strength.

1. Introduction

Small and medium-sized enterprises (SMEs) are the backbone of the EU economy: they represent 99.8 % of EU companies, almost 60 % of GDP (total value added) and almost 70 % of the total available workforce. European SME landscape can be also described by the new funding channels and actors that are rapidly entering the EU SME funding marks: private loan and bond funds, selective and diversified funds (both equity and debt), and e-platforms [1]. That is the main reason why focus on the research connected with improving processes conducted by SMEs is so important. One of the key concept that brings many opportunities is the idea of Industry 4.0 revolution. Authors are of the opinion that new technologies and ideas related to this concept need to be further researched to make it possible to use them in SME construction sector.

The aim of this work is to analyse current knowledge connected with the introduction of Industry 4.0 concept into industry with the special focus on SMEs related to the construction sector. The emphasis was put on defining the possible areas of research that need to be investigated to enable the introduction of the proposed concept into SMEs with the use of publications available in the Thomson Reuters Web of Science Core Collection database.
2. Industry 4.0 concept

Industry 4.0 (Ger. Industrie 4.0) is the concept relating to the idea of "industrial revolution", whose main objective is the integration of production processes with the information technologies and techniques. It combines production methods with information and communications technology. It assumes that products can be manufactured based on the individual needs of customers, for example sneakers that come with a tailor-made sole and a design selected by the customer, or a customised individually designed piece of furniture. Industry 4.0 makes it possible to produce items that are unique in excellent quality and at a price equal to that of mass-produced goods. Smart, digitally connected systems and production processes serve as the technical basis for this concept. Industry 4.0 also defines the entire life cycle of a product: from idea to development, manufacturing, use and maintenance – and ending on recycling of the product [2]. For better understanding this idea the development of the Industry 4.0 concept was shown in the Figure 1.

![Figure 1. Industry 4.0 concept development, [3]](image)

Historical data confirms that the first industrial revolution was connected with steam machine invention which enabled significant level of mechanisation compared to the previous industry level. 2nd industrial revolution was related to the beginning of the mass production in 19th century with electricity usage and assembly line creation. 3rd industrial revolution was connected with inventing IT and introducing technology into the production as well as the use of automation in processes. 4.0 level can be described as usage of cyber physical systems (CPS) connected with the digitalization and the Internet of Things (IoT) concept. Development time of the industry 1.0 was vast, as it took ages to invent steam powered machines. Between 1.0 and 2.0 version there were approximately 100 years. Level 3.0 was introduced after 70 years and now discussion is on 4.0 concept after 30 - 40 years form the last revolution. It has to be noted that in the short time an introduction of 5.0 version of this can be expected.

Industry 4.0 was initially developed by the German government to create a coherent policy framework to maintain Germany’s industrial competitiveness on the global market. Related terms used internationally include Internet of Things, Internet of Services, Industrial Internet, Advanced Manufacturing and Smart Factory. The main features of Industry 4.0 are [4]:

- Interoperability: cyber-physical systems (work-piece carriers, assembly stations and products) allow humans and smart factories to connect and communicate with each other.
- Virtualisation: a virtual copy of the Smart Factory is created by linking sensor data with virtual plant models and simulation models.
- Decentralisation: ability of cyber-physical systems to make decisions of their own and to produce locally thanks to technologies such as 3d printing.
• Real-Time Capability: the capability to collect and analyse data and provide the derived insights immediately.
• Service Orientation.
• Modularity: flexible adaptation of smart factories to changing requirements by replacing or expanding individual modules.

3. Thomson Reuters Web of Science Core Collection analysis

Web of Science (WOS) is the one the most recognizable scientific online database available for researchers on the market. It is product of “Thomson Reuters Institute of Scientific Information” (ISI), which arises from the Science Citation Index created by Eugene Garfield in 1960s. WOS includes above 12,000 [5] journals and comprises of seven different citation databases including different information collected from journals, conferences, reports, books and book series [6]. WOS core collection includes [7]:

• Science Citation Index Expanded (1945-present),
• Social Sciences Citation Index (1956-present),
• Arts & Humanities Citation Index (1975-present),
• Conference Proceedings Citation Index- Science (1990-present),
• Conference Proceedings Citation Index- Social Science & Humanities (1990-present),
• Book Citation Index– Science (2010-present),
• Book Citation Index– Social Sciences & Humanities (2010-present),
• Emerging Sources Citation Index (2015-present),
• Current Chemical Reactions (2010-present),
• Institut National de la Propriété Industrielle structure data back to 1840,
• Index Chemicus (2010-present).

For the purpose of the article the authors analysed available resources in the Thomson Reuters Web of Science Core Collection database. This base was chosen based on the availability for the researchers. Three search series were performed connected with the following key-words: Industry 4.0; Industry 4.0 & SME; Industry 4.0 & Construction. The scheme of the carried procedure is shown in Figure 2.

![Figure 2. Research procedure for the carried-out works](image)

The analysis procedure was begun by selecting a suitable database. In the 2nd step key words were selected for the purpose of the execution of search. After this step review of the results was performed to check if all possible articles were found. If not, authors decided to improve the key words selection and another search series was made based on the improved key words. Final number of the selected phrases is shown in Table 1. Next step was to analyse the results of each search. Authors decided to
prepare graphs summarizing obtained discoveries. Graphs are divided into 3 sections according to the 3 main keywords groups and covers: country division, languages used for the article preparation, document type, year of the publication, research areas and the journal-publication title. It has to be noted that all graphs that are presented in point 2 were prepared taking into account the total amount of appearances of the assessed features. Percentage was calculated using the real amount of publications, so total sum of percentage may exceed 100 % because the total quantity appearances exceeded real amount of publications.

Table 1. Identified key-words for the search process

| Industry 4.0 | Industry 4.0 & Construction | Industry 4.0 & SMEs |
|--------------|----------------------------|--------------------|
| Industry 4.0 | Industry 4.0 + construction | Industry 4.0 + SME |
| Industrie 4.0 | Industrie 4.0 + construction | Industry 4.0 + SME’s |
| Industry 4.0 + civil engineering | Industrie 4.0 + SMES | Industrie 4.0 + SME’s |
| Industrie 4.0 + civil engineering | Industrie 4.0 + SME | Industrie 4.0 + SME’s |
| Industry 4.0 + small medium companies | Industry 4.0 + small medium enterprises | Industrie 4.0 + SME |
| Industry 4.0 + small medium company | Industry 4.0 + small medium enterprise | Industrie 4.0 + SME |
| Industry 4.0 + small medium enterprise | Industrie 4.0 + small medium enterprises | Industrie 4.0 + SME |
| Industrie 4.0 + small medium enterprises | Industrie 4.0 + small medium companies | Industrie 4.0 + SME |
| Industrie 4.0 + small medium companies | Industrie 4.0 + small medium companies | Industrie 4.0 + SME |

It has to be mentioned that after performing the final search of the selected keywords 517 articles were received for the Industry 4.0 category, and only 8 articles were found for both the Industry 4.0 & SME and Industry 4.0 & Construction group. Results of the analysis in the form of graphs are presented in the following points 2.1, 2.2, 2.3.

3.1. Industry 4.0 keyword group results

Figure 3 shows the results of the author’s country and languages of the research works for the first set of keywords Industry 4.0. It has to be noted that the majority of the publication available in the WOS database comes from the German authors which is 48.4 %. People Republic of China authors created 12.4% of the articles and authors form Australia Spain and England are responsible for 5.4%. Considering language of the publication it was not a surprise that majority are written in English 95.3%, 4.3% in German and 0.4% in Chinese.

The majority of works were published as a proceedings papers which stands for 70,4 %. 24 % were articles in the journals, 4,2 % editorial materials (Figure 4). Graph showing publication year is very interesting. It shows that 62,9 % of all works were published in year 2016, 25 % in year 2015 and 7 % in year 2014. First publications in the database are from 2013. It indicates that the area of research connected with Industry 4.0 is relatively new, and growth of interest can be observed since year 2013.

Industry 4.0 concept covers many research areas. In the search results, there were in total 27 articles, from which the most popular was Engineering (37,4 %), Computer Science (21,3 %) and Automation Control systems (10,8 %). Articles were published in 116 publication titles, and the most popular was Procedia CIRP with totally 9,5 % of the publication share. It has to be noted that conference proceedings from IEE Conference on Emerging Technologies Factory Automation have many publications related to Industry 4.0 since 2013, which means that this concept is often mentioned during this event.
Figure 3. Country and languages results for first set of key-words: Industry 4.0

Figure 4. Document type and publication year for first set of key-words: Industry 4.0

Figure 5. Research areas and publication titles for the first set of key-words: Industry 4.0
3.2. Industry 4.0 & Construction key-word group results
The results from the analysis of the 2nd keyword group are presented below. It has to be mentioned that there were only 8 publications found using keyword phrases presented in Table 1, what implicates that in the area of Construction idea of Industry 4.0 is randomly raised, what gives the area for further research in this subject.

![Figure 6](image1.png)

**Figure 6.** Country, language and document type results for second set of key-words: Industry 4.0 & Construction

![Figure 7](image2.png)

**Figure 7.** Publication year and research area results for second set of key-words: Industry 4.0 & Construction

Figure 6 shows that half of the origin of publications were German, 37 % of them were form China and 13 % from England. It presents that the construction aspects in terms of Industry 4.0 revolution are mostly described by the German’s researchers. It is unusual that there were not found publications from the USA. Language of all the works was English and 75 % of publications were proceedings paper search results presented during the conferences, which is understandable, since relatively new concepts are firstly presented and discussed during scientific meetings.
Publication year and research area presented in the Figure 7 which clearly shows that the majority of construction related publication was prepared and published recently: 62 % in year 2016 and 38 % in year 2015. It corresponds to the general trend for Industry 4.0 publications. The majority of 57 % were in the area of engineering and the others were related to computer science research area.

3.3. Industry 4.0 & SMEs keyword group results
Results for the search in the database for SME-connected keywords revealed 8 documents with the categories being analysed results very similar to the 2nd search connected to the Industry 4.0 & construction sector.

Figure 8. Country language and document type results for third set of key-words: Industry 4.0 & SMEs

Figure 9. Publication year and research area results for third set of key-words: Industry 4.0 & SMEs

Figure 8 presents that all the publications have their origin in Germany and all of them were conducted in English language. 62 % were proceedings paper and 38 were articles. It can be noted that 50 % were published in 2016y and in 2015. 75 % of them are connected with engineering and 25 % with business economics research area.
Presented results showed that the area of research related to Industry 4.0 concept is relatively new and there is a limited amount of publications related to the construction industry or SMEs with connection to Industry 4.0 revolution. It can be also noted that the interest in this research areas is growing steadily since 2013 for Industry 4.0 and form 2015 for construction and SMEs areas and the majority of the publication are published in the conference proceedings, what is general trend that is observed in the new scientific research areas.

4. Industry 4.0 and Construction & SMEs paper discussion.
Authors performed deeper analysis of the total 16 publications related to Industry 4.0 & SMEs and Industry 4.0 & construction to define what research areas should be considered as a priority. It has to be noted that part of the examined publications discuss aspects related to sustainable development of enterprises and design and do not focus primarily on technical issues and Industry 4.0 development [8, 9, 10, 11].

In the analysed papers related to the concept of Industry 4.0 and SMEs are described, among others, research projects related to the preparation of research laboratories for the study of the phenomena associated with this concept. The research concerned, inter alia, aspects of preparing employees to work in a new environment of Industry 4.0 [12]. It has also been found that not all of the companies that employed workers are ready for the proposed new solutions and technologies changing work environment of employees. Other studies carried out are related to the use of specific technologies correlated to the concept of Industry 4.0 and were testing their usefulness in the context of SMEs, e.g.: the use of 3D printers for production optimization [13], work on software for easy management of production [14], or VR solutions for the processes [15, 16].

The authors of the cited studies indicate that there is a need for the implementation of projects aimed at introduction of methods for the digitization of SMEs and the introduction of IT systems, for accelerating the production [17]. It is very important, according to the authors, that during the implementation of the research work attention is paid to aspects of the dissemination of the positive effects associated with Industry 4.0 idea, because there is a very large dose of scepticism, especially among SMEs, which find it very difficult to use highly developed applications and technology concepts of Industry 4.0. This is due to the fact that these companies usually do not have enough manpower to search, test and implement new solutions, as well as their abilities to invest in new, untested solutions are limited by concerns about the loss of funds.

However, in order to further develop and maintain the possibility of competition in the market, these companies need to implement new technologies in order to optimize production to survive in the global market [12, 18]. The problem of implementations of Industry 4.0 concept among SMEs confirms the results of research carried out in Germany which showed that large companies are much better prepared to make changes [19]. This confirms the need to carry out research in order to develop procedures and methods for implementing the concept of Industry 4.0 among SMEs.

It should be also noted that the authors of the analysed publication show directly in their work that the research should be planned and carried out for the introduction of the concept of Industry 4.0 for SMEs [12, 14] and suggest specific topics where research should be developed, i.e.:

- Production (with the use of systems CPS) [20],
- Logistics [9, 21],
- Management and business models [10] with work on management systems at an angle of technical solutions for CMS systems [11].

Attention is also drawn to the expansion of research on technologies available already for the Industry 4.0 concept. In the construction sector, it is indicated that from a technical point of view, there are many unsolved problems to be faced, such as the lack of standards for many technologies, higher requirements for the equipment and the increasing need for communication networks. Compliance with regulations
and legal uncertainty are the issues that should be also taken into consideration. It is pointed out that in order to effectively implement the innovative concept of Industry 4.0 in the complex environment of the construction industry further efforts are needed in scientific research, both theoretical and practical [22].

5. Conclusions

Performed analysis on current state of knowledge connected with the introduction of Industry 4.0 concept into industry with the special focus on SMEs related to the construction sector in the Thomson Reuters Web of Science Core Collection database allows to draw the following conclusions:

1. There is a steadily increasing number of publications related to Industry 4.0 since first publication in year 2013.
2. There is a limited amount of publications related to the Industry 4.0 & Construction and Industry 4.0 & SMEs, which indicates that this filed of research in general needs to be further developed.
3. SMEs are the sector which needs to be developed using Industry 4.0 concepts, especially in Europe, so that it could be competitive to the global market.
4. Preparation of special research facilities design especially for tests on Industry 4.0 concept is a good solution for improving knowledge about the 4.0 revolution.
5. Detailed areas of research indicated by authors of the publications in the WOS database related to Industry 4.0 & SMEs and Industry 4.0 & Construction that should be further developed are:
   a. Production,
   b. Logistics,
   c. Management and Business Models.

Authors are of the opinion that further development in the areas indicated by researchers of the publications needs to be carried out to extend the area of knowledge related to the possibility on introduction Industry 4.0 concepts into SMEs and construction sector. Authors plan to perform further analysis on the level of Industry 4.0 of readiness for SME construction companies in Polish territory and are planning a further research in this area.

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