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Evaluation of Innovation Capabilities for Implementation of Additive Manufacturing of Metals at a Production Center. A Case Study

Evaluación de capacidades de innovación para la implementación de la Manufactura Aditiva con Metales en un Centro de Productividad. Un Estudio de Caso

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Abstract

Colombia faces technological, economic, environmental and cultural changes about the Fourth Industrial Revolution. Therefore, the National Government and the National Service for Learning – SENA -, are undertaking efforts to incorporate technologies to enable a digital and interconnected world. Thus, this paper seeks to identify the main challenges faced by SENA with regards to the application of Additive Manufacturing of Metals in the different sectors of the economy, and the implementation of training programs to contribute to the development thereof. Consequently, a case study is developed through evaluation of capabilities, identifying challenges and proposing an action plan for the institution. The results represent evidence regarding the main challenges faced by the CTMA -Center for Advanced Manufacturing-, regarding AMM. The findings enable identifying critical aspects for implementation and identification of technologies for strategic companies in the manufacturing sector and, additionally, that the CTMA has no formal structure for AMM, strategic planning, procedures, nor responsible parties to channel information and industry demands.

Keywords: *Advanced manufacturing; Additive manufacturing of metal; Fourth industrial revolution; Case study; Innovation capabilities.*

Resumen

Colombia enfrenta un cambio tecnológico, económico, ambiental y cultural de cara a la Cuarta Revolución Industrial, por tanto, desde el Gobierno Nacional y el Servicio Nacional de Aprendizaje - SENA, se están realizando esfuerzos en la incorporación de las tecnologías habilitadoras para un mundo digital e interconectado. Por eso, este trabajo busca identificar los grandes desafíos a los que se enfrenta el SENA frente a la aplicación de la Manufactura Aditiva con Metales o AMM por sus siglas en inglés Additive Manufacturing of Metals en los diferentes sectores de la economía y la puesta en marcha de programas de formación que aporten al desarrollo de esta, para ello desarrolla un Estudio de Caso, que a través de una evaluación de capacidades identifica d esafíos y propone un plan de acción a la institución. El resultado constituye una evidencia sobre los grandes retos que enfrenta el Centro de Manufactura Avanzada CTMA en la AMM, los hallazgos permiten identificar aspectos críticos en la implementación e identificación de tecnologías para empresas estratégicas en el sector de manufactura, además, el CTMA no cuenta con una estructura formal de AMM, planeación estratégica, procedimientos y responsables para canalizar la información y las demandas de la industria

Palabras Clave: *Manufactura avanzada; Manufactura aditiva con metales; Cuarta revolución industrial; Estudio de caso; Capacidades de innovación*[1].

1. Los términos clave han sido recuperados a partir del Tesauro de la Unesco

Introduction

Colombia is a developing country with great challenges at a national and global level, facing day by day the great boom of the Fourth Industrial Revolution (4RI), which is generating great changes in the future of work in the era of automation. According to experts, difficult times are generated and it is possible to find statements in this regard such as: "Several million jobs will be lost worldwide and others will be generated with new skills needed for the machine age, which will have major megatrends in three areas; physical, digital and biological" (Schwab, 2016, p. 19).

Therefore, one of the major commitments of the National Government and the National Learning Service (SENA) is to be able to incorporate new 4RI enabling technologies in the different economic sectors of society that will enable the acquisition of the necessary skills and knowledge to create an ecosystem in which the productive sector, academia and the community can interact, providing the necessary tools and training for work and thus generate value and skills for a more competitive, connected and unequal world, where the gap between rich and poor is becoming increasingly evident. Given the current technological change, SENA expects to provide training in accordance with the productive vocation of Colombia's departments and that this training will be supported by transversal strategies in the entity. Likewise, the sectoral guide for Science, Technology and Innovation - CTI programs and projects is modified to include the use, production, integration and appropriation of information and communication technologies, digital transformation and 4RI "which includes data analytics, Internet of things, distributed records, artificial intelligence, machine learning, 3D printing, virtual reality and augmented reality, among others" (Departamento Nacional de Planeación, 2018, p. 145).

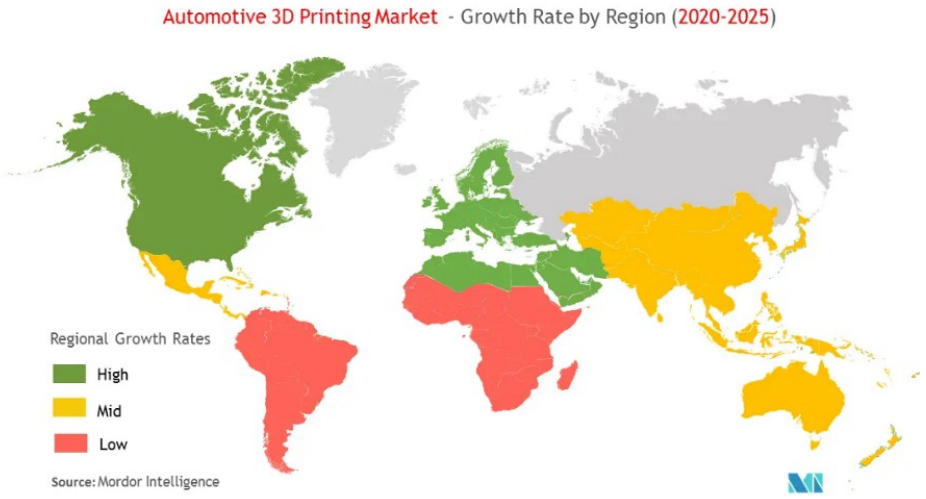
3D Printing (Additive Manufacturing or Additive Manufacturing AM) is a disruptive technology and one of the enablers of the 4RI that generates great changes at the technological, legal, business and market levels. This project works with 3D Printing with metals or Additive Manufacturing of Metals (AMM), which has great impact and is an essential part of the supply chain to manufacture parts, spare parts to reduce stocks and waiting times in all sectors of the military industry, aviation, biomedical, trade, among others.

At the local, departmental and national level, AM and specifically with metals is in a process of maturation and application in several countries in Latin America, but only Mexico is at the forefront in prototypes and development of this type of technology in processes, manufacturing and production of parts for the industry, thanks to the vision that disruptive technologies have in the development of Mexico, and that allow several public and private entities to form the Consortium of Additive Manufacturing (CONMAD). Among the objectives is the consolidation of Mexico's leadership in this area, it is estimated that, in the coming years, 40% of the products for the aeronautical and automotive sectors will be manufactured through AMM and plastics (CIDESI, 2017). In summary, this project faces the problematic situation that summarizes 3D printing with metals or AMM as one of the enablers of the 4RI that impacts the different economic sectors. The evaluation of technology capabilities is an opportunity to develop to know aspects necessary for its implementation, in this case we can speak of an opportunity.

Meanwhile, in Colombia, SENA's mission is to impact social and technical development by offering and executing comprehensive professional training for the incorporation and development of people in productive activities that contribute to the social, economic and technological well-being of the country (Servicio Nacional de Aprendizaje, 2019). Currently, strategies are being implemented at the national and local levels that allow the strengthening of skills in line with the 4RI era, focusing on those enabling technologies that are more in line with the Colombian territory.

WMA is one of those enabling technologies with great impact, which is in great expansion in regions such as Asia, the United States and the European Union, regions that continue to bet on this disruptive technology as can be seen in Figure 1. Therefore, in Latin America and especially in Colombia, urgent actions must be taken to enable development in the different economic sectors, to produce goods and services with high added value and generate new forms of manufacturing production, and thus, little by little, stop being a country with a high dependence on the extractive industry.

Figure 1.
Growth of additive manufacturing with metals



Source: Mordor Intelligence, 2021

Therefore, the objective of this project is to evaluate the capabilities for the implementation of the AMM of the Advanced Manufacturing Center (CTMA) of SENA in Pedregal Medellin, through the analysis of a business case and the implementation process in the same CTMA. The following specific objectives are used for this purpose.

Explore the context of AMM in the regional business environment. Identify WMA capabilities in the selected company and in the CTMA. Detect critical aspects of the selected case and match it with the needs of the CTMA and design an action plan for the AMM incorporation to the CTMA of SENA. Some propositions are put forward in this case, around the need to

to know how mature is the process of incorporation of the WMA in the companies of the region and what is the status of incorporation of the WMA in the company, among others.

Theoretical framework

This chapter describes the theory of resources and business capabilities, the importance of Industry 4.0 and the main enabler that is the AMM, also seeks to provide a context of this technology in Colombia, and the role of SENA as a training institution for work. A thread is given about the AMM and innovation capabilities, the main theoretical approach in the development of this project. It is an enabling technology of the 4RI, which is one of the great bets at world level for economic development, production, logistic and cost systems. The 4RI is the coined term, which refers to the different enabling technologies that are changing the way in which people interact, buy and sell products or services, develop new business models and are impacting the workforce by automating jobs. The AMM, which is the technology that this paper deals with, aims to identify key aspects for its implementation in a country, such as Colombia, which has one of the 4RI headquarters, currently located in Ruta N in the city of Medellin. Finally, the role of SENA and the CTMA of Medellin and their needs for the implementation of this technology in the manufacturing industry in the city are presented.

Innovation Capabilities

In the theory of resources and capabilities, the idea of considering the firm's resources as a source of internal growth goes back to and is supported by the work The Theory of the Growth of the firm, which highlights the importance of the firm's existing resources, even with respect to demand (Penrose, 1959). This suggests that the growth strategies of organizations are a function of resources, resources being understood as that which could be considered as a strength or weakness of a given firm (Wernerfelt, 2007). Therefore, competitive advantage and organizational growth are given by the organization's resources and capabilities, since these are valuable, rare, imperfectly imitable and non-substitutable. Resources can be classified as physical, human and organizational. Physical resources are technology, equipment and facilities; geographic location and access to raw materials; human resources are training, experience, judgment, intelligence and relationships; managerial and employee intuition. The main resources in organizations include the formal structure, formal and informal planning, control and coordination of systems; the relationships between groups within the company and between the company and other agents in its environment (Barney, 1991).

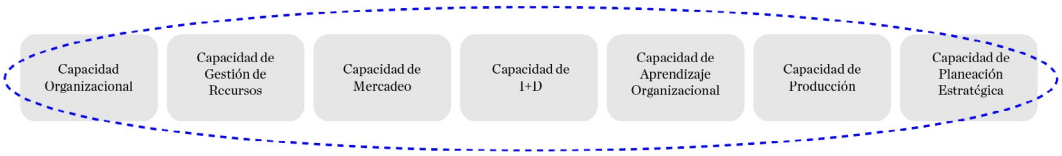
In terms of capacity building, these are understood as the skills that enable the configuration of competencies and resources (Teece et al., 2007). An organizational capability is the ability to develop a coordinated set of tasks through the use of organizational resources in order to achieve a particular result (Helfat & Peteraf, 2003). They are the ones that cause the creation, evolution and recombination of these other resources into new resources, for example, the creation of new resources.

The above in order to face the challenges of these times (Sher & Yang, 2005). Both technical and managerial capabilities are based on resources - information and knowledge linked to the capacity for innovation (López et al., 2004).

The classical authors of economic thinking and strategic thinking make importance of those organizational capabilities with the dynamics of technological innovation, called Technological Innovation Capabilities (Bogers et al., 2019), therefore, the relationship that exists between this type of capabilities and business performance plays a fundamental role in the generation and accumulation of capabilities through appropriate policies and strategies at the country, sector and company level (López et al., 2004). Recent studies have incorporated the evolution of dynamic capabilities given by sensing, sazing and transforming as a key aspect for the incorporation of 4RI disruptive technologies for developing countries (Aghimien et al., 2021).

From the perspective of resources and capabilities, it can be understood that behind innovation as a business process are the organizational capabilities that make it possible to obtain the company's products and services, so that the concept of technological innovation capabilities (TIC) refers to those generic and specific capabilities that the company possesses for carrying out innovations as a result of the organization's strategic and mission processes. The literature identifies multiple sources on organizational capabilities associated with technological innovation, such as Yam et al. (2004), Guan & Ma (2003) and Wang et al. (2008), and suggests that basically the capabilities can be grouped into R&D Capability, Resource Management Capability, Organizational Learning Capability, Strategic Planning Capability, Production Capability, Marketing Capability and Organizational Capability, which are grouped in Robledo et al. (2010), as shown in Figure 2.

Figure 2.
Technological innovation capabilities (STI).



Source: Prepared by the authors based on Robledo et al. (2010).

Industry 4.0, 4RI and Additive Manufacturing with AMM Metals

The 4RI concept was born in Germany, and seeks the continuous improvement and quality of its productive processes, generating the traceability of goods and services, this means the interconnection of all subsystems of the company to respond effectively to market requirements. It is a concept with which large companies are beginning to compete in the search for the self-materialization of processes, thus allowing optimization and quality in the different production systems of the companies. The 4RI encompasses a large number of enabling technologies that allow to have an interconnected and intelligent ecosystem, and increasingly competitive with a strong emphasis on

developed economies, which are managing to have a great impact on the production of new goods and services with high added value and competitive advantages over countries that do not have the necessary resources to devote to science, technology and innovation; therefore, the 4RI will be the big bet for the development and growth of the different sectors of the economy (World Economic Forum, 2017).

One of the enabling technologies of the 4RI is the AMM, which consists of the creation of metal parts through 3D printing, this technology has changed the way of making and producing parts for the different sectors in which it can be applied, such as; health, manufacturing, mining, aviation, automotive, with the application of this enabler is intended to improve the production of complex parts to perform, the reduction of stocks in warehouses, the manufacture of custom parts, the reduction of transportation costs and logistics. Currently this technology is very expensive given the degree of novelty it has and the incursion into different markets, different international consulting firms describe it as the backbone in the transformation of industrial production (CIDESI, 2017).

The WMA in Colombia and the Role of SENA

Colombia is a developing country that is currently making great efforts to improve the economy, become more competitive and generate added value in the different products and processes of the sectors of the Colombian economy. The WMA is in Colombia in a phase of study and review by public and private universities of higher education and training institutions for work, which are making significant progress in the application of this technology in different economic sectors, so far there is little information on the application of technology with metals in any sector, given the high cost, inputs and application.

Since 2018, the national government has had the 4RI and the orange economy as flags, the latter, mainly conformed by the cultural and creative industries. Both in order to create and boost the country's economy, for this, large strategic alliances are made with national and foreign companies such as Empresas Públicas de Medellín or Siemens focused on financing and/or training programs, which allow presenting Colombia as a country open and committed to disruptive techno- logies that are changing the way of living and working.

Given the great challenge that new technologies bring to the country, the Colombian government is making efforts both nationally and internationally to train in the skills needed in the jobs of the future, and to support the creation of companies that develop activities in products and processes in line with the 4RI era, which include: Cloud computing, big data, Internet of Things, smart cities, artificial intelligence, additive manufacturing, cognitive com- putation, collaborative economy, among others (Departamento Nacional de Planeación, 2018).

The Colombian government's commitment to be a country that aims to develop its economy hand in hand with technology and its advances has led it to install in Medellín one of the centers for the 4RI of the World Economic Forum (WEF), specifically in the Ruta N facilities. Through the National Director of SENA, the different education centers of this institution specialize in the following areas

in technologies in line with the productive sectors of the city and the department, currently, the CTMA of SENA Pedregal Medellin, has five areas of academic training, between graduate and complementary training which are: automation, automotive, manufacturing systems, electricity, ICT and electronics, each of these areas conducts studies, alliances and approaches at national and international level with disruptive technologies that mark the path of the city of Medellin, the department of Antioquia and Colombia (National Planning Department, 2018).

In Colombia, the manufacturing sector is one of the three sectors with the highest growth and development at the national level in different processes and products (Fedesarrollo, 2020), AMM so far is a "Cinderella" since there is little information about the potential of this disruptive technology in the Colombian economy. Some universities conduct studies on the subject, but very few work on MMA. In Latin America the first AMM center, CONMAD is a consortium in the city of San- tiago de Querétaro in the country of Mexico, which is a collaborative system has contributions from the public sector and the private sector, the lines of research developed in the consortium are focused on 2D and 3D additive ma- nufacturing, synthesis and processing of metallic materials (CIDESI, 2017). Recently, the Ministry of Commerce, Industry and Tourism and iNNpulsa ventured into the implementation of advanced and emerging technologies for the manufacturing sector with the new technological experiences program (N.E.X.T), which materializes the concept of advanced manufacturing, including 3D printing, as specified by the Analytical area in iNNpulsa.

According to Gartner studies, a company dedicated to technology research and consulting, which counts among its clients large companies and governments in the western world, presents in its magic quadrant curve, the possibility of implementing a specific development. In the particular case of AMM, it states that it is increasingly used in the medical, manufacturing and metal-mechanical sectors. This makes this technology an important link in the supply chain by 2030, to manufacture spare parts for commercial, military, automotive and certain consumer markets (Gartner Inc., 2018).

Methodology

This project was developed using qualitative research methods, specifically the one proposed by Yin (2006), the case study. For the collection of information, the innovation capabilities assessment tool (Robledo et al., 2010) was used as a reference (Robledo et al., 2010), which also allows the assessment of the information collected and a framework for analysis. Thus, a more general and complete vision of the use and implementation of technology in the selected company was obtained, and this allowed understanding the degree of maturity of the AMM there, as a reference business case in Antioquia, in addition to an assessment of the CTMA, using the same instrument. Thus, an action plan was proposed, regarding its implementation in the competitive context of the AMM industry in the region, which constitutes an applied research that resembles a consultancy (Kubr, 2000).

The validity and reliability of the case study was provided in its construction by the use of different sources of information, as well as by the review of documented information by

the selected company. At the CTMA level, the application of the instrument (Robledo et al., 2010) made it possible to create appropriate conditions for collecting information and making it reliable. Finally, the case provided results that may be replicable to other organizations and even sectors, in similar contexts.

Step 1. Design of the case study.

Table 1.
Case Design

Appearance	Description
Study Questions	The descriptive case study of the company in the sector, a leading company in innovation in disruptive technologies, while, the Center for Advanced Manufacturing Technology CTMA a public institution and with the mission of training for work, wants to be a leader in the training of enabling technologies necessary for the. development of the industry in Colombia. Therefore, the CTMA in the present case study aimed to solve: Why is it necessary to know how mature is the process of incorporating the WMA in the companies of the region? • What is the status of incorporation of the WMA in the company? • What strategies should be implemented by the CTMA to provide Technical, Technologist and complementary training programs in AMM?
Case Propositions	• The evaluation of the capabilities of the AMM process in the company allows to determine how mature it is and the knowledge and implementation of this technology in the organization, which in the future will serve as a competitive advantage in the environment. • The organization's skills in AMM contribute to making it more competitive in the target market with high value-added products and services. • Having an assessment of the state of knowledge and implementation of the AMM in the CTMA is useful to determine the degree of maturity of the incorporation of this technology. • The information obtained from the company and the CTMA will be inputs to establish an action plan for the CTMA.
Analysis of the study unit	The case study of this project is about a company in the metal-mechanic sector in the region, pioneer in 4RI enabling technologies, especially metal-mechanic industry with advanced process engineering and manufacturing. In addition, this entire project is recognized in the context of SENA, which in this particular case is the CTMA.
The logical relationship between questions and propositions	The research questions allowed us to follow a path in the case study in order to respond to the state of the WMA, which are aligned with the propositions since they are used for data collection and subsequent analysis of the different levels of the case. Therefore, there is a relationship between the questions and the propositions since they have the constructs from which the appropriate information is obtained. The result obtained by means of the semi-structured interviews allowed to have a more precise vision about the state of the AMM in the regional industry, this, by means of an evaluation given to the questions made in the collection of the information according to the method suggested by Jeston & Nelis (2008) the Business Process Management (BPM).
Criteria for the interpretation of the results	As noted, for the development of the project we reviewed the documents on maturity level of (Jeston & Neils, 2008) and the tool developed by Robledo et al., (2010), which describe the maturity of organizations as follows: 1) Initial state, there is no defined model or process and everything is done on the fly; 2) Repeatable, there is planning, the company begins to create and implement management and there is an increase in people looking at a process perspective; 3) Defined, documented and standardizes prices at the organizational level, management includes requirements, planning and monitoring throughout the organization, there is a greater drive in its pursuit to develop capabilities; 4) Managed, emphasizes process and service quality, is able to measure the status of its management and is firmly rooted in the strategic composition of the organization; 5) Optimized, is an essential part of strategic and operational management within the organization, includes effect prevention, technological change management and process change management, continuous improvement processes. It also includes reference instruments for the evaluation of innovation capabilities (Robledo et al., 2010). Given the maturity levels initially proposed and the results collected from the semi-structured interview tool, it was possible to establish the status of the AMM and make a diagnostic description of the implementation in the industry and by the CTMA.

Source: Prepared by the authors based on Yin's proposal (2006).

Table 1 shows the proposed case design.

Preparation for data collection

The information necessary to conduct the case study was obtained from the manager of the company in the sector and the SENNOVA leader of the Center. The application of the instrument was directed to the areas of research and innovation, planning direction, strategic management coordination, which are in charge of the manager and in the case of the CMTA, the SENNOVA leader. In addition to the contributions of information from the company and SENA, based on secondary information. Therefore, there were two types of sources.

Primary Source: the semi-structured interviews for the company and for the SENNOVA leader were conducted with a script of semi-structured questions, elaborated from the work of (Robledo et al., 2010), with the purpose of inquiring about the necessary information that will lead the evaluator to identify the degree of maturity in each capacity and the capacity in each of the organizational dimensions. The open part of the interview was focused on knowing what is done (practices) for innovation in the AMM enabling technology and also on the results obtained in the organization. This was to know the context of the capacity both in the organization and in the CTMA in relation to the AMM enabling technology. For the collection of information, 56 semi-structured questions were asked in order to have a common thread and to have a general statement about the manager's performance in the capabilities of the organization and the AMM.

Secondary Source: the search was aimed at identifying the innovation processes with specialized technology in heat treatments, the advanced engineering laboratory IHT-LAB, *contract manufacturing* process*,* these were collected through documents and files provided by the company in the sector, the documents reviewed for the diagnosis point to policies, internal regulations, documents prepared by the research and innovation area for various purposes, but that document to a large extent the progress made in the subject.

As for SENA, information was collected from the institutional strategic plan (Servicio Nacional de Aprendizaje, 2019) SENNOVA Antioquia strategic projects, web page, additive manu- facturing project (SENA-CTMA, 2020), previous 2030 scenario reports and CTMA reports for 2021.

Step 3. Collection of information

The company in the sector and the SENNOVA leader of the CTMA authorized the application of the interview, and appointments were made to apply the instrument with each of the heads of the selected areas.

Data analysis, which constitutes **step 4.** It is fed with the results, which are presented in the items results and discussion. The data were grouped in an Excel template, where the different answers are crossed according to capacity and dimension; subsequently the data were

examined, categorized and analyzed through triangulation between the primary data obtained through the interviews, the secondary data from files and documents provided by both institutions and the established theory of innovation capabilities and maturity among them; this increased the reliability of the results, textual analysis software such as Atlas IT was not used, since the volume of information was not so high and could be done "manually".

As for secondary information, we had institutional information such as organizational structure, management report 2020, website, business lines, suppliers, customers, strategic plan, customer expectations, political and economic environment, strengths and weaknesses of the company. While **step 5** constitutes the construction of this report. It also involu- cra the recommendations expected in the project.

Results

The Company. It belongs to the metal-mechanical sector, has as business lines, the manufacture of furnaces, engineering services and contract manufacturing, and focuses on innovation, enhancing the design of high-performance technology with environmentally responsible solutions and competitive costs, has a working methodology based on think + do + improve + produce, which has allowed them to participate in disruptive projects in the manufacturing industry, including additive manufacturing. 100% of its customers are from abroad, among which it is possible to highlight customers in the United States, Holland, India and Peru. 70% of the company's suppliers in the sector are foreigners from countries such as France, India, Germany and the United States, the remaining 30% are national suppliers.

The organization's strategic plan highlights the expansion of the heat treatment business line through the acquisition of new sales representatives in Europe and Asia and the consolidation of the network of existing representatives in the United States, as well as the growth of the contract manufacturing and engineering services business line, and finally the consolidation of the organizational structure to support accelerated growth.

The CTMA. It is a public institution of training for work founded 60 years ago, is one of the 118 training centers that are currently engaged in training for work in the 33 regions in Colombia, the CTMA is located in the northern complex of the city of Medellin in which technical and technological programs and short extension courses are offered in the areas of electricity, automation, ICT and electronics, automotive and manufacturing, the Center in its organizational structure is made up of a technical committee and sectoral tables that support its sub-direction, in making the decision, The Center's organizational structure is made up of a technical committee and sectoral committees that support its sub-direction in taking actions regarding the programs needed by the companies, as well as administrative, academic and professional training coordinators. It also has a research group in automation, industrial communications, pedagogy and alternative energies (GACIPE) since 2010, which is organized with the SENNOVA leader in charge of the articulation of the projects in the national calls for proposals and the research seedlings.

Review of primary sources from the company and CTMA capability assessment.

This assessment is built with an assignment of scores according to the descriptors of the maturity scale, from one (1) to five (5), which establish the status of each of the capabilities of the Jeston and Neils (2008) instrument and the tool developed by Robledo et al. (2010), as noted in the case design, where the scores indicate an assessment of how mature the capability is. The results are usually represented graphically and on a scale of 1 to 5 and are accompanied by an interpretation of them according to the information provided by both the company in the sector and the CTMA and the verification of evidence as suggested by the same instrument and the conduct of the interviews. It is also specified that not all dimensions were assessed for all capabilities. The main findings are presented below.

Strategic Direction Capacity. According to the results obtained for the strategic management capability, the informal organization and personnel dimensions achieve a rating of (2) "Repeatable", indicating that they are in a "Repeatable" state of maturity, where a beginning in the accumulation of capabilities can be observed, since they have performed WMA work for companies outside Colombia and are familiar with the use of this 4RI enabling technology. The possible impact on the company and the manufacturing sector in Antioquia, which is one of the fastest growing sectors at the national level, can also be found in a recognition of the WMA.

In the analysis of the "Technology", "Formal Organization" and "Strategy and Results" dimensions, which are in a "Repeatable" state (2), it can be observed that the company is starting to make prototypes with AMM technology, and is beginning to accumulate capacity, promoting practices with minimal involvement in the management of this process and of personnel in technology. At the formal organizational level, there are no positions associated with technology; it is not visible in the organization's organizational chart. In the strategy and results dimension, the company has a limited scope, no measurable results and little or no employee involvement in the WMA.

In the case of the CTMA, the state of the strategic direction capacity according to the measurement on the maturity scale indicates that the five dimensions assessed obtained a valuation between one (1) "initial", bearing in mind that the technological dimension is carrying out actions to be in a classification (2) "Repeatable", but it still does not have a strategic definition of the WMA. Neither does it have a specific procedure, nor an institutional strategy. The Center has developed internal initiatives such as the MAMNCO research seedbed, which belongs to the GACIPE research group, is developing prototypes with the Universidad Escuela de Ingeniería de Antioquia, seminars, talks and approaches to Mexican companies on the WMA, but in general the process is very incipient.

R&D capacity. In the R&D capacity, the results are very conclusive, it can be said that the Technology dimension is in a state (2) "Repeatable" in which it is given by the generation of ideas, and the management of projects with advanced technology that allow to enhance the capacity of the company to generate new ideas, and the management of projects with advanced technology that allow to enhance the capacity of the company to generate new ideas.

pacity. WMA work has been carried out for foreign companies, and the recognition and learning of the technology is beginning. For the analysis of this capability, the dimensions strategy and results, formal organization and personnel are in a state (1) "Initial", where it is evident that the organization has a limited scope of AMM initiatives, little involvement of personnel in the process, projects are worked on as they go along, and the main idea is to obtain clients from abroad.

On the part of the CTMA In the R&D capacity, the dimensions evaluated are at a level of maturity between an initial state one (1) "Initial", showing how beyond the first experiences in relation to AMM with prototypes, there are already instructors who are leaning towards practices that promote additive manufacturing with a more or less clear perspective of the process and its documentation.

Resource Management Capacity. In this capacity, the company in the sector has qualified personnel for the different processes and handling of technological tools for AMM work. In this capacity, only the technology dimension was taken into account, so the objective is to identify and analyze the company's resource allocation in technologies corresponding to AMM equipment, design software, process innovation, and work methodologies that allow having a vision of the budget planning available for such technology, After the analysis it was found that the capacity is at a maturity level (1) "Initial", which shows that it is an incipient process in which AMM strategies are not yet clearly promoted, this is because the organization has not yet clearly identified the impact on the manufacturing sector, nor is it well developed or accepted for which the company has an urgent need to enter the market and make products for the industry.

For the CTMA, the evaluation of this capacity shows that actions are carried out to allocate the necessary resources for AMM, through the SENNOVA call for projects, but these are disjointed and without an appropriate designation. The aforementioned actions do not have an outline and marked lines, which could aim to improve the implementation of the MMA in the CTMA, it is not established how the resources are managed and how to get them, therefore it is in a state of maturity (1) "Initial".

Relationship Capacity. According to the results obtained, the "strategy and results" and "technology" dimensions are at level (2) "Repeatable", where the organization is making prototypes for companies that work with AMM in the United States, Holland, India, Peru, which allows them to have knowledge of the technology, the company clearly identifies direct competition from German companies (RUBIG GMBH, PLATEG GMBH) and in Aus- tria (ELTROPULS GMBH), it also has new entrants a Romanian company of low cost equipment, it is not direct competition because it aims to another market segment but may become competition in the future (IONITECH).

Industries in Colombia are currently conducting empirical studies, alliances, symposiums, research seedbeds, and innovation hubs related to the WMA,

reviewing the limitations and opportunities of technology, the application of technology in the marketplace, with the digital economy, and with the support of the WEF's 4th industrial revolution headquarters located in Route N.

The CTMA obtained a score of 2 in all dimensions of relationship capacity, which places it in a state of maturity (2) "Repeatable", in which there is evidence of the existence of strategies and guidelines for seeking relationships with other centers, universities in a formal manner, there is no defined process, some people in the organization are beginning to see the importance of structuring it and promoting some practices that favor the WMA.

Production Capacity. Of the three dimensions evaluated in the production capacity, two of them, "personnel dimension" and "formal organization dimension" were located at a maturity level of (2) "Repeatable" according to the evidence found during the interview, which shows that the company has trained personnel and a hierarchical structure that allows having a defined procedure for the continuous improvement of the processes and learning from the AMM prototypes, In the "strategy and results" dimension, the analysis showed that the maturity level is (1) "Initial", the company has not defined strategies for technology production and does not see in the short term to contemplate it within its processes as a determinant of success. CTMA is a public institution for job training, so its production capacity was not evaluated.

Discussion

Due to the nature of this project, rather than a discussion of the results, a proposed action plan is presented with the consolidation of the CTMA's evaluated capabilities, hence the activities for adoption by the Center. It is suggested to start with the sensitization and commitment of the Center's Directors, in order to materialize and institutionalize the current initiatives. As it can be observed and Annex 1 elaborated from the proposal of Scott et al. (2014), a general action plan is elaborated, it is framed within the main actions that arise from this work and according to the results obtained in relation to the evidences found, constituting the starting point to strengthen the innovation management process of the Center in relation to the WMA.

Desired condition

The Center should move to a "Managed" state of maturity (4), which seeks to have greater momentum in the search for capacity development and to do so in a consistent manner by increasing the number of people who look at the CTMA from a WMA perspective. It should also make a combination of different methods and tools for the construction and consolidation of strategic approaches to technology.

In a state of "Managed" maturity, it will allow to carry out actions that substantially improve the formal organizational capabilities and technology capacity, where attitudes and intentions to promote training programs are evidenced, according to the challenges of the 4RI and the vocation of being a "Managed".

vice of the country.

A maturity level four (4) "Managed" will achieve the ability to identify, acquire and appropriately allocate the necessary resources for the implementation of training activities and programs in line with the 4RI.

Conclusions

The contributions obtained in the process of the sector company and the CTMA and the theoretical review of the center allowed the consolidation of a proposal for the CTMA, according to the results obtained in the evaluation of the capabilities, since contrasting the theory with the results allows the delivery of a specific action plan adapted to the training center.

Evaluating innovation capabilities with the methodology proposed by CIDET, adapted to the manufacturing sector, provided the CTMA with an overview and a proposal that went beyond strengthening capabilities, since it was possible to identify that the essential link between the Center's capabilities and the experience of the sector's companies reflected the critical points faced by SENA and that this is where innovation efforts in AMM should be focused.

The work manages to holistically integrate the results obtained in the assessment of skills with a projection of the company in the sector and the CTMA, towards the incorporation in the CTMA in AMM and this allows to finally deliver the proposal for the center in training programs in line with the vocation of the sector.

With the implementation of the methodology, it was identified that the CTMA must take actions to incorporate the AMM into a formal process within its strategic direction, for which it is necessary to identify the importance of this and that some of the valued capabilities be strengthened through the organization of the process.

With the company of the sector and CTMA, the results obtained show that although in the city there is talk of innovation in AMM, it is still necessary to appropriate the topic specifically in the manufacturing sector, seeking to articulate the theory to the conscious practice, so it is necessary to internalize the concept of AMM, which can be evidenced in the day-to-day practices.

The development of the project shows the need to develop other competencies and work methods, which are not only specific technical knowledge, but also previous business experience, conviction, the study of the issues in AMM, and to propose an independent work methodology to comply with the development of this.

Recommendations

After a detailed analysis of the primary and secondary sources evaluated in this project, it was determined that the Center's AMM innovation initiatives are in a state of "poor definition" and there is no formal structure, so the CTMA must consolidate the AMM process in the organizational structure that allows it to have instructors, The Center is called to become a center of excellence in advanced manufacturing technologies. Therefore, efforts must be made to consolidate the Center as a leader in disruptive technology, allowing it to begin to generate culture, knowledge and experience.

It is important to continue strengthening the innovation capabilities of the AMM, for which it is important to continue with the project initiatives and prototypes that are being generated in the manufacturing chain, which will allow the center's instructors and apprentices to continue learning technology and knowledge.

It is also vitally important to formalize national and international agreements with companies in the manufacturing sector that are beginning to undertake technology initiatives, which will make it possible to have an ecosystem in this area and to begin to build knowledge networks in the sector and in the country.

It is necessary to continue with the technological surveillance and preliminary studies for the acquisition of state-of-the-art machinery within the CTMA, which not only allows participation in the productive sectors of the region, but also strengthens the training processes of the apprentices associated with its technical and technological programs through research activities in association with industry and academia.

Among the technologies associated with the AMM, which are to be adopted within the center as a tool for strengthening its programs and foresight in this field, the most appropriate technology to be acquired to enable training, research and technological services is the Powder Bed Fusion.

Market analyses should be conducted with companies and machinery representatives for powder bed fusion technology to determine the best technical option for the acquisition of this technology by CTMA.

With the identification of potential customers and partners that the CTMA could have with the acquisition of a powder bed fusion metal printer, there is evidence of a great applicability in the region in sectors such as aeronautics, medical and automotive with cooperation between industry and academia.

ANNEX 1. GENERAL ACTION PLAN*.

Gaps Found	Target	Shares	Responsible	Result
Low capacity development addressing strategic in AMM	Define within the organizational structure, roles and budget relevant to AMM activities	For further development of the capacity to strategic direction, it is necessary that and public policies defined for the development of the region's economic and social development. this capability by seeking to have a line of action and documentation that will enable it to begin to lead AMM processes at the local level of centers and at the national level.	Coordination Academic Manufacturing.	Group defined with roles, budget and responsibilities.
Little interaction with other national or international stakeholders International programs and training of trainers of AMM		On the other hand, the CTMA, as a job training center, must begin to engage in exchanges with international benchmarks. that will enable them to be leaders in training and training of trainers in accordance with the needs of the 4RI.	Academic Coordination, SENNOVA Leader and SENNOVA Leader MAMNCO Seedbed Integral Professional Training Leader	AM Technology Watch. Programs with guidelines, policies and other elements that standardize the way in which CTMA undertakes projects of AMM.
Low budget investment annual dedicated to projects of R&D at AMM	Implement the policy of designation and attainment of resources for initiatives of AMM.	It is important for SENA to allocate a percentage of the annual budget devoted to development projects R&D, hence it is also important to earmark a percentage of the annual budget dedicated to projects that generate impact for training of the trainees, the purchase of software equipment to begin to take the lead on the part of the CTMA, programs and initiatives in AMM.	Deputy Director CTMA SENNOVA Leader CTMA. Coordinator Academic Manufacturing.	Policies defined within of the action plan of the CTMA. Budget built with items specified for AMM projects. Role defined with responsibilities.
Incipient strategies and clear guidelines for relate to others Centers, Universities and little dissemination and promotion to the The use of the agreements within the CTMA.	Strengthening relationships with the EIA, Faculty of Minas, SENA I Brazil and CIDESI Mexico, relationship with Centers, National and international public and private universities	It is recommended to implement strategies and clear guidelines for relating to others Centers, Universities, that allow to develop joint R&D projects, in addition to disseminating information about and promote within the CTMA the use of the current agreements. It is recommended to formally establish and carry out alliances with SENAI of Brazil, EIA and CIDESI of Mexico. Have an agenda of AMM events and define participation in them.	SENNOVA Leader CTMA. Seedbed Leader of Research MAMNCO. CTMA instructors. Deputy Director of the Center. Regional Director SENA Antioquia	List of Centers, Institutions, Universities and classified by areas of interest of WMA and others. Agreements established and disclosed

*Positive, not accompanied by performance

Source: Own elaboration based on (Scott, A., Duncan, D., & Pontus, 2014).

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