Industrial Automation,Technology and Analisy of Necessary Maturity

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Abstract

The theme of this article is revealing the major change in production schemes for industry 4.0, with the development of technologies that involve concepts of Cyber-Physical Systems (CPS Cyber-Physical Systems), Internet of Things (IOT) and Big Data, supported by communication networks and connectivity with 5G Mobile Technology, and microeconomic concepts applied in production. Methodology: The methodology used was the application of a mental research map, together with the company's management, to demonstrate the points that need to be synchronized in the company, the IMPULS maturity assessment model (Lichtblau et al. (2015) was segmented for the SKM company to implement industry 4.0 automation, in order to achieve the objectives of technological evolution in production . Result: The main results of the research show the company's needs to evolve in some items mentioned in the challenges for industry 4.0 of the National Confederation of Industry, 2016, providing gains in the quality and quantity of production and, simultaneously, offering better prices to consumers. Conclusion: Automation not only affects production itself, replacing manual labor with robots and computerized machines, but also provides enormous productivity gains by integrating different tasks with project development, administrative management and production. This work aims to provoke a discussion regarding the main technical points of application of the Microeconomic concept in technological advancement aimed at industry 4.0 and 5G Technology, and in training in automation aimed at a new attitude of the engineer, more creative and with the necessary skills in terms of multidisciplinarity and integration.

Keywords: First 5G Mobile Technology, Secound Automation, Third Industry 4.0

1. Introduction

In the continuity of the Industrial Revolution 1.0, 2.0 and 3.0, we are in the Industry 4.0 phase, which presents the connection between intelligent devices, both in the production chain and in the logistics of organizations. That is, connecting machines, systems and assets with the intention of creating intelligent networks to evolve production control. Below are the summaries in Figure, 1, of the evolution of the industry in Brazil through phases of industrial revolution, phase 1 Steam Machines, phase 2 Mass production/Electricity, phase 3 Computer/Automation in industry and internet connection and Phase 4 Physical cyber system, IOT/5G (APREPRO, 2019).

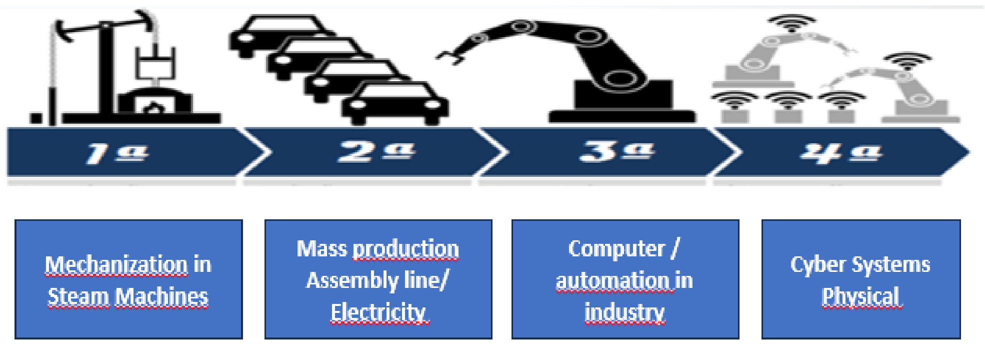
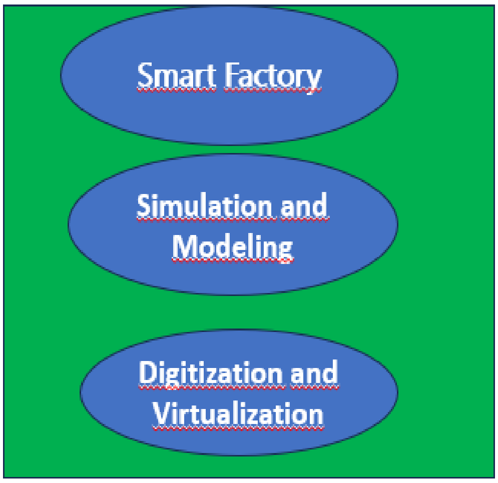


Fig. 1. Industrial Revolution 1,2,3 and 4.0. Aprepro IX Brazilian Congress of Production Engineering, 2019.

The term "Industry 4.0" was created in Germany, specifically at the Hannover Fair in 2011. The expression became publicly known that same year through the "Industrie 4.0" initiative, with the presence of businesspeople, politicians and members of universities with proposals for analyzes and measures to strengthen the competitiveness of German manufacturing through digital transformation (KAGERMANN; LUKAS; WAHLSTER, 2011 apud HERMANN; PENTEK; OTTO, 2015).

In recent years, there has been a major change in production schemes. The justification is the great competition between companies and the great development of technologies involving microprocessors, robots, artificial intelligence, communication networks, among others. It can be seen that the different production strategies aim for one objective, that of increasing competitiveness. It consists of increasing competition in terms of cost, availability, innovation, quality. Among the ways to achieve this goal is industrial automation. Some key concepts and technologies related to the Industry 4.0 environment were listed by OESTERREICH & TEUTEBERG (2016) in their investigation of the state of the art regarding the topic. As a result, 20 concepts/technologies are presented, grouped into 3 groups, as illustrated in Figure 2.



Cyber-physical systems; Embedded systems; Radio frequency identifier; IoT; Automation; Modularization – prefabrication; Additive manufacturing; Product life cycle management; Robotics; Human-computer interaction

Simulation tools; Simulation model; Augmented reality; Virtual reality; Mixed reality

Cloud computing (5G), Big data (5G); Mobile computing (5G); Social media (5G); Digitization (5G)

Fig.2. Author - adapted from Oesterreich & Teuteberg, 2023.

The information presented portrays a general overview of Industry 4.0, in which the groups with the highest number of associated technologies are respectively: Smart Factory, Digitalization and

Virtualization and Simulation/Modeling. This list facilitates the direction of research on Industry 4.0 and a better visualization of the scenario based on the terms present in the literature.

Cyber-Physical Systems, also known as Cyber-Physical Systems (CPS), comprise a structure that enables integration between virtual and physical environments. Cyberphysical Systems are integrations of computers, networks and physical processes, in which networked systems monitor and control physical processes, which in turn, return production data, causing a constant cycle of information exchange to take place. Kagermann et al. (2013) define Cyber-Physical Systems as a set composed of intelligent machines, storage systems and production facilities, capable of exchanging information, triggering actions and controls autonomously and harmoniously, this functioning in real time in the Smart Factory environment.

The Internet of Things, or Internet of Things (IoT), is a development trend in the communication technology sector (MIORAND et al., 2012). IoT enables physical devices to connect to a network to exchange information/data between different levels of hierarchy.

Big Data is an approach in the area of Information Technology that makes it possible to carry out optimized data simulations in real time, generating time and cost savings, as well as reducing risks (KAGERMANN et al., 2013). It consists of the systematic processing of large volumes of data generated by the use of sensors and networked machines. Big Data is a challenge for the implementation of industry 4.0, as it consists of a set of data (volume + variety + speed + veracity + value) collected from different sources (machine sensor data, quality data, data from logistics, among others), making it necessary to adopt a computing infrastructure that stores, processes and manages information. The lack of standardization in data management is a barrier to operationalization, given that the current industry environment has heterogeneous and non-standardized information. In this sense, efforts must be directed towards improving knowledge in knowing how to acquire, use and interpret the real value that all this data generates, thus assisting in decision making (KHAN and TUROWSKI, 2016).

2. Literature Review

The development of Industry 4.0 in Brazil involves challenges that range from investments in equipment that incorporate these technologies, to the adaptation of layouts, adaptation of processes and forms of relationship between companies throughout the production chain, creation of new specialties and development skills, among others. The crossing of information that allows you to connect the purchase order, production and distribution autonomously, without people needing to make decisions all the time, for example, will require new forms of management and engineering throughout the production chain, as presented in Figure, 3, (CNI Challenges for industry 4.0 2016).

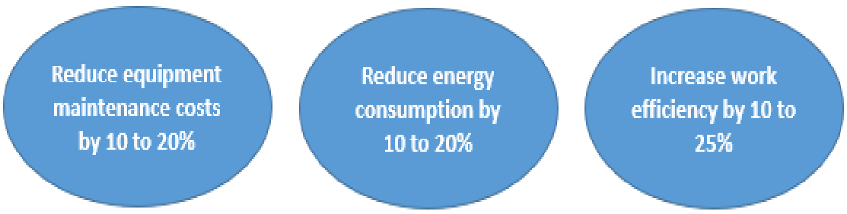


Fig.3. CNI Challenges for industry 4.0, 2016.

The change in the traditional business model and the way society communicates in general has created the need to evolve the concept of wireless connectivity to the Fifth Generation of Mobile Technology (5G), in order to enable new ways of defining monitoring and performance guarantee, as well as the quality of service and the level of user experience. The newest generation of mobile communication provides substantial changes in data transfer rates, support for a large number of connected devices, reduced latency time, and consequently, support for communications between devices in real time. It heavily utilizes cloud-related technologies in its core network so it can better

meet the elasticity of demand and resources. Additionally, it supports seamless migration and roaming between radio access technologies that will coexist. (IDEC.ORG, 2020)

The contextualization of the subject involves the analysis of maturity that an industry must have to implement the 4th Generation of Industry (4.0), the 5th Generation of Mobile Technology (5G), the Microeconomic concept in production, and the expected results in order to place agility and functionality in business and reduce the delay in industrial development compared to developed countries.

As defined by ITU-R (2015) (International Telecommunication Union), 5G is a system designed to meet the IMT-2020 requirements established by the ITU-R M.2083 specification as presented in Figure 4. These parameters are considered as requirements strategies for the development of 5G. Measurement requirements such as 20 Gbps Downlink Peak Data Rate and 10 Gbps Uplink, experienced by users at a Downlink rate of 100 Mbps to 1 Gbps and 50 Mbps Uplink. Better spectral efficiency compared to 4G technology (IMT-Advanced). Furthermore, we obtain three times the Traffic Capacity per area of 10 Mbps/m2, with a Latency of 1 ms and Connection density of 10 million devices/km2. Energy efficiency is better compared to 4G (IMT-Advanced) with 100 times the mobility reaching 500 km/h, proportional to data traffic. Figure, 4, shows the main parameters of IMT-2022 (International Mobile Telecommunications), (ITU-R, 2015).

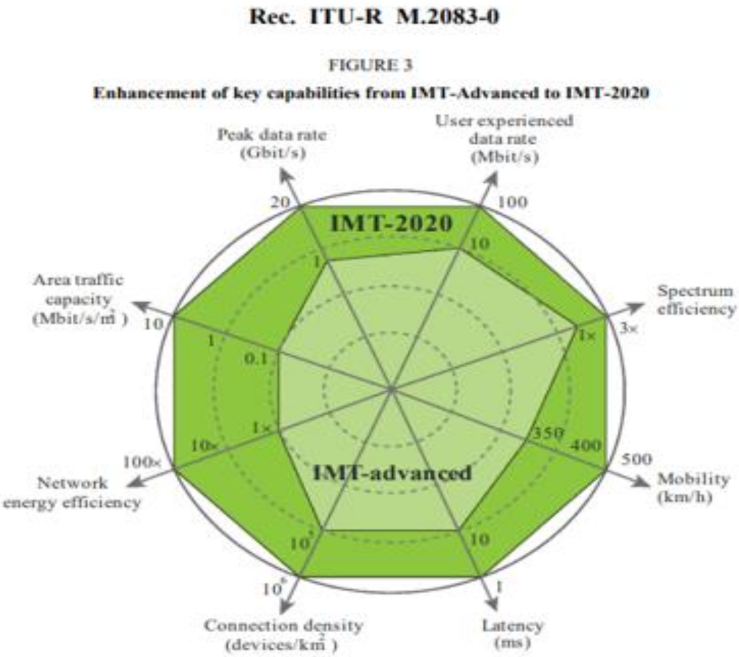


Fig.4. IUTR-R,2015.

The adoption of 5G technology as a technological alternative to solve the growing demand for communication reflects an evolution in the telecommunications sector as a whole, and particularly a new advance in the use of mobile telephony. Within a scenario of technological convergence, which has brought together a multitude of activities such as exchanging messages, watching videos, banking, shopping and many others, 5G tends to multiply applications on cell phones and increase and intensify Internet-based connections in Things (IoT- Internet of Things), contributing to the development of industrial automation, among other areas (IDEC.ORG, 2020).

In the context of microeconomic analysis in production, the current phase of the industry with automation will promote an increase in supply and reduction in production costs in production companies, taking into account the applied microeconomic calculations (IDEC.ORG, 2020).

The choice of production process depends on its efficiency. Efficiency can be assessed from a technological point of view or from an economic point of view as shown in Figure 5 (VASCONCELLOS, M. ANTONIO, 2015).

Technical (or technological) Efficiency: Between two or more production processes, it is that process that allows the same quantity of product to be produced, using a smaller physical quantity of production factors;

Economic Efficiency: between two or more production processes, it is that process that allows the same quantity of product to be produced, with a lower production cost.

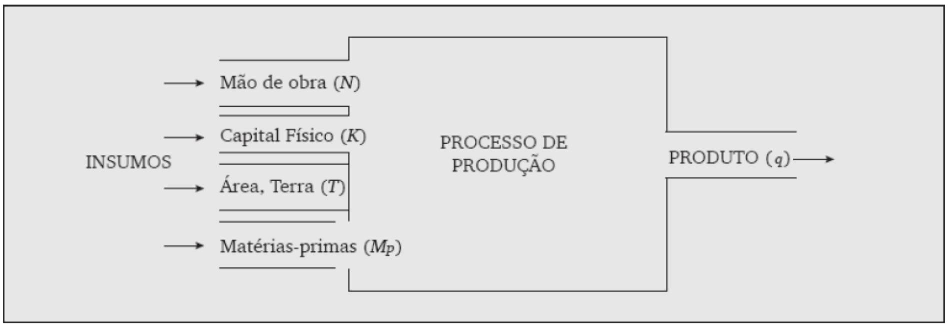


Fig. 5. The production process. VASCONCELLOS, M.Antonio 2015.

With the implementation of new Technologies (Intelligent Industry Concept), the cost of production/manufacturing falls, increasing its technical productive efficiency OEE (Overall Equipment Effectiveness) (VASCONCELLOS M. ANTONIO, 2015).

Supply: is the amount of a given good or service that producers and sellers are willing to sell in a given period. The general function of offering a good or service is determined by the following variables, where the variable (T) Technology contributes to the productive differential (VASCONCELLOS, M. Antonio 2015).

The application of a research mental map, together with the company's management, is necessary in order to demonstrate the ideas that need to be synchronized for the implementation of automation, in order to achieve the objectives of technological evolution in production.

3. Methodological Proposal

The application of a mental research map, as shown in Figure 6, together with the management of the company SKM Eletro Eletrônica LTDA, is necessary to demonstrate the ideas that need to be synchronized for the implementation of automation, in order to achieve the objectives of technological evolution in production (YIN, ROBERT K, 2010) .

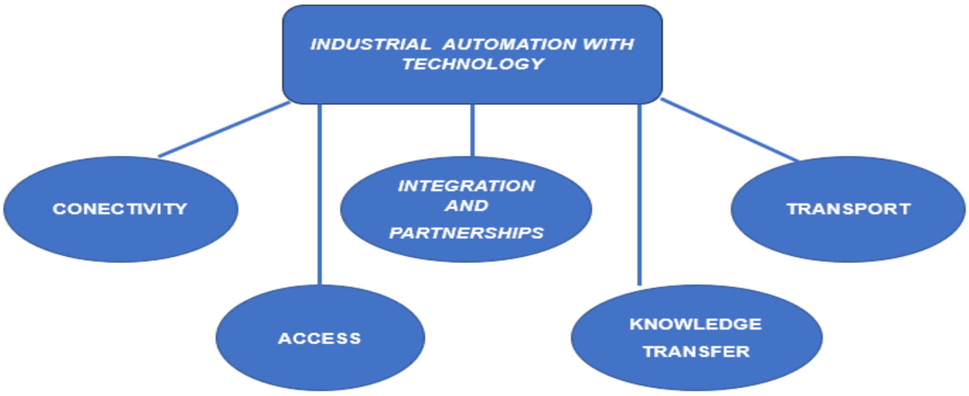


Fig.6. Author Mental Research Map ,2023**.**

- CONNECTIVITY: Allow connectivity of all devices in a company with management for decision making

- TRANSPORT: Enable the transport of logical information with the cybersecurity of 5G connectivity.

- ACCESS: Enable secure access for everyone involved to the Industry 4.0 system

- KNOWLEDGE.TRANSFER: Define and develop necessary capabilities

- INTEGRATION AND PARTNERSHIPS: Develop integration and partnerships with customers and suppliers in the Horizontal and Vertical production chain.

To support strategic planning, the company must carry out, in this first stage, self-assessment research on processes, analyzing their level of maturity and the objective they wish to achieve. To this end, it is recommended to use a model to assess organizational, economic and technological maturity. In this way, resources are directed to a quantitative and qualitative assessment of the level of complexity of the technology used, people management, investments, tangible and intangible assets and maintenance policies, for the implementation of the company's digital transformation (ENEGEP, 2017).

The Industry 4.0 IMPULS maturity model, was chosen (Lichtblau et al. (2015), as it is more transparent and suitable for the scenario of automation implementation for the SKM Company. This model was developed by the German Machine Manufacturers Association (through the IMPULS Foundation), with the support of companies representing the German industrial sector and research institutions such as IW Consult and the Institute for Industrial Management (FIR).

As a premise for analyzing the company's maturity, internal research must be carried out with employees and managers, which evaluates a minimum of requirements that must be observed in order to clarify the items necessary for the implementation of Automation, considering 5 dimensions (qualities) for 27 applications in the associated areas (quantities) of functions, as shown in Figure, 7.

In the relevance of this research, the company intends to evaluate the need for automation in each sector, in order to achieve excellence in the production process, with the evolution of equipment and resources performing, with applied training.The IMPULS maturity assessment model was segmented for the SKM company into 5 dimensions and with 27 applications in the areas associated applied with the respective dimensions. These dimensions are presented as pillars of industry 4.0 and the 27 applications in the associated areas present greater detail and rigor.

DIMENSIONS	AREA ASSOCIATES APPLIED
AUTOMATION FUNCTION	Production Engineering IT HR Logistics
SENSORS (DEVICE)	Production Engineering IT HR Logistics
CONECTIVITY/IOT/ CYBER/ CONVERGENCY	Production Engineering IT HR Logistics
MONITORING/KPIs/ CLOUD/ BIGDAT	Production Engineering IT HR Logistics Operational Directorate
ADAPTATION (MARCHINE LEARNING)	Production Engineering IT HR Logistics Operational Directorate

Fig. 7. Author, Adapted K Lichtblau et al, 2015.

The board of directors of the company SKM defined and chose the human resources of the company's areas and their functions in the associated areas of Production, IT, Engineering, Logistics, RH and Management, to carry out the interviews (research) considering the questions related to the five (5) dimensions (qualities), as shown in Figure 8

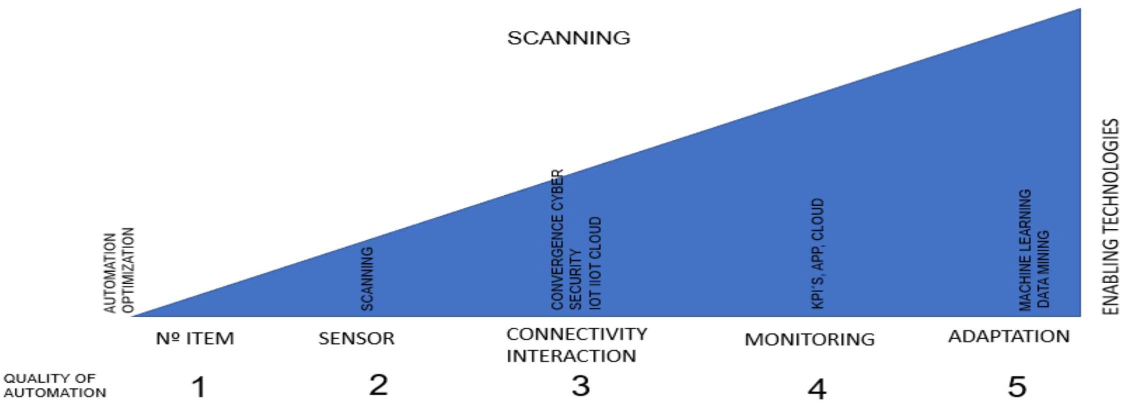


Fig. 8. Author Qualitative Maturity (5) evolution towards Industry 4.0, 2023.

Questions (research) asked for associated areas:

1. Status of the **automation** function related to the sector?

2. Status of **devices** (Sensors) in the area?
3. **IOT Cyber convergence** connectivity status and function integration?
4. **Monitoring** status (KPIs), Cloud, Big Data / function management?
5. **Adaptation status (Machine Learning**) for this function?

Associated areas and Function X:

Production (P) Function: Production supervisor
Engineering (E) Function: Engineering coordinator
Information Technology Function: (IT) IT Technologist
Logistics (LOG) Function: Production control
Board of Directors (DIR) Function: Operational Director
Human Resources (HR) Function: HR Management

The assessment resulting from the responses to the questionnaire that this maturity model includes classification of each of these dimensions into 5 possible levels. What defines the level of each dimension will be the lowest level reached by the areas associated with the respective dimension. With the classification of the different dimensions, a general characterization of the company is made at the level of industry 4.0 through 5 levels of evaluation.

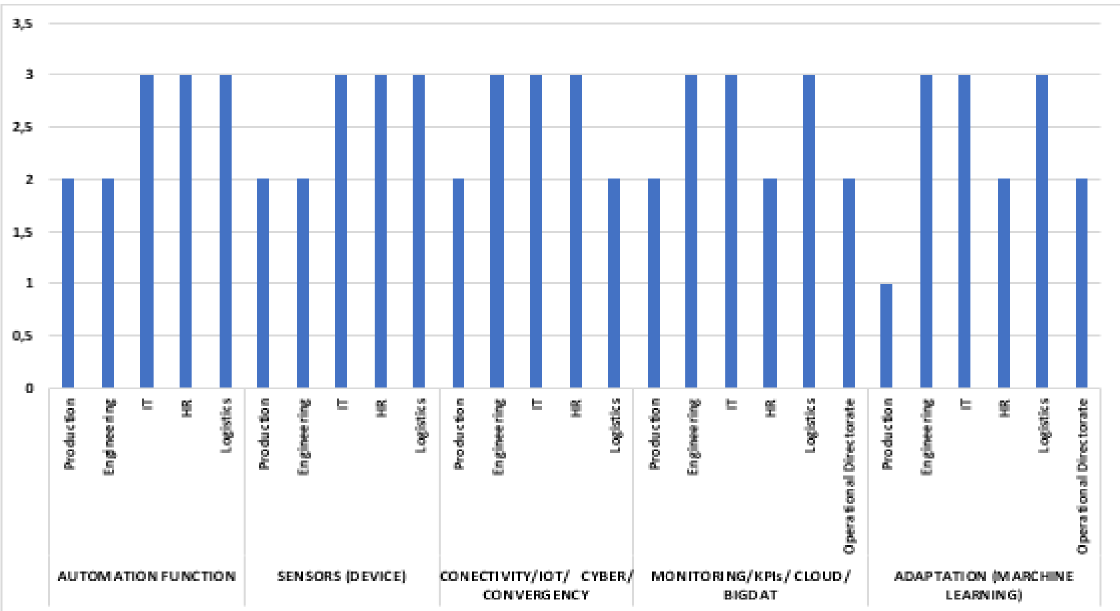
• level 0 “Outsider” - Company that does not have I4.0 capabilities and knowledge.
• level 1 “Beginner”- Company that already has some pilot projects underway in some areas and some investments.
• level 2 “Intermediate” - The company at a strategic level is in an initial phase of implementing and evaluating I4.0 concepts.
• level 3 “Experienced” - The company already has an I4.0 integration strategy formulated
• level 4 “Expert” - The company is an expert in using an I4.0 strategy and controls key indicators
• level 5 “Top performer”- The company is at the maximum level of implementation of its I4.0 strateg.

The report under analysis Figure, 9, presents the most detailed assessment level of each dimension for their respective Applied Associate Areas.

DIMENSIONS	AREA ASSOCIATES APPLIED	LEVEL
AUTOMATION FUNCTION	Production	2
	Engineering	2
	IT	3
	HR	3
	Logistics	3
SENSORS (DEVICE)	Production	2
	Engineering	2
	IT	3
	HR	3
	Logistics	3
CONECTIVITY/IOT/ CYBER/ CONVERGENCY	Production	2
	Engineering	3
	IT	3
	HR	3
	Logistics	2
MONITORING/KPIs/ CLOUD/ BIGDAT	Production	2
	Engineering	3
	IT	3
	HR	2
	Logistics	3
	Operational Directorate	2
ADAPTATION (MARCHINE LEARNING)	Production	1
	Engineering	3
	IT	3
	HR	2
	Logistics	3
	Operational Directorate	2

Fig. 9. - Evaluated Level of Dimensions for Associated Applied Areas, 2024.

In Graphic, 1, evaluation notes are shown in graphic form of the company's maturity in dimension items (qualitative) and applications in associated areas (quantitative), defined by production engineering, to continue a strategic analysis and decision-making regarding implementation of Industrial Automation, in the areas of Production, Engineering, Information Technology (IT), logistics and Management, presenting the Assessment Notes.



Graph 1 – Automation Maturity assessment notes, 2024.

Analysis of Results. (Search example).

With a more detailed analysis of the responses to the survey using the IMPULS model at the company SKM, it was possible to verify flaws in some key areas of Industry 4.0. According to K Lichtblau et al. (2015), it is essential that companies that are classified with low levels of maturity need to train their resources for the integration of I4.0, not only by hiring specialized employees and training existing ones, but also by integrating technologies adjacent to Industry 4.0.

A Planning and Control in Maintenance Management necessary for company SKM for the implementation of Industry 4.0 also absorbs 5G mobile technology in its entirety. The decision-making process of Company managers is based on probabilities, possibilities and/or alternatives.

This process is present in all administrative functions, such as Planning, Directing, Controlling and activating changes in production, in order to meet what is defined in the 5 Stages of the Strategic Plan, as shown in figure ,10. (SUZANO, 2010).

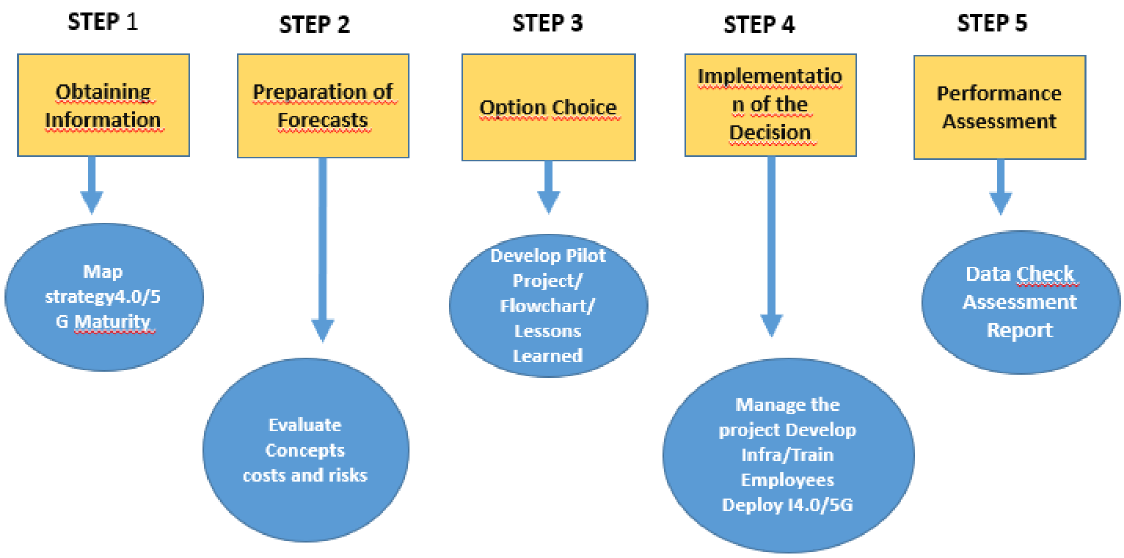


Fig. 10. Author , Strategic Planning for Automation implementation, 2024.

4. Expected Results

As a result, let's say that in the short term, digital transformation is planned that will boost the productivity of industry 4.0 on a large scale with 5G, faster and with greater data transmission capacity. A study carried out by Nokia, a Finnish telecommunications and technology company, and the consultancy and research company Omdia reveals that the expected impact of the fifth generation (5G) in the country is US$ 1.2 trillion in the period from 2021 to 2035 (THIS IS MONEY , 2022).

This volume of money is capable of adding one percentage point per year to the Brazilian GDP, becoming one of the engines of the economy in the coming years and the lever for resuming growth post-pandemic (ISTO É DINHEIRO, 2022).

5. Final Considerations

The successful automation process is achieved through the union of important factors, such as: the use of methodological approaches that simultaneously consider the technological, organizational and social aspects of the problem; the definition and implementation of a scientific policy in which Industrial Automation Networks, government, industry and universities participate effectively, in their respective roles; and training in automation oriented towards a new attitude of the engineer, more creative and with the necessary skills in terms of multidisciplinarity and integration. In order to obtain better control of the large amount of information that circulates in an automated company, it is important to use an automated industrial network, for better control of processes, reducing losses of raw materials and time. As the data to be processed is not manipulated manually, the margin of error in its processing is greatly reduced. The Author, (2022).

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