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# INDUSTRY 4.0 –REALITY AND THE GLOBALIMAGE

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**ABSTRACT**: Industry 4.0, the fourth industrial revolution is here and it is irreversible. This article presents the importance of understanding the newest industrial revolution for world economies, furthermore from an economical and managerial point of view, introduces the concept of Industry 4.0 together with related Internet of Things, Smart Factory components and then finally acknowledges the evolution at a global perspective looking at programs and policies in the major industrialized countries as well as in development countries from Eastern Europe and Asia.
**Keyword:** Industry 4.0, Internet of Things, Smart Factory, Forth Industrial Revolution, Automation

## I. INTRODUCTION

Why is it important to discuss the Fourth Industrial Revolution- the so-called 'Industry 4.0' phenomenon? Simply because, asis the case with any revolution, its fast-moving and disruptive character will bring radical changes to the value chain of any traditional enterprise. Further, Industry 4.0 will change design and production systems, the manufacturing operation, logistics, the after-market and other services– and so will have a global effect on the major features of our economic, political and social environment. However, as was the case with previous revolutions, its spread will not develop at a uniform pace or simultaneously in all countries and regions, or in all sectors of the economy. One of the reasons for this is that the investment needed for such technology is enormous and its payback time will be long -perhaps even longer than the life–time of the product itself - whilst strategies are generally shaped for shorter periods. Earlier industrial revolutions were all triggered by technical innovation: the late18th to mid-19thcenturies' water- and steam-powered factories, the early 20th century's division of labour, together with the universal use of electricity, and the1970s'introduction of the programmable logic controllers (PLC) & IT systems - leading to automation.

Believed to be fuelled by the Internet, the 4.0 concept had made strong progress in Germany by 2011, striving for a reliable interconnection and integration of production units through cyber communication. It mainly includes concepts, su1ch as the Internet of Things, the Intelligent or Smart Factory (Factory 4.0), Big Data ([1]).Digital communication through large networks allows communication and knowledge sharing not only between man and machine but also between machines and between products and machines (social machine network), leading to the introduction of autonomous systems with self-decisional control. Such systems will need to extract and interpret a huge amount of data in real time (Big Data) to store it (Cloud infrastructure), to access it at a high velocity rate (5 G networks) whilst being mobile. The Smart Factory's main goals are high levels of adaptability and flexibility in processes, the extremely efficient use of resources and the tight integration of suppliers, customers and of other players involved in the value chain.

Industry 4.0 emerges vigorously - not only in regions with traditional industries, such as North America and Western Europe, but also in South-East Asia and emerging countries.

Despite the relocation of production to lower cost countries, industries remain strong in countries such as Germany, Sweden, Austria and Switzerland where the manufacturing industry still remains important in terms of its contribution to GDP and employment and where the labour cost it is significantly higher than in emerging or developing countries. Faced by intense competition in their sector, by the liberalization of taxes on goods and by trade deals between the EU and China, companies from Western Europe, especially the export-driven German companies with their forward thinking strategy, will adopt intelligent automation in a Smart Factory since they wish to offer highly customized products, rapid delivery, excellent quality and highly competitive prices.

The relocation of manufacturing operations and logistics in East European countries brought advanced technology, and this will determine the increase of value added activities, foster industrial growth and the 'stickiness' of technological knowledge. It will also structurally change the economic environment, and may transform the social landscape: the unbalanced demand/supply of high-skill competences (engineers, programmers, IT specialists, consultants and managers) and will shift the traditional labour market. Due to the huge current trend for innovation through automation, there is visible an accelerated demand for industrial robots and for automation equipment and software ([2], [6]).

Industry 4.0 is in its infant phase, and it will probably take two or three decades to become wide-spread, but once the process is underway, there is no turning back. Currently, the potential of Industry 4.0 for national and regional development is not well-known, and so, as Industry 4.0 is a valid response to the changing environment and to challenges of the future, it should be assessed and incorporated into short and long term development strategies, as a vector of innovation and for convergence.

## II. The Industry 4.0 Framework

Then mentioned in the German government's coalition agreement as a long term development strategy project, the term appeared at the Hanover fair in 2011. Nevertheless, 'Industry 4.0'does not yet have a universally accepted definition. Recent authors have, in fact, tried to offer a succinct version even if it does not cover all its elements. According to these, Industry 4.0 is not simply another commercial market fashion, but a confluence of trends and technologies promising to reshape the way things are made ([15]). From a technological perspective, Industry 4.0 will bring such concepts as the Internet of Things and the Internet of Services into manufacturing, where the centre is the smart factory comprising smart infrastructure: smart mobility, smart logistics, smart grids, smart buildings and smart products ([5]). From an economic point of view, the concept takes another, more complex form of supply chain, vertically and horizontally integrated where virtual and physical realities are merged ([2], [4]).

Industry 4.0 is there where production systems are capable of taking decisions autonomously; where, therefore, centralized factory management is replaced by a decentralized, self-organized one ([11]). In such an environment the product is intelligent, that is, it is based on the information received from the cyber system (Big Data System)and is able to move by itself on the production line along an optimal route to the needed operation([11]). In order to respond to the call for highly customized products, Industry 4.0 implements vertically integrated, flexible and reconfigurable systems –the Smart Factory ([11]).There are four trends which lead to Industry 4.0 (although the term 4.0 is not related to these):

- big data: the rapid development of the network capability in terms of velocity, reach, connectivity, bandwidth and volume of data
- advanced analytics: powering business intelligence
- human-machine interface allowing inter-communication between human-machine, machine-machine, product-machine
- emergence of virtual reality systems allowing access to virtual information/ reality the increasing capabilities of robots and 3D printing ([2], [15])

Moreover, the Fourth Industrial Revolution has been waiting in the antechamber for some time, having being preceded by the lean Toyota system revolution in the 1970s, by outsourcing and relocation of manufacturing in the 1990s and by automation post-2000 with the introduction of enterprise resource planning (ERP) and manufacturing execution systems (MES) ([15], [11]).Given the global reach of the companies, these improvements are no longer able to deliver the best performance, and cannot respond to demands for highly customized products in low volume ([10].). It is argued that, for example, when the lean system is used it will keep the inventory at minimum, reduce waste in processes (i.e. waiting, over-processing, moving etc) but it is less focused on technology, and, being confined to the factory, it is not capable of allowing interconnection between individual business units across regions or even globally ([9], [15]).

The nine technologies which are transforming the traditional manufacturing system and will be part of Industry 4.0 are: autonomous robots, simulations, horizontal and vertical integration, the Internet of Things (IoT), Cyber security, the Cloud, additive manufacturing, augmented reality and big data and analytics ([15], [23]). The Smart Factory vision is described as being organized in four deeply integrated layers: physical resource layers which are designed as smart objects and can communicate with each other, industrial network layers, cloud layers and supervisory control terminal layers. The smart things on the production floor are socio-autonomous, meaning that there is no hierarchy between them, that they are capable at the same time of taking decisions by themselves and sharing information and behaviours with each other as in a social network. In this society of things (internet of things) the objects are able to cooperate, reconfigure and organize themselves, and from here was derived the "smart" appellation. The physical resources layer holds a network of objects: machines, robots, RFID, sensors, actuators, vision systems, conveyors, controllers and products. The smart objects are classified into different types of agent which coordinate each other and negotiate between them in order to fulfil the necessary tasks and align themselves to the factory goals and key process indicators. This makes possible autonomous decisions and high flexibility. The industrial network layer allows communication between smart objects, and between smart objects cloud and supervisory layers. The cloud is responsible for collecting and analysing the massive data from the physical layer, such as machine status and process information and giving feedback on the general system performance which is used to adjust and enhance the autonomous agents. The factory's coordinator and the information system reside 'on cloud'. The cloud cooperates with people through the supervisory control terminal layer ([9], [11]). The Smart Factory is able to meet individual customer needs, and through concepts such as Manufacturing-as-a-Service, allows last minute changes to orders and could be shared by different customers ([18], [8]). These customers could cooperate in a network linked by their similar needs in terms of products and services –so forming a Virtual enterprise which has no physical head-quarters or legal form ([8]).

Passing from theory to practice, German research by the Research Centre for Artificial Intelligence (DFKI) in Kaiserslautern demonstrates the smart factory concept using industrial applications of state-of-the-art information and communication technologies. To conclude, the smart factory is a – still visionary-multi-vendor, self-organized and highly modular production system based on the socio-autonomous smart things, multi-agents which have coordination, feedback, and support from cloud-based big data. However, the huge investment required for implementing industry 4.0 and for transforming organizations mayor or be feasible only in those cases where the return on investment –ROI -and the payback period are short, usually less than 2-3 years, and it is certainly less attractive when these periods are longer. Nevertheless, those companies which do not include this in their vision and move later into Industry 4.0, or those which don't consider the need for transformation, are in danger of losing market-share due to low competitiveness, and so the cost of non–automation could be still higher ([15], [23]). On the other side, positive news which is reported for the future of automation and Industry 4.0 is that the payback period for industrial robots with a life cycle of 10 years shortened to 1.7 years in 2015 from 11.8 years in 2008, and it is forecast to be reduced to 1.3 years in 2016 ([24]).

To illustrate the economic impact of Industry 4.0, a profitability vs capital intensity graph is reproduced (Fig. 2) and shows that the forecast investment in Industry 4.0 will increase profitability in Europe at a much higher rate than that in traditional industry.

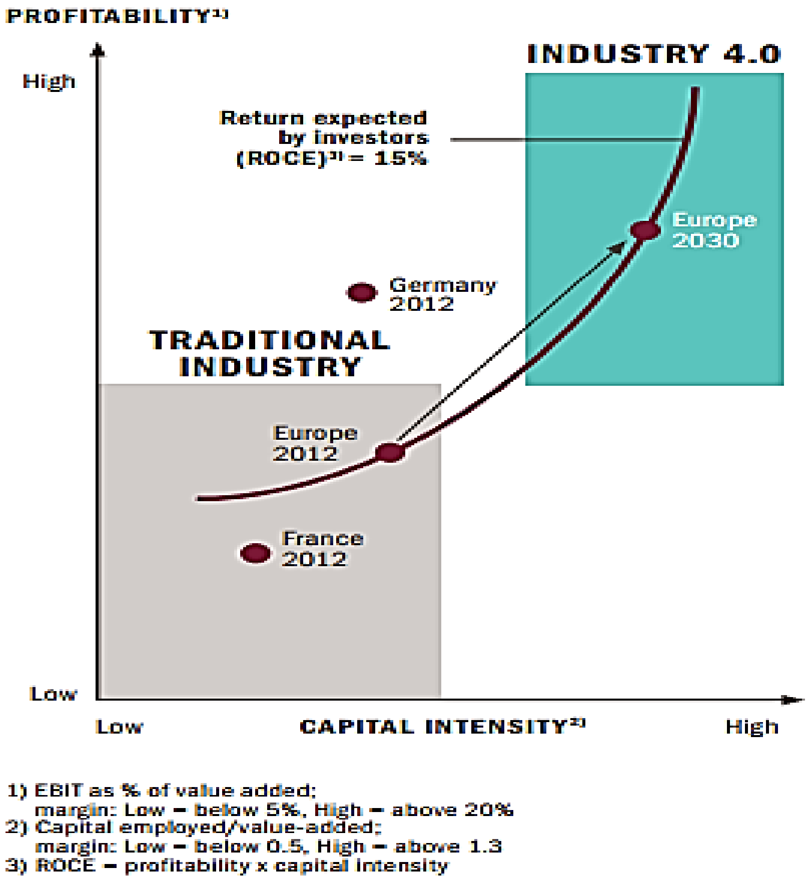



Fig 1. Profitability vs Capital Intensity. Source: Roland Berger

In 2030 the return expected by investors (ROCE) is 15%, although it can be seen that the return was already higher in Germany, in 2012 ([1]).

## III. INDUSTRY 4.0 - CURRENT WORLDWIDE SITUATION

As Industry 4.0 is only in its infant stage, there are few adequate statistics available, and so, in order to give an image of the current situation we analyse data from industries which comprise it, such as: automation, robotics, ICT and innovation, together with facts and figures from other national and corporate policies towards Industry 4.0.

*A. Automation and robotics.*

The global automation market reached 340 billion EUR in 2013, of which the European market share was 93 billion EUR. China's market share was the highest (29%), followed by the US (12%), Japan (8%) and Germany (6%). With respect to exports of automation products and systems, Germany is the first with 29 billion EUR followed by China with 27 billion EUR ([5]). The market for industrial automation solutions is estimated at 140 billion EUR in 2015 ([12]). The US market will remain the biggest market for ICT demand, worth 725 billion EUR, whilst in Germany the software market is 75 billion EUR and growing continuously. As for industrial robots, another important intelligent component of the Smart factory, Industry 4.0, at the end of 2014 the population of industrial robots stood at 1.5 million units, and the value of robot sales increased by 29% compared to 2013 to reachUS$10.7 billion, an all-time record ([14]). Forecasts for global demand are set to increase nearly 11% per year to 2016 to $20.2 billion, a higher demand for service robots in the detriment of industrial robots ([13]). The market for robots is/and will be dominated by of group of five countries: the USA, Japan, Germany, China, South Korea, the most important share held by the US ([13]).

Furthermore, the most robots are produced in Japan, the US, Germany and South Korea, these four countries accounted for 70% of the global production in 2011 ([13]).An interesting indicator is the national average robot density, which is the number of robots n operation per 10,000 employees per country, and is provided by the International Federation (Fig. 2). Their figures show that South Korea has the highest density, seven times higher than the average, followed, at a long distance, by Japan and then by four European countries (Germany, Sweden, Denmark and Belgium) and then by US.

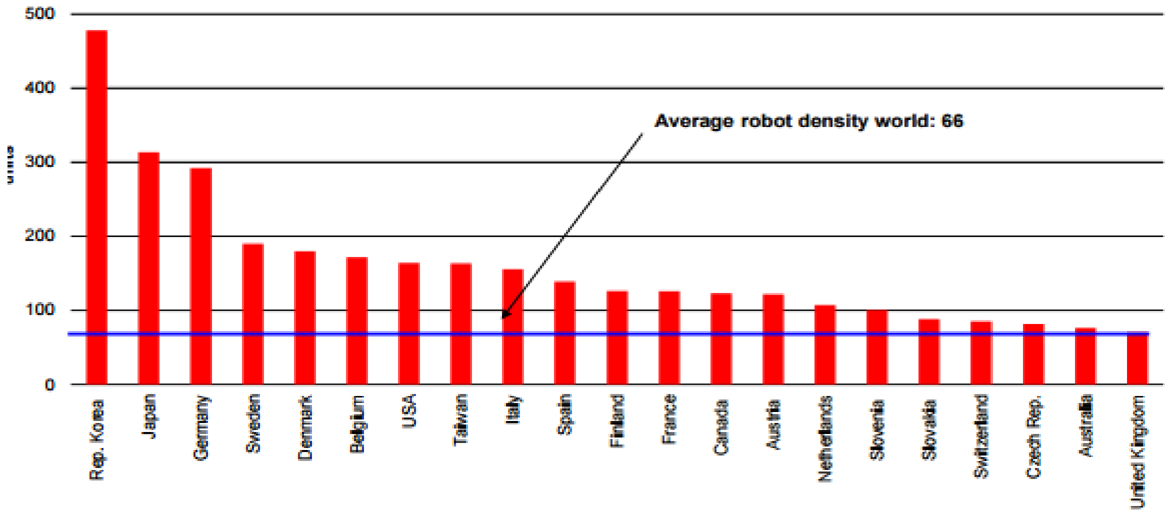



Fig. 2. The average robot density in the world. Source: IFR

Industrial robots are currently employed mainly in five industries, the biggest market being the automotive industry followed by Electrical/Electronics, Metal, Chemical, rubber and plastics, Food and Other industries (Fig. 3).

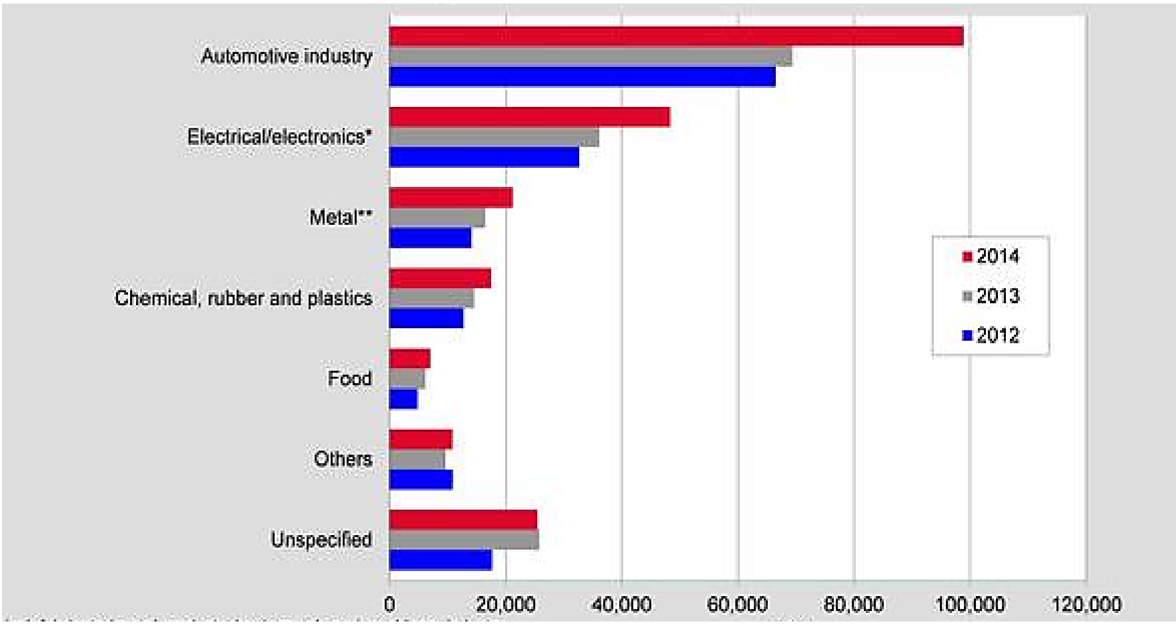



Fig. 3. Estimated worldwide annual supply of industrial robots by industry. Source: World robotics 2015, IFR 2015.

One interesting fact to be mentioned is that, following the automotive, the electronics industry is the second largest market. Despite the fact that most electronic devices are produced in low –cost countries, the demand for robots has also increased there. Indeed, the IFR's data show that China boosted the population of its robots by 50 thousand in 2014 and will add 100 thousand in 2017. One possible reason might be the high productivity, efficiency and precision of industrial robots.

*B. Innovation.*

BCG (the Boston Consulting Group) offers an alternative approach to determining where the global heart of Industry 4.0 is to be found today. We should examine the innovation strength of countries and companies ([3]). According to BCG, in 2014 the strongest innovative companies are American, and, in fact, in the top ten companies there are seven from the USA, whilst in the top 20 there are 14, with 2 of the others coming from Europe and 2 from Asia ([3], [23]). In addition, in the top ten 'up-and-coming companies, there are five from the USA ([3], [23]).

*C. ICT.*

With respect to ICT, the presence of most of the largest software companies: SAP, Software AAG, Telekom and the local subsidiaries of IBM and HP, Germany is in pole position for implementing Industry 4.0 in Europe and, indeed, in the world. Other European companies from the UK (ROLLS-ROYCE) and France (DassaultSystèmes) are playing a leading role in building the basis for Industry 4.0 through intelligent application of 3D printing and clouding ([5]).

## IV. INDUSTRY 4.0- RELATED FACTS & POLICIES WORLDWIDE.

In the USA the term Industry 4.0 is not widely used, but the government and companies are working on preparation for the fourth industrial revolution ([3]). One of these initiatives to promote the Industrial Internet is Industrial Internet Consortium (IIC), established in March 2014 by five big companies: Intel, Cisco, GE, IBM and AT&T. These companies and other US global companies (Google) are engaged in developing "intelligent" projects ([3]). Also worth mentioning is the American body Advanced Manufacturing Partnership (AMP). formed by R&D, business and political communities with the goal of mapping a course for investing and furthering the development of the emerging technologies" Moreover the US government's investment in research into cyber physical systems CPS reached $100 million ([7]) whilst spending on financial support for advanced manufacturing increased annually by 19% to $2.2bn in 2013. ([6],[3]) Additional funding has also been allocated since then.

The EU has already made available funding for R&D programs for the Internet of Things through the Seventh Framework Program for Research (2007-2013). A fund of 2.4 billion euros has been set up to develop ARTEMIS technology. This comprises eight sub-programs such as "Manufacturing and Production Automation" and CPS. Further, the world's largest R&D program, the "Horizon 2020" (2014-2020) research program has allocated a sum of 80 billion euros for funding R&D projects. ([5]).

Germany, despite being a high-wage economy, is the only country where industry's share in GDP has increased and will continue to do so. An interesting fact is that 60% of German companies are in the medium-high technology field, much higher than the 40% of US companies. ([3]). Universities and big industrial companies such as Siemens, SAP, BMW, EADS, ThyssenKrupp Steel AG, Bosch etc, have associated in joint research and development activities on the implementation of Industry 4.0 (). The German government and companies initiated Industry-Science Research Alliance and 4.0 Platform, an association (BITKOM, VDMA and ZVEI) for Industries 4.0 ([5]). The fourth industrial revolution (Industry 4.0) is an immense opportunity for industrialized, high-wage countries such as Germany, who, in order to retain industry and to increase their market potential for manufacturing, have adopted a dual strategy of implementing CPS in manufacturing and marketing of this technology and its products ([5]). A survey carried out in Germany in 2013 by BITKOM, VDMA and ZVEI revealed that 47% of participating companies are said to be already involved with Industry 4.0, and, of these, 18% are doing research into Industry 4.0, and an astonishing 12% said that they already had Industry 4.0 in practice. The greatest challenge for these companies was the standardization of products and processes but also IT security. Companies such as Trumph-first social machines-, Siemens- Industry 4.0 solution in medical engineering, Bosch and many more have already named themselves as suppliers of Industry 4.0 ([5]).

Hungary's Industry 4.0 national technology program and a GINO yearly development fund of $8.2m is to be used by SMES for develop the future factory's industry 4.0 applications, network and manufacturing models. Most recently, the EPIC project was formed to support the implementation of Industry 4.0. Numerous institutions participate in this project, including: the Hungarian Academy of Science's Research Institute for Computer Science and Automation, two faculties from Budapest's Technical and Economics University, and four institutions of the Fraunhofer-Gesellschaft (FhG) under the coordination of the National Innovation Office (NIH) ([25]).

China'spolicy for implementing advanced manufacturing featured in the 2011-2015 Five YearPlan, where 'High-End' strategic industries are in focus in order to achieve Chinese supremacy in these domains. The government made available a huge fund as subsidy, tax reductions and stimulating incentives of 1.2 trillion euros are available to companies for this purpose. Among the Chinese government's priorities is R&D for the Internet of Things and its applications, "industrial control and automation. In the city of Wuxi, in Jiangsu Province, was established an "Internet of Things innovation zone" with 300 companies employing more than 70,000people ([5]).

In Japan, to stay in the race, 30 Japanese companies launched the "Industrial Value Chain Initiative"-an alternative to Industry 4.0. Japan might be more advanced than its counterparts in implementing the Industry 4.0, and not only on the technological, but also the psychological side. Indeed, Japan has strong industries ideal for Industry 4.0, such as the automotive, electronics and digital industries ([20]).

To illustrate the level of Japanese preparedness for Industry 4.0, and as can be seen in table 1, of the top 9 intelligent robot producers, 5 are Japanese, whilst, by the number of installed robots, Japan occupies first place.

| | Company | No of installed robots | Country |
|---|---|---|---|
| 1 | Fanuc | 400,000 | Japan |
| 2 | Yaskawa | 300,000 | Japan |
| 3 | ABB | 250,000 | Switzerland |
| 4 | Kawasaki | 110,000 | Japan |
| 5 | Nachi | 100,000 | Japan |
| 6 | Kuka | 80,000 | Germany |
| 7 | Denso | 80,000 | Japan |
| 8 | Epson | 45,000 | Japan |
| 9 | Adept | 25,000 | USA |

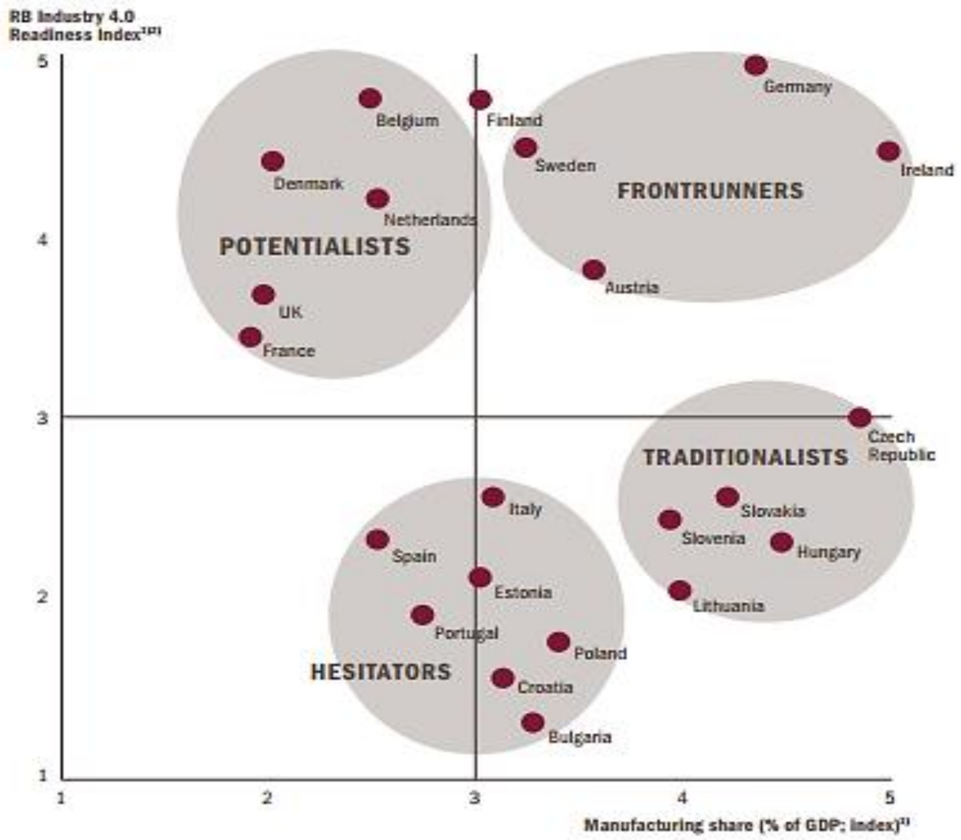
Table I. The Top 9 Producers of Intelligent Robots. Source www.roboticsandautomationnews.com

In South Korea, in June 2015 the government initiated Manufacturing 3.0 program, with a budget of $175m, which is to promote the spread of smart factories and ICT in the whole manufacturing process – this in order to improve the level of customization and so the level of competitiveness of industry. With respect to other similar programs in Germany and the USA, the difference lies in, among other things, the formidable support given to SMEs for setting up smart factories and in the discrete step-by step approach of this industry to conversion ([22]).

In India, the Government's Five-Year Plan (2012-2017) set up an innovation fund covering public and private investments in R&D, allocating 2% of GDP for this purpose. A Cyber-Physical Systems Innovation Hub is being introduced for research into high-end areas such as humanoid robotics. The German company Bosch, together with Indian research groups, have allocated 22.8 billion Euros for research related to developing Information Technology ([5], [26]).

## V. INDEX OF READINESS FOR INDUSTRY 4.0

To indicate more accurately the Industry 4.0 status in the EU and forecast its future, strategic consultant Roland Berger proposed an index of readiness for Industry 4.0, and, further, RB Industry 4.0 readiness, by country. The index comprises two categories of values: first is the "industrial excellence" made up of a combination of production process sophistication, the degree of automation, workforce readiness and innovation intensity, and, second, the "value network" which includes: high value added, innovation networking and internet sophistication. A1-5 scale is used for both categories, 5 meaning the country's readiness is at maximum. In Fig. 4, the RB index is plotted against the share of Manufacturing as a percentage of GDP for each country.




1) 1- Low, 5- High 2) Adjusted to outliers Cyprus, Latvia, Luxemburg, Romania, Greece

Fig.4. RB Industry 4.0 index by country

As can be seen, the European countries can be grouped in four clusters easily identified in the RB Industry 4.0 graph: Front-runners, Potentialist, Hesitators and Traditionalists. Ireland, surprisingly lead the Frontrunners cluster, along with Germany, Austria and Sweden- these countries are truly future-oriented. The Potentialist cluster is formed by West European countries where the trend towards de-industrialization is accentuated, but they have economic and R&D potential to catch up with Industry 4.0. The Hesitators group consists of countries with a low industrial base and fiscal problems and which are not keen to capitalize on future opportunities. East European countries such as the Czech Republic, Slovakia, Slovenia, Lithuania and Hungary are mostly low-wage countries and so form the Traditionalist cluster.

## VI. CONCLUSION

The fourth industrial revolution Industry 4.0 started a very few years ago, to reach a point of no return. As in the case of the previous industrial revolutions, its pace and intensity are far from being uniformly distributed over the globe, and, in fact, it is as yet limited to a few countries. These countries, the European Union, have special programs with constant budgets to offer incentives and funding for Industry 4.0 components. In Europe, Germany seems to be taking the lead over other countries, as its long term public-private strategy is to implement Industry 4.0. Other non-European countries where the Industry 4.0 term is not very well-known, such as the USA China, Japan, India and South Korea are following a similar step-into-the-future vision, promoting strong and clear policies for the future development of Advanced manufacturing, Internet of Thing, Cyber-Physical System, Manufacturing 3.0 and making great progress towards them. On the other hand, those countries with low -wage costs, with a low industry-to-GDP ratio or those which have not yet stepped into Industry 3.0 (the automation phase)will have a lesser chance to join the Industry 4.0 group. In Eastern Europe, countries such as Hungary, despite being a low-wage country and being classified in the traditionalist group, by the Index of Readiness for Industry 4.0, is currently building the foundation for Industry 4.0. The important share of industry in GDP and the presence in Hungary of some of the largest companies where automation is more likely to be employed, had been the main contributors to achieve increased number of industrial intelligent robots as well as the appearance small and medium companies offering automation solutions - that is integrators- for the whole supply chain. To achieve high competitiveness in a fast changing and challenging global economic environment, the governments and companies should adopt a clear policy for implementing Industry 4.0 and its components.

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