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Literature Review: Industry 4.0 Implementation Towards Intelligent Manufacturing Companies

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Abstract: ***Facing the growing challenges in the industrial sector and making more progress, is becoming one of the major concerns of companies nowadays. Process digitalization and automation seems to be one of the most efficient solutions that requires to verify the readiness of the company, its capabilities and develop new clear plans for improvement. In this paper, we will introduce the industry 4.0 concepts that present the turning point of the end of the conventional centralized applications, while describing the enabling technologies that interfere with this change.***

Keywords: Digital transformation, Industry 4.0, readiness level, Business-IT alignment and integration, Challenges and solutions

1. Introduction

The major challenge facing the industrial companies nowadays is moving from basic conventional application to highly value-added digitalized companies. In other words, converging from old- fashioned manufacturing entities into smart factories that include cyber-physical systems managed by IoT platforms. This represents the main key to improvement, attracting new clients and boosting production. For this, the implementation of Industry 4.0 which integrates both business and technical skills in a coherent way, seems as a must to ensure higher productivity while being more flexible, more customized and encouraging excellency.

This new approach, first appeared in Germany in 2011 as a fourth industrial revolution, is based on several heterogeneous data and incorporated algorithms, Cyber Security (CS), Cloud Computing (CC), Big Data (BD) technologies, Internet of Services (IoS), Internet of Things (IoT), and so on [1]. Hence, adapting Industry 4.0 will enhance smart productivity, facilitate solving problems and make better decisions. Since this “revolution”, the industry 4.0 gathered the research community attention and lots of initiatives were addressing the theme; such as the German Industry 4.0 platform [2] and the “Industrial Value Chain Initiative “in Japan [3]. The scope of Industry 4.0 has expanded from focusing on the automation of processes to an added-value business problem. The adoption of such a concept is being noticed in manufacturing companies from different sectors; mainly automobile, aerospace, transportation and heavy machinery; to clearly achieve high business benefits.

Many researchers are showing big interest towards the understanding of the Industry 4.0 concept, Issaa et al. [4] established a framework to assess companies to develop their own appropriate roadmap to succeed their digital transformation. Firstly, a framework was constructed to ensure business change and technology implementation where various levels are considered. Secondly, the roadmap will be issued to illustrate the integrative approach which contains the overall phases that need to be taken in order to deploy new technologies (1. Task force setup 2. Evaluation of digitalization and classification 3. Definition of focal points 4. Generation of use cases 5. Estimation of their impact 6. Final selection of use case). Machado et al. [5] evaluated digital readiness of seven different companies from different sectors by applying a self-check tool, identifying challenges and best practices to have an improved digitalization. According to their study, it has been proved that a mature company is the one that makes digitalization a core part of the organization, has clear digital strategy and works on building skills allowing the implementation of such strategy. As for the challenges, the main ones concern the balance between tactical, strategic, operational and financial KPIs, Workforce with different ages and lack of digital skills. Dalenogarea et al. [6] focus in their study on anticipated advantages of the industry 4.0 concept technologies on industrial fulfillment of Brazilian emerging companies (e.g., Big Data, Manufacturing Execution Systems, Cloud Services, etc.). The adoption of such technologies has the ability to boost production lines flexibility as well as enhancing resources and energy savings throughout CPS integration for information processing and decision making. Jeske et al. [7] present in their work an integrated analysis of previous studies, conducted by IFAA in Germany, mainly focusing on the metal and electrical industry (years 2015, 2017 and 2019) about the development and tendencies of digitalization and its effect on productivity, administration and human resources’ efficiency. In fact, productivity seemed to be increasing after 3 to 8 years from the adoption of digital transformation. As for the management aspect, the impact on lean methods was represented on a chart combining statements such as Lean Method is required for digitalization or Lean Methods are no longer required. Lastly, adoption of digitalization approaches allows more content, temporal and spatial flexibility to employees. Jasiulewicz - Kaczmarek and Gola [8] gave an overview about the contribution of adoption of the Industry 4.0 concept for developing sustainable manufacturing. This can be mainly achieved by the reduction of maintenance costs, elimination of negative environmental impacts as well as improving work environment conditions (safety and ergonomy). To attend these objectives, deployment of Information of Things is required, starting with the usage of Smart Machines based on three main components: physical, smart and connectivity. The deployment of Big Data analysis to improve maintenance processes and help identifying the data that is crucial for making good decisions in the future. In addition to this, the Maintenance Analytics Concept (MAC) was introduced in alignment with Big Data analysis, which through the understanding of information, makes maintenance actions very easy, following 4 steps of analytics: descriptive, diagnostic, predictive and perspective. Bilgeri et al. [9] presented in their work the major IoT organizational issues faced by manufacturing companies during their digital transformation journey. For this, they conducted 16 in-depth interviews with eleven companies, where they found that the main problem is in fact an organizational one. Hence, they came up with actionable guidelines to face the problem while deepening their understanding of the organizational archetypes.

Even if digitalization transformation is gaining increasing attention in research and practice, it is noticed that so many firms are still struggling to realize its transformation potential [10]. This is mainly due to the fact that the concept is not fully understandable and confusion persists seeing the various approaches that appeared. This can be clearly noticed since many manufacturing companies have adopted the concept, still they only tackle the feasibility study and not the digital transformation in its whole aspect. The main reason behind this is the lack of understanding of the link that exists behind business and technology to meet production needs, and only consider industrial digitalization as an adoption of pure IT projects.

2. Research question

Seeing the importance of the Industry 4.0 concept in companies and the struggle that can be faced while trying to implement it, we are trying from this work to create a literature review for Industry 4.0 implementation starting from the understanding of the concept as well as its related aspects. To do so, a literature review over the enabling technologies of the industry 4.0 concept will be presented, focusing mainly on the state of the art. Besides, challenges and solutions that face the digital transformation will be presented. In addition to this, the readiness capability and the Business-IT Alignment and Integration aspects will be presented as the main two aspects of the industry 4.0 concept.

Readiness capability stands for the improvement stages of a company, as a consequence of digital transformation implementation. As for Business-IT alignment and integration, mainly focuses on whether the chosen technologies fit the organization business strategy and objectives.

This paper is structured into three main sections, starting with the main challenges that are faced by the manufacturing industry and some solutions. The second section presents a theoretical framework of readiness capability. The third section will treat the Business IT-alignment and integration model. Lastly, the last section will mainly shed the light on the Industry 4.0 concept definition and main key technologies.

3. Digital transformation-Challenges and Solutions

Since many manufacturing companies tried to implement or adopt digital transformation and failed, it is important to understand the main challenges that they face to come up with solutions and succeed in their conversion towards smart companies [11].

The major challenge concerns the continuing adoption of traditional processes. In fact, with everything being connected digitally, handling organizational matters and decision making should no longer be paper-based. For this, companies need agile digital solutions replacing outdated processes. Besides, it is important to check where the company stands when it comes to change. In other words, it should be checked if employees are ready to let go of traditional processes and have the ability to get out of their comfort zone, incorporate new technologies and try new approaches. To depict these kinds of problems, effective communication is advised. If managers notice that employees resist, they should start by discussing the importance and potential of this new approach as well as spreading the culture of high commitment. Another challenge is the limited use of automation. In fact, several repetitive and time-consuming tasks are performed manually resulting in human resource consumption as well as high cost. Where the importance of encouraging the usage of automation to reduce time consumption and boost production. The fourth major problem is budget restrictions. It is crucial to be aware that all kinds of industrial improvements require some sort of investment that varies according to the company size and revenues. To lead manufacturing companies toward digital transformation, proper planning for the investment process as well as having a long-term vision are highly recommended. In addition to this, some companies try to introduce new technologies without proper knowledge. For this, forming employees when possible, hiring external expertise or even hiring new employees becomes a must. Lastly, for any organization that aims to converge towards digital transformation, Cybersecurity presents a major concern since all data and system networks will be exposed to the internet. For this, vulnerability issues should be detected and documented in addition to the deployment of protection layers ensuring the safety of the system.

Before deciding whether to adopt the digital transformation or not, manufacturing industries are in need of running some evaluation tests to see if they are capable/ready for the process. Starting with the evaluation of the readiness capacity, also called maturity capacity.

4. Digital Transformation-Maturity

Maturity or readiness capacity of a certain manufacturing company, concerns the growth levels and potential of development during sequential periods. This is mostly outlined using a time-development level matrix. In order to evaluate a company's readiness level, various approaches exist based on: Value Chain and Value System Analysis (VCA/VSA) [12], Balanced ScoreCard (BSC), Porter's Five Forces Analysis (PFFA), Product Life Cycle Analysis (PLM), etc.

Starting with the VCA/VSA, Porter and Heppelman [13] studied how the nature of smart products could affect the value chain of a company. In fact, smart products require the accommodation of design processes and enhanced services through the incorporation of Internet of Things (IoT) technologies. These latter generate huge amounts of data that may be useful as a reference for improving future product, analyzing marketing and after sales services. However, the adoption of such processes requires very high security management to protect the flow of data to, from and between product technology stacks.

Wolf and al. [14] presented a balanced scorecard allowing a successful application of the capability model by identifying four main scenarios. The first scenario consists of using the model of capability, by company managers, as a way to stimulate their organizations through information obtained from other companies' experiences. In the second one, managers may deploy the capability model as an argument to defend their tendency towards using digital services. As for the third layout, managers may use the model to come up with a new agreement and develop an estimation of the ability levels. Finally, the fourth layout consists of using the capability model to convey the current situation of digital facilities, raise internal awareness and see where improvements are required.

As for the PFFA's model, Porter and Heppelman [13] confirm that even if IoT technologies are crucial and represent an advantage while being integrated into companies. Still, the rules of competence remain the same: i) Implementing smart products, ii) Connected products to capture usage data among customers, iii) Customized products, iv) setting precises to better capture value, v) extending value-added services. As can be noticed from these five forces, they mainly focus on the customer satisfaction by providing a better understanding of the product performances.

Finally, the Product life cycle management which is of crucial importance in giving the opportunity to integrate data issuing from engineering and design with the production department and quality analysis. De Carolis and al [15], highlighted the importance of this aspect in addition to some other 'ingredients' in order to improve performance in manufacturing companies.

Among recent studies in the field, Jallouli and al [16] presented a new approach for assessing the firms' ability for digital transformation. This model/approach is mainly based on the split of the objects of rating and the assembly of their features into domains. These latter are set as follows: methodical management, growth and evolution of the firm's architecture, readiness of business process, sophistication of data management and human resources' readiness. As for assessing companies' readiness for digital transformation, authors came up with a set of criteria to be respected (see Table 1).

Table 1: Criteria for Assessing companies' readiness for digitalization

Domain	Bold
Methodical management	• Uniformity of objectives • Quality of evolution organization • Sophistication of feedbacks (internal and external)
Growth of the firm's architecture	• Adopting IT for understanding the business needs • Linking IT to business strategies
Readiness of business process	• Business processes standardization, integration and automation
Sophistication of data management	• Data management, structuring and quality
Human resources readiness	• Motivation for change • Digital competence

Among the most recognized models within the area of information systems, the Capability Maturity Model (CMM) [17] can be cited. This model helps software organizations to control their processes towards engineering and management excellence. In fact, the CMM model determines the current process maturity of the organization, identifies the issues and provides improvement strategies. The CMM model is based on five stages of software procedure readiness. Starting with the very first level, where the software procedure is distinguished as ad hoc, and where little procedures are defined. The second level "Repeatable", where fundamental procedures are confirmed to keep track of cost, schedule and functionalities. The third level "Defined" includes software procedures meant for organization and activities related to engineering and soft skills. These activities are documented, standardized and integrated into standard software processes for organization. The fourth level "Managed" evaluates the quality of both software and processes. The last level "Optimizing" where feedbacks of the processes are gathered to make continuous process improvement. Issa el al [4] presented an updated capability maturity concept, directly related to the Industry 4.0 concept, defining four main levels. The first level "No Industry 4.0" where the system is considered as an ad-hoc, hence no well-defined systems are highlighted. The second level "Department level" sees the digital transformation as a technical problem that can be handled on a department level. Generally, the engineering department is the first one to look into digital transformation or industry 4.0 implementation. The third level "organization" mainly handles digital transformation as a business problem that requires an overall vision and defined strategy. The fourth and last level "Inter-organization" considers digital transformation as a business issue covering the supply chain. Hence, adopting the

Industry 4.0 concept must consider the necessity of the value/supply chain collaborators.

5. Digital transformation- Business IT-Alignment and Integration

The concept of Business-IT alignment and integration first appeared in the 1980s, where the idea is to implement IT technologies in alignment with companies' business strategies. In fact, even if this concept has been highlighted again since 2000, still, researchers are trying to figure whether the implementation of IT will be of business value for the company in comparison to its competitors. Carr in his work [18] affirmed that only obtaining information technologies does not matter in a company to make it outstand its competitors. In fact, according to him, since their price has decreased, having such tools (e.g., data storage, data processing and data transport) in a firm is becoming standardized and affordable to all. Hence, investing in IT can become more disadvantageous than it being good for a company's development. A company can overpower its competitors by having something that they don't have or doing something that they can't do. In addition to this, a company can steal the march of its challengers by having a superior vision on the deployment of up-to-date technologies. Still, the problem that executives always fall into, is that they think that opportunities will be indefinitely available. On the other hand, Radhakrishman et al. [19] challenge Carr's assertions by suggesting that effective use of IT in companies can put forward highly added values to it by creation of managerial capabilities. In fact, deploying IT to create unique, effective, and hard to copy organizational capabilities might give the investing firm an advantageous differential value over its competitors in the national/international market.

Effect of IT integration into firms can be categorized, according to researchers, into three main categories. Starting with its influence on the Economic level, where most studies focused on macroeconomic indicators investigation and their outputs. Bailey [20] evaluated productivity growth, in different work sectors in the U.S., during the 1970s. It appeared that the observed slowdown that took place in most industries was caused by the combination of three main factors: i) interrelated disruptions to the economy, ii) not an enough fast technology integration into old-lines industries and iii) fast innovation in electronics that didn't help into a growing productivity. Bresnahan [21] estimated the social gains from use of mainframe computers in the financial services sector (banks, finance, and insurance) during the period 1958–1972, which were increasing, using the derived demand curve for a new technology. Roach [22] went through a comparative study of the efficiency of information workers with that of the production workers, from 1970 until mid-1980s, proving that the relation between IT adoption and economical outputs can sometimes be positive and at times negative. Which describes what's called "IT Productivity Paradox" [23] where even if technology changes are noticed as being accelerating, productivity remains weak.

Moving to the industry level, researchers studied the influence of IT adoption on industrial productivity. Siegel and Griliches [24] confirmed the presence of a positive correlation between productivity growth (not acceleration) and investment in computers. Kelley [25] analyzed the effects of IT on the efficiency of production in a specific process survey data from 584 different establishments engaged in the machinery process. Results showed that the usage of programmable automation is beneficial, especially within accumulated experience and repetitive opportunities. Berndt and Morrison [26] explored the relationship between investments in IT and industry performance measures for two-digit manufacturing firms from 1968 until 1986. Two main findings were reported, first the relationship between the profitability and high-tech intensity is insignificantly different from zero. Besides, for both labor and multifactor productivity, the relationship between their growth and high-tech intensity is negative. It can be easily noticed that, like the mixed results presented in the economic level studies, no agreement between IT and production growth has been confirmed on the level of industrial productivity.

Lastly, companies' level studies assessed the relationship that links IT adoption and managerial performance variables, mainly productivity and profitability. Mahmood and Mann, reported in their work [27] that the relationship between individual IT investment and organizational performances is weak. The strategic and economic performances were weakly related to the IT deployment only when grouped by means of canonical correlations. Diewerie and Smith [28] presented throughout their paper an accounting framework for inventories treatment when measuring the productivity of a distribution firm. It was shown that large gains are possible to be attained, especially by the computer revolution which appeared and allows firms to track their sales and purchases while minimizing inventory holding costs. Hitt and Brynjolfsson [29] proved through their investigation that IT investment has a positive impact on increasing productivity and creating substantial value for clients. However, it wasn't shown by any evidence that this IT implementation has a remarkable effect on business profitability. From what has been mentioned before, it can be concluded that when IT is used in an efficient way it can interact with intermediate managerial processes and results in highly added value to the business model of the industry. Hence, effective usage of IT in alignment with strategies, business processes and organizational structures is a must.

6. Industry 4.0 implementation

A. Definition of the Industry 4.0 concept

Industry 4.0 is a concept linked to the digitalization of manufacturing processes, which represent the fourth revolution in manufacturing. The first industrial revolution revolved around mechanization through the usage of water/steam power. While the second englobed mass production and assembly lines deploying electricity. As for the fourth revolution, it takes what has been initiated in the third revolution, which concerns the rise of digital technology in manufacturing industries, with the adoption of computers and automation [30] to achieve a higher level of efficiency and productivity.

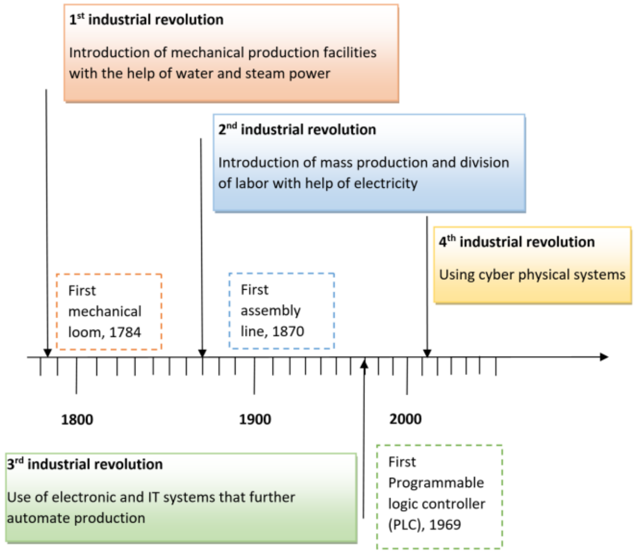

Figure 1: Industrial Revolution History

While the second revolution which started in 1870 and continued to 1989, englobed mass production and assembly lines deploying electricity. This major development allowed powerful countries to specialize in steel, chemistry, oil and plastic sectors [31]. As for the fourth revolution, it takes what has been initiated in the third revolution, which concerns the rise of digital technology in manufacturing industries, with the adoption of computers and automation [30] to achieve a higher level of efficiency and productivity. The aim of industry 4.0 is to improve production efficiency, make it faster, lower its costs and less wasted by deploying connected robots [32]. These goals can be achieved by deploying sensors to perceive the process and allow data analysis. The development occurred by industry 4.0 implementation is related to the combination of cyber systems and physical systems as well [32].

B. Key Technologies for Industry 4.0

Industry 4.0 is characterized by highly developed digital processes and IT tools. It mainly focuses on creating smart systems that connect with each other; as is the case for machine-to-machine or machine-to-human interactions, while managing the flow of information from the systems interactions [33]. With this integration, that constitutes the foundations of Industry 4.0, flexible solutions as well as smart making decisions can be obtained to better place the manufacturing organization in the top rank of the competitive environment. The main key to successfully attain such objectives is the will to change and the human contribution that should be improved through development of professional skills in the domain. The building block of such a strategy is the integration of engineering capabilities and tools throughout production systems networks as well as horizontal and vertical integration.

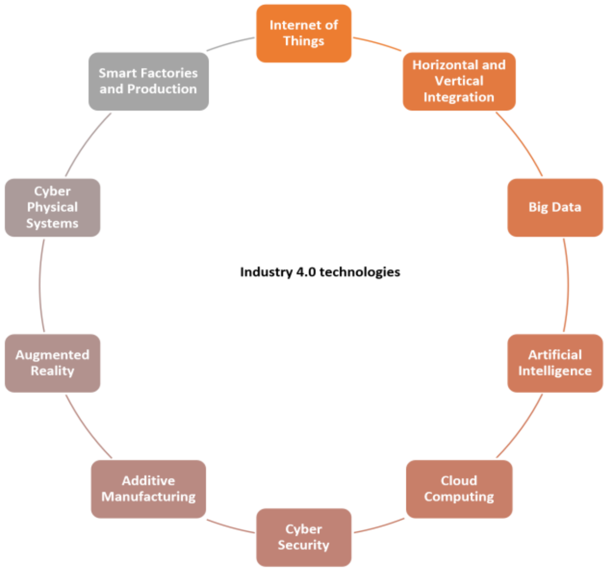

Figure 2: Industry 4.0 Key Technologies

a) Internet of Things (IoT)

This new technological concept allows machines to remain connected and communicate with each other using the internet [34]. This will allow companies and manufacturing organizations to become an intelligent environment by establishing networks that include production processes [35]. The IoT concept allows obtaining data with smart analytics, easy problem resolution through the adoption of the end-to-end automation processes and, finally, providing value for humanity [36].

b) Horizontal and Vertical Integration (H/V I)

As its name refers to, horizontal and vertical integration requisites hybrid interrelations and digitalization of all the levels of the business. This will allow transition to be successfully made and better dealing with problems and challenges in production processes. Besides, reaching a more flexible structure that can easily adapt to simple updates [37].

Big Data (BD)

Adopting Big Data analytics may help managers to acquire production and consumption data whenever they need it. This will help them track the manufacturing' as well as consumers' activities, which will help them come up with new strategies to better place the firm in the competitive market.

c) Artificial Intelligence (AI)

AI is the science of making machines intelligent and using computers to understand human intelligence [38]. The main objective is to create rational results regarding some possible issues, taking instant decisions by having a way of thinking at human level [39]. In most manufacturing firms, the AI tools help assembling data from sensors, storing it, analyzing it and using it for fault detection tests in future maintenance actions.

d) Cloud Computing (CC)

In the manufacturing area, CC is seen as a technique of production linking dispatched production resources to a line, by establishing cyber physical lines to lower production costs and enhance productivity [40]. This technology will help the transfer from traditional manufacturing business models to the persistence of smart factory networks.

e) Cyber Security (CS)

It is a science that aims to keep network shared information secure and under control. In fact, it is considered as a crucial component of the manufacturing industry, since it will help keep data protected from external threats such as the destruction of data or duplication in the best-case scenarios.

f) Additive Manufacturing (AM)

Also called 3D print, it is becoming one of the most important key technologies of industry 4.0 since it helps create sophisticated objects using advanced attributes (new materials, complicated shapes, etc.) [41], by printing layer on layer, from 3D models or drawings.

g) Augmented Reality (AR)

AR is defined as an enhanced version of the physical world that is achieved through the usage of digital elements (visual, sound, etc.) that can be delivered via technology [42]. This technology is important since it enables having access to information at another level by increasing virtual sense of information [43].

h) Cyber Physical Systems (CPS)

CPSs' are defined as the structures that include integration and allow communication between the cyber world and the physical world [44]. This tool helps enabling changing and dynamic needs of production as well as enhancing its efficiency.

i) Smart Factories and Production

According to Radziwon et al.[45], a smart factory is the one that provides flexible and easy to use production processes, to solve complex production problems by changing boundary conditions. This can mainly be obtained by combining software, hardware and machines together in a way that will reduce the number of labor and decrease wasting resources. Besides, following this approach, potential collaborations between industrial and non-industrial parties may see the day, since the turning key is dynamic organization.

7. Conclusion and perspectives

Industry 4.0 concept appeared as a fourth industrial revolution that makes the interaction between human and technology more consistent, through the combination of internet-related world and concrete world. The adoption of such a concept is a must if a manufacturing company aims to keep up with the growing competition, due to the increasing demand of customized products and services. Even if the topic brought the attention of many researchers and managers around the world, they still find difficulties in implementing the concept in the real world due to the lack of understanding and the persistent confusion. In this work, which is based on state of the art, we presented the challenges faced during the digitalization processes and solutions, introduced the industry 4.0 concept, its key technologies and the two main aspects that need to be evaluated or be present to succeed the implementation process; mainly checking the readiness capacity and making sure to integrate IT in alignment with the companies' business model.

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