

# Resource Management and Technological Cooperation Model for Emerging Aerospace Industries in Developing Countries

Anibal Jara Olmedo<sup>1\*</sup> , Danilo Chavez Garcia<sup>2</sup> , Orlando Boiteux<sup>3</sup> 

## Abstract:

The aerospace industry is a sector characterized by its high technological complexity and investment requirements, and has therefore developed around major clusters worldwide. These clusters serve as hubs for innovation processes, technology transfer, and supply chain integration. However, limited research has focused on the early stages of industrial development or on contexts lacking established organizational cooperation structures—conditions commonly found in developing countries. This study proposes a resource management and technological cooperation model in which anchor firms act as facilitators and driving forces for interactions among government, industry, and academia. The model assesses the developmental stage of the aerospace sector by analyzing scenarios and prioritizing firm-level interactions with each component of the so-called Triple Helix, thus establishing a comprehensive management perspective. Through a case study of a region exhibiting a concentration of aerospace-related organizations—yet not formally structured as a cluster—the findings validate the proposed model and highlight its utility in optimizing resources and enhancing intersectoral collaboration.

**Keywords:** aerospace industry, cluster, management, universities, government

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## 1. Introduction

The aerospace industry represents a sector with significant potential to contribute to the economic and technological development of countries due to its impact on mobility, trade, and national defense. Various organizations are linked to this industry, including service providers, related suppliers, training centers, and governmental entities. However, resources and technological collaboration among these organizations present considerable challenges that must be effectively managed.

Therefore, this paper aims to evaluate how an organization within the aerospace industry manages its operations in the sector and to propose management models that holistically encompass the various dimensions of the industry. Additionally, the paper seeks to assess and prioritize the elements being managed, recognizing that aerospace companies must direct their efforts toward the factors that most significantly influence their business development—factors that may, in turn, be shaped by the state of the industry as well as the economic, political, and social conditions of the region in which the industry operates.

This study proposes a resource management and technological cooperation model tailored for organizations within the aerospace industry in developing countries or regions where cluster-type organizational and cooperative structures have not yet been established. The model is based on the Triple Helix framework and aims to strengthen interactions among government, academia, and industry by promoting initiatives that enhance resource efficiency and drive technological advancement in the sector. To achieve this objective, the following research questions need to be addressed:

1. What management models can be adapted to the structural, institutional, and operational conditions of the aerospace industry in developing countries?
2. What methodological and procedural components should be integrated into a model that enables the management of resources and technological cooperation initiatives in the regional aerospace industry?

## 2. Literature Review

### 2.1 Aerospace industry

The aerospace sector involves the conception, engineering, and manufacturing of aircraft, as well as the provision of associated services. It spans various domains, including civil, governmental, and military aviation (Lakemond & Holmberg, 2022) (Holtström, 2022). This industry is integral to international commerce, mobility and national defense. It is distinguished by its advanced technological developments (Arista et al., 2022), rigorous regulatory frameworks, and substantial commitment to research and innovation (Pereira et al., 2022) (Ciampa & Nagel, 2020)

From a manufacturing standpoint, the aerospace industry is structured as a hierarchical pyramid. At its foundation are producers of basic components, with increasing complexity as these elements are integrated into larger systems, culminating in the final assembly of aircraft. This stratified configuration positions aircraft manufacturers or system integrators at the apex, thereby defining a hierarchy among firms not only in terms of organizational roles but also in the flow of

<sup>1</sup>Dirección General de Posgrado, Universidad Nacional de Cuyo, Mendoza, Argentina.

<sup>2</sup>Departamento de Automatización y Control Industrial, Escuela Politécnica Nacional, Quito, Ecuador.

<sup>3</sup>Facultad de Ingeniería, Universidad Nacional de San Juan, San Juan, Argentina.

\*Corresponding author: anibaljara@fae.mil.ec

knowledge (López et al., 2015). A relatively small number of Original Equipment Manufacturers (OEMs)—notably established companies such as Airbus, Boeing, and Embraer—are primarily responsible for the integration and final assembly of aircraft (Woo et al., 2021). These OEMs delegate the production of various components to a tiered network of suppliers, each specializing in different levels of technological complexity (Lanotte et al., 2020). This distributed model has enabled OEMs to lower production costs and benefit from the technical expertise of specialized suppliers (Kazemina, 2021).

Consequently, the aerospace industry operates as a globally interconnected supply chain encompassing manufacturers, system integrators, suppliers, and component producers (Caliari et al., 2023) (McGuire & Islam, 2015). In parallel, a market has also developed for maintenance, repair, and operations (MRO) services, which are intrinsically linked to the integration and functioning of aircraft systems (Karunakaran et al., 2020) (Hodges & Mo, 2018)

The technological complexity of the aerospace industry (Elsouri et al., 2021), along with the substantial investments it requires, promotes the concentration of industry stakeholders within global industrial agglomerations or clusters (Abysova et al., 2021). These aerospace clusters facilitate the consolidation and integration of specialized business groups within the sector, thereby attracting small and medium-sized enterprises (SMEs) as targeted suppliers. Typically, such clusters unite companies, universities, research institutions, and government entities, all of which are aligned with sector-specific development strategies and supported by state policies aimed at advancing the aerospace industry (Lucena-Piquero & Vicente, 2019).

Through the use of shared infrastructure, collective expertise, and research, development, and innovation (R&D&i) capabilities, these industrial clusters encompass a broad array of industry segments, including the production of components, aircraft manufacturing and assembly, and the development of cutting-edge technologies (Silvestri et al., 2022). Some of the long-established aerospace clusters are found in the United States, France, Germany, the United Kingdom, India (Santos et al., 2019). Nonetheless, the global expansion prospects and emerging opportunities within the aerospace sector have encouraged the involvement of countries beyond the traditional industrial centers (Vértesy, 2017). This shift has opened pathways for nations that do not possess the advanced technological infrastructure typically found in established aerospace hubs (Speldekamp et al., 2020). The globalization of the aerospace value chain has presented a substantial opportunity for developing economies (Lee & Park, 2019); however, due to the sector's high technological demands, firms must compete not only at the national level but also against international players (Liangrokapt & Sittiwatthanasiri, 2023). Within this framework, the formation of regional clusters becomes increasingly important, offering an environment where small and medium-sized enterprises (SMEs) can, in certain cases, demonstrate greater competitiveness than larger firms (Wang et al., 2018).

In this context, the management of the industry—that is, the actions and strategies employed to plan, organize, and optimize resources—

has been approached from various perspectives. Management models and efforts within the sector have primarily focused on innovation management (Weerasinghe et al., 2024), supply chain management (Huq et al., 2021) (Manville et al., 2021), research collaboration (Quintana-Amate et al., 2017) (Meski et al., 2021), technology transfer (Chandra Nagaraju et al., 2019), networks (Lazzeretti et al., 2019) (Luna-Ochoa et al., 2016) among other key areas. However, there is a notable lack of studies that specifically address models incorporating the simultaneous management of these dimensions alongside the diverse stakeholders involved in the aerospace industry (Alfalla-Luque & Medina-López, 2010). This gap is particularly evident in developing countries that have not yet reached the status of a fully developed cluster—that is, where organizations are geographically concentrated but lack formal linkages, supportive public policies, and advanced technological capabilities (Ribeiro et al., 2022).

### 3. Methodology

The study was grounded in a systematic literature review (Riaño-Casallas & Rojas-Berrio, 2023), wherein resource management and technological cooperation within the aerospace industry were explored through the concepts, research, case studies, and insights presented by various scholars in their publications. Subsequently, a thematic analysis (Gioia et al., 2013) (Braun & Clarke, 2006) facilitated the synthesis of the findings, enabling the development of a comprehensive overview of relevant themes, key identifiers, and aspects related to the management of the aerospace industry, leading to the establishment of seven overarching management dimensions.

Based on this foundational knowledge, we developed a model for resource management and technological cooperation, synthesizing the relevant sectors, stakeholders, necessary management topics, and potential development scenarios for the aerospace industry. To mitigate potential biases inherent in the researcher's analysis and to enhance the study's methodological rigor, the proposed model was reviewed by three experts in the aerospace domain. The experts were selected based on a set of criteria that included a minimum of ten years of professional experience in the aviation sector, at least four years in executive or managerial roles within an aerospace company, and demonstrated involvement in activities connected to other stakeholders in the aerospace ecosystem—such as civil aviation authorities, commercial, military, or state operators, as well as academic institutions and research centers, among others. The model was initially introduced to the experts in person through a general one-hour briefing session. This was followed by one or more subsequent sessions during which each component of the model was examined in detail, allowing the experts to provide suggestions, propose adjustments, and offer corrections.

Once the management model was defined, a procedure was developed to assess the management of the aerospace industry, which also involved prioritizing alternative management topics. To achieve this, the multi-criteria decision-making method known as the Analytic Hierarchy Process (AHP) was employed (Torres-Barreto et al., 2024) (Rasmussen et al., 2023). The application of multi-criteria decision-

making techniques enabled the establishment of a preference ranking among the proposed management alternatives, the selection of the most suitable options, the acceptance of the most advantageous alternatives, and the determination of the optimal combination.

To prioritize the various aspects to be managed, the factors at each level were analyzed by a panel of experts using the Delphi technique, employing hierarchical criteria (Llamas & Barón, 2020) (Reguant-Álvarez & Torrado-Fonseca, 2016). For the Analytical Hierarchy Process (AHP), a panel of fifteen experts was selected to minimize forecasting error (Herrera et al., 2022), with an upper error threshold set at 5% (Michalus et al., 2015) (Dalkey, 1969). The expert profile required a minimum of two years in a managerial role within an aerospace company and at least five years of experience in the aviation sector. The experts evaluated the significance of various sectors, general factors, and specific considerations relevant to aerospace industry management. Each expert was asked to rank the management aspects—specific, general, and sectoral—on a scale from 1 to  $n$ , where  $n$  represented the total number of aspects within each category. The ranking assumed that 1 indicated the least important aspect, 2 the

next in importance, and so on, with  $n$  representing the most important aspect.

Based on the evaluations provided by the experts, the research team conducted pairwise comparisons of the specific management aspects within each general management category. These comparisons were used to determine the relative weights of the specific aspects. In cases where the comparisons displayed inconsistencies, a consistency improvement mechanism was applied. Pairwise comparisons were also carried out among the general management aspects within each management domain, as well as among the management domains within the overall management structure of the industry.

We used the results of the prioritization to derive priority vectors for each aspect, which allowed for the formulation of dimensionless polynomials across the different levels of the model. At Level 2, each dimensionless polynomial represents a general management aspect as the summation of its corresponding specific management aspects (Level 3), each multiplied by coefficients reflecting the priority or importance assigned to the development of those aspects.

$$GenAsp = PV_{SpecAsp1} SpecAsp1 + PV_{SpecAsp2} SpecAsp2 + \dots + PV_{SpecAsp n} SpecAsp n$$

Where:

*GenAsp: General managerial aspect*

$PV_{SpecAsp n}$  Priority vectors for a specific management aspect

*SpecAsp n: specific management aspect*

Level 1 focuses on general management aspects, which are categorized according to distinct management sectors. The previously established methodology is applied to derive a dimensionless polynomial that captures management performance within each sector. This

polynomial is formulated as the summation of individual general management aspects, each weighted by a coefficient that reflects the relative priority or importance attributed to the development of that specific aspect:

$$SEC = PV_{GenAsp1} GenAsp1 + PV_{GenAsp2} GenAsp2 + \dots + PV_{GenAsp n} GenAsp n$$

Where:

*SEC: management performance of one sector*

$PV_{GenAsp n}$ : priority vectors for a general management aspect

*GenAsp n: general management aspect*

Finally, at Level 0, the analysis is conducted using the management sectors, which are integrated within the overarching management framework of the aerospace industry. By applying the previously

developed methodology, the final dimensionless polynomial is derived, representing the aggregated management performance across all three sectors (SEC):

$$AerIndMn = PV_{SEC1} SEC1 + PV_{SEC2} SEC2 + \dots + PV_{SEC n} SEC n$$

Where:

*AerIndMn: management performance of the industry*

$VP_{SEC n}$ : priority vectors for a sector

*SEC n: sector*

Upon completion of this process, a prioritized evaluation procedure for the management model was established. For the application to the case study, it is necessary to evaluate scenarios that represent management performance across each specific aspect. These scenarios are assessed using the values provided in Table 1.

**Table 1.** Score for evaluation of scenario

| Scenario Evaluation     | Score |
|-------------------------|-------|
| Incipient               | 5     |
| Structured planning     | 10    |
| Operational development | 15    |
| Consolidated            | 20    |

Using these values, the minimum and maximum thresholds for each polynomial can be determined, providing a performance indicator for the aerospace industry within the range ( $0 \leq Polynomial_i Level_j \leq 20$ ). Intermediate performance intervals for the indicator *Polynomial Level<sub>j</sub>* were also defined, as shown in Table 2.

**Table 2.** Scoring range for achieved results.

| Achieved Results        | Scoring Range |
|-------------------------|---------------|
| Incipient               | ]0-5]         |
| Structured planning     | ]5-10]        |
| Operational development | ]10-15]       |
| Consolidated            | ]15-20]       |

## 4. Results

### 4.1 Management Model

To propose a management model for the aerospace sector in developing countries, the following foundational models and management-related elements were considered:

- 1. The Sábato Triangle** (Sábato & Botana, 1968), a framework designed for the implementation of science and technology policy, which identifies three core actors: the government, the scientific-technological infrastructure, and the productive sector. In this model, the government functions both as the policy designer and executor; the university sector represents the scientific-technological infrastructure, providing technological capabilities; and the productive sector represents the demand for these technologies. The model emphasizes the need for continuous and dynamic interaction among these three actors to promote innovation and development.
- 2. The Triple Helix Model** (Etzkowitz & Leydesdorff, 2000), which fosters innovation through synergistic interactions among universities, industry, and government, particularly within the context of the knowledge society. This model highlights the emergence of hybrid institutional arrangements and the overlapping roles of these sectors in driving innovation and regional development.

- 3. The Quadruple Helix Model**, a conceptual extension of the Triple Helix introduced by (Carayannis & Rakhmatullin, 2014), incorporates the user or civil society as a fourth central actor within the innovation system. In this configuration, user participation is seen as essential, as it influences the definition of products, services, and delivery methods. Industry, government, and academia contribute by providing the necessary tools, knowledge, environments, and skills to enable user-driven innovation. Additionally, both industry and public organizations benefit from innovations initiated or co-created by users.
- 4. Seven overarching management aspects**, identified through a systematic literature review and expert interviews within the aerospace industry. These key aspects include: government policy (GPo), business opportunities (BOp), cooperation networks (CNt), supply chain management (SCH), technology transfer (TTr), knowledge management (KHm), and research, development, and innovation (RD*i*).

To assess the management of the aerospace industry, it was essential to determine the positioning of each required management aspect across various levels, considering different scenarios. For this purpose, a procedure was proposed to evaluate the current state of management within the aerospace industry, taking into account the progress made toward ideal scenarios for each management aspect. The model encompasses the three sectors of the Sábato triangle, integrates the user perspective as central from the Quadruple Helix model, and connects the overarching management aspects that were identified.

The proposed model highlights the strategic interconnection among three key sectors: government, industry, and academia. These sectors are conceptualized as the vertices of a triangular framework that underpins the model's structure. At the center of this framework lies the company, which acts as the integrative agent responsible for coordinating interactions and facilitating collaborative dynamics from the three sectors. This approach is business-centric, focusing on the essential requirements organizations must address to enter, sustain, and succeed in the complex environment of the aerospace industry in developing countries.

The management model asserts that governments are pivotal collaborators in the development of the aerospace industry, both through the formulation of supportive policies and by facilitating the substantial investments necessary for the sector. The government sector (GOB) comprises key stakeholders, including aviation authorities and state entities. Aviation authorities are national or international organizations responsible for certifying operators, manufacturers, and service providers to participate in the industry. State entities refer to governmental bodies such as national and regional governments, ministries, and similar institutions that allocate resources or implement policies that influence the aerospace sector (Ahrens, 2020).

The second sector of the model is the industry sector (IND), which encompasses key stakeholders such as manufacturers, operators, national suppliers, foreign suppliers, and other aviation-related

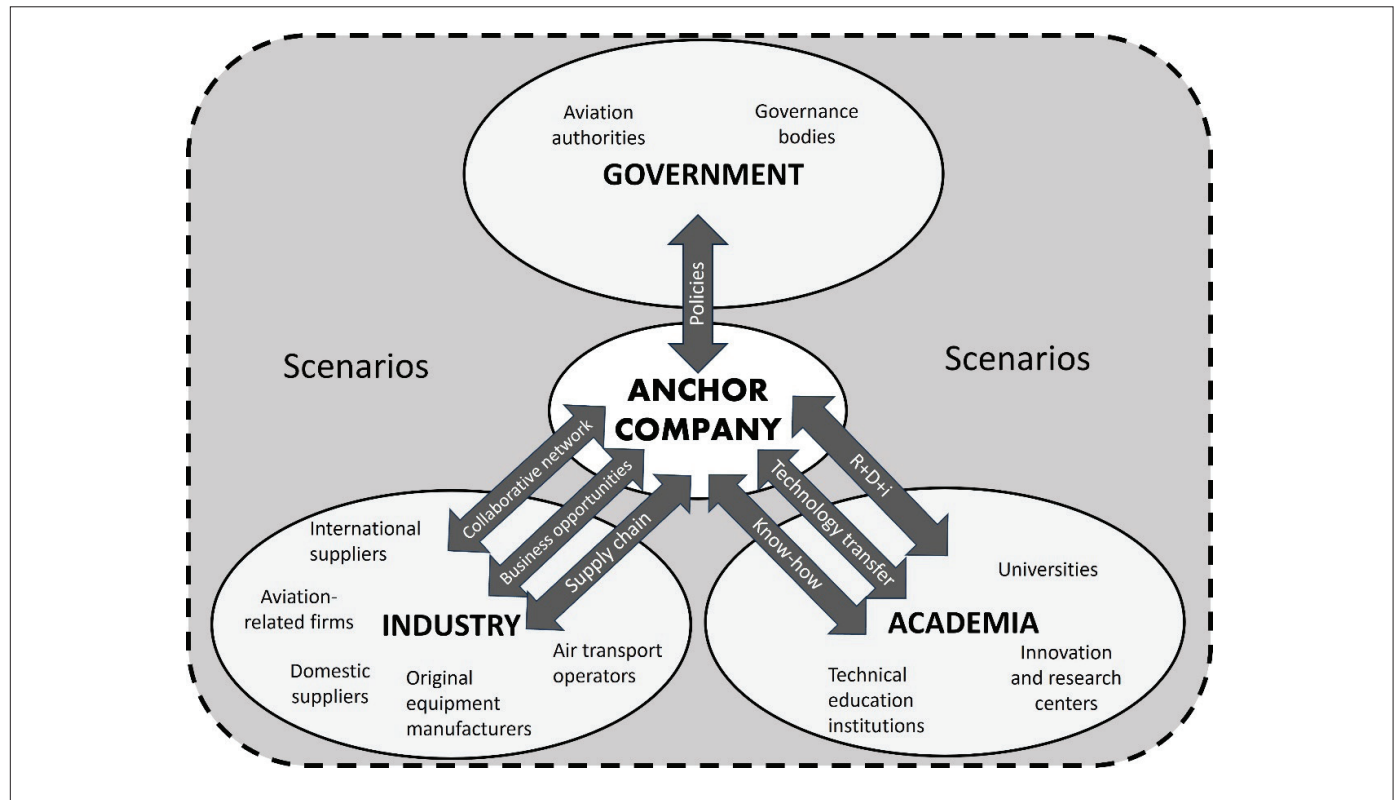
companies. While manufacturers may not necessarily have a physical presence in the business development area or region, they exert significant influence within the sector through requirements and certifications that facilitate the growth of local enterprises. Operators oversee aircraft fleets and, depending on their size and scope, may also manage specialized service workshops. Foreign suppliers are differentiated from national suppliers primarily due to their broader influence in developing countries, where there remains considerable technological reliance on international sources. Among these actors, it is crucial to establish management mechanisms that can vary in form, scope, and configuration. As part of a global value chain, companies must be capable of forming collaborative networks, seizing business opportunities, and developing an efficient supply chain that enables them to overcome the technological and commercial challenges inherent in the aerospace industry (Amankwah-Amoah, 2021).

The third sector of the model is the academic sector (ACD), which includes key stakeholders such as universities, technical institutes, and research centers. Universities differ from technical institutes in terms of complexity, size, and diversity, whereas technical institutes are characterized by their higher degree of specialization in academic

programs, particularly in technical fields. Research centers, in turn, may operate independently or in collaboration with universities, companies, or other private and public organizations. The academic sector serves as a vital source of specialized human resources for the industry, while also providing targeted training programs. In cases where technological knowledge is lacking within the industry, universities and technical institutes offer an alternative through their research, development, and innovation (R&D&I) programs, which can be applied within the industry to create new products and services (Teirlinck & Khoshnevis, 2020). Moreover, technology transfer should leverage the knowledge development capabilities of academia, facilitating the application of this knowledge within the aerospace sector.

Although the seven overarching management aspects can be addressed across multiple sectors (government, industry, or academia), for the purposes of this model, each aspect has been associated with a single sector where optimal results or greater impact are expected to be achieved. This approach does not preclude the possibility that certain management activities may also be conducted in other sectors. The graphical representation of the model is presented in Figure 1.

Figure 1. Representation of the resource management and technological cooperation model.



The management model is structured across three analytical levels, with government, industry and academia representing Level 1. Within each of these sectors, the seven general management aspects constitute Level 2, while specific management elements are defined

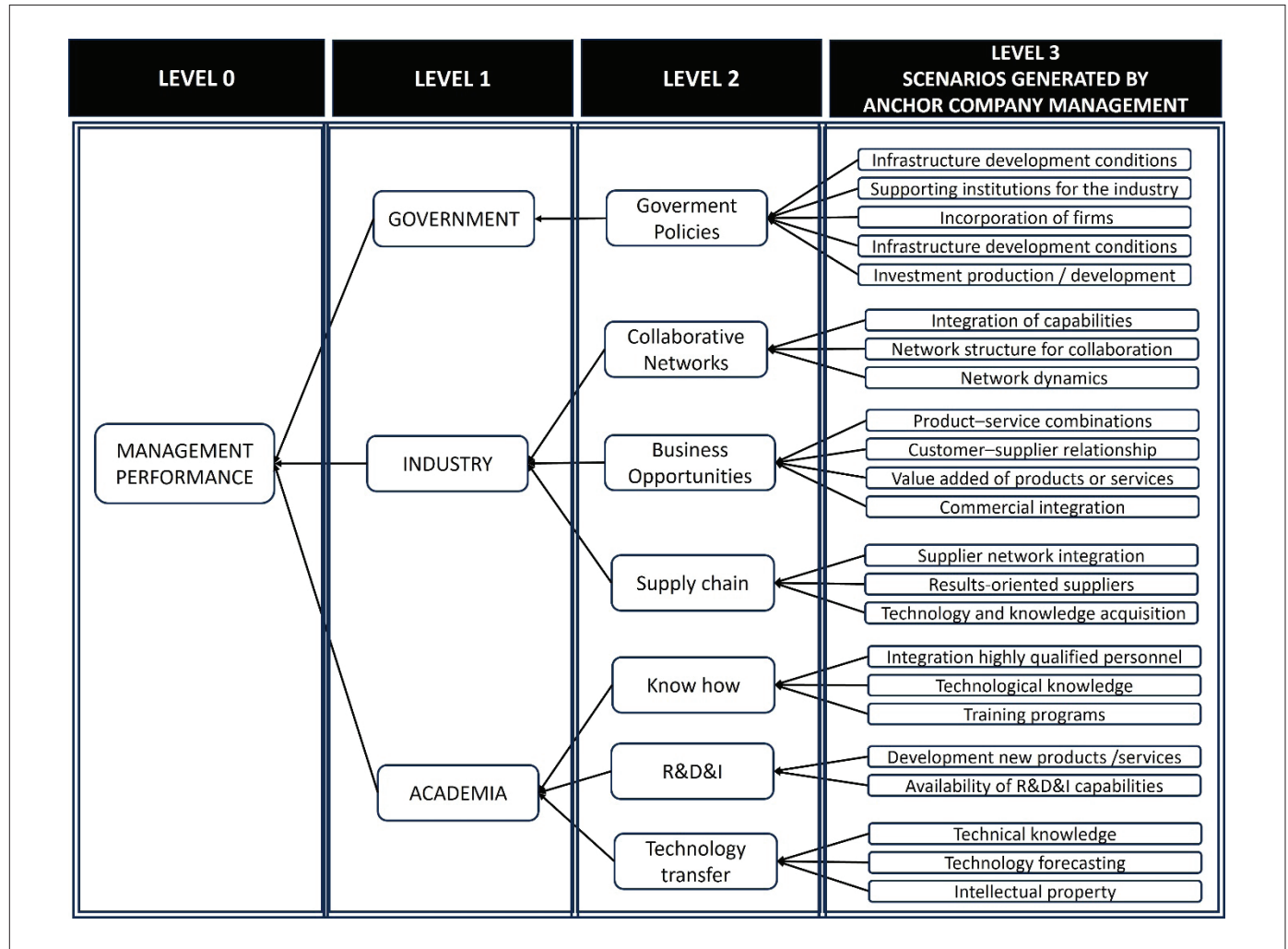
at Level 3. For each specific element, scenario-based constructs have been developed to enable a quantitative assessment of management practices, while also incorporating a qualitative dimension through the definition of context-specific scenarios.

Each of the seven general management dimensions is represented by a dimensionless polynomial function that incorporates its corresponding specific management elements. For instance, in the case of government policies (GPO), the model integrates specific variables such as Infrastructure development conditions (Idc), Supporting institutions for the aerospace industry (Isi), Incorporation of anchor firms

(Aci), Support for the development of the local industry (Lid), and Investment in production and development (Pdi).

A comprehensive mapping of the sectors, along with their general and specific management dimensions and corresponding abbreviations, is provided in Figure 2.

Figure 2. Management levels, aspects, and scenarios of the model



For each specific management aspect, four developmental scenarios were formulated to assess the level of progress within the aerospace industry. The model is specifically tailored to the context of developing countries, where the aerospace sector is undergoing a gradual process of evolution. The proposed scenarios follow a sequential trajectory, beginning with an initial stage characterized by the emergence of basic sectoral activities, followed by a phase centered on industry structuring and strategic planning. This is succeeded by a stage of operational development and scaling, culminating in the consolidation of the aerospace industry.

This structured progression facilitates the assessment of firm-level performance through case study analysis by identifying the developmental stage reached in each management dimension. With the

anchor company placed at the center of the model, the scenario underscores concrete achievements and advances in management practices, thus contextualizing the firm's current position within the resulting broader dynamics of the aerospace industry.

#### 4.2 Case Study

##### Case Study Description

To demonstrate the applicability of the proposed model, a case study was conducted in the central region of Ecuador, specifically in the provinces of Cotopaxi and Tungurahua, where entities related to the aerospace industry were identified. In the city of Latacunga, located in Cotopaxi province, several organizations connected to the aerospace sector are present; however, these entities have not yet formed a

consolidated aerospace cluster. One of the government-led initiatives linked to the sector began in 2009 with the renovation of Cotopaxi International Airport. Despite this effort, airport operations remained inconsistent, ultimately leading to the suspension of commercial and cargo airline services in 2017. Currently, the airport is primarily used for military purposes, private aviation, and for servicing national and international aircraft requiring maintenance.

The regional aerospace industry is mainly oriented toward maintenance, repair, and overhaul (MRO) services. Within this context, the Ecuadorian Air Force maintains a base in Latacunga, which serves as the main hub for the country’s largest fleet of military transport aircraft. This base also hosts logistics units responsible for line maintenance. Additionally, the Air Force Maintenance Center (CEMAF) specializes in the repair and servicing of accessories, parts, and components for military aircraft. Furthermore, DIAF operates as the largest MRO organization in the country, providing major maintenance services to both national and international operators. These services include inspections, engine overhauls, and extensive structural modifications, which are also extended to various government institutions. Supporting this ecosystem is a network of local suppliers based in the region, which provide auxiliary services and supply critical components.

In terms of academic support, the Armed Forces University (Universidad de las Fuerzas Armadas, ESPE), headquartered in Latacunga, is the only higher education institution in Ecuador offering aviation-related technical programs open to the general public. The region also hosts two technical institutes dedicated to the training and professional development of Ecuadorian Air Force personnel. Approximately 35 minutes by car from Latacunga, in the city of Ambato, is the

Research and Development Center (CIDFAE), a facility exclusively devoted to aerospace research. CIDFAE is strategically located next to the Chachoán aerodrome, which serves both as a landing strip for small aircraft and a test site for aerospace technologies and innovations. Other universities in the region also maintain linkage and collaborative research programs with this center.

**Application of the Model**

For the application of the proposed model, DIAF was selected as the anchor company, based on its legal mandate, technical capabilities, and strategic position within the aerospace market. Established in 1992 as a public organization with administrative and financial autonomy, DIAF is legally authorized to conduct aircraft maintenance, assembly, manufacturing, and supply activities. Operating in the city of Latacunga with a 3,900 m<sup>2</sup> hangar, the organization has, for over three decades, remained the only entity in Ecuador capable of providing major maintenance services to both national and international aircraft, supported by certifications issued by aviation authorities from multiple countries. DIAF’s ability to service commercial, private, governmental, and military aircraft enables it to maintain a diversified client base as well as an extensive network of suppliers and commercial partners. These characteristics position DIAF as a suitable and effective anchor company for the selected case study

Within the proposed framework, the resource management and technological cooperation model was implemented through an evaluation procedure based on scenario analysis to determine the current state of industry management. Management performance was assessed using Level 3 scenario simulations, each corresponding to a specific management aspect. These scenarios illustrated potential achievable conditions, as outlined in the example presented in Table 3.

**Tabla 3.** Establishment of scenarios to support local industrial development

| Evolutionary scenarios                                                                                                                                                                                                                         | Rating |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|
| There is institutional support and protection for the development of the local industry through industrial policies and legislation, enabling the sector to overcome the technological and market barriers inherent to the aerospace industry. | 20     |
| Support and protection plans for local industry development, including industrial offset policies, are currently being implemented to help overcome the technological and market barriers characteristic of the aerospace sector.              | 15     |
| Support and protection plans for local industry development, including industrial offset policies, are in place to overcome the technological and market barriers inherent to the sector.                                                      | 10     |
| There is no support or protection for the development of the local industry, nor are there industrial offset policies in place to overcome the technological and market barriers inherent to the aerospace sector.                             | 5      |

The achieved scenarios were defined through structured interviews conducted with company executives, allowing for the identification of conditions aligned with the current operational context. These findings were corroborated by secondary sources, including corporate documents, internal reports, business policies, strategic plans, contracts, and annual management reports. Based on this information, an Achieved scenario was formulated for the company and subsequently compared against the proposed evolutionary scenarios in

order to assign an appropriate rating. This comparative assessment enables a systematic evaluation of resource management and technological cooperation within the aerospace industry.

**Management with Government**

The general aspects of government policy management are presented in Table 4, which outlines the specific management components along with the evaluation of the current scenario achieved under the proposed management model.

**Table 4.** Scenarios achieved through government policy management

| Specific management aspect                               | Current scenario                                                                                                                                                                                                                                                                                                                                                      | Evaluation              |
|----------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Conditions for Industry Development (Idc)                | The region has industrial development infrastructure previously used by national and international cargo operators that ceased operations the airport. Agreements with state entities have enabled the availability of industrial spaces and facilities for expanding aerospace capabilities, including certified services such as engine repair.                     | Operational development |
| Supporting Institutions for the Aerospace Industry (Isi) | The government lacks specific programs or institutions for the aerospace industry. Sectoral development plans have failed to consistently prioritize or include the industry. Government-funded projects, such as an initiative to assemble crop-dusting aircraft, lacked continuity.                                                                                 | Incipient               |
| Incorporation of Anchor Companies (Aci)                  | No long-term benefits have been achieved to encourage national companies to organize industrial clusters or attract large international corporations to act as anchors for inclusion and participation in the global aerospace sector.                                                                                                                                | Incipient               |
| Support for Local Industrial Development (Lid)           | There is support for local industry development, especially through public procurement policies prioritizing local suppliers for state entities. This helps overcome technological and market barriers in the aerospace sector. Under this framework, the company is a supplier of strategic goods and can act as a main contractor for complex maintenance services. | Operational development |
| Investment in Production and Development (Pdi)           | No government stimulus programs or financing schemes have been established for aerospace industrialization. Additionally, as a financially autonomous public entity, the company faces credit restrictions and cannot access public investment programs available to private enterprises.                                                                             | Incipient               |

Government policy management is represented by the following dimensionless polynomial:

$$GPO = 0.22 Idc + 0,15 Isi + 0,19 Aci + 0,26 Lid + 0,18 Pdi$$

$$GPO = 0.22 (15) + 0,15 (5) + 0,19 (5) + 0,26 (15) + 0,18 (5)$$

$$GPO = 3,3 + 0,75 + 0,95 + 3,9 + 0,90$$

$$GPO = 9,8$$

Government policy management is currently in the configuration phase, with significant gaps remaining, primarily in the establishment of supporting institutions and in investment directed towards production and development.

**Management with Industry**

For the industrial sector, the initial evaluation focused on the general aspect of collaboration network management, taking into account specific management components through scenario evaluation, as outlined in Table 5.

**Table 5.** Scenarios achieved through collaboration network management

| Specific management aspect                | Current scenario                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Evaluation               |
|-------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| Integration of Capabilities (Ica)         | The company has successfully integrated additional technological capabilities and resources through formal agreements and partnerships with international corporations and companies. These agreements allow access to specialized suppliers whose capabilities are not cost-effective or technically feasible to develop in-house. Through this integration, the company provides services to small fleet aircraft in the country, which require occasional services but whose contract values make these tasks attractive. The agreements facilitate the provision of certified technicians for maintenance tasks, as well as certified services such as engine overhauls and component repairs. | Consolidated             |
| Network Structure for Collaboration (Nts) | A local network structure for horizontal and vertical collaboration between companies has not yet been established, nor have initial integration mechanisms or access to complementary resources been put in place to exploit sector business opportunities. All collaborations are currently ad-hoc and temporary, based on specific contracts. Collaborative structures and models have been proposed but are still under study for potential implementation.                                                                                                                                                                                                                                    | Structured planning      |
| Network Dynamics (Ntd)                    | Relationships with partners possessing complementary resources have been developed on a case-by-case basis, focused on contract fulfillment. These collaborations are limited to maintaining competitive advantages, developing new products, or managing knowledge, without reaching the level of technological investment or economies of scale.                                                                                                                                                                                                                                                                                                                                                 | Operational development. |

The management of collaboration networks presents the following dimensionless polynomial:

$$CNT = 0.40 Ica + 0,32 Nts + 0,28 Ntd$$

$$CNT = 0.40 (20) + 0,32 (10) + 0,28 (15)$$

$$CNT = 15,40$$

The management of collaborative networks is currently in the consolidation phase, largely driven by the integration of capabilities and the established network dynamics.

Table 6 presents the specific management aspects related to business opportunity management, along with an evaluation of the current scenario achieved under the proposed management model.

**Table 6.** Scenarios achieved through business opportunity management

| Specific management aspect                | Current scenario                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Evaluation              |
|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Product-Service Combinations (Cps)        | Business solutions have been successfully offered to the aerospace industry, comprising integrated combinations of products and services that include performance support through maintenance, operation, and/or training. This has been achieved through agreements with manufacturers/integrators, enabling the provision of complex services such as performance-based logistics or so-called product-service systems.                                                                                    | Consolidated            |
| Customer-Supplier Relationship (Rcs)      | The core of the business model is built on the interaction within a triad composed of the company as a solution provider, its suppliers, and the client. The relationship with military forces and state entities has been consolidated within the provider-client dynamic, thereby strengthening the company's negotiating position with suppliers. This has led to a local aerospace industry structure characterized by higher entry barriers for new players, reinforcing the company's market position. | Consolidated            |
| Value Added to Products or Services (Vps) | The company's offerings possess high added value, primarily through maintenance services, positioning it at the upper levels of global supply chains. This capability enables the company to serve both domestic and international markets, particularly those that are more sophisticated and demanding, thereby allowing for higher profit margins.                                                                                                                                                        | Consolidated            |
| Commercial Integration (Cin)              | The company has achieved a strong integration of commercial relationships with its suppliers and international partners. Agreements with manufacturers/ integrators facilitate continuous and direct technical support to clients, establishing the company as the primary option for operators—especially in the military and government sectors—thus securing a dominant position within a limited local market.                                                                                           | Operational development |

Business opportunities are represented by the following dimensionless polynomial:

$$\begin{aligned}
 BOp &= 0,33 Cps + 0,22 Rcs + 0,16 Vps + 0,29 Cin \\
 BOp &= 0,33 (20) + 0,22 (20) + 0,16 (20) + 0,29 (15) \\
 BOp &= 6,6 + 4,4 + 3,2 + 4,35 \\
 BOp &= 18,55
 \end{aligned}$$

Business opportunity management is currently at a consolidation stage, primarily driven by the integration of both products and services. Nonetheless, further development is recommended to enhance this dimension and ensure sustained long-term growth.

Finally, with respect to the overall supply chain dimension, Table 7 presents the specific management components along with the evaluation of the scenarios currently achieved, as assessed using the proposed management model.

**Table 7.** Achieved scenarios in supply chain management

| Specific management aspect                 | Current scenario                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Evaluation              |
|--------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Supplier Network Integration (Sni)         | Given the nascent local structure of the aerospace industry's development, the company has developed and established a global supply network comprising numerous firms that provide goods and services.                                                                                                                                                                                                                                                                                                                               | Operational development |
| Results-Oriented Suppliers (Ros)           | The company acts as a provider of integrated solutions that extend beyond the capabilities of a single firm. As the main contractor, it coordinates suppliers and consolidates inputs, serving as the central hub of information between suppliers and the final customer. However, there is no direct co-responsibility from the suppliers regarding the performance of the final product or service delivered to the end client. Both domestic and international suppliers are primarily focused on provision rather than outcomes. | Structured planning     |
| Technology and Knowledge Acquisition (Tka) | A high level of technology and knowledge is acquired from suppliers through the co-development of maintenance programs, in which specific capabilities are certified for the company. Personnel are trained, enabling the replication of services, and machinery/equipment is acquired along with the associated technological know-how.                                                                                                                                                                                              | Operational development |

Supply chain management is represented by the following dimensionless polynomial:

$$\begin{aligned}
 SCh &= 0.32 Sni + 0,24 Ros + 0,44 Tka \\
 SCh &= 0,32 (15) + 0,24 (10) + 0,44 (15) \\
 SCh &= 4,8 + 2,4 + 6,6 \\
 SCh &= 13,8
 \end{aligned}$$

According to the model, supply chain management is currently at a developing stage, primarily driven by the acquisition of technology and knowledge. Nonetheless, further advancement is necessary to enhance performance and move toward a consolidated level.

**Management with Academia**

For the academic sector, the general aspect of know-how management is presented first, along with the specific management dimensions and their corresponding evaluations, as shown in Table 8.

**Table 8.** Scenarios achieved in know-how management

| Specific management aspect                      | Current scenario                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Evaluation              |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Integration of Highly Qualified Personnel (Hqp) | Regarding technical staff, the academic sector—comprising universities and technological institutes—shows an adequate output of technicians. Internship agreements facilitate the availability of this workforce, who have been integrated into various DIAF programs, effectively becoming the first employment option for recent graduates. However, there is a lack of locally available personnel with advanced degrees in science and engineering specific to the aerospace domain. As a result, collaboration is managed through partnerships with foreign universities, allowing the integration of students or recent graduates into local entities. Nevertheless, their presence is typically temporary and limited to specific project contributions. | Operational development |
| Technological Knowledge (Tkn)                   | Information and knowledge that enhance technical management capabilities are available through the interaction between academia and industry. However, there is no systematic mechanism for capturing, retaining, and reusing this knowledge, which limits its accessibility and application across different organizational challenges.                                                                                                                                                                                                                                                                                                                                                                                                                        | Operational development |
| Training Programs (Tpr)                         | The company has benefited from training programs for engineers and technicians in techniques, procedures, and cross-cutting support skills. However, these are not directly applicable to the aerospace field. Training has primarily focused on software tools, applied programs, and administrative tools of a general nature.                                                                                                                                                                                                                                                                                                                                                                                                                                | Incipient               |

The management of know-how is represented by the following dimensionless polynomial:

$$KHm = 0,41 Hqp + 0,20 Tkn + 0,39 Tps$$

$$KHm = 0,41 (15) + 0,20 (15) + 0,39 (5)$$

$$KHm = 6,15 + 3,00 + 1,95$$

$$KHm = 11,1$$

The management of know-how is categorized at the level defined as Operational development, primarily due to the integration of highly qualified personnel.

Next, for the general aspect of research, development, and innovation management, the specific management aspects and scenario evaluation currently achieved under the proposed management model are presented in Table 9.

**Table 9.** Scenarios achieved through research, development, and innovation management.

| Specific management aspect               | Current scenario                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Evaluation              |
|------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| New Product or Service Development (Dps) | The company participates in the outcomes of projects focused on the development of technological solutions for the aerospace sector, in collaboration with the national aerospace research center.                                                                                                                                                                                                                                                                                                                            | Structured planning     |
| Availability of R&D&I Capabilities (Cav) | Certain scientific and technological resources are available through the aerospace research center, including software applications, test benches, and proprietary tools and equipment. These assets can be utilized to provide the necessary engineering support for analysis, inspection, and testing of aerospace mechanical components. Additionally, the center provides access to a national university network, allowing the use of general-purpose laboratories with procedures applicable to the aerospace industry. | Operational development |

The management of research, development, and innovation presents the following dimensionless polynomial:

$$RDi = 0,46 Dps + 0,54 Cav$$

$$RDi = 0,46 (10) + 0,54 (15)$$

$$RDi = 4,6 + 8,1$$

$$RDi = 12,7$$

The management of research, development, and innovation is at a planning or configuration stage, primarily driven by the availability of capabilities.

For the general aspect of technology transfer, Table 10 presents the specific management aspects with the evaluation of the current scenario achieved under the proposed management model.

**Table 10.** Scenarios achieved with technology transfer management

| Specific management aspect         | Current scenario                                                                                                                                                                                                                                                                                                                                                                                   | Evaluation          |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| Technology Transfer Programs (Ttp) | There are currently no agreements with academic institutions to establish national or international technology transfer programs directly applicable to the aerospace industry.                                                                                                                                                                                                                    | Incipient           |
| Technology Forecasting (Tfr)       | Among academic entities, the aerospace research center is the only institution that performs basic identification of certain technologies. However, no roadmap or framework is established to define parameters regarding the interaction between market products and technological innovation. As a result, there is limited capacity to reduce uncertainty and optimize the company's resources. | Structured planning |
| Intellectual Property (Ipr)        | The research center has developed patents in electro-optical systems and communication systems, which have been tested as prototypes on military aircraft. However, there has been no commercialization of these patents by the company, as they are not part of its current portfolio of products or services, and the patents have not yet reached a production-ready stage.                     | Structured planning |

Technology transfer management presents the following dimensionless polynomial:

$$TTr = 0.47 Ttp + 0,27 Tfr + 0,26 Ipr$$

$$TTr = 0.47 (5) + 0,27 (10) + 0,26 (10)$$

$$TTr = 2,35 + 2,70 + 2,6$$

$$TTr = 7,65$$

Technology transfer management is currently at a planning or configuration stage, primarily due to the absence of formal technology transfer programs.

At level 1, the dimensionless polynomial represents the management within a sector as the sum of each of its general management aspects, weighted by coefficients that determine the priority or importance of the development of each specific aspect.

$$GOB = GPo = 9,8$$

$$IND = 0,33 CNT + 0,36 BOp + 0,32 SCh$$

$$IND = 0,33 (15,40) + 0,36 (18,55) + 0,32 (13,8)$$

$$IND = 5,08 + 6,68 + 4,42 = 16,18$$

$$ACD = 0,40 KHm + 0,32 RDi + 0,28 TTr$$

$$ACD = 0,40 (11,1) + 0,32 (12,7) + 0,28 (7,65)$$

$$ACD = 4,44 + 4,06 + 2,14$$

$$ACD = 10,64$$

At level 0, the dimensionless polynomial represents the management executed in the aerospace industry as the summation of the management actions carried out in the three sectors of the model, multiplied

by coefficients that define the priority or importance of the development of each sector.

$$AerIndMn = 0,37 GOB + 0,43 IND + 0,20 ACD$$

$$AerIndMn = 0,37 (9,8) + 0,43 (16,18) + 0,20 (10,64)$$

$$AerIndMn = 3,63 + 6,96 + 2,13$$

$$AerIndMn = 12,72$$

The findings of the research revealed that resource management and technological cooperation within the aerospace industry in central Ecuador are significantly limited, primarily due to the lack of integration among key sector stakeholders. The application of the proposed model facilitated the evaluation of management activities, considering a company as the central unit of the model in terms of resource utilization and technological cooperation.

## 5. Discussion

The proposed model exhibits notable differences compared to approaches described in previous studies. While it shares the conceptual foundation of the Triple Helix (Simões et al., 2020)—framing the relationships among government, industry, and academia as a mechanism for fostering innovation and technological development—it is specifically oriented toward resource management and technological cooperation in contexts where intersectoral relationships are marked by limited organizational structures. Although it aligns with the Quadruple Helix approach by incorporating a fourth sector (Miller et al., 2018) (González-Martínez et al., 2021) the model is distinguished by the inclusion of the anchor company as an additional actor, functioning as the facilitator and driving force behind interactions among government, industry, and academia. This contrasts with other models in which coordination efforts are typically led by government or academia, particularly in regions with well-established innovation ecosystems (Ibusuki et al., 2020).

In this regard, the model constitutes a particularly relevant alternative for Global South contexts, where the absence of consolidated industrial clusters, inter-firm networks, and institutional coordination mechanisms constrains technological and resource cooperation. Unlike classical Triple Helix approaches - which implicitly assume the existence of mature ecosystems and relatively balanced institutional capacities - the proposed model explicitly acknowledges the structural asymmetries characteristic of developing countries. In such contexts, an anchor company with consolidated technological capabilities, organizational maturity, and institutional legitimacy can play a catalytic role by integrating interactions that would otherwise remain fragmented. This perspective provides a collaborative governance architecture for initiating the development of productive and technological ecosystems in the absence of pre-existing clusters, thereby extending the applicability of Triple Helix-inspired models to emerging contexts.

At the resource management level, the model incorporates the analysis of both general and specific managerial aspects that a company should prioritize in its interactions with each of the government, industry, and academia sectors, thereby establishing a comprehensive

management perspective. Unlike other models emphasize particular elements such as supply chains, technology, and suppliers, this model seeks to optimize systemic efforts and promote structured collaboration across multiple dimensions. Moreover, it introduces metrics based on the Analytic Hierarchy Process (AHP) as a quantitative component, allowing for a diagnostic assessment of the current management scenario within the aerospace industry. This quantitative element is uncommon in management model studies and constitutes a methodological innovation for prioritizing activities in resource-constrained contexts.

Additionally, the model emphasizes coordination at the local level, in contrast to other models that structure the industry around corporations and foreign investment (Luna et al., 2018) (Kowalski, 2020), which have primarily driven the formation of aerospace clusters. This dynamic enables the anchor company to mobilize resources from government, industry, and academia to consolidate its position within the aerospace sector, while simultaneously fostering an environment conducive to the sector's development. This approach facilitates the model's adaptation to the current developmental contexts of emerging regions, with scalability aligned to the country's productive realities.

From a theoretical perspective, the model enriches the discussion on technological cooperation and management by considering the aerospace industry as an application field and integrating new approaches into the Triple Helix model, specifically oriented toward industries in consolidation. The incorporation of the anchor company as the central coordinating entity introduces a significant variant compared to traditional models, which typically emphasize the key drivers as government, industry, or academia. In this way, the anchor company assumes a hybrid role, both as a productive unit and as the coordinator of the aerospace industry ecosystem. Theoretically, the model expands upon the Triple Helix concepts by integrating management aspects for each of the three sectors and identifying the relevant stakeholders involved in these management activities.

From a practical standpoint, the model proposes evaluation scenarios and multicriteria decision-making tools, with procedures applicable to companies in the aerospace sector. These tools can be used to optimize efforts in scenarios characterized by resource constraints and cooperative structures. The implementation of the model allows companies to characterize their current situation, identify priority management areas, and establish new strategies. Therefore, the model provides a framework to strengthen the development of companies in the aerospace sector, with practical implications projected into two main areas: i) improving resource management efficiency, and ii) strengthening intersectoral cooperation.

Despite the significant contributions of the proposed model, certain limitations must be acknowledged regarding its implementation. First, the model is grounded in the specific context of the aerospace industry in the central region of Ecuador. As such, its applicability to other regions or industrial sectors requires careful consideration of differences in development levels, capabilities, organizational structures, and economic conditions. Second, although the model's emphasis on resource and technological management is pertinent, the effective implementation of the evaluation tool depends on the availability of precise information to identify relevant scenarios—an aspect that may prove challenging in industrial environments that are still in the process of consolidation.

Based on the results obtained, several avenues for future research are identified. One important area involves the analysis of strategies to strengthen international cooperation in the aerospace sector of developing countries, which could enhance access to advanced technologies and complementary resources. Effective resource management, coupled with well-structured technological cooperation strategies, has the potential to significantly increase the sector's competitiveness.

Furthermore, the model opens up new opportunities for research in the field of collaboration in technological management. It is recommended to pursue a deeper empirical validation of the model in other regions within developing countries, allowing for a comparative assessment of the model's applicability under different industrial development frameworks.

## 6. Conclusions

The proposed model has proven to be an innovative tool, specifically tailored to a region lacking a defined structure for intersectoral collaboration. By enabling resource management across government, industry, and academia, the model integrates local capabilities and promotes collaborative engagement. One of the key findings is the positioning of the anchor company as the central facilitator of relationships, adapting the model to an industrial clustering scenario that is still in the process of consolidating both its capabilities and its collaborative framework.

Additionally, the integration of multi-criteria tools has contributed to a more structured approach to activity prioritization and resource management, addressing a gap in existing models that often lack either qualitative or quantitative criteria in their decision-making processes. This methodological enhancement facilitates the evaluation of outcomes derived from management and technological cooperation, providing insights into the industrial conditions achieved and the corresponding efforts and resources mobilized by companies within the aerospace sector.

In terms of relevance, the model offers a viable alternative for other industrial sectors and regions aiming to strengthen technological cooperation and enhance resource management, as it is replicable in contexts facing similar challenges related to industrial or technologi-

cal development. Its explicit consideration of the conditions prevalent in developing countries makes it particularly innovative in promoting technological advancement.

Moreover, the model's contribution lies in its ability to integrate theoretical constructs from diverse approaches with practical applications. By embedding classical frameworks such as the Triple Helix within the specific context of the aerospace industry and incorporating a decision-making mechanism through the Analytic Hierarchy Process (AHP), the model advances the theoretical literature on intersectoral cooperation. Additionally, it provides a valuable reference framework for future research in comparable settings, particularly in developing countries where strengthening the aerospace industry remains a strategic priority.

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