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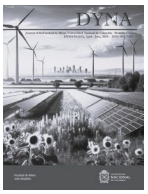

UNIVERSIDAD NACIONAL DE COLOMBIA

Advancing in Artificial Intelligence and circularity to create a sustainable ecosystem in Colombia

María Mercedes Bernal-Cerquera, Milton Januario Rueda-Varón & Maira Alejandra García-Jaramillo

Facultad de Ingeniería, Universidad EAN, Bogotá, Colombia. mbernalc560@universidadean.edu.co, mramon.d@universidadean.edu.co, magarcia@universidadean.edu.co

Received: October 30th, 2024. Received in revised form: May 2nd, 2025. Accepted: May 9th, 2025

Abstract
Within the search for a way to connect the circular economy and sustainability, efforts must be generated from governments to spread the importance of a route stimulated towards recent technologies, especially the implementation of artificial intelligence facilitating society a sustainable future. Therefore, the objective of this research is to identify the main enablers that allow a sustainable and circular transformation, through a theoretical review and a statistical analysis, using the principal components technique and a bivariate correlational analysis. This study shows that one of the main challenges for the future in terms of the circular economy to achieve sustainability and align with the digital transformation in Colombia, refers to the greater development of the Colombian Departments associated with the circularity of resources and the emergence of employment opportunities.

Keywords: project management; artificial intelligence; circular economy; innovation; sustainable development.

Inteligencia Artificial y economía circular para impulsar un ecosistema sostenible en Colombia

Resumen
Dentro de la búsqueda de una forma de conectar la economía circular y la sostenibilidad, se deben generar esfuerzos desde los gobiernos para difundir la importancia de una ruta dinamizada hacia tecnologías recientes, en especial la implementación de inteligencia artificial facilitando a la sociedad un futuro sostenible. Por ello, el objetivo de esta investigación es identificar los principales habilitadores que permiten una transformación sostenible y circular, a través de una revisión teórica y un análisis estadístico, utilizando la técnica de componentes principales y un análisis correlacional bivariado. Este estudio demuestra que uno de los principales retos a futuro en materia de economía circular para lograr la sostenibilidad y alinearse a la transformación digital en Colombia, se refiere al mayor desarrollo de los Departamentos colombianos asociado a la circularidad de los recursos y al surgimiento de oportunidades de empleo.

Palabras clave: gestión de proyectos; inteligencia artificial; economía circular; innovación; desarrollo sostenible.

1. Introduction

Currently, the most used economic approach is the linear economy, which refers to taking raw materials, transforming them, and finally discarding what is no longer useful. This model must be changed to an economy that generates value and is regenerative to keep the planet safe from the constant negative impacts that threaten it. In order to provide guidance to organizations to leave the linear economy behind, the BS:8001-2017 standard has been developed in the United Kingdom, which Colombia has taken as an example with its technical guide from the Colombian Institute of Technical Standards (Icontec) GTC 314:2020 [1], to implement the principles of the circular economy in companies and ensure sufficient robustness when putting it into practice.

On another hand, the circular economy requires the support of technology and under the scheme of a digital transformation, the Colombian national policy on artificial intelligence is related, framed in the National Council of Economic and Social Policy (CONPES) 3975 of the National

How to cite: Bernal-Cerquera, M.M., Rueda-Varón, M.J., and García-Jaramillo, M.A., Advancing in Artificial Intelligence and circularity to create a sustainable ecosystem in Colombia. DYNA, 92(237), pp. 73-79, April - June, 2025.

Planning Department [2], whose objective is based on taking advantage of the strategic use of digital technologies to generate value at a social and economic level in different Colombian sectors. This policy seeks to reduce barriers and enable the conditions to generate innovation from the digital field, creating the necessary conditions to prepare Colombia for the economic and social changes that imply the adoption of a technology such as artificial intelligence.

Living in a world of finite resources, people must act quickly in building the necessary conditions to create a sustainable ecosystem, very different from the current one, and this is achieved by making the most of the technology that can serve as an enabler within the circular economy to achieve the sustainability that the planet requires so much. This economy empowers companies, cities, regions, and nations in sustainability [3] and it is said that there is a strong link between the circular economy and sustainability [4,5]. Many countries have been adapting their principles to achieve sustainable growth, in such a way that the use of all available resources is maximized [6,7].

Adopting strategies to achieve a circular economy requires the adoption of structural changes that go hand in hand with technological development, the fourth industrial revolution and innovation [8]. From this perspective, this revolution has the potential to generate significant changes in society [9]. It is based on the integration of different technologies and its primary objective is to increase the efficiency of production systems to obtain greater profits with their results [10]. By creating a highly flexible production model of personalized and digital products and services, a system is created that allows continuous interactions between people, products, and devices [11].

The result of these transformations is that increasingly complex processes will be seen, but at the same time they will be more sustainable within a profitable environment. On the other hand, the technologies of the fourth industrial revolution provide solutions to the environmental problems that must be faced. They are those technologies that transform the industry and carry out control and monitoring to mitigate any negative environmental impact [12]. In turn, quality and competitiveness are combined to generate such solutions [13,14] and provide a powerful framework for radical improvements in resource efficiency [15-18].

The challenging times that the world has had to face since 2020 with the arrival of the Covid 19 pandemic, and currently with Russia's invasion of Ukraine in the first quarter of 2020, completely break the traditional scheme of businesses and encourages conducting a digital transformation with sustainable models aimed at the well-being of society. Colombia has not been left behind in this transition since there has been an increase in the use of technological tools that help the transformation towards a digital world. From 2016 to today, entrepreneurs have reported an increase in their process productivity by adopting technologies that allow them to be more competitive in the market [1].

But despite this positive impulse, not all organizations are aligned in search of that path that leads to continuous improvement. The challenges that companies face, are focused on lack of knowledge about the adoption of recent technologies, lack of mentality, lack of a clear business model, lack of human capital, leadership, budget, and others. According to the digital transformation survey carried out among Colombian entrepreneurs in 2019, it is evident that there is a high percentage who claim to know emerging technologies. One of them that presents a considerable proportion is artificial intelligence [19].

This means that an important path has already begun to be established in Colombia regarding said digital transformation, but is this transformation aligned with sustainability? And what will happen in the future if the resources of industries and the entire planet are depleted faster than expected? This is where it is important to analyze whether organizations work holistically to address not only this digital transformation but also sustainability and the different paths to reach it, such as the adoption of a circular economy that is the set of regenerative strategies from the design of its processes, products, and services, allowing the closure of the different cycles that characterize it.

The following research questions are established that will be resolved in this study: How do the principles of the circular economy that lead to sustainability relate to the guidelines established by the Colombian national government related to artificial intelligence to achieve a digital transformation? What are the main enablers to establish an ecosystem where circularity and artificial intelligence converge, giving way to sustainability in Colombia?

2. Methodology

The methodological design of this research has a quantitative, descriptive, and correlational approach. The starting point is the theoretical review, which seeks to analyze the phenomena under study such as the fourteen principles of artificial intelligence contained in Conpes 3975, considered the National Council of Economic and Social Policy, which formulates a national policy focused on digital transformation. The circular economy principles of the BS-8001:2017 standard is also investigated, consisting of systemic thinking, collaboration, innovation, value optimization, responsible management, and transparency, these being the fundamental components to carry out a transition to circularity. Finally, the departmental innovation index in Colombia (IDIC) for the year 2022 is evaluated, which shows the Colombian reality according to the National Planning Department, since this secondary source contains indicators related to the main themes of the study.

From the sources consulted, a statistical analysis is carried out using the variables that have been validated by experts and by Cronbach's alpha, yielding a result of 0.967. Reason why it is determined that it is coherent and reasonable to continue with the development of the investigation. Then, the principal component variable reduction technique is applied to evaluate the essential variables that should be considered for the study. Subsequently, a bivariate Pearson correlational analysis is performed, which yields results that determine the closest associations between the variables. With the findings, a relational model is built and complemented with a set of methodological questions to know if there is a complete understanding of the research topics. The software used in this research is RStudio.

3. Results

As one of the research results, Fig. 1 presents the relationships between the variables of the principles of artificial intelligence, the components of the principles of the circular economy BS 8001:2017 and the variables of the IDIC departmental innovation index.

This model in Fig. 1, visualizes the relationship between the different variables. In each quadrant of the graph are located the principles of artificial intelligence that are associated with the IDIC indicators. All of them, regardless of the position in which they are located, are related to the concentric axes that each represent a component of the circular economy.

After reviewing the official secondary sources of the research topics, and to demonstrate the Colombian reality, the results of the official innovation indices in Colombia published by the National Planning Department, an official entity in the country, are taken and validated with Cronbach's alpha which gives a result of 0.967. This index has a group of variables that make it up. They are called pillars of innovation such as Institutions, Human Capital and Research, Infrastructure, Market Sophistication, Business Sophistication, Knowledge and Technology Production and Creative Production. Each of these pillars guides the different departmental innovation indicators in Colombia.

On the other hand, within the statistical procedure carried out in the research, the reduction of variables is carried out considering only those that are most significant according to the results obtained by the factorial technique of principal components. Regarding the correlations between the most relevant variables according to the Pearson test applied in the results of the Departmental Innovation Index in Colombia, they show that the variables Production of knowledge and technology, Creative Production, Institutions, and Infrastructure are the most influential of all due to their P value result as shown in Fig. 2.

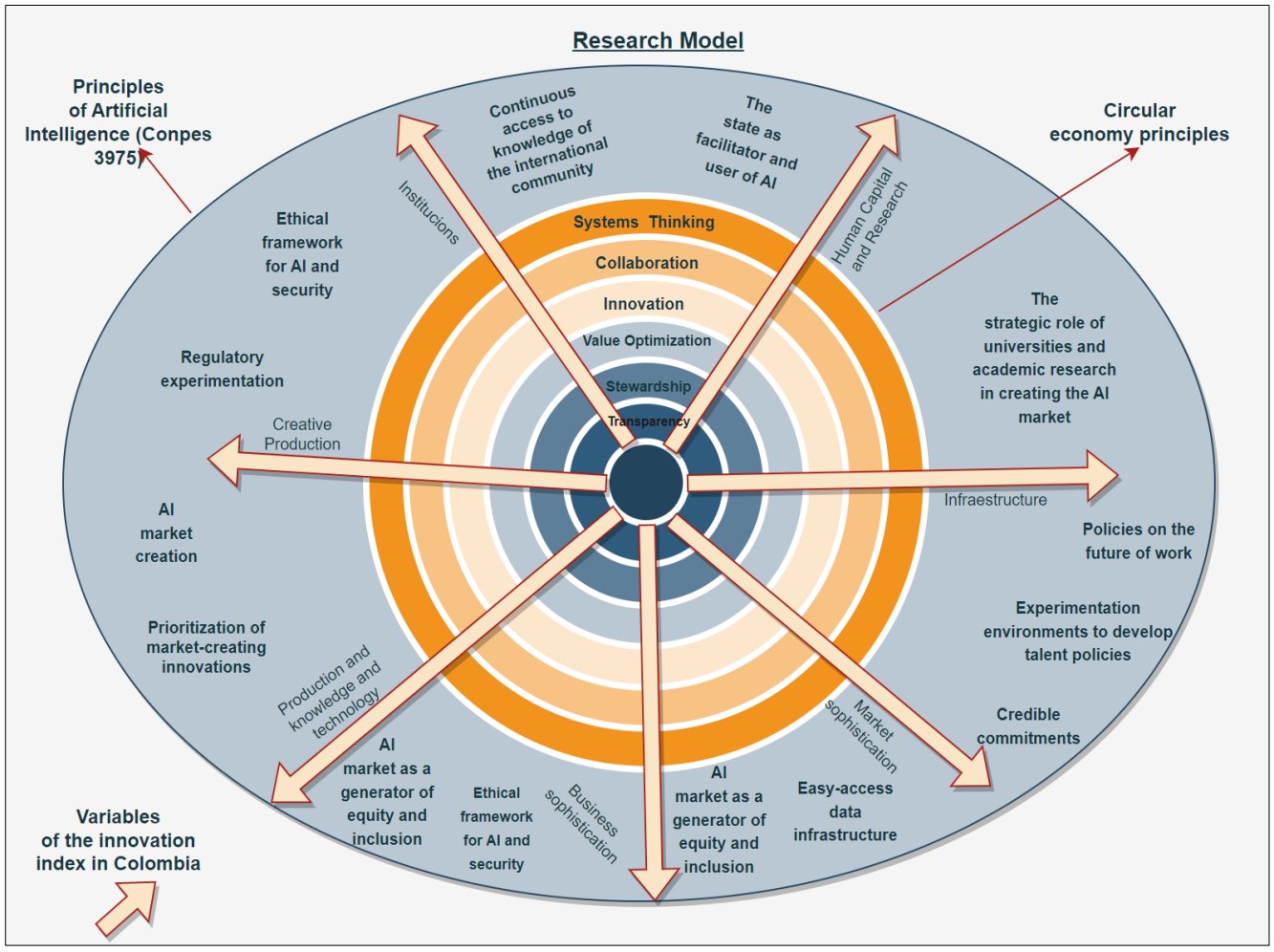

Figure 1. Research variable relationship model.
Source: Elaborated by the authors.

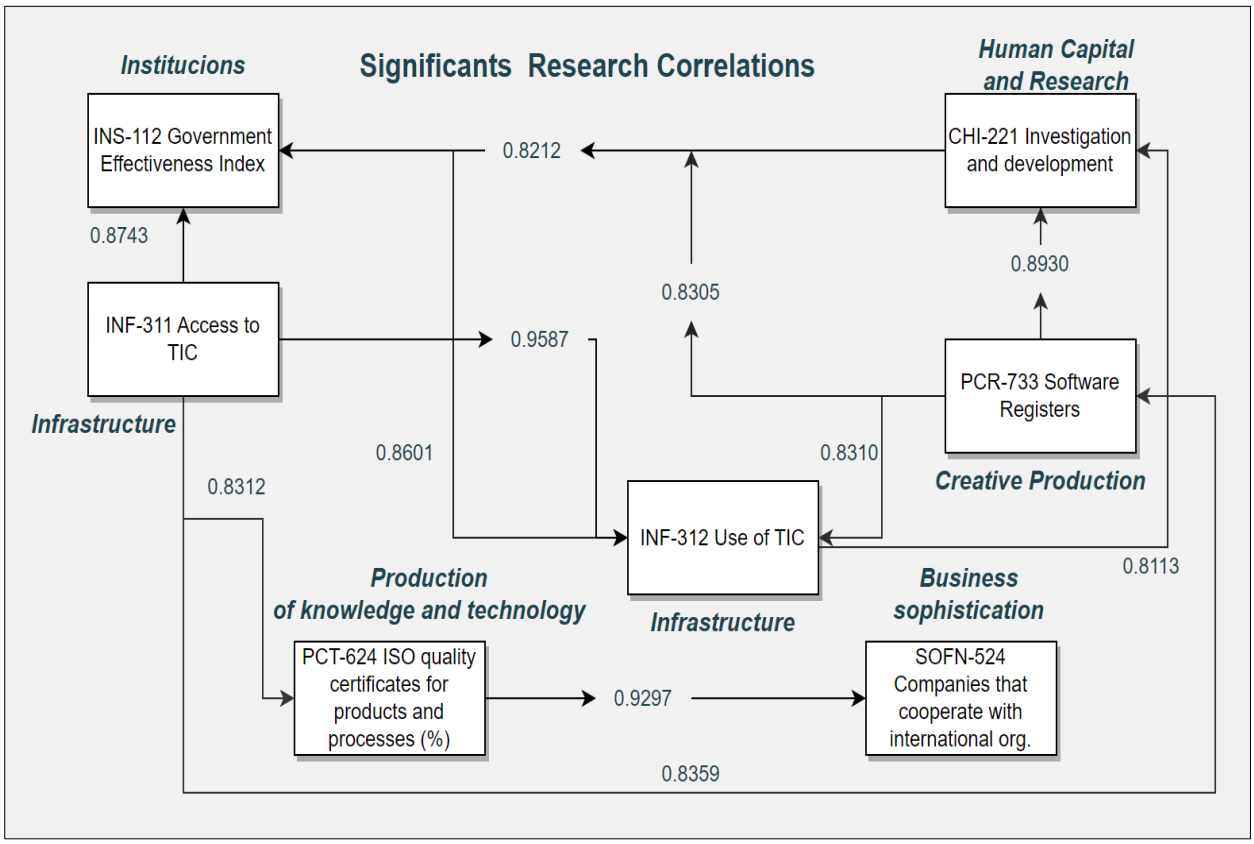

Figure 2. Correlation diagram of research variables
Source: Elaborated by the authors.

There is a strong relationship between business sophistication and the production of knowledge and technology in the study showing a p value of 0.9297. Here the importance of technological support in business is evident since it allows leverage to be enabled to obtain the expected results that the leaders of the organizations have proposed in their strategic planning. It can also be validated that research and human capital are the agents in charge of managing creative production within a business ecosystem. Their correlation shows a p value of 0.8930, a significantly high value with respect to the other binary relationships found in the statistical analysis. Technology also connects with that human capital that will focus on research and development.

Other important relationships that stand out are ICTs, referring to access to information technologies in Colombia and digital government; the Regulatory Environment, which includes policies and regulations under the framework of knowledge creation; Higher Education, referring to the coverage rate of Colombians in university institutions, graduates in engineering sciences and international mobility.

To complement the findings obtained in the research, a set of questions is presented in Fig. 3 that will guide the reader to determine what they need to know regarding the principles of artificial intelligence connected with other questions that focus on relating and validate the principles of circular economy. This figure is useful for those researchers who want to go a little deeper into the topic of study.

Reviewing the results, it is evident that the most significant elements of the statistical exercise carried out are associated with the principles of artificial intelligence highlighted by CONPES 3975, which are focused on establishing guidelines to implement artificial intelligence in Colombia, guaranteeing a ethical, innovative adoption and at the same time responsible for its execution in business and daily life. In Fig. 2, you can see all the variables considered in this research. Likewise, there are the principles of the BS 8001:2017 standard that intervene transversally in the other research variables such as systemic thinking, collaboration between actors, innovation, value optimization, responsible management, and transparency.

When considering innovation, you can think about the circular economy, since its objective is to adopt regenerative and restorative processes in a creative way, breaking traditional schemes of repetitive, routine processes that produce waste without thinking about extending the useful life of the products, inputs, and materials. This is where research and development play a fundamental role in the innovation that is proposed in a business environment. Societies urgently require human capital that is thinking about proposing alternatives to improve the quality of life, and this can happen with the circular economy. But it requires an enabler that drives it and allows it to resonate, and this enabler is technology and in particular artificial intelligence can cause this effect.

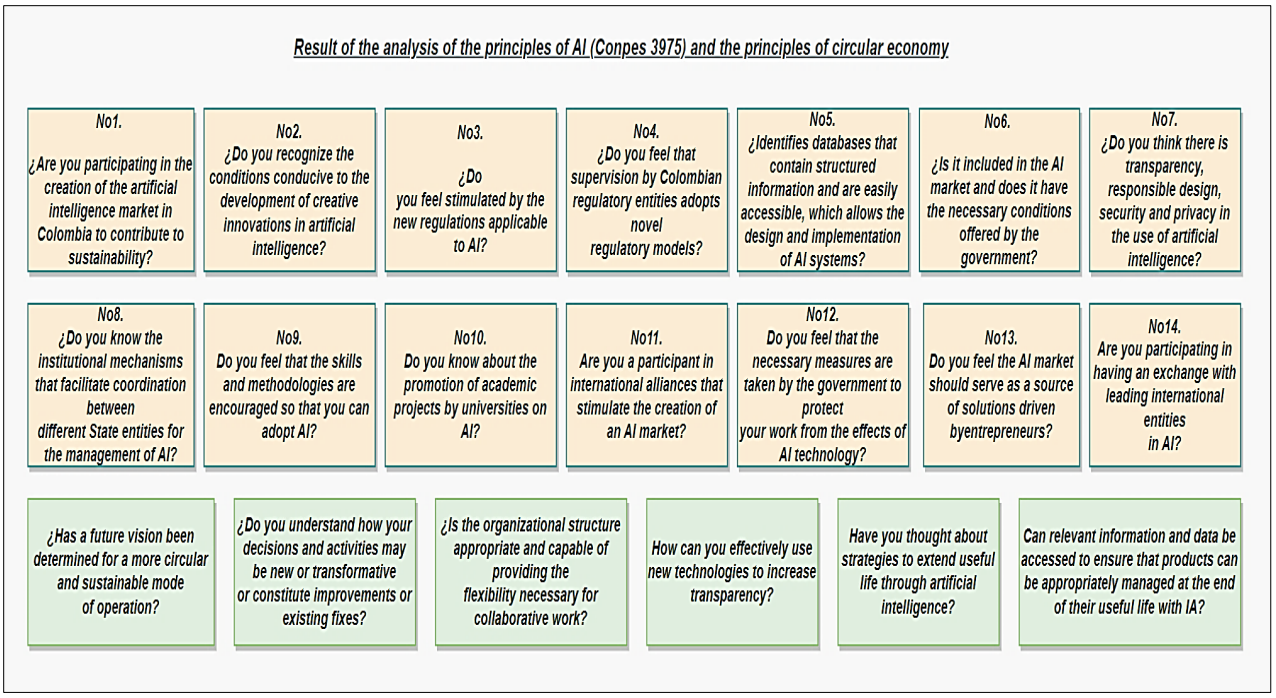

Figure 3. Results of the analysis of the principles of AI (Conpes 3975) and the principles of circular economy.
Source: Elaborated by the authors.

Furthermore, collaboration in the supply chain is not only important for economic performance but also for environmental performance [20] and must be thought and acted holistically [21,22], addressing systems thinking. This is key to understanding complex systems [23] and is part of the principles of a circular economy. It is a set of analytical skills that can help identify and understand systems and design changes to produce desired effects. It includes the ability to conceptually understand and map the structure of a system including its elements, interconnections, flows and feedback loops [24].

Another of the fundamental points in a circular economy is transparency. When all the people who are part of an organization know where they are going, they begin to work with that common goal in mind. That is why it is necessary to provide the essential information so that the guidelines of each of the processes are clear. In addition, better decisions can be made when it comes to seeing an entire panorama of the reality that is experienced from its beginning to its end. That visibility will give leaders an opportunity to establish better strategies for their organizations.

All the above must be complemented with responsible management within the community, understanding and valuing each of the axes of sustainability. Each action leads to the impact of something that contributes to the collective, therefore, it is necessary to understand that the function that each member of the community has is aimed at providing value. The circular economy also focuses on finding ways to optimize its processes and the use of all its resources. It is necessary to identify opportunities to see possibilities for improvement in what has already been established. It is necessary to continually work in search of cost reduction, higher income, adapting to the change from a transformation to a scenario that leads to the use of each of the parts of the system, including the people who are immersed in it.

On the other hand, local and global pressures from the government, the community, and consumers to achieve sustainability objectives motivate us to investigate modern technologies that can help organizations implement environmental strategies and achieve optimal corporate environmental performance [25]. The circular economy is the way to continue existing in an ecosystem with so many challenges to overcome. It is necessary that on this path systemic thinking, innovation, collaboration, value optimization, responsible management and transparency of each of the actions carried out to meet the established purposes within an organization be considered. These principles are the fundamental foundation to be able to survive on this planet, overcoming day by day the obstacles and difficulties that we must go through.

It is evident that in the respective departments of Colombia, investment is being made in Research and Development, which leads to a high percentage of innovative companies in the country. This means that Research and Development is a crucial factor for organizations to transcend the path of innovation. Likewise, by investing in activities conducive to innovation in companies, coordination with knowledge organizations will be facilitated, there will be greater industrial specialization and greater cooperation with international companies. If there is a greater percentage of innovative companies in Colombia and the number of scientific and technical publications that leads to the production of knowledge increases, then the high technological content will increase and there will be greater

quality to the extent that ISO certifications are evident. products and services in companies.

From the theoretical review regarding the principles of the circular economy nested with the Colombian public policy established on digital technologies and artificial intelligence, it is evident that to achieve sustainability in a society it is necessary to have policies agreed upon with interested parties that can be coordinated and monitored to achieve greater competitiveness. They must be supported by innovative technologies such as artificial intelligence that allow an economic result to be achieved with fewer resource inputs, waste reduction and cost savings.

The circular economy shows great promise to make this transformation towards a more sustainable and prosperous society where organizations can comprehensively rethink how to better manage their resources but in a unique way than the traditional one, to obtain financial and environmental benefits. and social. This is achieved if innovation acts as an engine to generate circularity. The innovation ecosystem presents an opportunity to establish a regenerative economic model that makes it possible to achieve behavioral change in society to appreciate and support innovations as part of the solution.

On the other hand, digital technologies and the advance in alternative materials have opened new opportunities. Regulations and economic instruments play a key role in driving innovations in a circular economy. For this to happen more smoothly, strategic partnerships are needed between entrepreneurs, universities, public and private institutions, and government to translate innovations into viable and inspiring business models.

1. Conclusions

According to the results obtained by the statistical analysis, the main enablers that allow a sustainable and circular transformation are Research and Human Capital, Creative Production, Technological Infrastructure, Institutions, Knowledge Production, and Business Sophistication. Therefore, it is detected that for a business to be innovative, it must have the support of technology to enhance the production of knowledge and in this way propose significant contributions. It is vital to be connected to the circular economy so that any new idea or one that improves processes that already exist has circularity incorporated.

The circular economy must have a series of principles that strengthen it so that it meets its objectives of being regenerative and adding value. That is why it must be accompanied by innovation, a fundamental factor to adapt to change, either by creating something new or by improving it. If you want to make a transformation from a linear economy to a circular one, you must have innovative proposals that allow this transformation. But this cannot be a reality if there is no support from an entire community. This is where it becomes evident that you cannot move forward without the collaboration of others. This is another fundamental principle that helps the circular economy create a cycle supported by the improvement and redesign of its processes, products, and services, counting on each of those involved to carry out these changes.

Responding to the research question, it is concluded that the guidelines of the principles of artificial intelligence, analyzed in the results of the study, are aligned with the circular economy to achieve a sustainable and leveraged transition hand in hand with technology, whose mission is focused in promoting novel ideas and innovative business models that contribute to the well-being of society and the competitiveness of the nation.

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M.M. Bernal-Cerquera, she earned a PhD. in Process Engineering with *Cum Laude* distinction from EAN University, a MSc. in Supply Chain Management from EAN University in Colombia, and a BSc. in Industrial Engineering from the Universidad de Antioquia Her experience is in multinationals at both Colombia and abroad, specializing in process improvement and consulting. Now, is professor in Bogotá Colombia at EAN University in Engineering faculty.
ORCID: 0000-0002-1373-4631

M.J. Rueda-Varón, Dr. in Statistics from the University of Konstanz, Germany. MSc. in Statistics. Sp. in Analysis and Financial Administration, Statistician, and research professor - Director of Doctorates at EAN University with more than 25 years of experience in information analysis. Experience in different universities, lecturer and consultant in project development in public and private sector companies. Specialist in advanced information analysis techniques, statistics and applications, data analysis and information methodologies, projects, engineering, economics and business.
ORCID: 0000-0002-0338-5327

M.A. García-Jaramillo, she received her PhD. in Technology from the Universitat de Girona, Spain, and BSc. Eng. in Computer Science Engineering from the Universidad Francisco de Paula Santander. She is currently a full professor at EAN University. She has led and participated in multiple research and innovation projects related to IT in Colombia and Europe.
ORCID: 0000-0002-6539-4149