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SCIENCE, TECHNOLOGY AND INNOVATION SYSTEM IN CUBAN ENVIRONMENTAL RESEARCH CENTERS. APPROACH TO A METHODOLOGICAL INSTRUMENT

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Abstract: This paper proposes a (simplified) model to support strategic decision-making processes associated with the management of the Science, Technology and Innovation System (SCTI) in Cuban environmental research centers, aimed at improving their institutional performance with social responsibility. The consideration in the model of the classic functions of Morin and the continuous cycles of quality management, supported by the dynamics of the Deming cycle of continuous improvement (PDCA), constitutes a methodological contribution for its application to the management process of the aforementioned system in this type of institution. To achieve these purposes, a systemic approach oriented to the management of technology and innovation was adopted, with the integration of adequate engineering and management tools. The science, technology and innovation construct, its characteristics in Cuba and the contributions of previous research are analyzed, delving into the most used concepts, approaches and tools.
Keywords: Science, technology and innovation system; technology and innovation management; environmental research centers.

INTRODUCTION

Science, technology and innovation (STI) activities continue to be reaffirmed as a necessary and timely area of scientific knowledge in the interest of human well-being and sustainable development from the most diverse approaches. Concern about the use of CTI in response to the pressing needs and demands of society continues to be significant. As Fernández Capote et al. (2020), "...interpretative models are strongly proposed where society is positioned as the foundation of techno-scientific use, beyond the backdrop historically attributed to the social subject in the relationship of concepts" (p. 45). Sometimes successful results are achieved that arise from the effort and participation of all. However, some of the achievements, especially the most successful ones, are the result of a conscious, constant and deliberate search for innovation opportunities that, although they do not always materialize, set the standard to follow in terms of action and creation of capabilities are concerned. This transcendental role assumed by knowledge transformed into innovations makes it necessary to develop skills and competencies for the management of said process, which consequently also implies the consolidation of capacities and connections so that its management is effective. Consequently, Technology and Innovation Management (GTI) is further recognized as a key function in organizational management. Its conception appropriate to specific organizations and contexts, as well as its implementation in these, continues to be a need that has been reflected in numerous publications ranging from the classics of mandatory consultation and other more current ones in this field (for example, Schumpeter, 1939; 1967; Sábato and Botana, 1968; Morin, 1985; Morin and Seurat, 1989; Escorsa Castells and Valls Pasola, 1997; Pavón Morote and Hidalgo Nuchera, 1997; Hidalgo Nuchera et al., 2002; Phaal et al., 2006; ter Haar, 2018; Tidd and Bessant, 2021), to other more recent studies carried out by different authors from our country and geographical area (for example, Brito Viñas et al. (2001); Solleiro Rebolledo and Castañón Ibarra, 2017; Quezada Torres 2019 ; Díaz-Canel Bermúdez, 2021). Several of these sources refer to approaches in different sectors, such as: companies, agriculture, tourism, government and other public services.

The GTI arose at the beginning of the 1980s of the last century, when an attempt was made to improve the competitive position of companies through technology

management and its link with business strategy. This approach presented many points of contact with the management of innovation, which is why both expressions began to be used interchangeably due to the diffuseness of their borders. Several authors agree with the use of the GTI, integrating in a single denomination all the topics related to research, development and innovation activities (R+D+i) and the optimization of the use of technology, as essential resources in the processes. production, both goods and services.

Likewise, and based on the original contributions of Morin (1985) and Morin and Seurat (1989), it is argued that the implementation of the GTI is carried out through the application of several key functions (active and support) that characterize it. Although there are several management approaches, where the functions that make up the GTI are conceived from different perspectives, derived to a certain extent from the objectives and application contexts, but which essentially maintain the foundations of the traditional and classic ones, as noted by, for example, Escorsa Castells and Valls Pasola (1997), Brito Viñas et al. (2001), Solleiro Rebolledo and Castañón Ibarra (2017) and Quezada Torres (2019), among others. It also continues to insist on the international standards of quality and innovation management systems that have been widely used in organizational management, allowing innovation initiatives and processes to have the support, resources and adequate management., as well as that the organization identifies and addresses the opportunities and risks it assumes towards continuous improvement. In addition, knowledge management is decisive as the basis of the GTI, which according to Woodside et al. (2018), is specified as an action plan to transfer knowledge, develop the necessary skills in organizations to assimilate, enrich and share it, as well as protect it if required.

In Cuba, CTI policies have been recognized in the programmatic documents approved by the 6th, 7th and 8th Congresses of the Communist Party of Cuba (PCC) as essential for the achievement of the vision of the nation and the sustainable development of the country. In addition, in the Economic Chapter of the Constitution of the Republic approved in 2019, a reference to STI activities is included for the first time as essential elements of the economic and social development of the country, where the need to implement an institutional framework is also recognized. and regulatory that promotes the links between the results of the research activity and the productive and service processes (Rodríguez Batista and Núñez Jover, 2021). The Ministry of Science, Technology and the Environment (CITMA) is the governing body in charge of directing, executing and controlling these policies, promoting their coherent integration, with adaptations for each sector of the economy.

In this context, CITMA directly attends scientific institutions that cover research in the social sciences, natural sciences, environment, metrology, seismology, nanotechnology, and coordinates the work of research centers, prioritizing research in the field of biotechnology, renewable energy, climate change, food production, among others.

In this direction and due to the process of reordering and institutionalization in the country, several actions have been undertaken in recent years, including: the functional reorganization of the sector, updating the legal framework and improvement of the SCTI in the different levels. As Rodríguez Batista and Núñez Jover (2021) affirm, the new legal provisions approved, like the policies that gave rise to them, seek to create an ecosystem

conducive to innovation in the country -including science and technology activity- that contributes to generalize the successes obtained in various fields such as medicine and the biotechnological and pharmaceutical industry. These include the introduction of incentives, both institutional and individual -linked to the scientific production of researchers and the impact of their results-, the existence of institutions and interaction mechanisms and the creation of new non-existent economic figures in the country, such such as: science and technology parks (PCT); interface companies between universities, science, technology and innovation entities (ECTI) and the productive and service sector; and high technology companies (EAT).

The foregoing constitutes evidence that reinforces the criterion that STI activities have a systematic nature, are closely related to the production, dissemination and use of new knowledge in the different fields of science and technology with an impact on the economy and the society, including research and development (R&D), innovation and associated scientific and technological services, specialized productions, interface activities and technology transfer (Consejo de Estado, 2020). All this requires the generation and creative assimilation of new knowledge and advanced technologies, to implement solutions, in many original cases, appropriate to the special Cuban circumstances.

This main challenge continues to be conditioned by the demands to obtain prompt and high-quality results, maintaining the necessary synergy between the parties interested in activities where there is an increasingly high degree of uncertainty and risks multiply. Therefore, we must insist on seeking these opportunities through the GTI, to also improve the performance and success of organizations.

Despite the serious limitations for the development of the productive forces, positioning knowledge as the engine of national development and positioning it differently according to priorities, continues to be an urgent need. The country cannot base its economic and social development on the reduced domestic demand, nor on the export of primary products, nor on the extensive use of the labor force. Labor productivity and high value-added exports need to be significantly increased in order to respond to social demands, offset the decline in the economically active population and generate resources for further development. Specifically related to the theme and among other no less important matters, it will have to anticipate and mitigate the effects of climate change and other natural phenomena, use the limited natural resources available in a sustainable manner and preserve its unique ecosystems for future generations.

Undoubtedly, successful, environmentally friendly organizations are required, with a high capacity to energize, introduce and communicate the results of science, satisfy the needs and expectations of their clients / users and other interested parties, with the active participation of workers, and a constant use of innovative management tools that guarantee a philosophy of continuous improvement. In this situation are the research centers that carry out studies related to the protection and conservation of the environment, organizations that must achieve greater effectiveness and relevance in their performance.

Precisely with this main objective, this research is carried out, which, among other aspects, establishes the bases for the development of a methodological instrument to support the strategic decision-making processes associated with the management of the SCTI in Cuban environmental research

centers due to its particular characteristics, oriented to the GTI function and its relationship with other organizational processes, through a systemic approach and integrating relevant engineering and management tools for its application.

DEVELOPMENT

SCIENCE, TECHNOLOGY AND INNOVATION ENTITIES

In Cuba, as established by Decree-Law No. 323 (Consejo de Estado, 2014), ECTI is understood as the organization "... whose fundamental activity is scientific research, innovation, scientific and technological services, and specialized productions with added value" (p. 2). In turn, the programs and projects constitute the basic cell to regulate the process of organization, planning, elaboration, approval, financing, execution, evaluation and control of CTI activities; these are expressed in the CTI Plan, integrated into the National Economy Plan at all levels of organization. The System of Programs and Projects is part of the country's SCTI and its functions include defining the procedure that establishes CTI priorities, and that they fully correspond to the strategies and priorities of economic and social development for each period determined at the different levels., as well as with the trends of global scientific and technological development. The programs and projects respond to national priorities, established by CITMA, in conjunction with the Central State Administration Bodies (OACE), Higher Organizations of Business Management (OSDE) and Provincial Administration Councils (CAP) or even, to corporate and institutional interests.

The STI programs constitute a set of diverse STI activities, organized into projects that are related to each other and whose objective is to comprehensively solve a problem identified in the priorities at their level, aimed at achieving results of specific impacts in a determined period.. They are characterized by the integration of the scientific, academic and productive entities that participate in their execution, interdisciplinarity and multidisciplinarity in the search and application of knowledge and by the specific impact to be achieved in a defined time horizon. While CTI projects constitute the fundamental organizational form on a temporary basis, for the planning, execution, financing, evaluation and control of R+D+i activities and tasks, in order to materialize specific objectives, obtain impact results and contribute to the solution of the problem that determines its implementation, either its own or the program in which they are inserted. The so-called scientific-technical services (SCT) are those own services, commissioned by the state or others, of high added value that are based on existing scientific and technological knowledge that are carried out through the demonstrated use of intellectual capacities and materials of a proven level of specialization., with impact results for the economy, science, technology, the environment and in any other sphere of society. These services can be developed on a repetitive basis or not to be marketed in the country or abroad.

For their part, specialized productions are those with a high level of distinction; generally conceived as a complete cycle within the same institution or as a productive chain, the result of an intensive application of STI that gives it high added value and a significant impact on the economy and/or society. They are carried out as support for a CTI project, for tests or trials and when their limited volume of production does not warrant a transfer of technology for the assembly of a productive process of mass production. They can also be carried out repetitively or not and can also be marketed in the national or foreign market.

In accordance with their mission and operating principles, the ECTIs are classified as a Research Center (CI), Center for Scientific and Technological Services (CSCT) and Development and Innovation Unit (UDI). Specifically, the CIs and according to their form of financing, can be self-financed, budgeted with special treatment or, exceptionally, totally budgeted. Within the form of self-financed operation, the science and technology company is recognized. Decree-Law No. 323 (Consejo de Estado, 2014) establishes the requirements that the ECTI must meet, to be considered a CI. Due to these demands, CIs must constantly evaluate the performance of their SCTI. In a general sense, and notwithstanding the generally favorable results obtained in CTI projects, TC services and specialized productions, it is considered that the quality and added value of the expected impacts must be consolidated, by integrating the GTI, evaluating to what extent the organization has the capabilities to achieve it in a stable and sustainable manner, and the minimum degree of maturity required of said competencies, as well as considering existing approaches and tools for continuous improvement and support for decision-making throughout the process. In turn, it is necessary to evaluate the efficiency of management, understood within the framework of the original research that supports this work, such as: the relationship between the results of the SCTI and the resources used to obtain them according to the different activities and processes developed. and intrinsically related to effectiveness and its impacts.

SCIENCE, TECHNOLOGY AND INNOVATION SYSTEM

The system approach of CTI activities is necessary. According to international standards, in a SNI there is an interaction between five (5) main subsystems: the productive, the science and technology, the educational, the financial and the administrative-regulatory that provides the bases, defines the rules of the game and provides the incentives for innovative activities (García Capote, 2015). Criterion very close to the original conception supported by Sábato and Botana (1968) of the construction of a national system from successive sectoral triangulations.

In Cuba, a process of construction of the national science and technology base began in 1959, which resulted in the creation of 53 new research centers in the exact and natural, medical, technological, agricultural and social sciences. Then, in the mid-1970s, specialized institutions were created, not just for carrying out the research itself, but for preparing and proposing to the Government a policy for conducting scientific and technological development. With the intention of highlighting the set of institutions of these research centers and their possible interrelationships, the expression "National Science System" began to be applied in this context, although intuitively or spontaneously and because it was used for these purposes in other countries. and Technique" (García Capote, 2015).

This is how several stages and processes passed, reaching the 90s, where the economic and social development of the country was severely affected by the disappearance of the socialist camp, thus beginning a hard stage with dissimilar economic deficiencies. An intense investment policy was developed in the scientific field, especially in biotechnology, medical equipment and the medical-pharmaceutical industry. A space known as the Western Havana Scientific Pole was created, and various agricultural and livestock research centers were built in different provinces, and provincial scientific

poles. Starting in 1994, with the creation of CITMA, the SCTI was institutionalized and perfected, as an organizational form that allows the participatory implementation of the scientific and technological policy that the Cuban State and its system of institutions establish for a determined period, of accordance with the country's economic and social development strategy and the science and technology strategy that is an essential part of it.

At present, the STI policy continues to be redesigned in the context of updating the Cuban Economic and Social Development Model (MDES) from a multidisciplinary and intersectoral perspective, and of an effective integrated management of the SCTI, since it is not only the responsibility of CITMA in particular nor is it exclusively a matter of scientists and their institutions. Solid and stable connections are required between universities, research centers, governments at all levels, state, cooperative and private companies, and other stakeholders (for example, PCC and other political and mass organizations, as well as others from civil society). Cuban civil), backed by advanced, pertinent and motivating legal regulations that increasingly favor systemic interactions between innovation actors with the holistic approach that is intended; for example and among others, in Decree-Law No. 7 (Consejo de Estado, 2020) that establishes the SCTI, its fundamental components, principles, functions and organization, as well as Decree No. 40 (Council of Ministers, 2021) that dictates the Regulation for its application. However, the Cuban SCTI is still considered to be weakly interconnected (Díaz-Canel Bermúdez, 2021). In the same way, the three national innovation surveys -including the most recent- applied by CITMA, also show limited progress in terms of innovation, with slight changes in the ways of carrying it out and priorities, with some exceptions such as in the sector biopharmaceutical, with closed R+D+i cycles and effective connections of the CTI with the national economy. However, there is a slight trend towards gradual and sustained improvement in several indicators that, if maintained, would be very favorable (CITMA, 2019).

MODEL (SIMPLIFIED) FOR THE MANAGEMENT OF THE SCIENCE, TECHNOLOGY AND INNOVATION SYSTEM

As conceptual support of the methodological instrument proposed to be developed in the original research, a problem-solution type model is presented (Figure 1), as a contribution to the SCTI management process in Cuban environmental research centers.

The solutions derived from the SCTI are not temporarily static, but are subject to the influence of a generic group of factors (political, social, cultural, economic, technological, organizational and environmental) that sustain their dynamics and that casuistically can influence differently in greater or lesser extent, on the general results obtained by the institution and that the management process must promote for the sake of its quality and relevance. At the base of the model, and taking the CTI priorities and the annual plan as a strategic reference, the axis of the proposed solution is located, which is structured, organized and managed around the functions for the GTI mentioned above, appropriate to the process of SCTI management in the studied context. Although these functions are defined with apparent independence, in organizational practice they are closely interrelated and even overlap in specific cases, as Quezada Torres (2019) also points out in his research and which in this case are: Diagnose, Monitor, Plan, Evaluate,

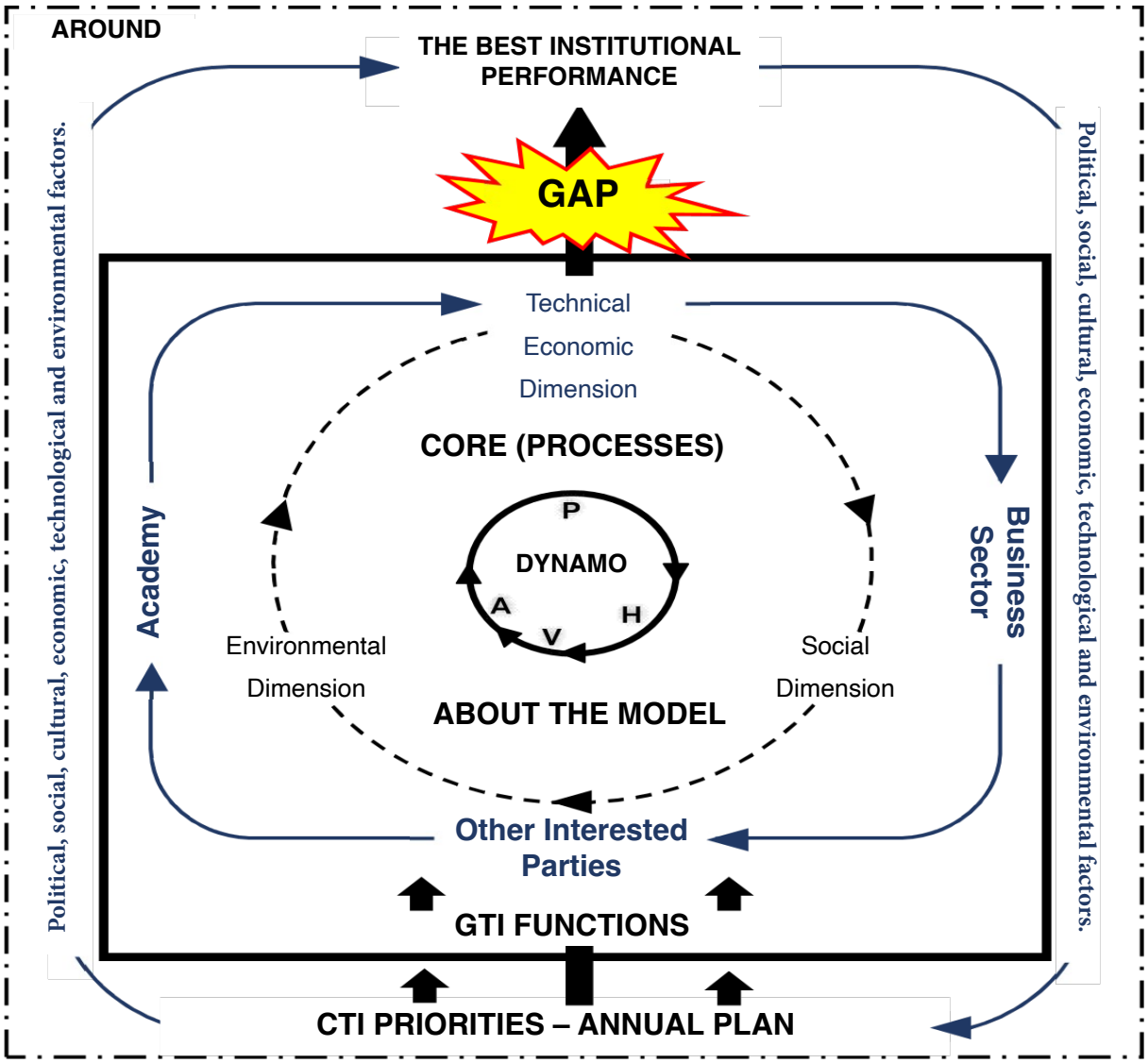

Figure 1. Model (simplified) for the management of SCTI in Cuban environmental research centers.

Source: self made

Enable/Enrich, Protect and Communicate.

Directly linked to the SCTI, four (4) areas of collaboration are represented (State, academia, business sector and other possible interested parties), in correspondence with the objectives of the research and with the well-known "N-tuple helix" (Leydesdorff, 2012) that allow the creation and/or consolidation of capacities among the actors involved with the aim of achieving a synergy that contributes to both their own development and that of the country. In the specific environment (scope of performance) of the SCTI in the entity, the three (3) main dimensions that characterize the process (social, environmental and technical-economic) are related, associated and conditioned to its systemic approach, current requirements and their interrelationship.

The center represents the core of the model, determined by the six (6) main processes (subsystems) that make up the SCTI; two (2) keys or functional: CTI project management and CT service management; and four (4) support or transversal: management of integration actors, management of TC results, management of TC capacities, management of the link and internationalization, and its dynamo. In turn, although the entities under study understand the constant need to seek strategies to increase customer / user satisfaction and improve institutional performance, quality management is incorporated as a dynamo of the model as an explicit process, since that it is essential to meet the requirements of a project and/or service, with the proper use of human, environmental, economic, administrative and technological resources, thereby guaranteeing better performance of the entity. This interaction and coinciding with ISO (2015), Quezada Torres (2019) and León García et al. (2021), in its internal execution logic, it must occur in an environment of continuous improvement that maintains its dynamics, supported by the PDCA cycle (Deming, 1989): Plan-Do-Check-Act.

The implementation of this model, adapted to each specific context, is "operationalized" by means of a general procedure and other associated specific ones that will have their respective phases and execution steps (in a logical sequence) that will consider both the stages of the Deming Cycle indicated above, GTI functions and a set of engineering and management tools organized in the style of a "Tool-Box". In addition, a Balanced Scorecard (CMI) will be incorporated into this methodological instrument, supported by a computer platform that will enable comprehensive evaluation, the effectiveness and efficiency of the process, with a proactive approach and continuous improvement for decision-making. All of the above is part of the original research that is carried out on this object of study.

CONCLUSIONS

- The GTI, conceived as a strategic factor and conceptually incorporated into the SCTI management process in Cuban environmental research centers, causes a synergy in the organization's strategy that must have an impact on the achievement of objectives, improvements and benefits, both of the entity itself and of society as a whole.

- The proposed model constitutes the conceptual support of the methodological instrument that is being developed, and a methodological contribution that will allow systematic support for decision-making processes at a strategic level, associated with the management of STI activities in the entities under study. Its subsequent implementation and implantation will allow its relevance to be demonstrated.

- The constant need to seek strategies to increase the satisfaction of the interested

parties and improve institutional performance, justifies the incorporation of quality management as an explicit dimension in the management of the SCTI.

- The consideration in the model of the defined GTI functions and the continuous cycles of quality management, supported by the dynamics of the Deming cycle of continuous improvement (PDCA), constitutes a methodological contribution to its application in the management of the SCTI. in these types of institutions.

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