INDUSTRY CONCEPTS 4.0 ASSOCIATED WITH THE DYNAMIC CAPACITY APPROACH IN THE MANUFACTURE OF MEDICAL AND HOSPITAL PRODUCTS FOR RADIOPROTECTION APPLIED TO NUCLEAR MEDICINE

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ABSTRACT

The research presents the implementation of concepts of the industry 4.0 under the approach of the dynamic capacity in the economy of the industrialization of products and equipment for the radioprotection applied in nuclear medicine. The use of dynamic capacity makes it a direct link channel and enables the identification of strengths and opportunities within the company. The impacts of the fourth industrial revolution have brought about profound productive changes in companies and all the technology applied in them is involved in creating a new working environment. In a decentralized and highly connected manner, Industry 4.0 develops strategies to more efficiently leverage the information generated in industries, bringing new opportunities and incentives to innovate and compete globally. The strategy of manufacturing new products through the new industrial revolution allows the company to be independent of third parties, reducing the cost of production, increasing profits, having more autonomy and dominating its own technology.

KEYWORDS: *Industry 4.0. Dynamic Capacity. Radioprotection. Medical-Hospital Equipment*

I. INTRODUCTION

The history of man is marked by several revolutions that have had significant impacts on the development of contemporary society as new methods and innovations have been included within industries.

The First Industrial Revolution between 1760 and 1840 in England, with the gradual replacement of the craft and machine methods, the exploitation of coal as alternative energy to wood and other biofuels, and the increasing use of steam energy. [1] In the late eighteenth-century steam engines and the use of hydraulic power revolutionized the industry great breakthrough and the Second Industrial Revolution arose. [2]

We witnessed the arrival of new and solid forces that required companies to react. These forces include impulsive growth in science and technology; threats to health, safety and the environment; growth of consumerism; and intensification of international competition in terms of quality. [3]

With the current industrial landscape, companies are looking for a new structure for continuous improvement with new technologies, and together with people, they adapt quickly to changes and are more demanding in the quality of products and services, with significant impacts on the development of new methods and innovations within industries.

Targeted at the needs of customers, companies are structuring themselves, organizing their processes and standardizing their products or services. The use of industry 4.0 concepts drives growth qualifies and ensures loss-reducing production, contributing to the organization's financial growth and perenniality.

In essence, it is stated that Industry 4.0 is a major technological revolution that will reshape manufacturing industries and social and economic life more broadly. In other words, we are at the beginning of a new industrial revolution. [4]

The processes related to Industry 4.0 could reduce equipment maintenance costs by up to 40%, reduce energy consumption is up to 20% and increase work efficiency by up to 25%, which could impact Brazilian GDP by approximately US $ 39 billion by 2030. [5]

The main objective of this article is to present the study of the implantation of the concepts of industry 4.0 through the dynamic capacity in an industry of hospital medical products and equipment. As specific objectives: it is intended to describe the company's process, to collect data on the production process and to analyze how the concepts of industry 4.0 apply in the manufacture of equipment and products for radioprotection in nuclear medicine.

In this context, this article aims to raise the concepts and pillars of this new industrial revolution related to the approach of dynamic capacity and analyze the importance of productivity and tool to reach new levels of competitiveness in the manufacture of its products. The present research was organized in the following stages: concepts about Industry 4.0, contextualization of the industry of medical and hospital products for radioprotection applied to nuclear medicine, methodology, results, and discussion, conclusion.

II. CONCEPTS

2.1 Innovation

Innovation actions consist of incremental improvements, wherein all sectors of the company, hierarchical levels, and collaborators; it is the result of a systematized, organized, controlled and measured process and not necessarily a sudden inspiration of an individual. [6]

The innovation can be outlined as follows: Innovation = Idea + Implementation of actions + Result. In other words, to be considered innovation, it is necessary to implement it and obtain an advantage over other competitors in the market. [7]

Innovation is one of the main drivers of economic growth [8], and in that sense, some developing countries have invested in policies that increase their capacity for innovation. Although several factors interfere with the capacity for innovation and the results of the country's economic growth, the entrepreneur plays a significant role. [9] It is he who identifies the country's policies and leverages them to leverage innovation.

In this way, industry 4.0 is a bias to be explored to seek improvement of products and medical-hospital equipment for radioprotection applied to nuclear medicine.

2.2 Industry Concepts 4.0

Industry 4.0 is a recent concept that was mentioned for the first time in 2011 in the Hannover Fair in Germany. This involves the main technological innovations applied to production processes in the field of automation, control and information technologies). [10] The Fourth Industrial Revolution can be explained according to Table 1:

Table 1. Period and characteristics of the Industrial Revolution. Adaptaded [11,4]

Industrial revolutions over time		
Industrial Revolution	**Period**	**Characteristics**
First	1760-1840	Mechanization; caused by the construction of railways and the invention of the steam engine.

Second	Beginning at the end of the 19th century	Mass production; with the rise of electricity and the assembly line.
Third	Beginning in the 1960s	Digital revolution; increase by the development of computing and the Internet, when it becomes common to use electronics and T.I. in production processes.
Fourth	in progress	Fusion of technologies and interaction between physical, digital and biological media.

The Industry 4.0 concept combines the technological achievements of the last few years with the vision of the future where there are intelligent and automated production systems in which the real-world is connected to a virtual world, ensuring more efficient use of the available information. [12]

Within the Industry 4.0 framework, organizations will have the capacity and autonomy to schedule maintenance, predict failures and adapt themselves to new requirements and unplanned changes in the production processes. [13]

The fourth revolution provides the groundwork to Industry 4.0 with an application of modern information and communication technology and connected with the integration of automation industry, data networks, and contemporary manufacturing technologies like intelligent production, human-computer interaction, 3D printing, remote operations, etc. [14,15,16]

In the fabrication of the future, plants and management will need rapid product development and flexible production in complex environments. "An intelligent factory will present communication between humans, machines and similar products in a fully integrated way". [17]

In this way, it allows the creation of value at the most diverse levels and it is important to analyze the impact and challenges that companies will face in this new revolution. The impact goes beyond simple digitization to a much more complex form of innovation based on a combination of multiple technologies that will force companies to rethink the way they run their businesses and processes. [18]

2.3 Pillars of the Industry 4.0

Information technology has come to aggregate in the pursuit of continuous improvement. It is essential to highlight the importance of tools such as the Internet of Things (IoT), Cloud Computing, Big Data, among other pillars that are present to help in terms of efficiency and productivity. Figure 1 lists the digital technologies that have been fermenting for some time. Some are not yet ready to be applied on a large scale, but many have already reached a point where their high reliability and lower costs begin to make sense for industrial applications. [19]

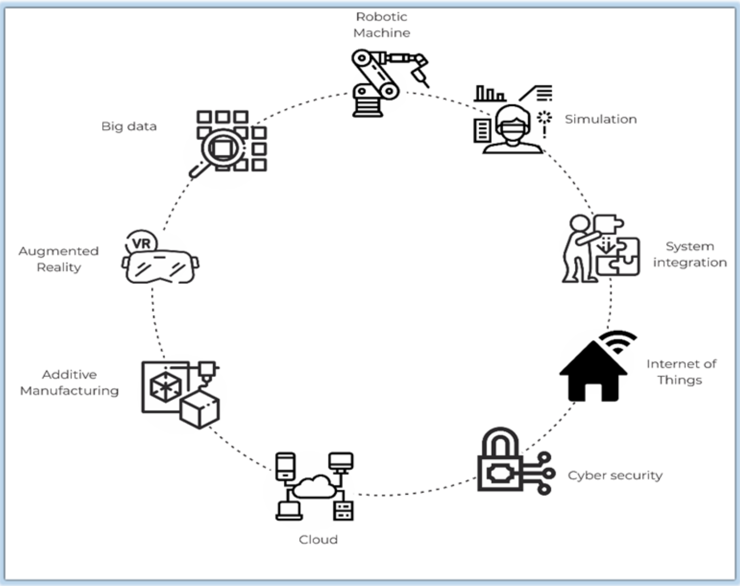


Figure 1 - Networks and relationships with Industry 4.0

The integration of productivity technologies with information technology directly reflects benefits at the end of the production chain, impacting consumer improvements.

2.4 Big Data

Big data is a platform to generate massive data gathered from the user's communication using digital devices such as tablets, smartphones, and laptops. With the numeric figures of data gathered particularly from the huge data amount, facts of statistics are being generated among the digital devices such as mobile phones, computers or laptops to extract the value of the social network. [20]
The Big Data's focus is on the "extremely large set of data generated from technological processes and practices, such as social media, operational technologies, Internet access and sources of information. distributed information, telephony, etc. ". [21]
Also, Big Data as a relation between volume and data source whose value depends on technological solutions for storage and analysis. [22]. The Big Data is not just a software or hardware product, but a set of technologies, processes, and practices that allow companies to analyze data that they did not have before access and make decisions or even manage activities in a much more efficient way. [23]
Continually it takes powerful analysis tools to give it meaning. Data are numbers, words, or other signals that represent discrete facts about objective reality. They can be verified and validated, but they have no meaning unless they are interpreted and contextualized, giving rise to the information/product. [1]

2.5 Additive Manufacturing

Additive manufacturing (AM) consists of manufacturing parts by selectively adding material to an object's cross-layers [24]. Additive Manufacturing (AM) is a set of emerging technologies that manufactures three-dimensional objects directly from digital models through a process of adding material, which can be polymers, ceramics or metals. The different techniques are used to generate such layers, as laser sintering, and various materials can be processed, including metals and ceramics. [25]
Additive manufacturing (AM) has gained attention recently for being a more intelligent and greener way of manufacturing. In comparison with traditional subtractive manufacturing (cutting, milling, grinding, etc.), this technology produces fewer amounts of waste and facilitates the creation of complex geometries. Also, AM is revolutionizing the way of producing because it allows customized products to be released at relatively low cost and faster than ever before, mainly prototypes and on-demand objects. Also called 3D printing, additive manufacturing comprises a variety of technologies. The ASTM F42 has arranged AM in seven categories: material extrusion, powder bed extrusion, vat photopolymerization, material jetting, binder jetting, sheet lamination and directed energy deposition. [26]

Chart 1, ASTM F42 classification for the AM technologies. Adapted [26].

	ASTM F42 Category	**Technology**	**Raw material**
1	Material extrusion	Fused Deposition Modeling (FDM)	Thermoplastics, ceramics slurries, metal pastes
		Countor crafting	
2	Powder Bed Fusion	Selective Laser Sintering (SLS)	Polymers
		Direct Metal Laser Sintering (DMLS)	Atomized metal powder, ceramic powder
		Selective Laser Melting (SLM)	
		Electron Beam Melting (EBM)	
3	Vat Photopolimerization	Stereolitography (STL)	Photopolymers, ceramics
4	Material Jetting	Polyjet/Inkjet Printing	Photopolymers, wax
5	Binder Jetting	Indirect Inkjet Printing (Binder 3DP)	Polymer powder, ceramic powder, metal powder

6	Sheet Lamination	Laminated Object Manufacturing (LOM)	Polymer film, metallic sheet, ceramic tape
7	Direct Energy Deposition	Laser Engineered Net Shaping (LENS)	Molten metal powder
		Electronic Beam Welding (EBW)	

Due to the high acquisition costs of additive manufacturing machines, the planning and programming of parts to be processed in these machines play a vital role in reducing operating costs, offering services to lower-cost customers and increasing the profitability of companies that provide these services. [27]

2.6 Dynamic Capacities

From the definitions established by Winter (1964) on the thematic dynamic capacities, that is, also known as a practice and knowledges that can be identified inside or outside a firm, is a subject for large researchers to relate theories to the operational practices of industries, interconnecting the themes: intellectual capital; organizational routines; industrial processes and company culture. [28]
The use of dynamic capabilities as a way of explaining the dynamics of alliances, or stages that alliances are based on dynamic capacity. It can be identified to be able to improve the product, renewing the strategy, or production plan, to change the routines or the traditional way of working. Furthermore, the term is translated from the English term Dynamic Capabilities. [29] This translation is based on people with an ability or an ability to perform actions. For example, equipment does not produce without qualified operators, that is, knowledge and manpower to operate. [28] In this way, the theory of production capacity cannot be compared with the theory of dynamic capabilities.
To identified the intelligence inside and outside the firms are presented as a sequence of tasks, that is, of specific activities within the process in a production line of the company. It can be identified to improve the entire product, renewing the strategy, or production plan, to change the routines or the traditional way of working [29]. The firm always thinking about innovation startup, quotes: "if the company renews itself or innovates faster, competition diminishes in a general way, interconnecting the approach capabilities dynamics ". [28]
Therefore a deep look at the inside of the companies, we have hidden capabilities, to be identified that can guide in the globalized market. However, capabilities are also often used to construct configurations of new resources in pursuit of advantages and to make use of them is to protect, update, visualize opportunities, to innovate and to extend to keep the company competes against the competition. [30]
The Dynamic Capabilities allow the company to generate superior profits enabling the development and production of differentiated products and services that reach new markets. [31]

2.7 Contextualization of the Industry of Medical and Hospital Products for Radioprotection Applied To Nuclear Medicine

The medical-hospital and dental equipment industry is characterized as multidisciplinary, while being dependent and fostering the evolution and innovation of technologies from different areas of knowledge. This dynamism of the sector is mainly due to the demand for incorporation of technologies by health systems, and the need to offer products that are compatible with the technological advances. [32]
This points out that due to the lack of a specific product development model for medical equipment, according to the Brazilian scenario, the industries in this sector end up seeking tools and models from other branches, adapting them to their reality. [33]
This scenario corroborates the motto of the research, to seek solutions and improvements, through innovative methodologies, as well as the application of technologies to the production environment. Therefore, despite seeking innovations, medical device developers should value the safety and expected performance of the products. [34]
Within this context, there are processes for the manufacture of medical and hospital products aimed at radioprotection applied to nuclear medicine (MN).
Nuclear medicine is a medical specialty responsible for the diagnosis and treatment of diseases through unsealed radioactive sources. [35, 36]

In addition to this brief concept on nuclear medicine, there are three principles, which should be carefully observed in the products produced by the company studied and should be followed to users on radiation protection: time, distance and shielding.
The time, since the dose absorbed by IOE (occupationally exposed individual), is directly proportional to the time of exposure; distance as the intensity of the radiation decreases with the inverse of the square of the distance, that is, as the distance between the radiation source and the individual increases, the exposure is reduced rapidly and, finally, the shield, which allows reducing a very low level of radiological exposure. [37]

III. METHODOLOGY

The methodology used in the elaboration of this study was developed as follows: it was initially defined the type of scientific method of the research as being inductive through observation, relationship between them and generalization of the relationship followed by the level of exploratory research where it was carried out in relation the question of research on the subject of the new industrial revolution, through the bibliographical survey, interviews and case study, where we obtained existing concepts that can be applied in the company.
Based on these considerations, the research was designed as a field study because it was carried out in an Industry and Commerce of products and medical-hospital equipment aimed at radioprotection. Before this study was collected and analyzed the data in the places where they originate, that is, with employees of the company under study.
The area defined for the study is the produce department of the company from August to November 2017. To finalize the analysis and interpretation of the results qualitatively and quantitatively through tables, tables, and graphs that allow the reader a better interpretation of the text, facilitating its analysis.

IV. RESULTS AND DISCUSSION

The place of study is in a medical-hospital product and equipment industry focused on radioprotection in nuclear medicine, more specifically the field study was applied in the company's products department. The company has 80 m² (eighty square meters) of constructed area, five (5) employees that work in commercial shifts. The company at the end of 2017 had approximate billings of 150 thousand reais.
Figure 2 represents some products developed and produced in the company, such as: shielding for radioactive material, eluate shielding, syringe shielding for radioactive material and shielding through the 3D printer. The shields consist of the body and the cover of the steel product, the upper base of the cover made by lead and the armored shield produced by copper. The only component of this product that is not made by the 3D printer is the part that contains the glass that is cast. The modification proposed in this product, through 3D printing, changes its current composition (steel, lead, and copper) by filaments polylactic acid (PLA), whose diameter 1.75mm. Accompanying the steel modification by PLA filaments the syringe shielding is more practical to use, including fully removable and multi-colored pants. Photographs 1, 2, 3, 4 and 5 are pre-and post-elaborate shields using the 3D printer.

Figure 2. Products

The company has a production cost of the shields for radioactive material and valuate in the amount of R $ 580.00 / unit. For commercialization costs R $ 997,60 / unit. With the modification of the parts by the 3D printer, the cost of the material will cost R $ 499,00 / unit. and the sale price is R $ 998.00 / unit. Table 2 shows changes in production costs, sales, profit, and the production time per unit of these products, where it was verified that the use of the 3D printer for the manufacture of the shields obtained a reduction of costs of R $ 81.00 per unit and an increase of 28% of profit per unit for the company, due to the new process.

Table 2. Alterations of the shields for radioactive material and eluate shielding.

Change the cost of Shield per unit		
Unit	**Lathe**	**3D printer**
Cost/Production	R$ 580,00 unit.	R$ 499,00 unit.
Sales	R$ 997,60 unit.	R$ 998,00 unit.
Profit	72%	100%
Production time	16 hours (because it is 8 hours / day worked), resulting in 2 days.	10 hours (external finish made by the lathe) + 2 hours of finishing done by the 3D printer (bottle protector and lid)

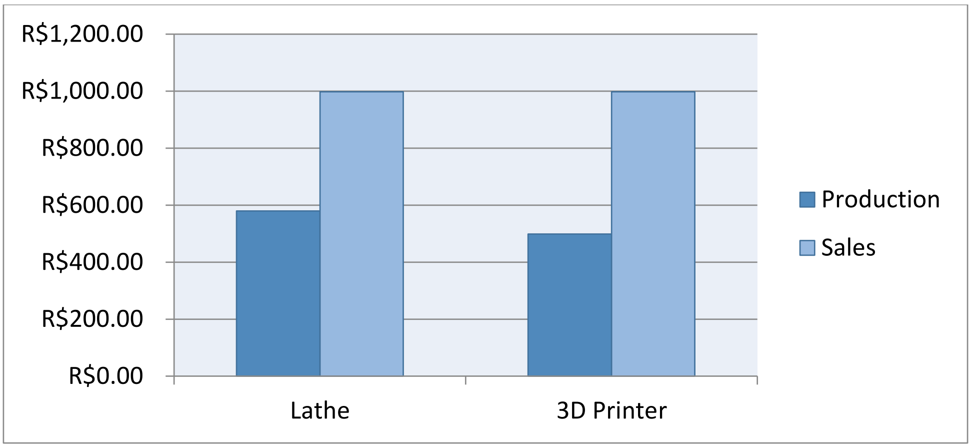
Table 3 shows the change in cost, sale, and profit of the syringe shields produced by the lathe that will be replaced by the 3D printer. It can be seen that the use of the 3D printer to manufacture the syringe shields had a cost reduction of R $ 80.00 per unit. Besides, there was a 21% increase in profit per unit for the company.

Table 3. Changing the syringe shields

Change cost of the syringe Shields per unit		
Unit	**Lathe**	**3D printer**
Cost / Production	R$ 600,00 unit	R$ 520,00 unit
Sales	R$ 798,00 unit	R$ 800,00 unit
Profit	33%	54%
Production Time	8 hours	6 hours

Finally, the results of the initial production rounds were evaluated to incorporate changes and improvements in the product and its manufacturing process, with a reduction of 4 hours for the first process according to table 2 and 2 hours for the second process, according to table 3. The strategy of manufacturing these new products allowed the company to be independent of third parties, reducing the cost of production, increasing profits, having more autonomy and dominating its technology, ie developing its dynamic capacity.
Graph 1 shows a better perception of the data obtained from the cost of production and sales per unit, according to Table 2.

Graph 1 – Production vs. Sales Chart



A significant difference is observed in the two production processes, where the 3D printer has a lower cost of production, because its raw material is cheaper, having a higher profitability compared to the lathe, also having better productivity, obtaining a shorter time of production where it does not have manual labor and the use of materials that attack the environment.
This 4.0 industry process will make the 3D printer an important tool in the company's production process. The company's future trend is to broaden the spectrum of 3D printable materials. This is one of the reasons that led the company to invest in this technology. The estimate of billing from the year 2019, will have a 40% increase with this technology implanted and expanded for the development of hand prosthesis and elbow braces.

V. CONCLUSION

Unlike the other industrial revolutions, Industry 4.0 finds itself with an initial period and the results visible although this revolution still is premature. Aiming at the future of production and dissemination of information, it is understood that Industry 4.0 is reaching to improve the quality of products and services on an ongoing basis, whose investments will bring returns over time due to the benefits they bring in terms of agility and flexibility to meet an increasingly demanding market.
The initial objectives of this work were to describe the types of products manufactured by the company studied with the industry applications 4.0 associated with the dynamic capabilities approach. It was possible to develop a reference model that contemplates the functional and technological aspects of the production of these products and make a proposal for improvement in the productive process of the company.
The challenge for the company is to follow these innovations that will not only affect production but also models of education, business, consumer habits and social and cultural aspects in the coming years. Through this study, other research may be developed as a guide for future projects or studies of alternative materials, the use of augmented reality and simulation for the manufacture of new products and equipment.

In addition to the knowledge acquired about the new industrial context, the achievements, the challenges and, above all, the opportunities. The present work reinforced the importance of practical teaching of engineering, integrated into the reality of the company.

VI. FUTURE WORK

For future work, the elaboration of a new layout for the company or any other type of company that adopts this culture, to implant the new technologies in the productive process, allowing several advantages that can be obtained concerning the production, such as: decrease of lead time, elimination or minimization of some types of losses, reduction of intermediate stocks, production balancing, better organization of the work sectors, among others.

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