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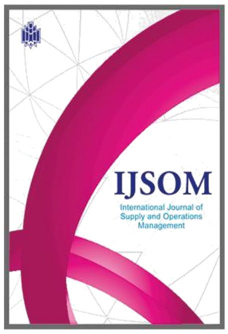

Towards Identification of the Hierarchical Link between Industry 4.0, Smart Manufacturing and Smart Factory: Concept Cross-Comparison and Synthesis

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Abstract
The industrial sector has historically been linked to the prosperity, development and evolution of nations, hence to the genesis of the philosophy of competitiveness, mainly at the manufacturing level. An environment is in perpetual adaptation to trends, and the best example is the change of industrial ideology, as was the case in the past. The global society is facing the same challenges. Customer demands are becoming more and more specific and personalized, which means that factories have to innovate in terms of production and management of mudas in an eco-environmental context closely followed by several global organizations. Information and communication technologies have become the joker to master in order to stay in a market that is global and very competitive. At the heart of this evolution is the emergence of the Industry 4.0 concept, which includes a key element that is intelligent production in factories of the future that can meet different obstacles. The purpose of the current research on one hand is to highlight the relation between I4.0, smart manufacturing and smart factory, and on the other hand to present a synthesis of Industry 4.0 national initiatives linked to the fourth industrial revolution worldwide.

Keywords: Industry 4.0; Smart Manufacturing; Smart Factory; Challenges; Initiative.

1. Introduction

Due to the widely spread globalization that is accompanied by advance in technology and interconnected processes, a continuous development is occurring in the industrial sector and different businesses are dealing with new and various challenges as mentioned by Yongxin Liao, Deschamps and Loures (2017). Throughout the history of humankind, four stages of industrialization are commonly identified (industrial revolutions) and the concept of industry, as cited by Fabian Hecklau , Mila Galeitzke, Sebastian Flachs (2016) ,in its fourth evolution is subject to a digital transformation with an intelligentization of manufacturing processes. The fourth industrial revolution became a trendy topic in many manufacturing conferences, thanks to two main acting forces, the first one is government plans, and the second one is consortium of leading companies in technologies of information and communication. The fourth stage as introduced by Selim Erol, Andreas Jäger, Philip Hold, Karl Ott and Wilfried Sihn (2016), is based on latest technologies and core components such as Cloud Computing, Internet of Things, and Industrial Internet of Things which may seem visionary but are quite realistic concepts. Internet and embedded systems (supporting technologies) play the role of the skeleton in the integration of human actors (agents), machines, materials, products and processes, within organizational parameters, resulting in a new type of intelligent value chain of the industry 4.0. In this digital age, companies are constantly pushed to cope with new advances in technologies and industrial patterns to answer the market need and be up to date to face competitiveness. Whether called "Industry 4.0" in Europe or "Industrial Internet of Things" as in the United States of America, its core concept or layer is "smart manufacturing" which enables manufacturers to converge the physical, digital worlds combining sophisticated hardware and software adapted to each kind of industrial activity, sensors, connectivity, and massive data to produce smarter products, more efficient processes and more closely knitted customers, suppliers and manufacturers.

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Information Communication Technologies (ICT) is in the midst of reshaping modern manufacturing and The Industry 4.0 brings forward interconnected factors such as Digitization of the technical network and the integration of the economical complex grid while digitizing the products themselves and the offered service. František Zezulka, Petr Marcon,Vesely, Sajdl (2016) presented all these elements as push for a new market genesis pairing it with a unification of communication systems. The structure of the remainder of paper is as follows. The first section presents a brief literature review, detailing the process conducted to collect the pertinent articles, elaborating the steps of how data was consulted based on the inclusion and exclusion criteria, succeeded by the preliminary results of the first screening. The last sub-section addresses the paper orientation and the research scope. The second section is about the Industry 4.0 phenomenon, starting by a definition of the concept, and then presenting its main technologies and key components, its design principles, impact and challenges. Finally a question mark on the aim of the fourth industrial revolution purveys an indication of the subsequent parts. The third section tackles the concept of Smart Manufacturing, defining it and considering its relation to Big Data. Thus, it introduces its main characteristics, supporting technologies, moving on to the portrait of international efforts by leading countries on the matter, and then broaches the Smart manufacturing conjecture, main pillars, and challenges. The fourth section deals with the aim of the revolution, Smart Factory, explaining the concept, setting forth the general surmise, and pinpointing the various aspects of its recurring challenges. A subsection is also included demonstrating the difference between a traditional plant and a smart one so that we exhibit the added value of the evolution. The fifth section reports the results found during the research in the form of a comparative synthesis between the 3 presented concepts discussed on four points including their definitions, the interest of the concept, their key elements as well as their challenges. The last section deals in more detail with international efforts on national policies and initiatives undertaken regarding the migration to industry 4.0. Among the findings of the section is the need for government support as a key actor to push forward digitization, as well as the educational system to supply the market with the right skills sets.

2. Review of the Literature

The adopted approach was build up on the PRISMA model (**1**Moher et al) depicted in Figure 1, beginning with identifying the key words and the desired time frame, then establishing a first screening while considering few criteria, looking for eligible papers from different sources and databases, starting the filter process, reviewing the selected ones and close scrutiny analyzing them.

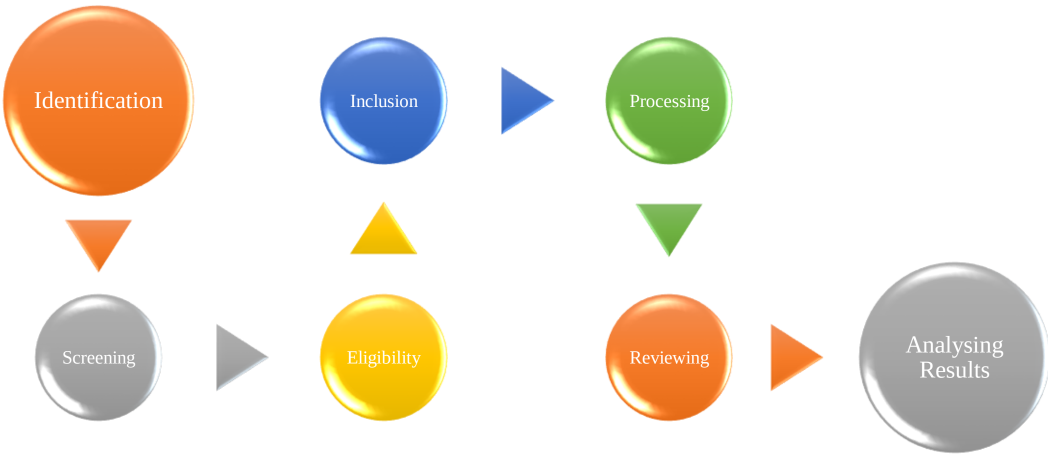

Figure 1. Review Steps

2.1. Consulted Databases and Paper Collection Steps

The research was conducted by looking for four key elements as shown in Table 1, which are Fourth Industrial Revolution, Industry 4.0, Smart Factory, and Smart Manufacturing. The systematic search used three electronics databases, namely Springer, Science Direct, and Google Scholar to collect academic research papers that are less than 10 years old and meet these conditions: have one of the identified words in the title, key words, or abstract, be written in English, and are published in journals, conferences proceedings, books, over the 2010-2019 time period.

[1] Moher et Al (2009) : PRISMA MODEL

Table 1. Keywords

	Google Scholar	Elsevier (Title, Topic)	Springer
Industry 4.0	837 000	122,112	135,475
Fourth Industrial Revolution	455 000	10,956	5,445
Intelligent / Smart Manufacturing	287 300	41,884	34 616
Smart Factory	94 100	7,619	4,983

2.2. Inclusion and Exclusion Criteria

Each collected paper was reviewed while considering inclusive and exclusive criteria presented in Table 2.

Table 2. Exclusion & Inclusion Criteria

	Criteria	*Explanation*
Exclusion	Search engine	The paper is written in a foreign language besides English, only its title and summary are in English.
	Without full text	Without full text to be assessed
	Loosely related	A quick mention to industry 4.0
Inclusion	Partially related	Research about the fourth industrial revolution Research about the smart manufacturing
	Closely related	Papers specifically related to smart factory and Industry 4.0
	Full text accessible	Access to full text

Borderline Condition 1: Some sources did not allow a full text access, but since their shared paragraph, preview, or figure was considered important and contained meaningful information, they were added to the references even though they were scarce. Additional conditions of elected sources: They were published within 2010 to 2019 time period, contained at least one of the identified key words or more in their abstract or title, and were written in English. The first step was to screen the papers/ reports and filter those which were loosely linked to the keywords. Then according to the second exclusion criteria, those with no access to their full text -apart from the borderline condition explained above- were eliminated. Then, all the papers from various sources that passed the second stage were briefly reviewed to exclude papers that did not focus primarily on Industry 4.0, or the fourth industrial revolution was not their main concern. The final step was to study all eligible papers in detail. Borderline Condition 2: Some reviewed articles were not included in the proposed time frame, but they were read because they contained useful information and were first works of same authors whose latest works were published between 2010 and 2019.

2.3. Data Collection Method

The total number of sources examined after going through the literature review steps explained above is 45, consisting of 25 Journals, 11 Conferences, as well as 9 Economic and Forum reports. Table 3 and Figure 2 below show the different academic sources reviewed per year.

Table 3. Conferences Sources/ Year

Year	2013	2014	2015	2016	2017	2018	2019
Number of Articles	1	1	1	5	1	0	2

Other than articles from journals, books, conferences, workshops, there were some useful economic reports from world organizations or consulting groups.

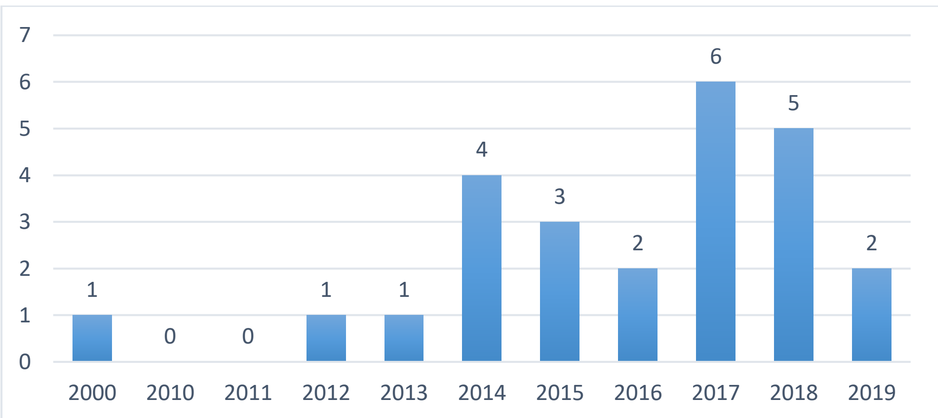

Figure 2. Screened Journal / Year

*Borderline Condition N°2

2.4. Preliminary Results

From our reading various papers and articles, we noticed few similarities based on the authors' nationalities, universities, and the uptake of the founding definition of the concept. So, we decided to emphasize certain points:

- ✓ The top scholars publishing in the years considered in this study are mainly Asians especially from Chinese, USA, and UK universities.
- ✓ All selected papers have mentioned the German Initiative concerning "Industry 4.0", and some of them relied on it to define the fourth industrial revolution.
- ✓ Most of the Countries, whose government launched the national policy to shift onto the new industrial age, have an estimated end-of-project interval$[2020-2030]$.
- ✓ The total number of countries concerned by the emergence of the 4.0 concept taken up in various papers and reports is 18 including USA, France, Germany, UK, China, Japan, South Korea, India, Spain, Malaysia, Taiwan, Canada, Italy, Netherland, Sweden, Singapore, Mexico, and the region of Europe.
- ✓ From 2011 to 2013, all published national initiatives were from developed countries especially from North America and Europe.

2.5. Paper Orientation and Research Scope

The main purpose of this paper is to synthesize all the international efforts of the leading countries at migration to the Fourth Industrial Revolution, and to shed light on the differences between Industry 4.0, Smart Manufacturing and Smart Factory. The orientation of the conducted review is in line with six fundamental questions that were established beforehand and considered relevant to the scope of this humble paper as seen in Table 5.

Table 5. Guiding questions

	Question	Reason
Q1	What are the enabling features of Industry 4.0?	The main objective of these questions is to understand the concept and delimit the various parameters involved.
Q2	What are the main principles of Industry 4.0?	
Q3	Who is working on industry 4.0?	To analyze not only the extent of research on the concept but also the different current perspectives.
Q4	What is the link between Smart Manufacturing and Industry 4.0?	To differentiate between the two notions and to detect the link between the two.
Q5	What are the main challenges for both?	Because each concept has obstacles to tackle; Determine the challenges for each concept.
Q6	What is Smart Factory?	To validate the link between the industrial revolution and the factory of the future.

The aforementioned questions represent the main chapters or sections of the work presented, which in fact clearly show the purpose of the paper to the reader. From question 1 to question 3, we dedicated the whole section 2, Q4 & Q5 address the third section; Q6 is linked to the third concept and Section 4.

Throughout these sections, the aim of the paper is to accent the link among the three concepts and attempt to decipher their hierarchical relationship.

3. Industry 4.0

According to Ray Y. Zhong, Xun Xu, Eberhard Klotz, Stephen T.Newman (2017) , the phenomenon Industry 4.0 emerged as a German strategic national initiative with the aim of creating smart manufacturing plants where manufacturing technologies and tools are upgraded and transformed by[2] Cyber Physical Systems, the Internet of Things, the Internet of Services and Cloud Computing.

3.1. Industry 4.0 Concept

The concept became prominent in the last few years; Keliang Zhou, Taigang Liu, Lifeng Zhou (2016) portray it as an embrace of the industry to a set of technological boosts and strengthening that facilitate having a high impact in the ongoing industrial terrain. The term "Industry 4.0" first appeared in a paper published in 2011 by the German government which had resulted from a plan for high tech vision and strategy for 2020. Since 2016, the I 4.0 concept has had a significant impact, following a publication on the phenomenon at the World Economic Forum by its founder. I 4.0 has become the term that describes the impact of technological advances of the last century: Everything is changing whether it is social norms, economic development or even national policies. Industry 4.0 is a part of the fourth revolution. Figure 3 shows all the four revolutions and focuses more precisely on the relationship between digitalization of processes, structural and organizational transformation, productivity, and cost reduction in a manufacturing environment.

[2] Kagermann (2013)

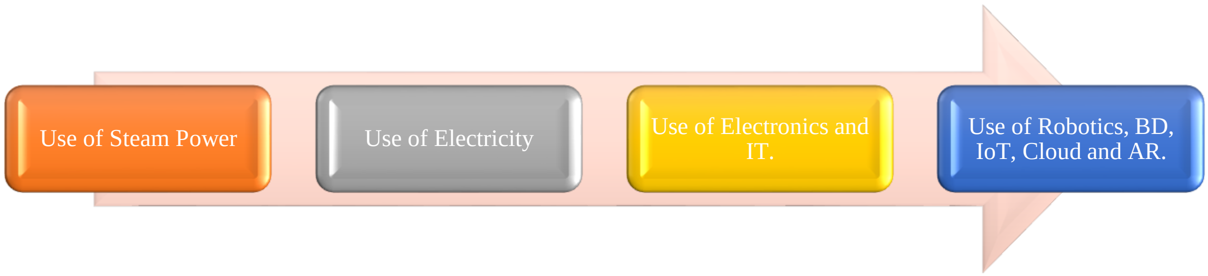

Figure 3. Industrial Revolutions

3.2. Industry 4.0 Key Components

Industry 4.0 principle (Keliang Zhou, 2016) is to adopt new manufacturing technologies explicitly explained in Table 6, computer and automation technologies in parallel embracing the network communication technology, while basing it on a shift to digital manufacturing. Industry 4.0 set of technologies can be divided in two principal layers[3]: front end technologies and base technologies (Alejandro Germán Frank, 2019). The front end technologies consists of smart supply chain, synchronization of production with the suppliers with the objective of reducing delivery time, irregularity in stocks and information distortion that produce bullwhip effect. Smart Manufacturing is based on an adaptable manufacturing system where there is multitude of lines that are flexible and adjustable automatically, and where instant production processes are launched to help attain customized products, Smart Products, that can provide data feedback for new product development, as they can provide new services by presenting new solutions to customers, whereas the base technologies consists of Cloud, Big Data, CPS, and IoT. The front-end technologies are apprehensive with operational and market's needs. The smart supply chain and smart product are interconnected with the central axis of the first layer's technology which is smart manufacturing. The base layer is described, Fei Tao, Jiangfeng Cheng, Qinglin Qi, Meng Zhang, He Zhang and Fangyuan Sui (2018), as a layer that supports technologies; their ultimate goal is to facilitate and allocate connectivity and intelligence for front-end technologies. This specific layer is the key driver to enable Industry 4.0 phenomenon, it allows the connectivity of front-end technologies in an integrated manufacturing system.

Table 6. Main technologies of Industry 4.0

Cyber Physical Systems - Jay Lee, Behrad Bagheri, Hung An Kao (2015).	Its purpose is to enable the management of interconnected systems to interact with both environment the physical and the virtual one, integrate and coordinate operations and processes, control them, while proffer data for a frequent assessment with the help of Big Data Analytics. CPS once used in a production context are called cyber physical production systems, and their main trait is allowing a connection crossing all levels of production.
Internet of Things – Eleonora Borgia, (2014).	Represents the link and Connection between physical things and the internet, endowing everyday object with intelligence, its vision goes further than just collecting information, it lets them interact with their environment and interconnect with other smart objects, allowing an exchange of data and triggering actions through the net.
Internet of Services – Daniele Miorandi (2012).	A just born concept giving business and technical basis for business network between service providers and customers. It impacts the value creation inside the value chain.
Cloud Computing	Facilitates the exchange, sharing of voluminous data between sub systems, plants, systems. It renders access to shared computing resources easy , Jay Lee, Hung An Kao and Shanhu Yang (2014).
Big Data Analytics	Processing voluminous, complex, huge amount of data from a variety of sources and formats to make sense and better decisions. The data source may be the processes, the product, and the customer information, Sarah El Hamdi, Abdellah Abouabdellah and Mustapha Oudani (2019).

3.3. Industry 4.0 Challenges, Impact and Design principles

The fourth industrial revolution is based on traditional factories and combines their strengths with the latest technologies; the products of this new industry are intertwined into digital and physical processes. (Rainer Schmidt et All, 2015) find it a disruptive way of proceeding, which changes the traditional knowledge of supply chain, business models and processes. The manufacturing is the most impacted sector within the fourth industrial revolution. The previous vision was mass production of special products with special resources, however, with the unexpected arrival of the phenomenon the manufacturing vision shifted to the mass customization. An approach that is not void of complexity: The manufacturing processes and operations will be deeply influenced by the technological advances and developments (establishment of smart factories). The productivity increase as argued by Alan Alves Pereira and Fernando Romero, (2017), has always been the core of every shift in industrial revolutions, nevertheless, with the current concept of the industry 4.0, the whole supply chain will be affected, meaning from the manufacturing of the products to development and engineering processes to outbound logistics. The industry 4.0 was designed, Figure 4, as an upcoming industrial revolution that oversteps the targeted increase of productivity as a sole objective of evolution, Chiara Cimini , Giuditta Pezzotta, Roberto Pinto, Sergio Cavalieri, (2019) work based this evolution on three main pillars which are, first, virtualization, i.e. being able to monitor physical processes with the help of cyber-physical

[3] Alejandro German Franck et al (2019)

systems; second decentralization - delegation of decision-making to CPS enabled embedded computers, and finally time collect of data, that is, the ability to react in time.

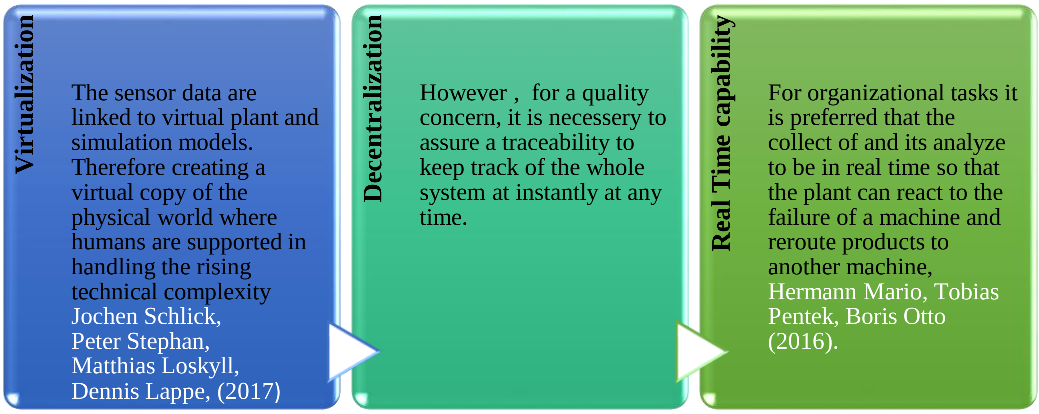

Figure 4. Design Principles

3.4. The question is what is the Aim of Industry 4.0?

As seen in Figure 5, is it to achieve Smart/Intelligent Factory or increase various factors such as efficiency, productivity, mass customization, and energy awareness?

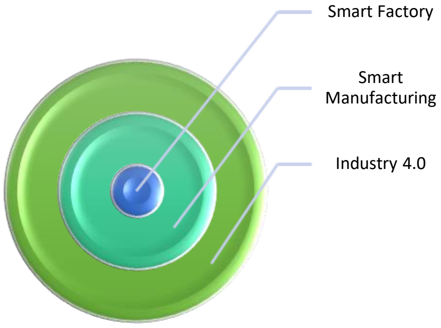

Figure 5. Core of Industry 4.0

Through our readings, it turned out that the future of production, as it is insinuated by Industry 4.0, consists of a generalized integration, in which each manufacturing element autonomously exchanges information, triggers actions and controls.

4. Smart Manufacturing

4.1. Definition

Intelligent Manufacturing or Smart manufacturing uses latest technologies and advanced data analytics to empower system performance and its decision-making ability. Jinjiang Wang, Yulin Ma, Laibin Zhang, Robert X. Gao, Dazhong Wu(2018), promulgate that due to the spread of sensors and IoT, a huge increase in manufacturing data, data volume, as well as data velocity is felt and data analytics helps handle it with assessing and processing. Smart Manufacturing embraces a lot of latest information and communication technologies plus smart facilities, and helps create and spread a positive impact within the entire organizational structure. The data that is collected through sensors differs in its source, semantics and even formats, for example, the data may be collected via manufacturing tool, process, product line or people. Andrew Kusiak, (2017) assigns to Data modeling and analysis the role of being an important part of smart manufacturing; it is making it easy to handle increased high-volume data, as well as supports real-time data processing.

4.2. Smart Manufacturing and Big Data

In this subsection, we would like to clarify the intertwined tie among 3 interesting axes of smart manufacturing. The ensuing Figure 6 demonstrates the link between smart manufacturing and Big Data. Starting with retrieving data from smart connected devices, processes and objects, get the valuable data and understand within the company's environment what happened, for what reason and what is the action to take. Then make the decision about either the product, production, process to improve it and enhance it or all of them.

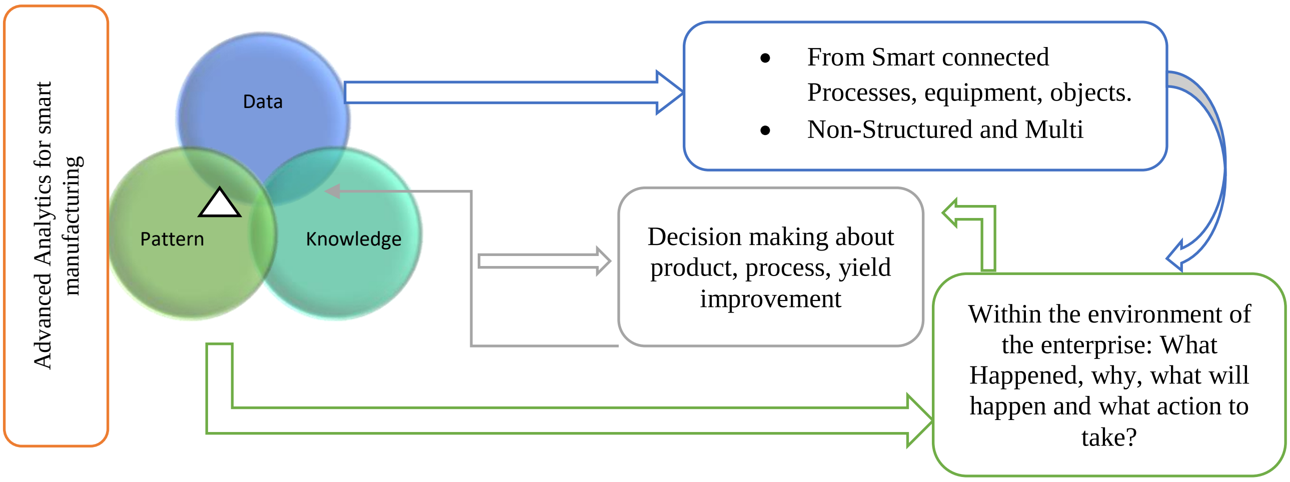

Figure 6. Trium Virat of Smart Manufacturing

4.3. Smart Manufacturing's Characteristics and Supporting Technologies

The manufacturing industry has gone through a lot of evolution, massive shifts from Fordism, Toyotism, flexible and reconfigurable manufacturing to cloud manufacturing, with the latest paradigm being born in 2000s. In this regard, as cited in Lihui Wang, Martin Törngren and Mauro Onori (2015) paper, multiple countries leaned on the question of the fourth industrial revolution and developed strategic thinking lead either but states 'council or leading companies to dress blueprints to transform manufacturing and take advantage of the emerging technologies; Figure 7 below details the major characteristics and the supporting technologies.

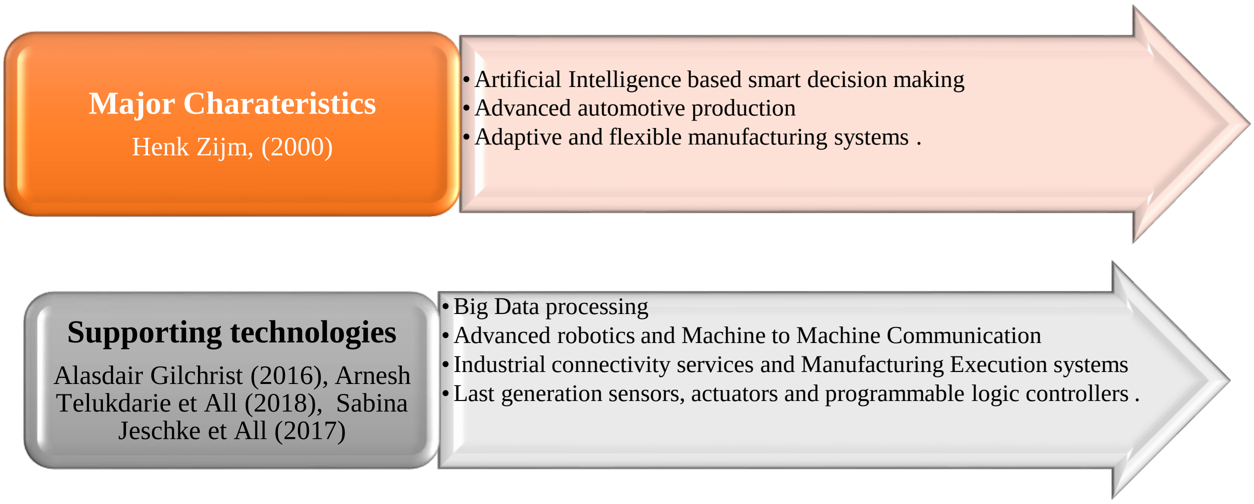

Figure 7. Characteristics of Smart Manufacturing

Smart manufacturing, also called Intelligent Manufacturing, Peng Wang, Robert X. Gao and Zhaoyan Fan, (2015), it refers to a new manufacturing pattern where manufacturing equipment monitored by sensors and connected via wireless networks is utterly supervised in order to elevate and boost the product quality by advanced computational intelligence and to increase system productivity while keeping in mind one of the ultimate and basic goals which is to reduce costs. Dazhong Wu, David W. Rosen, Dirk Schaefer, (2014) present the latest development progress in terms of Internet of Things (IoTs), Cloud Computing, and Cyber Physical System (CPS) as a provider of key supporting technologies for advanced modern manufacturing. Germany was the first country to introduce the framework of the fourth industrial revolution, and then it went on to be collaborative efforts among West European countries. Yuqian Lu, Xun Xu and Jenny Xu, (2014). Report on the smart manufacturing coalition in the United States, which created systematic framework to implement smart manufacturing; Similarly, China introduced in 2015 "Made in China 2025" to promote advanced manufacturing. In Table 7, international efforts by world leaders in Industry 4.0 are briefly portrayed.

Table 7. International Efforts

Country	***Year***	***Plan Title***	***Details***
Germany	2011-2013	Industry 4.0	Use of intelligent sensing and wireless sensors network to elaborate intelligent systems that communicate with each other independently and instantly. Work on Intelligent machines, smart products and CPS.
European Union	Horizon 2020	**Factories of the future** Loic Tassel (2019)	The initiative launched in Germany became a widespread wave throughout the western countries of Europe. Their joint effort is the biggest ever research and innovation program; its main focus is to define high added value manufacturing technologies for the plants of the future, plants that respect environment and are high performing and sustainable.
USA	2012	Industrial Internet of Things	The most prominent organization leading the research is Industrial Internet Consortium led by GE and Cisco. The concept was first introduced by General Electric, a leading entity in the US Industry. The idea is that smart decisions should be made by machines and humans, and for the first part of the equation to do its work, intelligent machines and advanced analytics are mandatory; the other key element of smart manufacturing is connected people. The majority of the research done in US emphases its interest on the top layer elements of smart industry such as cloud computing, big data, and virtual reality.
Japan	2015	**Industrial Value Chain Initiative** Yasuyuki Nishioka (2019).	The goal of the Japanese initiative is to combine manufacturing patterns, processes, tools, with information technology to design a new society in a world of manufacturing. So, to connect the businesses via internet; the IVI forums led by companies such as Mitsubishi, Nissan Motors and Fujitsu discuss how human-centric manufacturing will change with the IoT. They aim to put aside the individual competitiveness and go for a mutually connected system architecture based on scenarios collaborated upon previously. Japan is considered in a leading position worldwide for robotics and Internet of Things in production.
China	2015	**Made in China 2025 Initiative** Ling Li, (2018).	An initiative launched in May 2015 by the state's council in order to upgrade the nation's manufacturing capacity in selective sector such as Energy, Aviation, Agriculture, Health and to catch up to rivals like USA or Germany. It aims to increase innovative capability, promote a deep fusion between information and industrialization, and advance service-oriented manufacturing. The main contribution to aspire to is establishing an intelligent manufacturing standard system.

4.4. Smart Manufacturing Pillars, Challenges and Conjecture

As any concept, Smart Manufacturing leans on different kinds of principles and advanced technologies, Figure 4, adapted to manufacturing production systems. Smart manufacturing is based on data analytics as mentioned before and smart devices. The idea behind the implementation and emergence of this concept is to reach manufacturing solutions that will not only facilitate the processes, various operations and forecasting but also attain the ideals of manufacturing production systems that are sustainable.

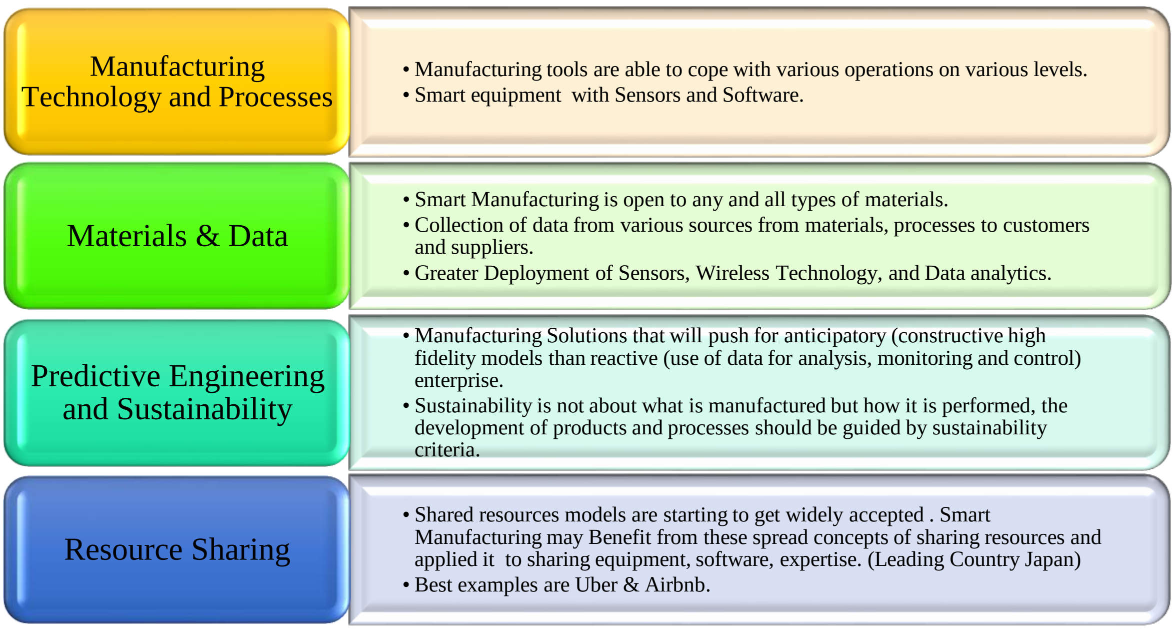

Figure 8. Four Pillars of Smart Manufacturing adapted from Andrew Kusiak (2017).

As the smart manufacturing offers opportunities, its reverse of the medallion uptake challenges, in the face of any change, is a resistance; the acceptance of this new and emerging manufacturing concept is the first challenge. The factory automation supported by the latest generation of robotics will create new jobs; this conversion of skills will be the second challenge. The educational establishments need to work on answering the job market needs and training a workforce that matches the defined description of future profiles. The transformation towards smart manufacturing is a huge and enormous task, and no single corporation can effectively do it on its own. Thus, the need for collaboration is immensely required, particularly when faced with market and technology uncertainty. One of the main challenges that will remain an issue regardless of the industry type is human and machine safety. Sameer Mittal, Muztoba Ahmad Khan, David Romero, Thorsten Wuest (2019), name Cyber security as the other important feature of the industry of the future, especially with the increasing volume of data that plays an important role in business competitiveness. Smart Manufacturing is increasingly dependent on data, which implies, the increase in data volume, data analysis, data storing and sharing processes is already happening around the world in many manufacturing sectors. Other than the dependence on data, there is a rise in reliance on modeling; since the data is voluminous, there is naturally an inquiry about the delivery of its value, and data-driven modellings approaches allow the integration of various parameters from products, processes, logistics. Dynamic predictive models build on these approaches will become a differentiating factor from traditional manufacturing.

5. Smart Factory: Concept and Challenges

5.1. Smart Factory definition

“Smart factories constitute a key feature of “Industry 4.0”. The Smart Factory is defined Henning Kagermann , Wolfgang Wahlster, Johannes Helbig, Ariane Hellinger (2013), as a factory that is aware of its environment and assists through embedded systems, Internet of Things and Cyber Physical Systems, people and machine in execution of their tasks .

5.2. Smart Factory Concept

Agnieszka Radziwon, Arne Bilberg, Marcel Bogers, Erik Skov Madsen (2014), depict One of the key aspects of the new industrial evolution which is Smart factory. They summarize the different addresses of the concept drafted through the fourth revolution descriptions by restraining to the creation of a self-aware intelligent environment, allowing real time communication of different manufacturing resources with a flexible structure, boosting the adaptive processes yield and adoption of smart solutions.

5.3. Comparison between traditional Manufacturing and smart Factory Manufacturing

In a try to exhibit the gap between the traditional plant and the smart factory, Table 8 below depicts seven major differences.

Table 8. Smart factory compared with the traditional factory

Traditional Factory production	Smart Factory production
• Production in a mass of specific products with fixed line of production. • Configured resources to the product manufacturing. • Limited approach by predetermining the input. • The change to the production setting is done by people with system down. • Communication between machines is not necessary. • The devices on the fields are not linked to the upper information systems. • The machines are preprogrammed and preconfigured to perform the wanted assignment or function.	• Production of multiple small lots products, on demand or upon request. • Various resources coexisting in the production system. • Dynamic switch between manufacturing of different products directly induces a dynamic switch in the needed resources per se. • Products, processes, people and machines are interconnected and interact with each other. • An operating factory in a networked environment. • Each entity has a control function enabling them to deal with organization dynamics. • Production of voluminous data with cloud processing.

The difference is apparent, the very philosophy of the two modes is opposed: At the traditional level, machines and information systems are tools to improve and manage the plant while at the intelligent level information systems and machines become important actors in the factory environment, because the information that emanates from them has a direct impact on the decision-making and, in turn, on the productivity and performance of the plant.

5.4. Smart Factory Challenges

IEEE Special section publications reports that Smart Factories need a smart pair of hardware and software, such as smart machines controllers, high bandwidth devices, sensors, actors, and big data analytics software linked to manufacturing and integrated systems. Another important key aspect identified by Christoph Herrmann, Christopher Schmidt, Denis Kurle, Stefan Blume, Sebastian Thiede, (2014), is sustainability brought up by the smart factory concept, the smart plant assists the enactment of sustainable production in a context where the leading industries in the well-developed countries are leaning towards energy awareness and sustainable development as a global challenge. Shiyong Wang, Jiafu Wan, Di Li, Chunhua Zhang, (2016), outline the smart factory as a bringer of novelty to business models and directly affect our lifestyle. However, as each innovative implementation faces challenges, to put into effect the move towards the smart factory, there will be some challenges that need to be dealt with. The Aim of Industry[4] 4.0 is to establish Smart Factory, a factory that has the ability to self-adapt, is reliable, has energy-awareness “Eco-Friendly”, and disposes of high level of cross later integration. Therefore, this kind of factory faces some challenges:

- ✓ Technical
- ✓ Structural
- ✓ Operational
- ✓ Managerial independence of the shop floor and the enterprise constituent system
- ✓ Interoperability: meaning that all CPS within the plant (carriers, assembly section, products) can communicate with each other through open nets, (Hermann Mario et All, 2016).

To meet these challenges, deep research and amelioration are needed keys to achievement especially in a standardized communication framework to be fully developed into a mechanism, efficient monitoring, effective and flexible manufacturing resource management, transparent data processing.

6. Main Results and Findings

In this part, we retrace the most relevant findings and we divide them into two major axes. First, a synthesis of the differences -from Table 9 to Table 12- between the 3 concepts on 4 tables and then a synthesis of efforts at the international level are presented.

6.1. Comparison of the Concepts

Table 9. Research Interest

Component	Industry 4.0	Smart Manufacturing	Smart Factory
Research Interest	79,5%	8,5%	12%

Through our research, we observed that the most prevalent concept from 2010- to 2019 is industry 4.0, a topic trend given the impressive number of papers, conferences and seminars dedicated thereto; followed by publications on smart factory with a sizable gap, in the third place we find smart manufacturing.

Table 10. Concept comparison

Component	Industry 4.0	Smart Manufacturing	Smart Factory
Concept	Started as a German national initiative, it is the concept that embraces technological boosts adapted to manufacturing production system.	The front-end technology layer to Industry 4.0, it uses advanced technologies to boost system performance and its decision-making ability.	A core feature of the Industry 4.0, the plant is aware of its environment, benefiting embedded systems.

Our second finding concerns our hypothesis stated in section 2 of the paper, and answers the question 'what is the objective of industry 4.0?'. By analyzing the definitions of the three concepts, we detect that not only are they intertwined, but that there is a hierarchical relationship between them.

Table 11. Comparison of the Main Elements

Component	Industry 4.0	Smart Manufacturing	Smart Factory
Key Elements/ Main technologies	The key elements are divided in front end and base layers, this last one is focused on the supporting technologies such Cyber physical systems, IoT, Cloud Computing, Big Data Analytics.	Its supporting technologies are big data processing, advanced robotics, M2M communication and the latest generation of connected devices.	Embedded systems, IoT, Cyber physical Systems Autonomous Machines. Real time communication of various manufacturing resources through connected devices.

This comparison reinforces the idea that the three concepts are intrinsically linked because they share advanced technologies; nevertheless, it is discernable that smart manufacturing is part of a layer of industry 4.0, and that smart

[4] Ray Y. Zhong et al (2017)

factory is based on certain principles of intelligent manufacturing. In other words, the assumption that the target of Industry 4.0 is to establish the smart plant is recognized.

Table 12. Comparison of the Challenges

Component	Industry 4.0	Smart Manufacturing	Smart Factory
Challenges	✓Complexity of manufacturing processes. ✓Reengineering processes. ✓Impact on supply chain. ✓Cyber security.	✓ Conversion of skills. ✓ Market and technology uncertainty. ✓ Human and machine safety. ✓ Dependence on Data.	✓ Technical challenge. ✓ Organizational. ✓ Interoperability. ✓ Skills sets.

Each concept has its share of challenges. Some challenges are transversal like the resistance to the digital transformation and all that it insinuates. Others are more specific for each concept, for example industry 4.0 is facing challenges related to process re-engineering and cyber security. For Smart Manufacturing, in addition to challenges inherited from Industry 4.0, market and technology uncertainty among others are tricky. Regarding Smart Factory, its challenges are directly tied to the organization of the plant, the skills sets and the Human Machine interaction.

6.2. International Efforts Synthesis

After launch of the initiative in Germany in 2011, it became widespread, first in European countries with the objective of establishing intelligent systems that communicate in an independent way and right away. In parallel, USA leading companies introduced the concept through their consortium, basing their approach on smart decisions that should be taken by humans and machines; to do so, they have concentrated their work on the technology layer such as Big Data and virtual reality. Whereas the Asian counterparts Japan and China both started their national policies in the same year with different patterns, inasmuch as the Japanese initiative is led by a forum constituted by the leading company in automobile industry, in a way their approach resembles the American one; their aim is to build a mutually connected system architecture, However, the Chinese initiative originated from the state's council, resembling the German Initiative, and their goal is to upgrade the nation manufacturing capacity in certain sectors.

7. Discussion

The countries involved in the industrial revolution will experience a change in their world ranking by 2020 as cited in Table 13; the estimates explained in the 2016 Deloitte report, reveals the new ranking of the power houses.

Table 13. Ranking by 2020, Source Yongxin Liao

1	2	3	4	5	6
USA	CHINA	GERMANY	JAPAN	INDIA	South KOREA

*Most European nations are expected to slip in the overall competitiveness rankings in the next two years.

Each National initiative or Public policy was established with a main focus as described in Table 14, to help with and/or answer the country's own needs and issues. Their focus may vary as it is shown in Table 10 but they all share common goals, collaboration among industries, collaboration beyond industries reaching academia and government agencies with an extension to labor organizations.

Table 14. Various Focuses of National Initiatives, Yongxin Liao et All (2018)

Country Focus	Innovation	Technology	Human	Product	Economy	Competitiveness
USA	X	X	X			X
Germany	X	X	X	X		X
China	X	X		X	X	
Japan	X	X	X	X		X

Japan may be the exception in establishing a focus on sustainability as an important pillar in their shift to industry 4.0, whereas both China and USA lean more on policy and physical infrastructure realization. After analyzing all the articles and reports, it became clear that the presumption that the leaders of the migration to industry 4.0 are the American and European poles no longer holds. Two poles lead the actual game, North America and Asia Pacific: Other than China, Japan and South Korea, the mighty five come in force, M.I.T.I.V stands for Malaysia, India, Thailand, Indonesia and Vietnam. They are establishing dominant positions as regional manufacturing centers Yongxin Liao, Eduardo Rocha Loures, Fernando Deschamps, Guilherme Brezinski, André Venâncio (2018) : From 2013 to 2019, the publications claim that all countries interacting with the concept of Industry 4.0 build their plans while considering minimum of two out of the three following pillars: Human, technology and Infrastructure. Their national policies towards the fourth revolution have actions related to research, education and modernization, even if the priority given to the technology differs from one country to another, Japan with its center of interest being advanced robotics, USA with a clear objective towards Internet of Things, or Germany paying particular attention to Machine to Machine.

Klaus Helmrich (2019) defines Governments as an essential actor in pushing forward national initiatives, they must provide the right regulatory impetus for research, infrastructure, IT security, and education, in a coordinated form :

- An ecosystem favorable to research applied to technology, in order to turn them into usable products.
- Reliable, available access and a good extent of information technology infrastructure are essential for Industry 4.0.
- Each digitization process must be accompanied by cyber security.
- The education system , (Craig A, et al Giffi, 2018) must be reoriented towards new development related to the digital world from software, programming, IT security to data analysis which represent Foundations intrinsic to the application of Industry 4.0.

Stephen J. Ezell, Robert D. Atkinson, Inchul Kim, Jaehan Cho, (2018) reported that most of the countries, after launching their national policies, started creating initiatives targeting factories, and those who are leading the change are most renowned companies such as General Electric, Siemens, and Mitsubishi. However, South Korea outstripped other countries by taking the step of independently establishing a policy and strategic vision for the smart factory, creating a ministerial branch of their Ministry of Trade, Industry and Energy to follow up and put forward a goal of 10,000 factories for SMEs by 2020.

8. Conclusion

This paper has two principal goals; the first objective is to review and analyze academic papers, industrial and economic progress related to the fourth industrial revolution while providing insights into various and different national initiatives and policies of the most developed countries. An overview of I4.0 is first captured by listing relevant journals and prominent conferences related to Industry 4.0 content. Followed up by examining the two most related topics to Industry 4.0, which are smart manufacturing and smart factory, special attention was given to various aspects as discussed by Paul Wellener (2019), like main challenges of the different key elements which are leading the revolution, for whatever reason. The other objective is more discreet; the aim is to prepare the ground for a future work whose main goal is to set a benchmark of the worldwide national policies in details, in addition to a work of profiling on the jobs which will disappear, and those which will be born following the industrial revolution that is under way. The spark of interest in this second objective is associated with one of the four aspects mentioned in the discussion section, which is education.While reviewing economic reports, universities ranking was reeled; once examined, it was clear that the power horses rankings leading the fourth revolution were also considered power horses in the educational system, since on first thousand ranked universities, USA, China, Japan, Germany, South Korea, and India have taken nearly 50% of the top ranks. This humble synthesis was limited by several factors like access to articles and databases as well as including English as the only language in the analysis, which could have filtered several interesting articles.

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