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Moving Towards Industry 4.0: A systematic review

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Abstract— This study is done to understand the new emerging technology in automation and data exchange called the Industry 4.0. This study centered on incorporating the articles published in the recent years to establish knowledge on the topic, further identifying areas for future research.

Keywords—Industry 4.0, Fourth Industrial Revolution, Internet of things, Smart factories, Cyber physical systems

I. INTRODUCTION

In the 70s and 80s the rise of machines was the first industrial revolution that worried many people due to reduction of manual workers. It started in 1784 with the introduction of the first machines that used steam for power. The second industrial revolution, which initiated in 1870, started the assembly line production system which mostly used electricity and mass production of components was possible in this period [34]. The third industrial revolution kicked off with the introduction of the first programmable logic controller in the year 1969 using automation [13]. Efficient machines and robots were used in automation of industries in which the computer system and automation is widely used to manufacture parts. Finally in the year 2013 the fourth industrial revolution concept is based on the internet of things, cyber physical systems and cloud computing to manufacture the components [2] .

As the real world and the virtual world grows rapidly together with the Internet of the Things (IOT), which has inspired organisations to start an epic journey towards Industry 4.0 [40]. Industry 4.0 has become a buzzword that describes the trend towards digitization and automation of manufacturing environments [26]. "Industry 4.0" appeared at the first at the famous Hannover Fair in 2011. It was a project strategy of the German Industry [5]. The term was later adopted in the year 2015 World Economic Forum (WEF) in Davos, Switzerland and also appeared in "The Fourth Industrial Revolution," by Klaus Schwab, who is the founder and president of WEF.

The industrial automation systems enable much innovative functionality by accessing the networks and cyber world which in turn develops latest business models, work processes and development. These changes will have a profound effect on society and people [20]. IT perspective of Industry 4.0 includes a new stage of production, networking data processing and data integration. Technologies such as Internet of Things, Big Data or Cloud Computing provides the key to Industry 4.0. Smart manufacturing, Internet of things (IOT) and Cloud-based manufacturing are said to be the foundations of the latest Industrial Revolution [20] [45][49][50].Industry 4.0 allows machines, components, products, individuals, properties and ICT systems to create a smart network in a complete value range [25].

A distinctive idea for Industry 4.0 was put forth by Hermann et al. (2015) using a the method of literature review. The review pinpointed four crucial elements Internet of Things, Internet of Services, Cyber-Physical Systems and Smart Factory. Smart Products and machine-to-machine communication are not discrete Industry 4.0 elements. It is the initiator of the Smart Products and Internet of Things are a sub element of CPS. The Fourth Industrial Revolution is similarly referred to as "Smart Industrial Product", "Industrial Internet" or "Integrated Industry" [17]. In other countries it is also called "Industry du Future" in France, in US it is known as , "Industrial Internet" and "Industrial 4.0" in German.

Currently Industry 4.0 is a new concept and there is a lack of efforts in the systematic review of the topic. The main goal of this paper is the address the gaps by studying in depth the research articles from different journals and conferences on the topic Industry 4.0 thus making it easier for future researches. This paper attempts to consolidate the literature reviews available on the topic and be presented in a form that the researchers and academicians to focus and establish their knowledge on the topic, further identifying areas for future research. The methodology followed here is of a four step process adopted from Mayring (2004). The number of publications made, country wise researches, keyword analysis, research methods used etc., are analysed to identify the gap that this paper addresses.

II. Definitions for Industry 4.0

Industry 4.0 is a combination of Cyber-Physical Systems linked in the supply chain and manufacturing processes with usage of the Internet of Things and Industrial developments [2]. A definition for Industry 4.0 is that it is an (r)evolution towards digitalization.

A very hazy definition for Industry 4.0 was made by the FU in 2011. It defines Industry 4.0 as:

1. "The term Industry 4.0 stands for the fourth industrial revolution. It is understood better as a latest level of control and organization over the value chain of the product lifecycle, it is focused on individual customer requirements. The cycle starts from the product idea. Then order placement in made and product goes through the development and manufacturing. Then it makes it way to product delivery for the end customer where the cycle moves to the end phase, recycling. The availability of relevant information in real time by connecting all activities of the value chain forms the basis for the fourth industrial revolution. The connection of systems, things and people creates self-organizing, dynamic, real-time optimized value-added connections across companies. They are further optimised in accordance with different criteria like availability, costs and consumption of resources." (PWC.DE)

As this definition seems to be complicated at a glance, a more accurate definition by Acatech, (2013) is given. It sees Industry 4.0 as

2. "[…] the technological combination of CPS into logistics and manufacturing with the use of internet of services and things in the industry process. They have implications for downstream services, value creation, work organisation and business models."

A much clearer definition of Industry 4.0, can be difficult to achieve. The Industry 4.0 definition is still complex and misleading. A few definitions will declare it as "making the manufacturing industry fully computerized" whereas, it can also be said as to "make industrial production virtualized". However, on an agreement it can also be said as "that it integrates horizontal and vertical channels".

The reasons for lack of consensus in the definitions of Industry 4.0 could be because the transformation of industrial manufacturing goes beyond the factory and looks at the end to end chain like warehousing, logistics, etc. Alsothe Cyber Physical Systems are also a factor of Industry 4.0. As all these evolutions are connected it is difficult to come to a single definition for Industry 4.0.

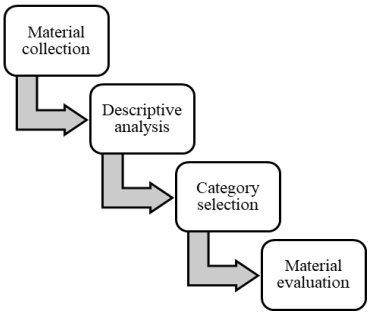
Like other emerging and latest technologies in the 21st Century, Industry 4.0 is not new. It's a reincarnation of a former theory which employs the latest technology. Industry 4.0 is a reevaluated technique for manufacturing that makes use of the newest and latest technological creations, especially in incorporating operational and information technology [8].

III. Methodology

Systematic literature review consists of a four-step process adopted from Mayring (2004). It is one of the successfully used methods in many literature reviews in operations management.

In the first phase leading databases such as Emerald, ProQuest, IEEE and Google Scholar were searched to congregate papers related to Industry 4.0 using keywords such as "Industry 4.0", "Cloud Computing", "Internet of Things", "Cyber Physical Systems", "Smart Manufacturing", "Big Data", etc... (Figure 2). Materials from white papers, reports etc. are not considered for this study.

During the second phase, the contents of these 52 papers were studied and classified based on their author's profile, keywords, research methodology and country of research and year of publications.



IV. Findings

A. Time distribution of Industry 4.0 related articles

With the rapid growth in the industry in applications and technology, various concepts have emerged. Therefore, many manufacturing industries have started their research on Industry 4.0.

In the year of 2013, the number of publications was less as Industry 4.0 was a new concept which was getting familiarized with industries. There is a considerable growth in publications since 2014 (Figure 1). Since then, the following years are witnessing a growth in publications. A Trend Analysis shows that in the further years there will be more publications to come. This show the inclination towards the adoption of Industry 4.0 is increasing.

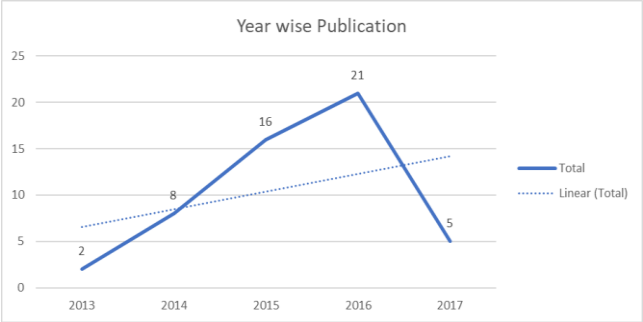


Figure 1: Year wise trend in publications

For this study, the articles collected and reviewed are more from conferences than journals that is, 65% of articles are taken from conferences and 35% from journals (Figure 2)

Figure 2: Contents taken from journals and conferences

B. Distribution of publications across different countries

The figure shows 17 countries have multiple publications till the present (Figure 4). Out of 52 articles, 52% of the publications are contributed by Germany, topping the list. Germany is the leaders of engineering and manufacturing. UK, USA and China follow with 6% of contribution. India has only a 2% of contribution to publication along with Taiwan, Sweden Italy etc... (Figure 3).

Many authors have published articles regarding Industry 4.0. They are contributed by academicians, professionals and both academicians and professionals. From the figure 4 or more authors have contributed to 24% of the articles published as of today (Figure 4).

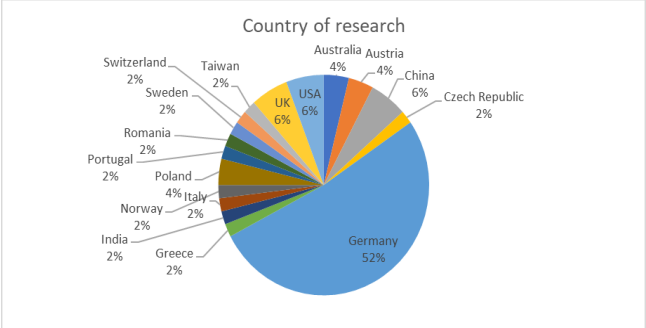


Figure 3: Country wise spread of research

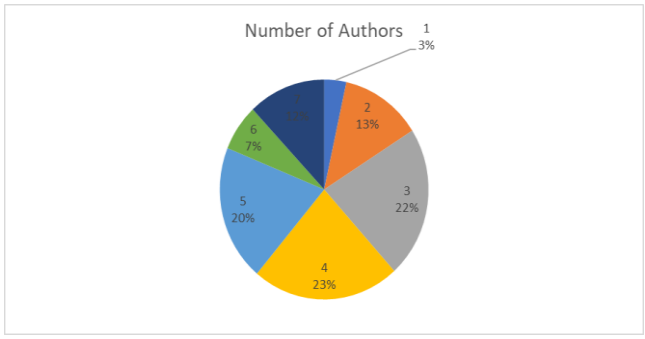


Figure 4: Number of authors

C. Analysis of research methodology

In this study, 27% of articles were quantitative and 33% qualitative. 40% of articles followed other methods (Figure 5).

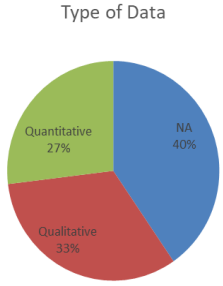


Figure 5: Types of data used for research

The researches were done by solving case studies, theoretical, models, literature review, and framework, conceptual and empirical approach. The most number of contributions to industry 4.0 was through conferences hence figure depicts that 27% of theoretical study was done followed by 23% of literature review (Figure 6).

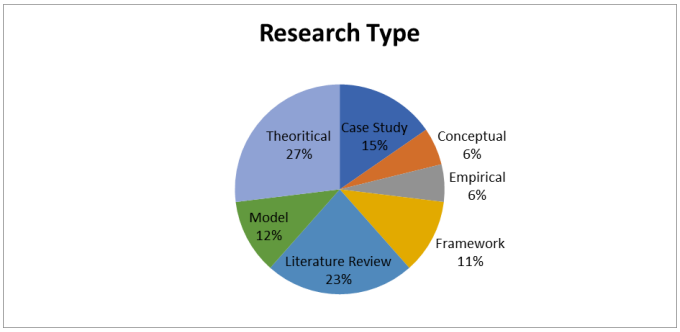


Figure 6: Research type used in the study

Germans had the most number of researches done comparing to other countries with most of their researches done in the year 2015 (Figure 7). The Germans are followed by UK with 2 researches in 2015 and 1 in 2016. USA follows UK with 2 researches in 2014 and 1 in 2016. Next came China with 1 in 2015 and 2 in 2016. Many countries like Austria, Czech Republic, Greece, Norway, Romania, and Taiwan have only started researches in the year of 2016. In 2017, Germany,

Poland, Portugal and Switzerland have done researches, with Poland having done 2 articles.

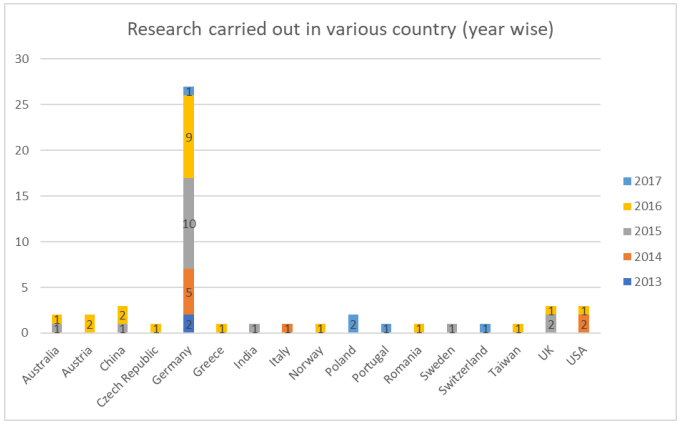


Figure 7: The research done in various countries year wise

Being the world leaders in Industry 4.0, Germany has adopted various research types like case studies (3), empirical (3), framework (3), literature review (7), model (3) and theoretical (8) approaches (Figure 8). Germany has followed the theoretical approach the most with 8 numbers of publications. They are followed by the UK who has adopted research types like Literature Review method (1), framework (1) and case studies (1).

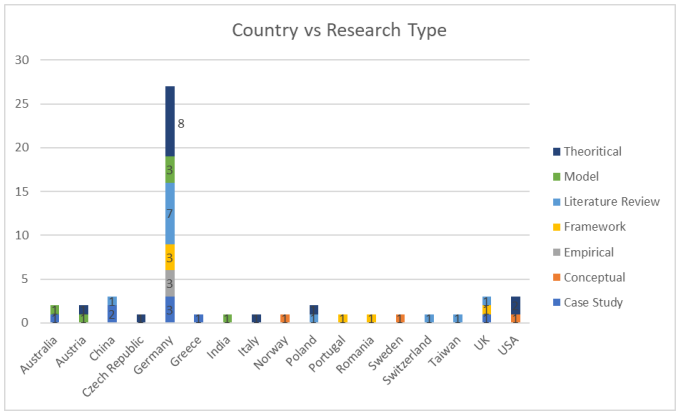


Figure 8: Different countries and research methods used

Figure 10 depicts that in 2016, the most types of researches were made. Methods such as theoretical approach (4), model approach (5), literature reviews (2), framework (5), Conceptual (1) and Case studies (4) were done. Model and framework methods were used the most in 2016 followed by the theoretical approach and case studies. From the years the trend shows a growth of the concept along with the research types.

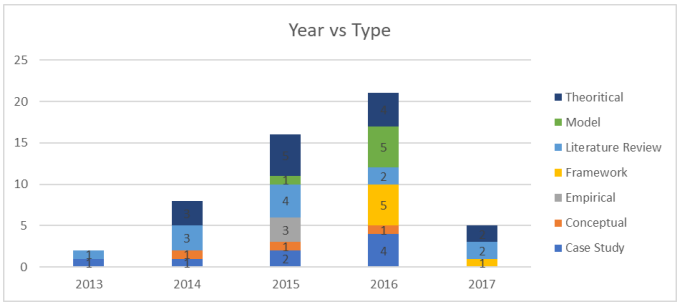


Figure 9: Change in the type of research throughout the years

Different researches use different data types (Figure 11). Quantitative data and qualitative data are used, and some are not applicable to both. The theoretical approach used 3 articles of qualitative data and the rest 11 uses other types of data which are neither qualitative nor quantitative. Literature review had 6 articles that use qualitative data and 6 which used none. Case studies were done with a qualitative data and 7 articles used quantitative data. Similarly,

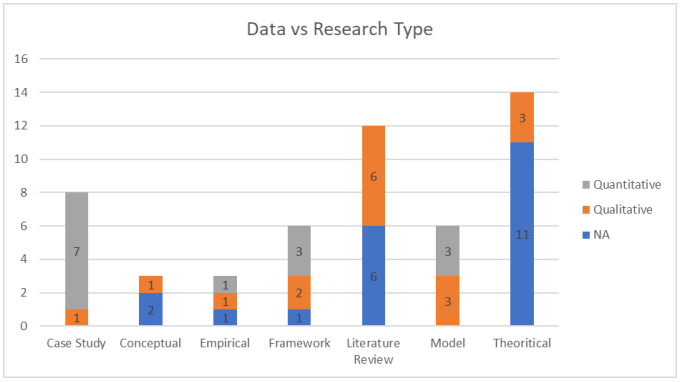


Figure 10: Data used for different research type

D. *Keyword Analysis*

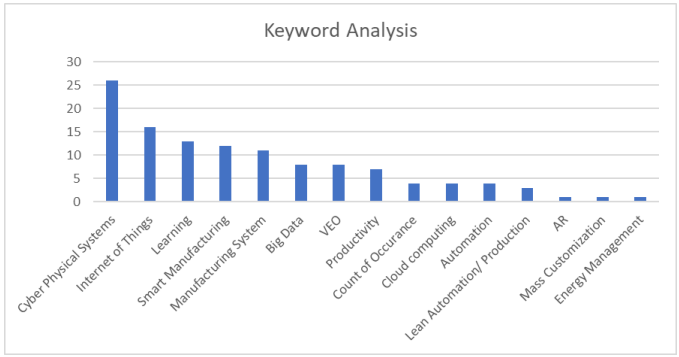


Figure 11: Keyword Analysis

Keywords of the papers were gathered to understand as to how authors have positioned their articles. Keywords conveying Industry 4.0 attributes were selected and grouped together (Figure 11). Multiple relevant keywords were also selected from the same article. Cyber Physical Systems and Internet of Things were expectedly related keywords that topped the list by appearing in 26 and16 papers respectively followed by

keywords such as learning and smart manufacturing is 13 and 12 papers respectively. Eleven papers and 8 papers contained keywords associated with manufacturing system and big data.

V. Discussion

A. Literature Review – gaps and agenda for future research

From the review, the author has found gaps from the articles. They are as follows:

- There is a need for the adoption of Industry 4.0 in various industries (manufacturing and IT industries) to study the impact of the improvement on the outcome of a company.
- Need for more conceptual methodology in research is required to easily interpret the concept and help to work more efficiently.
- Horizontal value chain helps Industry 4.0 to enormously merge step by step to give colossal suggestions in the industrial process.
- Industry 4.0 is found to have a presence in manufacturing industries the most with automation. Most industries like in construction, agro and food require a strong framework to meet the challenging demands in their activities.
- One of the most critical issues is that there is no generalised model for Industry 4.0 implementation for most of the industries. Hence there are no clear tool usages in various phases of the Industry 4.0 implementation.

B. Roadmap of Industry 4.0

Industry 4.0 combined with Internet of Things and Service, Cyber Physical Systems, Cloud Computing and Big Data have the potential to enhance industry performance, make new products and spark ingenious business models. It makes manufacturing devices to independently self-optimize.

The figure below shows the roadmap and development path of Industry 4.0. There are 4 different stages. They are:

Digital Beginner: Industrial companies are beginners on the path of industrial 4.0. At this level the initial digitization results are attained in all divisions as well as in discrete products and service portfolios. Compliance are not guaranteed in this stage and digital hazards are not documented.

Vertical Integrator: Is the second maturity stage of companies in Industry 4.0. Companies use integrated software also known as embedded systems and it allows internet based transmission of the product with the manufacturing mediums. The network existence provides market arrival by explicit online sites and product inventory.

Horizontal Collaborator: Is the third maturity stage that integrates the value chain with customers and stakeholders. It integrates customers, suppliers and subcontractors along the production line. It is better coordinated with logistics service providers and hence create proficiency with increase in quality, enhance the time for handling the process or shrink operating costs. Compliance is maintained throughout all the functions of the business and digital hazards are administered with improved methods.

Digital Expert: It is connected to its operative and executive processes worldwide and will virtualise these processes. The crucial executive procedures are globally improved according to the costs and control specification. The expansion of internet solutions for industries needs a large investment. One can follow many ways to achieve the title of digital champion. It should be based on its configuration of the existing product and service as well as on the operative and executive processes and capacity.

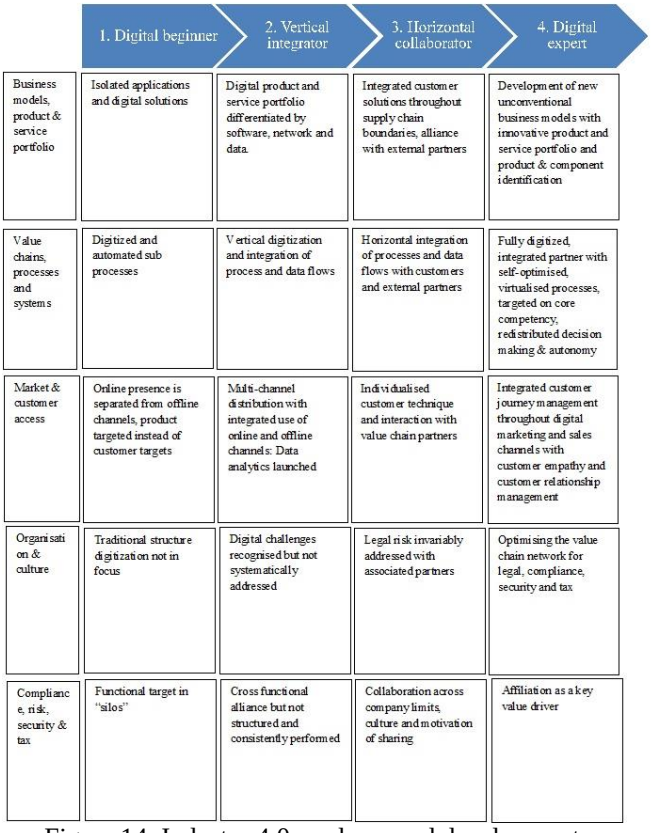


Figure 14: Industry 4.0 roadmap and development

C. Implications

The study is done in the field of Industry 4.0 spread in different industries of different countries using a systematic literature review. The study has identified Industry 4.0 attributes like research methodology adopted, type of industry, author profile and country of research which are important for researchers to understand how Industry 4.0 has evolved

through the ages in different industries. It also gives an insight into the contributions of authors from different parts of world. Researchers can refer to this study to learn amount the industry 4.0 spread in different industries. The advantages of Industry 4.0 can be understood so that practitioners can refer to it and create awareness among their workgroups. The research methodologies are discussed in detail. Out of 52 articles 27% used the theoretical approach. This shows that instead of theory building, practitioners should start working to find solutions for more practical problems. It is important that practitioners and researchers should be familiarized with the attributes of Industry 4.0 before starting their Industry 4.0 journey. Hence, this paper can be used as a reference for both researchers and professionals.

D. Limitations

Some papers on Industry 4.0 have only been published in which some of the articles might have been left out of the review because of the criteria for exclusion and inclusion which the researchers had developed to improve the accessibility of journals. Another limitation is that the spread is narrow which in turn failed in accounting tools used and waste elimination. Most of the articles have a theoretical approach rather than data driven or problem-solving approach. Hence, future researches can be done by focusing on the obstacles and critical success factors of Industry 4.0 in different industries.

VI. Conclusion

This paper consists and compiles various definitions of Industry 4.0 and aggregates the wide spread of articles based on Industry 4.0. This paper also presents a review of 52 research papers on Industry 4.0 from the 2013-2017. The review is done focusing on articles spread by analyzing the country spread, data and research methodology used in different countries and the number of authors.

Following conclusion can be drawn from the review:

- Countries like the UK, USA, Poland, Portugal, Czech Republic, India, Greece, Taiwan, Romania, etc. have published papers which show that Industry 4.0 research is conducted across the globe. Germany being the world leader and the major publisher and China is the major publisher in Asia.
- More research is based on descriptive studies rather than empirical studies.
- The number of conferences is more than journals which means that Industry 4.0 has a wide scope for further research.
- Most of the articles are focused on the theoretical approach which shows that it the base or the building blocks of Industry 4.0 is set though it lacks in data driven approach.
- Germany is the world leaders and the initiators of Industry 4.0.
- Germany followed different research methodologies to strengthen their research process.
- The success of Industry 4.0 depends on numerous factors and different dimensions.

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