

Industry 4.0: Conceptualization, Backgrounds, Developments and its applicability in Regional Context

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Abstract

The aim of this article is to provide a comprehensive review of specialized literature that includes conceptualization, background, developments and applicability concerned with the term “Industry 4.0” in regional context; seeking to determine the progress that has been achieved in recent years in this area.

The article allowed to response two main questions: What is the Industry 4.0?, Is it likely to be implemented in Regional Context?, these questions were supported with others questions: What is the environment of the Industry 4.0 and what are the reasons and motivations for its implementation?, What are the basic theories about industry 4.0 and what exactly do they consist of?, What are the differences among selected world regions in terms of the demand, fomentation and implementation of the Industry 4.0?. Now, the two main objectives of this work were: Describe the characteristics of the Industry 4.0; Analyse its applicability in Regional context; in specific, Identify and describe the environment of the Industry 4.0 together with its principle reasons for its implementation, Describe the basic theories of the Industry 4.0, Identify the requirements and differences of the Industry 4.0 in different world regions and Analyse the applicability and necessity of the Industry 4.0 in regional context.

This work is based on two investigation types: The first part, the characterization of the Industry 4.0, is descriptive. However, the second part, the investigation of the applicability, is explorative. The methods used in this work is inductive. In order to obtain the results for the second, exploratory part questionnaires will be used. The information obtained from this method will be analysed and presented in the last part of this work.

Keywords

Industry 4.0, Industrie, Automatization.

1. Introduction

The term “industry 4.0” was created by the German government in the second decade of the 21st century, and forms together with the so called project of the future “Industry 4.0” below the new high tech strategy for Germany, apart from other technological projects. It was selected thanks to the fact that the economy is on the threshold of the fourth industrial revolution, in which the real – physical- world and virtual world unite in a system, a so called Cyber Physical-System(CPS). This is only possible through the Internet of Things (IoT), which is a “new concept completing the evolution of communication and informatics, applying them to the objects, which allows a better interaction between them. It refers to a net of daily things interconnected through the internet” [1].

The two main questions to be answered within this work are: “What is the Industry 4.0?, “Is it likely to be implemented in a Regional context?” Supportive questions are: What is the environment of the Industry 4.0 and what are the reasons and motivations for its implementation?, What are the basic theories about industry 4.0 and what exactly do they consist of?, What are the differences among selected world regions in terms of the demand, fomentation and implementation of the Industry 4.0?. The two main objectives of this work are: Describe the characteristics of the Industry 4.0 and analyse its applicability in a Regional context.

This work is based on two investigation types: The first part, the characterization of the Industry 4.0, is descriptive. However, the second part, the investigation of the applicability, is explorative. The methods used in this work is inductive. In order to obtain the results for the second, exploratory part questionnaires will be used. The information obtained from this method will be analysed and presented in the last part of this work.

In the following the background elements about Industry 4.0 are explained, related investigation topics. The second section deals with results, discussions and conclusions.

2. Background

A thorough review of the recent literature has been carried out with the aim of determining the state of the art in the context of the research; This review was carried out in specialized databases of the Science Direct and Web of Knowledge platforms, as secondary sources of search and inquiry, in a time horizon between 2010-2016 and taking as a search strategy the developments, conceptualizations and applications in The theme of industry 4.0 and referencing categories such as: industry 4.0, internet of things, cyber-physical systems, among others that appear in the process of inquiry and search.

In this sense the following was found:

(Bauernhansl, 2014), speaks of the first three industrial revolutions in terms of: The first industrial revolution around 1750 with the steam engine and combustion engines. The second industrial revolution characterized by the division of labor and production in series with the help of electric power (Taylor, Ford) and the third industrial revolution in the early 60's with the development of electronics and ICTs. In this perspective (Manyika et al., 2012) and (Bauernhansl, 2014), the importance of industry in the economy in terms of productivity, innovation and export, additional to that proposed by Bauernhansl, 2014 and Saad , 2016) on changes in factors of production (energy, materials, knowledge and capital); In this same perspective (Danne, 2012) and (Bauernhansl, 2014) address the problem of complexity in production. According to these, for example, BMW offers 1020, 100,000,000,000,000,000 or 100 quintillions in theoretically possible ways of configurations or combinations of new cars. The complexity defined through the number of elements of a system and their interrelationships. It is not possible to describe all products and processes exactly. Since an exponential relationship between the variety of products and the volume of products per variety has been observed since 1850. They analyze factors such as: efficiency, diversity, demand and delivery capacity, increased availability, price elasticity and variability in production. And finally, (Venturelli, 2014) talks about the transition phase to the fourth industrial revolution with developments in communications networks, optimization of systems and databases, increased productivity, cost reduction and digitization, Decentralized control, the use of the internet of things and services.

On the other hand, (Brettel, Friederichsen, Keller, & Rosenberg, 2014) They raise the discussion about three main groups referring to studies on industry 4.0: individualization of production (mass customization, modularization, flexible and reconfigurable manufacturing systems, Distributed control, optimization itself, rapid manufacturing, and cloud computing); Collaborative networks and horizontal integration (distributed manufacturing, supply chain flexibility, supply chain visibility, internet of things and services) and digital integration (process chain virtualization, individualized data traceability, systems Real-time operations, simulation and modeling of products and processes, simultaneous planning of products and production processes); While (Geisberger & Broy, 2012) they talk about the drivers of industry 4.0 in terms of industrial development: the use of intelligent embedded production systems, mobile services and ubiquitous computing; The use of the internet as a business Web and the use of Web semantics and Web 2.0 methods. From the studies advanced by (Thompson & Parthasarathy, 2006) who discuss the laws of Moore and Metcalfe, the first based on the empirical observation on the density of components and changes in integrated circuits in the last 40 years and Its impact on industry 4.0. And the second, which says that the benefits of communication systems grow exponentially with the growth of its participants. And finally, (Kelkar, Heger, & Dao, 2014) who talk about the advances in implementation and the omission of risks in industry 4.0, changes in IT security (Wirnsperger, 2015), high investment costs Koch, Kuge, Geissbauer, & Schrauf, 2014) and (Wischmann et al., 2015), preservation of company secrets (Berwanger, Meckel, Wichert, & Bartsch, 2013), waiting for technical solutions, Stable and in the processes, administration of complexity, semantic unification in the communication between machines; The standards (DKE & DIN, 2016), legal insecurities (Plöger et al., 2015) and inadequate employee skills (Koch et al., 2014).

There are also the works of (Soder, 2014) and (Westkämper et al., 2013) who pose the developments of industry 4.0 from the advances in Computer Integrated Manufacturing; The works of (Syska, 2006), (Mählick & Panskus, 1993) and (Soder, 2014) who talk about developments in terms of Lean systems; The work of (Schlick, Stephan, Loskyll, & Lappe, 2014) who discuss technological developments: Internet of Things (Andelfinger & Hänisch, 2015) and (Paul, 2013), Auto ID Automatic Identification Systems Sarma et al., 2000), RFDI (Sarma, 2001) and (McFarlane, Sarma, Chirn, Wong, & Ashton, 2003) As well as the development of industrial communication (Kriesel, Gibas, Riedel, & Blanke, 1990), (Schnell & Wiedemann, 2008) and control techniques such as Ethernet, OPC UA (Schumacher et al., 2006) and Soft-PLC (Bayer, 2009), (Kaftan, 2016); (Stephan et al., 2009), the intelligent machine -planning, assembly, launching, operation and re-engineering. Configuration (Ollinger & Zühlke, 2013, p. (Schuh, Potente, Thomas, & Hauptvogel, 2014), who propose the automation of production defined as the technology related to the application of Based systems for the operation and control of production (O'Sullivan, 2009), (Büttner & Brück, 2014), (Hoppe, 2014), (Kusiak & Smith, 2007), (Hori, (Asare et al., 2012), and the European Commission (Wiener, 1948) (Lee & Seshia, 2015) (Kempermann & Lichtblau, 2014), who talk about horizontal integration, and (Lake, Laudon, & Schoder, 2010), (Lee, Bagheri, & Kao, 2015) (Fallenbeck & Eckert, 2014), who poses the security in the industry 4.0 and the work of (Pantförder, Vog El-Heuser, & Schweizer, 2009) who talk about human-machine interaction (Mayer & Pantförder, 2014).

4. Methods and Results

In order to analyze the applicability of the Industry 4.0 in a regional context were created a questionnaire answerable by company experts. First of all, it has to be mentioned that the lack of knowledge of the topic made it hard to find experts in answering the questionnaire. The help of national organizations was not given.

The questionnaire was created with Google Forms and made public though the same platform. (<http://goo.gl/forms/jw32iO9NtY>). It consisted of 9 general and 17 Industry 4.0 specific Questions being divided in 4 chapters. Only experts, having received the password beforehand to avoid public inexperienced responses, could have answered it. The questionnaire was divided in 4 chapters: Company classification: 6 questions, Knowledge of Industry 4.0: 2 questions, Industry 4.0 actions in the company and expected changes: 9 questions e Implementation and support necessities: 8 questions.

About Company classification.

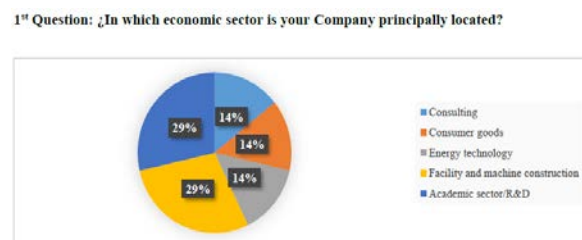


Figure 1. Results 1st Question: ¿In which economic sector is your Company principally located?

The distribution goes over various sectors being principally in the academic/R&D and facility and machine construction sector.

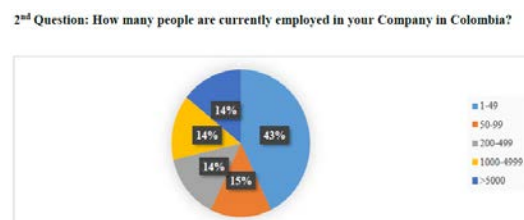


Figure 2. Results 2nd Question: How many people are currently employed in your Company in Colombia?

In most of the cases, the companies are small sized and employing less than 1000 people.

3rd Question: What is your main production type?

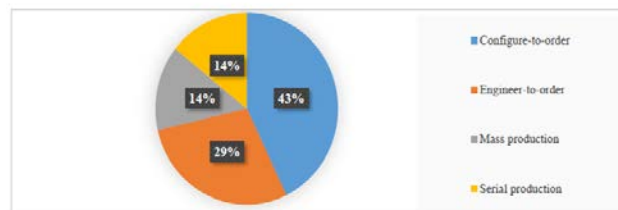


Figure 3. Results 3rd Question: What is your main production type?

The main production type is configure-to-order, followed by nearly equal other types engineer-to-order, mass-production and serial production.

4th Question: What management level are you in?

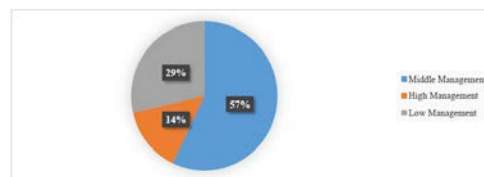


Figure 4. Results 4th Question: What management level are you in?

More than the half answering the questionnaire worked in the middle management, followed by 29% in the low management and only 14% the high level management.

5th Question: In what department are you working?

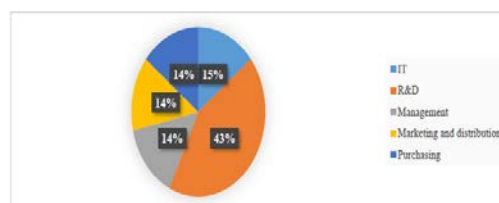


Figure 5. Results 5th Question: In what department are you working?

About 43% worked in the R&D department, followed equally by all others named: IT, Management, Marketing & Distribution, Purchasing.

6th Question: What is the operation range of your company?

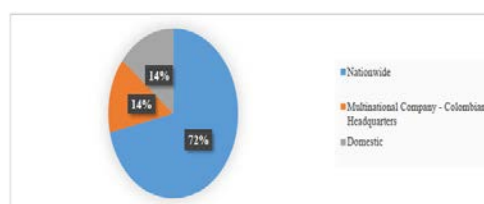


Figure 6. Results 6th Question: What is the operation range of your company?

More than two thirds operate nationwide, the rest are multinationals and domestic companies.

About Knowledge of Industry 4.0.

1st question: Do you know about Industry 4.0?

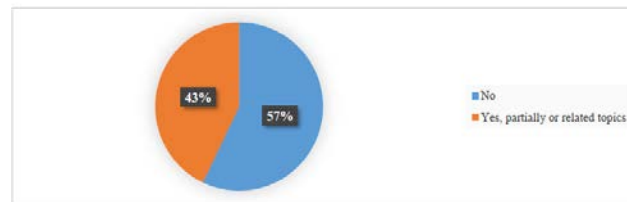


Figure 7. Results 1st question: Do you know about Industry 4.0?

Nobody answered Yes, but a little bit less than the half answered knowing partially about Industry 4.0 or related topics and the rest nothing.

2nd Question: Do you want to know more about Industry 4.0?

Almost all of those questioned wished to know more about the topic itself, which was offered during the questionnaire with connected PowerPoint slides or videos in order to be able to answer the rest of the questions.

About Industry 4.0 actions in the company and expected changes

1st question: Has your company planned or is it planning to implement any Industry 4.0 or related elements?

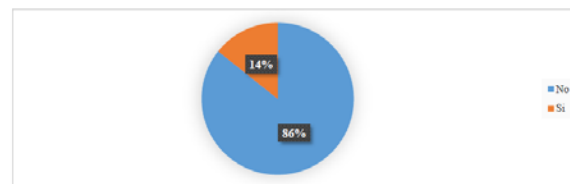


Figure 8. Results 1st question: Has your company planned or is it planning to implement any Industry 4.0 or related elements?

Nearly 90 percent answered not planning nor having implemented any industry 4.0 or related elements. The 14 percent have implemented or are planning elements in development projects or working with Industry 4.0 suppliers.

2nd & 3rd Question: Where do you think is Colombia and your company currently situated?

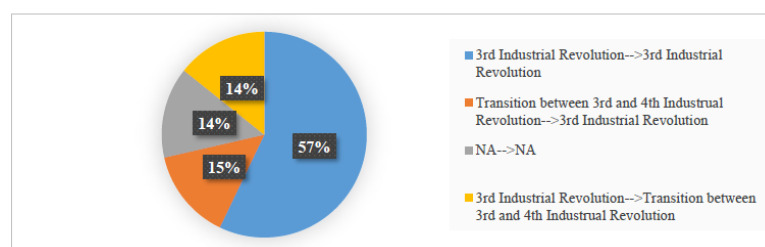


Figure 9. Results 2nd & 3rd Question: Where do you think is Colombia and your company currently situated?

57% answered that Colombia and their company are in the third Industrial Revolution, only 14 percent observed Colombia in the third revolution and their company already being in the transition to the fourth. Nearly equally 14% observed Colombia being in the transition to the fourth and their company being in the third. The same amount did not answer either one of the questions. A total of around 71% saw Colombia being in the third revolution, equal to the one thinking this of their company.

4th question: How do you evaluate the importance of the Industry 4.0 in general? (One being very important to 5 unimportant)

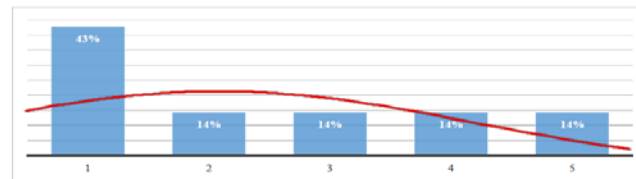


Figure 10. Results 4th question: How do you evaluate the importance of the Industry 4.0 in general? (One being very important to 5 unimportant)

Nearly half of the questioned saw a general high importance of the industry 4.0. The other half equally voted from important to no unimportant. The red line represents the standard normal distribution.

5th Question: How do you evaluate the importance of the Industry 4.0 in your company in the future? (One being very important to five unimportant)

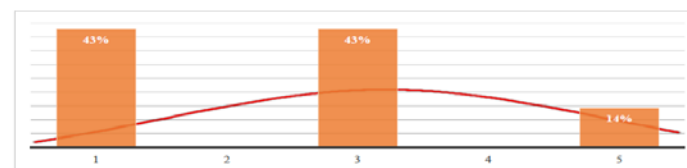


Figure 11. Results 5th Question: How do you evaluate the importance of the Industry 4.0 in your company in the future? (One being very important to five unimportant)

This question clearly led to a different answer as 43 % still voted being very important and 43% showing a medium importance and 14% a low importance. If you analyse the answers it can be seen that all persons voting the importance at a general high also think so for their company. Whereas all the twos and fours moved to a medium importance. The unimportance stayed the same. The red line represents the standard normal distribution.

The **6th** question is omitted due to a lack of answers. This multiple choice question asked about the opinion of horizontal and vertical integration in IT systems nowadays and in five years. Overall they showed a high agreement upon increasing levels.

7th Question: How much is invested in each area in IT support systems?

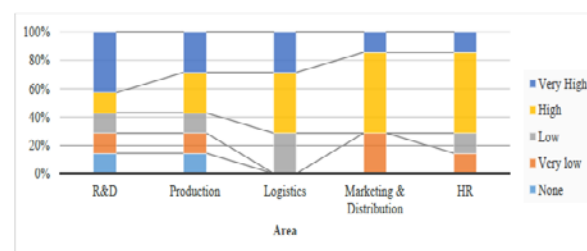


Figure 12. Results 7th Question: How much is invested in each area in IT support systems?

This showed mixed expenditures in the R&D department, higher expenditures in the production department, even higher expenditures in Logistics, Marketing & Distribution and Human Resources.

8th question: What impact are you expecting through the digitalization of business processes in each of the following?

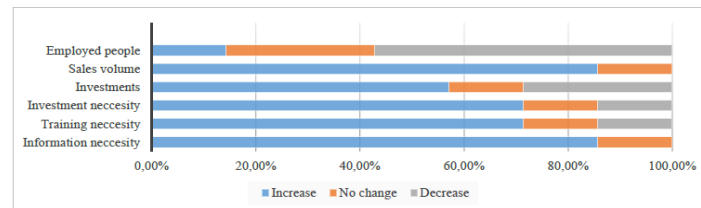


Figure 13. Results 8th question: What impact are you expecting through the digitalization of business processes in each of the following?

First of all, it can be seen that most of those questioned regarding the number of employed people, expect a drop or no change at all. Regarding the sales volume nearly 90% expect a rise and the other 10% no change at all. Overall the investment necessity is expected to rise together with the number of investments. Also training is required and more information is needed.

9th question: What priority does each topic have regarding digitalization and networking?

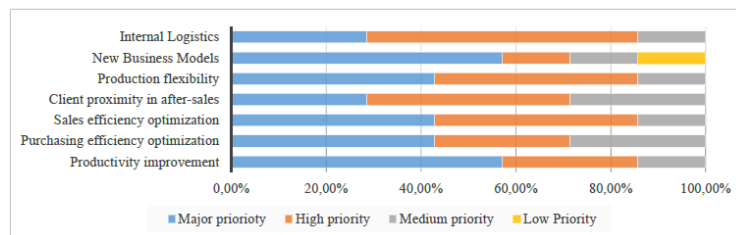


Figure 14. Results 9th question: What priority does each topic have regarding digitalization and networking?

The clear focus here is on new business models and productivity improvement where 60 percent marked it as major priority for its business regarding digitization and networking. But new business models were the only category showing low priority as well. Around 45% showed high priority in production flexibility, sales efficiency optimization and purchasing efficiency optimization. Less high priority, around 30% was shown in internal logistics and client proximity in after-sales. But if you sum major priority and high priority internal logistics, production flexibility, sales efficiency optimization and productivity improvement sum up to around 85%.

About Implementation and support necessities

1st question: Where are you seeing obstacles for adopting to the digitalization trend?
(multiple answer question)

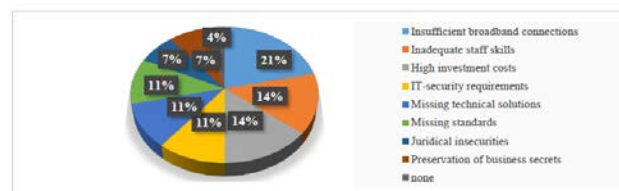


Figure 15. Results 1st question: Where are you seeing obstacles for adopting to the digitalization trend? (multiple answer question)

Clear obstacles for the implementation in Medellin are seen in insufficient broadband connections, followed by inadequate staff skills and the high investment costs. Missing technical solutions and standards and IT-security requirements were each around 11%. Those were followed by juridical insecurities and preservation of business secrets. 4% of the answers included no obstacles.

2nd question: Where are you seeing legal obstacles? (multiple answer question)

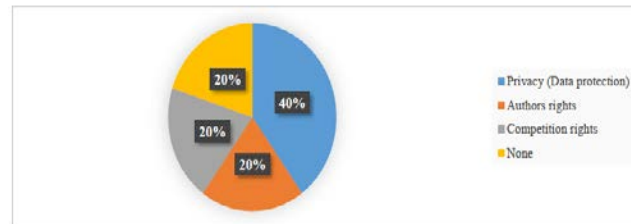


Figure 16. Results 2nd question: Where are you seeing legal obstacles? (multiple answer question)

Legal obstacles are clearly seen in the Privacy or data protection with a share of 40 percent, followed equally by authors rights, competition rights and no obstacles at all.

3rd question: In what topics do you see the necessity of training your employees?

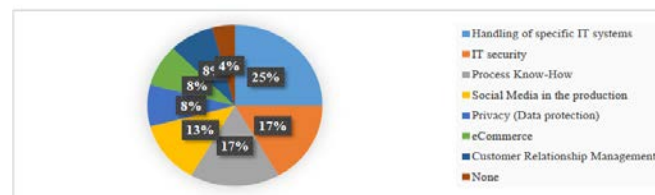


Figure 17. Results 3rd question: In what topics do you see the necessity of training your employees?

The handling of specific IT systems was mentioned the most times, around 25%, followed by IT security and process Know-How (17%). The social media in the topic is also seen as an issue (13%), trailed by Privacy (Data protection), e-commerce and Customer Relationship Management (each 8%). Also in 4% of the answers none was mentioned.

4th question: Do you think the industry 4.0 represents rather an opportunity or risk for the national industry?

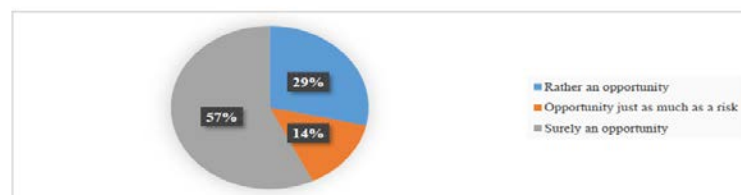


Figure 18. Results 4th question: Do you think the industry 4.0 represents rather an opportunity or risk for the national industry?

Around 57% see the Industry 4.0 surely an opportunity for the industry. 29% are more sceptical and see the Industry 4.0 rather as opportunity. 14% see the Industry 4.0 just as much as an opportunity as a risk.

5th question: What kind of support would you like to receive for implementing the Industry 4.0?

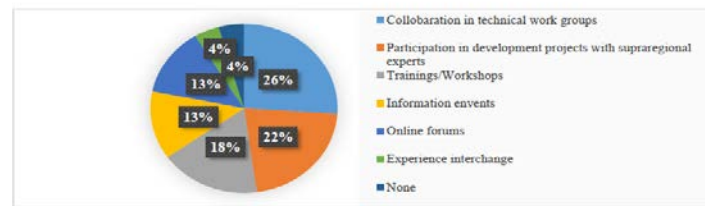


Figure 19. Results 5th question: What kind of support would you like to receive for implementing the Industry 4.0?

26% mentioned the collaboration in technical work groups, 22% the participation in developments projects with supraregional experts, followed by Trainings/Workshops (18%), information events (13%) and Online forums (13%). Less important was seen the experience interchange. Also in 4% of the answers none was mentioned.

6th question: In which transversal topics of the Industry 4.0 are you especially interested?

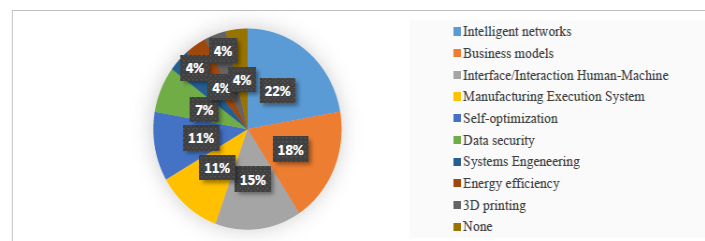


Figure 20. Results 6th question: In which transversal topics of the Industry 4.0 are you especially interested?

Frontrunners are intelligent networks (22%), Business models (18%) and Interface/Interaction between Human and Machine (15%). Also mentioned topics are Self-optimization (11%), Manufacturing Execution Systems (11%) and Data security (7%). Less mentioned topics were Systems Engineering, Energy efficiency and 3D printing (each 4%). Also in 4% of the answers none was mentioned.

7th question: How do you evaluate the support in the following levels for the industry in general?

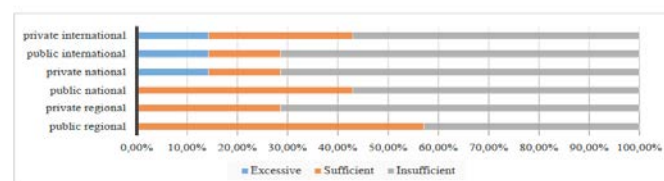


Figure 21. Results 7th question: How do you evaluate the support in the following levels for the industry in general?

Standing out is the figure of nearly 60 % seeing the public regional funding as sufficient. As well around 15% marked the private and public international spending as well as the private national spending as excessive, but as well in mostly all categories the spending was seen as insufficient (Average 60.1%).

8th question: How do you evaluate the support in the following levels for the industry 4.0?

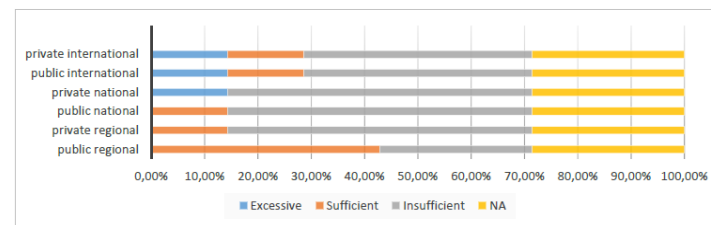


Figure 22. Results 8th question: How do you evaluate the support in the following levels for the industry 4.0?

Here the overall image looks a lot different, in the question before around 31% saw the funding as sufficient whereas here it dropped to the half. Besides the high figure of not applicable is with around 30% in average quite high.

5. Discussions and Conclusions

The collected information showed that the Industry 4.0 as it is, is not very known in a regional context only by related topics. This does not depend on the company size nor its operation range or type of production, but the people having known about the topic are either in the high or middle management and work in the R&D department or management. All these knowing about it or related topics opine that the Industry 4.0 is important for the economy and the company itself. The people not having known about the topic before did not see a big importance in the topic.

Until any pure project could be implemented the big obstacles need to be overcome: Improving the broadband connections, training the personnel and seeing the importance of the change and possible ROI.

The main obstacles are also reflected in the Global Information Technology Report 2015 where Colombia scored a 4.1, being 7 the highest and by this representing the 64th rank of 143: Its strongest points are in the Readiness, referring to infrastructure (4.3 - rose incredibly since 2012, internet bandwidth increased from 10 kb/s per user ca. 80!), affordability (5.9 - rose incredibly since 2012, fixed broadband internet tariff dropped by 50%!) and skills (4.9 – educational system and general skill of the people). The availability of latest technologies is pretty good at 4.6. But it lacked in the environment sub index (3,7- referring to political & regulatory and business & innovation environment) and the economic impact (3.2). It has also to be stated that the business usage still is quite low (3,5). Hampering the score is the venture capital availability at 2.6 and even worse, knowledge intensive jobs are at a decreasing rate at 16% of the workforce. Though it is worth mentioning that the capacity for innovation (3.5) is continuously rising as it is the intellectual property protection (3.5). (Dutta, Geiger, & Lanvin, 2015, p. 144) Please see figure 24 in the annex for more specific information. Indeed, the Global Information Technology Report refers to Colombia as a whole and it has to be assumed that numbers would vary in some categories, but in generally support the findings in a Regional context.

This leads to the conclusion that the environment for an Industry 4.0 in a regional context, Colombia is given, as technology is accessible and a juridical framework is given. Its implementation is only limited by the financial investment devotion and time to invest and install the technological environment, train skilled people and convince companies of its possible value creation.

As nation and region wide funding and promoting is not a driver in the industry, this project is rather a recommendation for SME to gain interest in this topic and if the ROI would be positive, start investing to accomplish competitive advantages. A possible way of implementation is given within this work and benefits are outlined. All together in regional context is already going a good and stunning way regarding innovation and possesses already a general outline of a framework for the Industry 4.0. Besides the private engagement the region itself could invest more in establishing a basic functioning framework and promote components of the Industry 4.0 in order to be a nationwide leader of the fourth industrial revolution, which besides is resulting in an advantage bringing competitiveness and international attentiveness.

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Biography

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