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Management System for Research, Development and Innovation (R&D+*i*) Design of R&D+*i* Management System for the Flavors and Fragrances Industry

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Abstract

Technology management is responsible for establishing activities and knowledge capable of generating value. The application of efficient technological management models has demonstrated sufficient capacity to be a factor of economic and human development. This research covers the design and validation of research, development and innovation management system for the flavor and fragrances industry.

The proposed system is the result of a qualitative analysis of factors related to R&D+*i* and a quantitative analysis of a Matrix Impact Cross-Reference Multiplication Applied to a Classification (MICMAC® method) of 38 isolated variables of the state of the art to develop technology management systems. 12 variables of high influence and dependence have been isolated and interrelated as key elements of the proposed management system. The study also offers a validated tool; by methodological experts, disciplinary experts in technology management and experts of the industry, to quantify the degree of implementation of the R&D+*i* management system.

Keywords: technology management, research and development (R&D), innovation, system management, Micmac® method, flavors and fragrances industry.

Codes JEL: O32 (Management of Technological Innovation and R&D).

1. Introduction

There is a strong relationship between the factors of: productivity, economic growth and innovation in the countries, a relationship that has shown the formation of gaps in development and social welfare over the years[1,2].
In several countries, the indicators: health, primary education, business sophistication, labor market efficiency, innovation and sophistication of factors represent the lowest competitiveness indices according to Klaus Schwab (2015)[3].

Global aspects of input innovation, such as: capital, advanced human capital, research infrastructures, market sophistication and global aspects of innovation products, such as: knowledge and technology, creativity, are describedas relevant aspects of the decrease in innovation indicators[4].

According to Bitran E., (2010)[5] It was fundamental for the strategy (2010 to 2020) to include in the competitiveness plans, business innovation and productive diversification for the continuous improvement of the productive matrix. For this, science, technology and human capital constitute 3 fundamental pillars. Therefore, a key factor to generate: differentiation, satisfaction, cost reduction for customers and improve long-term competitiveness is determined by the capacity and system used to innovate[6,7,8,9].

The objective of the research is to design and validate a prospective research, development and innovation (R&D+*i*) management system for a flavor and fragrance industry, which considers both the influence and the dependence of the key factors for innovation and technological management. The study was carried out under a mixed approach methodology. On one hand, it collects and isolates the qualitative factors of the state of the art that report an effect on the development of technological management and innovation and, on the other hand, quantifies the relationships of direct, indirect and potential influence of the key factors under the Matrix Impact Cross-Reference Multiplication Applied to a Classification (MICMAC®)[10, 11].

As a result, the study has integrated each isolated variable of the state of the art into a conceptual proposal of the R&D+*i* management process under a functional and interdependent logic to build the future. The study, in an attempt to glimpse and quantify the internal and external factors of the innovation process, addresses two questions.

What are the R&D+*I* key factors in the flavors and fragrances industry, which must be considered for the design and implementation of a management system? The second question arises after reflecting on the selective integration of key performance factors and their functional relationship in the target industry.

How is the relationship (direct and indirect) of the R&D+*i* factors of the flavors and fragrances industry structured? Contextualizing, the flavors and fragrances industry are made of technology-based organizations that, according to Euromonitor (2015)[12], allocate approximately 10% of their income to R&D using various sciences to develop food additives capable of create neuronal responses equal or similar to what the intake of food generates from natural sources without resorting to them[12]. These ingredients are incorporated in various food and industrial matrices, such as: ice cream, milk, desserts, baking dough, drinks, cleaning supplies and perfumes.

1.1. Technology management

Technological management is the process of managing different elements related to R&D, such as: R&D projects, negotiation of intellectual property, formation of research and development teams, monitoring of R&D projects, evaluation of results and technology transfer to the productive sector in order to contribute to the achievement of strategic and operational objectives in an organization[13, 14].

1.2. Innovation models

Innovation models are usually divided temporarily from: the first-generation model (push of technology and science), second-generation model (market pull), third-generation or coupling model, such as chain-link model, fourth-generation model (integrated model) and fifth-generation model (integrated systems). Which generate progressive, sequential and orderly staging processes. The description of innovation models available in the bibliography is abundant[15, 16], finding evolutionary models of innovation [17], theoretical models of innovation management[18], among many others [19, 20, 15, 21,22, 23, 24].

Some common elements among these proposals for innovation models are: they have some common variables in their conformation, the vast majority are born in developed countries and none have application in organizations or unions where a structural analysis of the organizational context has been carried out[18, 25, 26].

1.3. Innovation systems

The local, regional or national innovation systems include the set of innovation tools, the different phases of the process, the definition of the organizational structure, the forecasting of resources for innovation, the definition of policy, innovation objectives, evaluation methods and system monitoring. Innovation systems have a direct focus on the technological and economic development of a country, which emerges as a result of the synergy between its various components [25, 26, 27].

The Spanish Association for Standardization and Certification (Spanish acronym, AENOR) has described the main components of an innovation system (The UNE standard): people (knowledge, culture and direction), company (organization, structure and business model), process (management processes innovation and support) and environment (stakeholders)[28, 29, 30].

1.4. Innovation management systems

The standard UNE 166.002:2006 R&D+i Management: requirements of the R&D+*i* management system, born as a reference to optimize and standardize the innovation process and bases its operation on the continuous improvement cycle: planning, do, checking, act (PDCA). Updated in 2014, UNE 166.002: 2014, includes the accumulated experience of the market and the guidelines established in the European technical specification UNE-CEN/TS16555-1:2013 Innovation Management [28, 30]. UNE 166.002 is made up of around 35 sections. The pillars defined for a system are: The organizational context, leadership, planning, support, operational processes and performance evaluation of the R&D+*i* management system[28].

1.5. Instruments to measure innovation

The bibliography describes various instruments for measurement and diagnosis: Albacete degree of innovation of the European Center for Business and Innovation - (original acronym, CEEI)[32], innovation capabilities of the Catalan Institute of Technology - (original acronym, ICT)[33], technological and innovation profiles by Technological Management Methodology by Projects - (original acronym, MGT)[34, 35, 36], level of business innovation management of the Andalusian Center [37], instrument of innovation drivers[38], among many others [39,40, 41,42], which provide a theoretical and practical basis for measuring innovation.

Despite the abundance of instruments, on the one hand, holistic integration has not occurred, and, on the other hand, each instrument presents low integration of the variables defined as important in the review of the state of the art. It is for this reason that it has been designed and used a technology management and innovation instruments (TMII) to explore the performance of some flavors and fragrances industries of the Chilean Association of Flavors and Fragrances (official acronym, ACHISAF). TMII integrates the strengths of the instruments described in the state of the art and is structured from the 6 pillars proposed by the Spanish standard UNE 166.002[28]. TMII consists of 119 assertions distributed in: primary, secondary and tertiary categories[44].

2. Methodology

The study has a mixed methodological approach. On one hand, the qualitative analysis focuses on the definition of the dimensions, categories and subcategories of the model that have their origin in an analysis of the relevance of the isolated variables of the state to form a technology management system.

On other hand, the quantitative structural analysis of the influence of the variables was carried out from the collective reflection of a team of experts recruited from the industry. The selection and analysis of the most relevant variables, in which the system has been composed, has required the potential multiplication of the matrix resulting from the collaborative work of R&D+*i* experts recruited from the flavors and fragrances industry. For the analysis of the influence of the variables, the MICMAC® methodology developed in 1971 by Michel Godet has been used, and which bases its analysis on the classical properties of Boolean matrices[10, 11, 45].

The descriptive-correlational study aims to analyze, how is R&D+*i* management manifested in the flavors and fragrances industry? Placing special emphasis on understanding, what are the key variables that trigger R&D+*i*? and how is the direct and indirect relationship between these variables capable of managing R&D+*i* within the flavors and fragrances industry?

To check the validity of hypotheses in the industry, the study has quantified the performance of R&D+*i* management in 3 of the 8 flavors and fragrances industries grouped in ACHISAF[46] (sample size estimated for a 95% confidence, maximum acceptable error 20%, assumed variance 5%) through the TMII, devised based on the model proposed here. The TMII was published and described previously [44].

The 3 participating companies were selected after meeting the criteria of *i*) signing a confidentiality agreement and, *ii*) deadlines for delivery of the relevant information of the study. The sample of 3 companies sought to provide a general and non-exhaustive perspective of the economic sector and statistical representation of the members of the flavors and fragrances industries. The sample was made up of 1 industry with a global presence with more than a century of history, 1 with a Latin American presence and 1 with a national presence, the latter two with more than half a century of history. The sample, although they have good statistical power, faced the challenge of access to information by companies that did not want to quantify or expose their performance in R&D+i management.

2.1. Structural analysis

The structural analysis was carried out using the MICMAC® software developed by Michel Godet and applied to the key development factors of nuclear energy in 1974 with JC Duperrin from Alternative Energies and Atomic Energy Commission[10, 11]. The different phases of the method are as follows: listing the variables, describing the relationships between the variables, and identifying the key variables. An online version is available at: https://www.micmacprospective.com/en

For the enumeration of the variables, a list of dimensions identified after an extensive review of the state of the art of technology management measurement instruments, innovation, technology management models, R&D+*i* management systems, Oslo manual[47] and Frascati manual [48]. The list of variables and a brief definition are described in table 1.

For quantification of relationship between variables of the matrix. A double entry matrix analysis has been carried out by the multidisciplinary team recruited from the flavors and fragrances industry, in order to determine the direct and indirect relationship between the variables.

For each pair of variables, it was established whether, is there a direct influence relationship between variable i and variable j? If it did not exist, it was qualified with 0 (zero); otherwise, it was questioned and quantified if this direct influence relationship was: weak (1), medium (2), strong (3) or potential (P1, P2, P3) see Direct Influence Relationships (DIR) graphic 1.

Under a system perspective, a variable exists only because of its relationship with the other variables, for this reason the evaluation of direct and indirect relationships is very important. The MICMAC method for Cross Impact Matrices (Multiplication Applied for a Classification) consists of raising the structural analysis matrix to a power of successive values, in this way thousands and millions of lines are analyzed between the variables of the system, see graphic 1 and 2. This indirect classification allows us to confirm the importance of certain variables that, due to their indirect influences, play a main role (and that the direct classification of variables does not reveal)[10, 11]. To quantify the indirect relationships, the direct classification matrix has been raised in power until statistical stability is reached.

Equation (Eq) 1 summarizes the logic of measurement of indirect relationships according to Ballesteros et al., (2008) [10, 45].

$A^2 = A * A = (a_{ij})^2$, where $(a_{ij})^2 = \sum a^1_{ik} * a^1_{kj}$ *Where* A (a): system matrix. *i*: variable 1 with direct influence on variable j of the system under study. *j*: variable 2 with direct influence on variable i of the system under study. *k*: variable 3 of indirect influence on the variables i / j of the system under study.	Eq. 1.

Taking as input peripherals the quantification of influence between the variables used in the analysis of double-entry matrices (section 4.1.). The resulting matrix has been iterated 6 times until reaching 100% statistical stability of the system. To locate the key variables, the variables housed in the quadrant with the greatest influence and dependence on the system under analysis have been identified. (See map 1. Direct Influence/Dependence (MDI). Key variables).

3. Validation criteria

For the validation of the R&D+*i* management system, two justification criteria were previously proposed.

Criterion 1: % compliance with the antecedents noted by the MICMAC® method for structural analysis of matrices > 30 variables according to Godet, 1990[10].

Criterion 2: Evaluation of the system proposed by an expert from the R&D unit of the flavors and fragrances industry using a Likert-type parametric scale.

The validation process of the technology management and innovation instruments (TMII) was carried out incorporating corrections emanating from 3 methodological experts, 3 disciplinary experts in technology management and 4 experts associated with the flavors and fragrances industry. A description of the process is described in a recent publication[44].

4. Results

4.1. Influence matrix of the variables of the proposed system

The Direct Influence Matrix (DIM) describes the direct influence relationships between 38 isolated variables of the bibliography for an R&D+*i* management system, carried out by the multidisciplinary team recruited from the flavors and fragrances industry (see Table 1 and Matrix 1).

The variables that trigger innovation have been integrated following the guidelines of the structural analysis and bibliographic analysis of dimensions described in various instruments[31, 32, 33, 34, 35, 37, 39], manuals[27, 41, 47, 48] and standards of R&D+*i* management systems[28, 29, 30]. The resulting variables made it possible to generate a condensed list that excluded redundant variables (see Table 1).

Table 1. List of variables of the proposed R&D+*i* management system.

Nº Var.	Abbreviation	R&D+*i* system variable	Brief definition
1:	Pers_org_i	Internal organizational perspective	Formulate and establish an R&D+*i* strategy that allows achieving the objectives.
2:	Cap	R&D+i capabilities	Technological diagnosis, have information sources and sufficient know-how.
3:	Cult	R&D+*i* culture	Values, beliefs, rituals, among others, that leverage activities related to the strategy.
4:	Est_org	Organizational structure	Human resources with job and role descriptions for R&D+*i*.
5:	Práct	Internal practices	Internal activities (competition, idea banks, etc.) aimed at generating ideas, creativity and improvements.
6:	Pers_org_e	External organizational perspective	Stakeholders involved in the R&D+*i* performance of the organization.
7:	Merc	Market	Identify and analyze exogenous information to identify opportunities and ideas.
8:	PI	Intellectual property (IP)	Process the protection of information and knowledge with an IP instrument.
9:	Leg	Legislation	Regulatory, national and international matters related to R&D+i.
10:	Camb	Social changes	Trends, climatic, demographic and cultural changes that influence R&D+*i*.
11:	Nec_i	Implicit customer needs	It involves translating customer expectations regarding what is offered.
12:	Nec_e	Explicit customer needs	Systematics with which the organization welcomes and develops explicit requirements.
13:	Sginn	R&D+*i* management system, essential components	Auditable development procedures and records with management logic and systematics.
14:	Vis_est	R&D+*i* vision and strategy	Strategic technological program (STP), where innovation is key to success.
15:	Polit	R&D+*i* policy	Declaration, consistent with the "SPT" on intentions, objectives and principles R&D+*i*.
16:	Lid&comp	leadership and Senior management	Competent, dedicated and sufficient technical, financial and human resources to lead innovation.

		commitment	
17:	Def_unid	Definition of R&D+*i* unit	Innovation activities department with adequate working conditions ((including telecommuting).
18:	Det_R&O	Determination of risks and opportunities	Planning that includes estimating the probability of success and gaps between needs and the solutions developed.
19:	Plan_p	R&D+i project planning	It involves establishing clear objectives, tasks, deadlines, order and resources to use.
20:	PDCA	Continuous improvement	Recurring activity to increase the ability to meet system requirements.
21:	Segui	Monitoring of R&D+*i* projects (fallowup)	Activities (coordinated and controlled from start to finish), to achieve a goal.
22:	Unid_gg	Global R&D+*i* management unit	Unit that analyzes the context, plans, documents the process, results and leads the R&D+*i* management process.
23:	Asig_rec	Resource assignment	Responsible for offering tangible and intangible resources to develop projects.
24:	Form_C	Skills training	Plan and manage training activities related to innovation and R&D.
25:	Conc	Collective awareness training	Management activities for dissemination and recognition of the importance of R&D+*i*.
26:	Canal_C	Communication channels	Systematics to identify, access and present R&D+i results to users or clients.
27:	Act_int	Intangible assets	Activities that allow the generation, search, dissemination and use of knowledge.
28:	Colab	Collaboration and agreements	Formal and legal relationship of economic exchange between organizations (technology transference).
29:	Vig_tec_int	Technological surveillance and competitive intelligence	Selective and systematic process of compiling scientific and technological information.
30:	Unid_g	Project management unit	Department responsible for obtaining useful scientific and technological knowledge.
31:	Gest_i	Idea management	Systematic to generate, select and validate ideas with market interest.
32:	Desarr_p	Project development	R&D+*i* results development process with market interest.
33:	Exp_vinc	Exploration and engagement with the market	Process of transmission of technological scientific information to generate profit or advantage.
34:	Ind_est	KPI of strategic processes	Measurement of the level of performance of a strategic process.
35:	Ind_op	KPI of operational processes	Measurement of the performance level of an operational process.
36:	Ind_sop	KPI in support processes	A measure of the performance level of a support process.
37:	Audit	Internal audits	Objective internal systematics that verifies the degree of conformity of the system.
38:	Rev_dir	Senior management reviews	Reviews of the return on investment or profitability of innovation projects.

Source: Own elaboration from ®Micmac structural analysis

Matrix 1. Direct influence between the variables

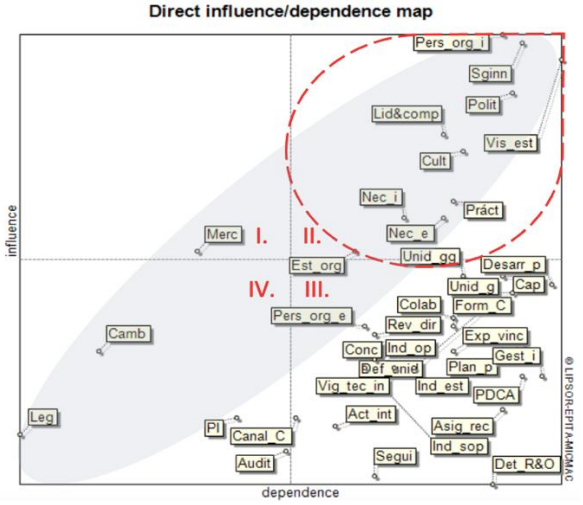
	1 : Pers_org_i	2 : Cap	3 : Cult	4 : Est_org	5 : Práct	6 : Pers_org_e	7 : Merc	8 : Pl	9 : Leg	10 : Camb	11 : Nec_i	12 : Nec_e	13 : Sginn	14 : Vis_est	15 : Polit	16 : Lid&comp	17 : Def_unid	18 : Det_R&O	19 : Plan_p	20 : PDCA	21 : Segui	22 : Unid_gg	23 : Asig_rec	24 : Form_C	25 : Conc	26 : Canal_C	27 : Act_int	28 : Colab	29 : Vig_tec_in	30 : Unid_g	31 : Gest_i	32 : Desarr_p	33 : Exp_vinc	34 : Ind_est	35 : Ind_op	36 : Ind_sop	37 : Audit	38 : Rev_dir
1 : Pers_org_i	0	3	3	3	2	1	2	2	0	1	3	3	2	3	3	3	3	2	2	3	2	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3
2 : Cap	3	0	3	2	2	2	1	2	0	1	2	2	2	2	1	2	2	2	2	2	2	1	1	2	2	1	2	2	2	2	2	2	2	2	2	2	1	1
3 : Cult	3	2	0	3	3	2	2	2	1	2	2	3	2	3	2	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
4 : Est_org	3	3	2	0	3	2	1	1	0	1	2	2	2	2	2	3	2	1	2	2	2	3	2	1	1	1	1	2	1	2	2	2	2	2	2	2	3	
5 : Práct	2	2	2	2	0	1	2	1	0	1	2	3	3	3	3	2	2	2	3	3	2	2	3	2	2	1	2	1	1	3	3	3	2	2	2	1	2	2
6 : Pers_org_e	2	2	1	1	1	0	2	1	1	1	2	2	1	2	2	1	2	2	2	2	1	1	2	2	1	1	1	3	2	2	3	3	3	1	1	1	1	1
7 : Merc	2	2	2	1	1	2	0	1	2	3	3	3	2	2	2	2	3	2	2	2	1	1	2	2	1	1	1	2	2	1	3	3	3	1	1	2	1	2
8 : Pl	1	2	1	1	1	1	1	0	1	0	1	1	2	2	2	1	1	1	1	1	1	2	2	2	1	1	2	2	1	2	2	2	2	2	1	1	1	1
9 : Leg	1	1	1	1	1	1	3	2	0	1	1	2	2	2	2	1	1	2	2	2	1	1	1	1	0	1	1	1	1	1	2	1	1	1	1	2	0	
10 : Camb	2	1	1	1	1	1	3	1	2	0	3	3	1	2	2	1	1	3	2	1	1	2	2	1	2	1	1	2	1	2	2	3	1	1	1	0	1	
11 : Nec_i	2	2	1	2	1	3	2	1	1	2	0	3	2	3	3	2	2	3	3	2	2	2	2	3	1	1	2	2	2	3	3	3	2	2	1	1	0	1
12 : Nec_e	2	3	2	1	2	3	2	1	1	2	2	0	3	3	2	2	2	3	3	2	2	2	3	2	1	1	2	2	2	2	3	3	2	2	1	1	0	1
13 : Sginn	3	2	3	3	3	3	1	2	0	1	2	2	0	3	2	3	3	2	3	3	3	3	3	3	2	2	3	2	2	3	3	3	3	2	3	3	3	3
14 : Vis_est	3	3	3	3	3	2	1	2	0	1	2	2	3	0	3	3	3	2	3	2	2	3	3	3	3	3	3	2	3	3	3	3	2	2	2	2	3	
15 : Polit	3	2	3	3	3	2	1	2	0	1	2	2	3	3	0	3	3	2	3	2	3	3	3	3	2	2	3	2	2	3	2	2	2	3	2	2	2	3
16 : Lid&comp	3	3	3	3	3	2	0	1	1	0	2	2	3	3	3	0	3	2	3	3	2	3	3	2	2	2	1	3	2	3	2	2	2	2	2	2	2	3
17 : Def_unid	2	2	2	2	2	1	0	1	0	0	2	2	2	2	2	2	0	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	1
18 : Det_R&O	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	1	1	0	1	2	2	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
19 : Plan_p	1	2	2	1	2	1	1	2	0	1	2	2	2	2	2	1	2	2	0	2	2	2	2	2	1	1	1	2	1	2	2	2	1	1	2	2	0	1
20 : PDCA	2	2	2	1	2	1	1	1	1	1	2	2	2	2	2	2	1	2	1	0	1	1	1	2	1	1	1	1	1	1	2	2	1	2	2	2	1	1
21 : Segui	1	2	1	1	1	0	0	1	1	0	1	1	2	2	1	1	1	2	1	2	0	1	1	1	1	1	1	0	1	1	2	1	1	2	2	2	1	1
22 : Unid_gg	2	2	2	2	2	1	1	2	1	1	1	1	2	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1
23 : Asig_rec	2	2	2	1	2	2	0	1	0	0	1	1	2	2	2	2	2	1	2	2	1	2	0	2	1	1	1	2	1	2	1	2	1	1	1	1	0	1
24 : Form_C	2	2	2	1	2	2	1	1	0	1	2	2	2	2	2	2	2	1	2	2	1	2	2	0	2	1	2	2	2	2	2	2	2	1	1	1	1	1
25 : Conc	2	2	2	2	2	1	1	1	1	0	1	1	2	2	1	2	2	2	3	2	1	2	3	1	0	2	2	1	2	2	1	1	2	1	1	1	1	2
26 : Canal_C	1	1	1	1	2	2	1	1	1	1	2	2	1	2	2	2	1	1	1	1	2	1	1	2	0	1	2	2	1	1	1	2	1	1	1	1	1	1
27 : Act_int	2	2	2	1	2	1	1	1	1	0	1	1	2	1	1	1	1	1	2	1	1	1	1	1	2	0	1	1	2	2	2	2	2	1	1	1	1	2
28 : Colab	1	1	2	1	1	2	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	1	2	0	2	2	2	2	2	2	1	2	2	1	1
29 : Vig_tec_in	1	1	1	1	1	2	2	1	1	1	2	1	1	1	2	2	2	2	2	1	1	2	2	1	1	2	2	0	2	2	2	2	2	1	2	1	1	1
30 : Unid_g	2	2	2	2	2	2	1	1	1	0	1	1	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	0	2	2	2	2	2	1	2	1	1
31 : Gest_i	1	2	2	1	2	1	1	1	1	1	1	1	2	2	1	1	1	2	2	2	2	2	1	2	1	2	2	1	2	0	2	2	1	1	1	1	1	1
32 : Desarr_p	2	2	2	1	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	2	0	2	2	2	1	1	2	
33 : Exp_vinc	2	1	2	1	1	2	2	1	1	2	2	2	2	2	2	1	2	2	2	2	1	1	1	1	2	1	1	2	2	1	2	2	0	1	1	1	1	2
34 : Ind_est	2	2	1	1	2	1	0	1	0	0	1	1	2	2	2	1	2	2	2	2	1	2	2	1	1	2	2	2	2	1	2	2	1	0	2	2	2	2
35 : Ind_op	2	2	2	1	2	1	0	1	0	0	1	1	2	2	2	1	2	2	2	2	1	2	2	1	1	1	1	2	2	2	1	2	0	2	2	2	2	
36 : Ind_sop	2	2	1	1	1	1	1	1	0	0	1	1	2	2	2	1	2	2	2	2	1	2	2	1	1	2	2	2	2	1	1	2	2	0	2	2	2	
37 : Audit	2	2	1	1	1	1	0	0	0	0	1	1	1	2	2	1	2	1	1	2	1	1	1	1	1	1	1	1	2	2	2	2	1	1	2	2	0	2
38 : Rev_dir	2	2	2	2	2	2	0	1	0	0	1	1	2	2	2	1	2	2	1	2	1	2	2	2	2	1	2	2	2	1	2	1	2	2	2	2	2	0

Source: Own elaboration based on MICMAC® analysis.

4.2. Relationship between variables of the matrix

Next, map 1 Direct influence and dependence between variables is shown. The variables are projected on a Catesian plane of influence (Y axis) and dependence (X axis). Its distribution allows four categories to be identified: type (I) called autonomous variables (strongly influential, but weakly dependent on the rest of the variables), type (II) called key variables demarcated with a dashed line of color red (strong influencer and strong dependent on the rest of the variables), type (IV) called resulting variables (weak dependent and weak influential) and type (III) variables called evolution variables (strong dependent, but weak influential on the system).

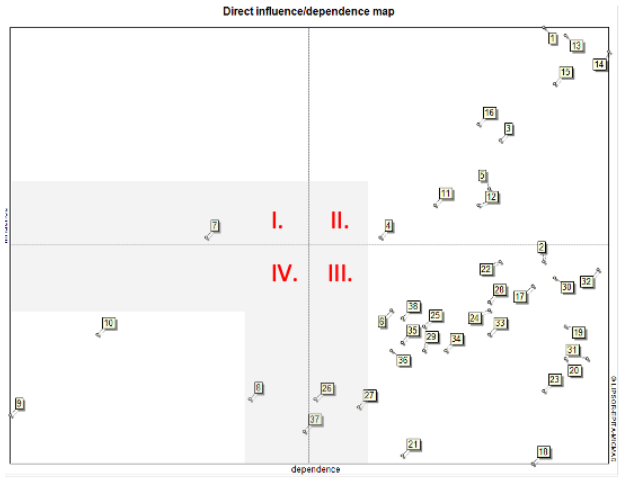
Map 1. Direct Influence-Dependence



Source: Own elaboration based on MICMAC® analysis.

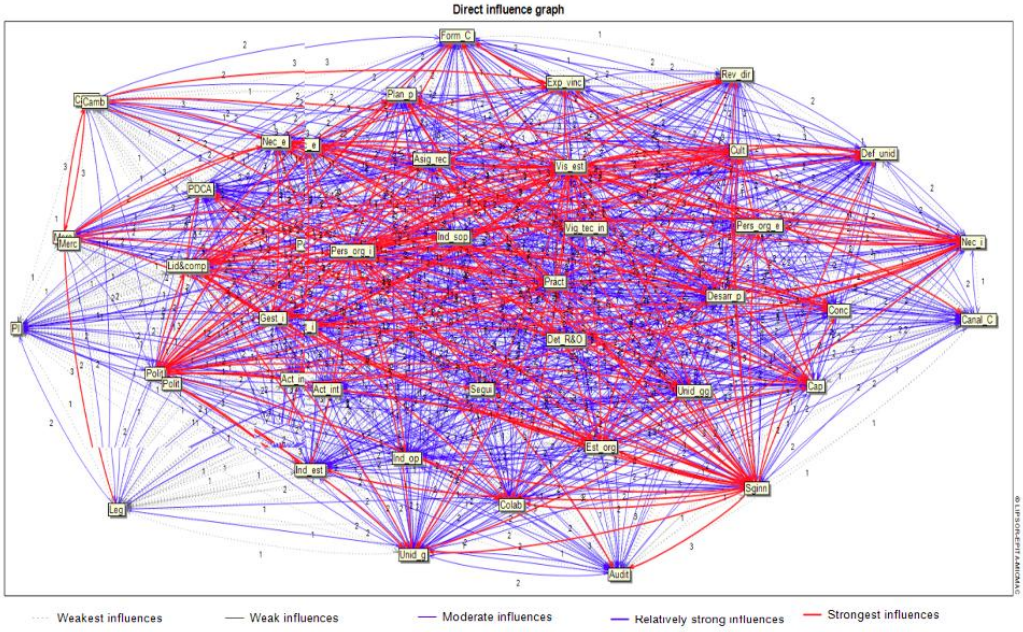
Map 2 of areas of weakly differentiated and/or neutral variables is shown in a gray figure.
Finally, graphic 1 and 2 shows the Direct Influence Relationships (DIR) and Indirect Influence Relationships (IIR), respectively, separated into relationships of weaker influences (dotted line), weak influence (black solid line), moderate influence (blue solid line), relatively strong influence (blue solid wide line) and strongest influence (wide solid red line).
Graphic 2. Indirect Influence Relationships shows (in green arrows) the interaction nodes of the key variables and the rest of the variables.

Map 2. Zone of weakly differentiated and/or neutral variables



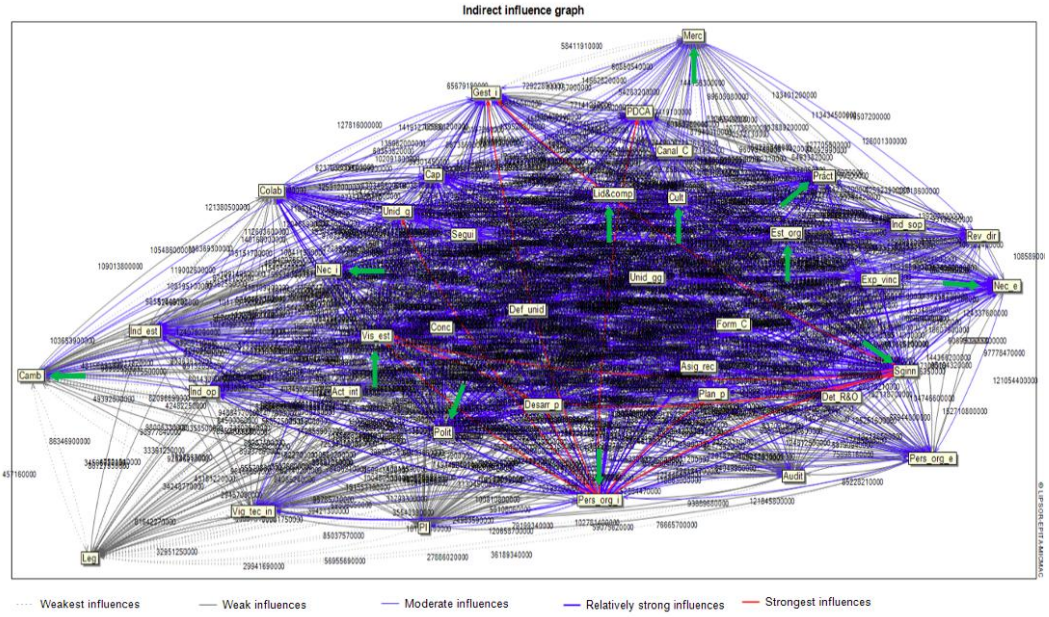
Source: Own elaboration based on MICMAC® analysis.

Graphic 1. Direct Influence Relationships (DIR)



Source: Own elaboration based on MICMAC® analysis.

Graphic 2. Indirect Influence Relationships (IIR)



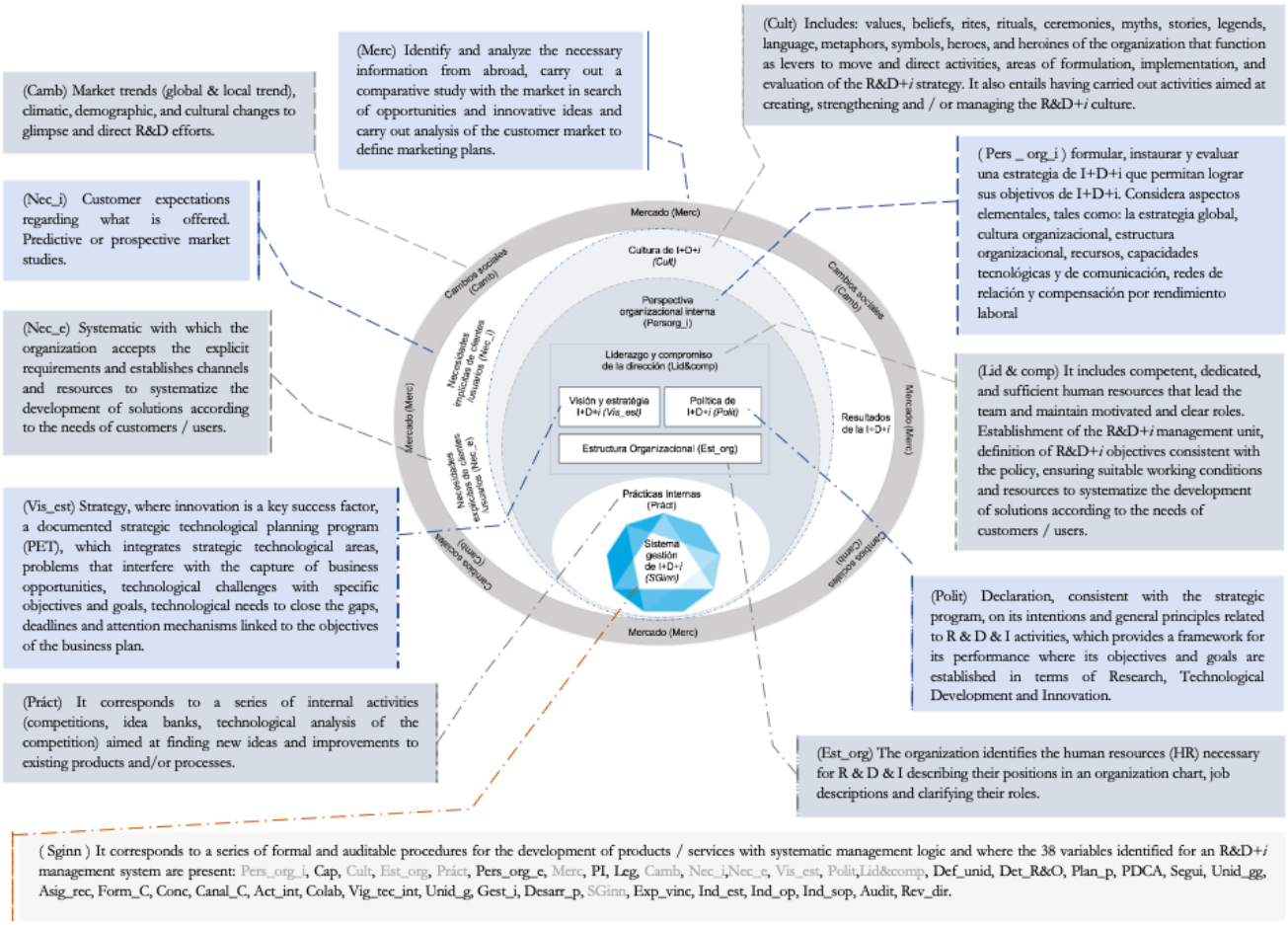
Source: Own elaboration based on MICMAC® analysis.

4.3. Design of R&D+*i* management systemfor the flavors and fragrances industry

The results of the structural analysis of the system, added to the analysis of sub-systems of the cartesian plane and strategic axis of the variables of the system (map 1 and map 2), have allowed to establish the area of motor skills and dependence of the variables that would originate an effect of evolution to the management system R&D+*i* current and on which the "resulting variables" would be implemented (quadrant III). A conceptual design of the management system is illustrated in figure 1.

To design a customized R&D+*i* management system for the flavoring and fragrances industry, a total of 12 variables (10 key variables and 2 autonomous variables) have been ordered considering the axis of the strategy, lines of strong influence of the relationship maps generated in the structural analysis and the relationship of the variables described in the bibliography.

Figure 1. Definition of parts of the R&D+*i* management system



Source: Own elaboration based on MICMAC® analysis.

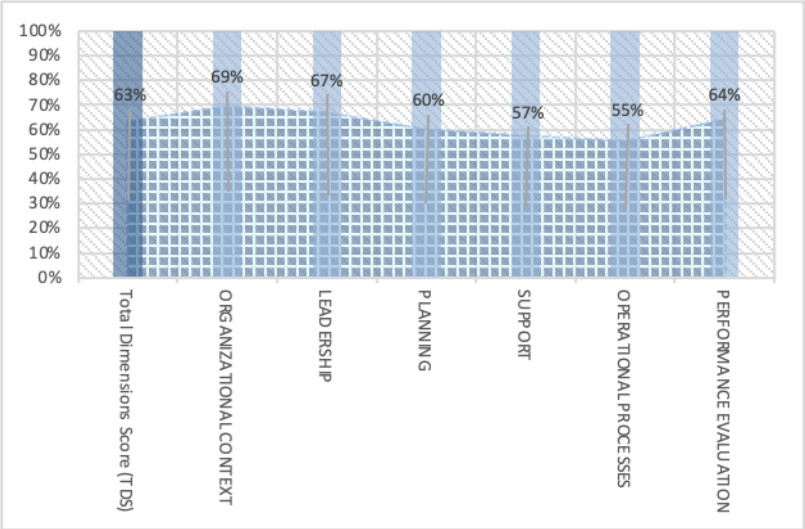
4.4. Quantification of variables: An exploratory analysis in the industry

This order allows aligning this research with standardization criteria for innovation management. The proposed system has isolated 16 primary categories, 30 secondary categories, and 8 tertiary categories that make up the causal relationships from highest to lowest, respectively. This logical and sequential structure allows diagnosing cause/effect relationships between variables (see graph 3 to 5, table 1 to 4).

The instrument described here (TMII)[44] and the design of the R&D+*i* management system have been arranged in 6 dimensions of UNE 166.002, as a homologation and reference structure: CONTEXT, LEADERSHIP, PLANNING, SUPPORT, OPERATIONAL PROCESSES AND PERFORMANCE EVALUATION [28].

The results obtained from a sample of companies in the flavors and fragrances industry of Chile are shown as the arithmetic mean of the degree of implementation of the management system, tables 2 to 5. Additionally, graphs 3 to 6, show the average global performance of the industry in the 6 pillars and primary, secondary and tertiary categories, respectively.

Graph 3. Results of the pillars of the system R&D+*i*



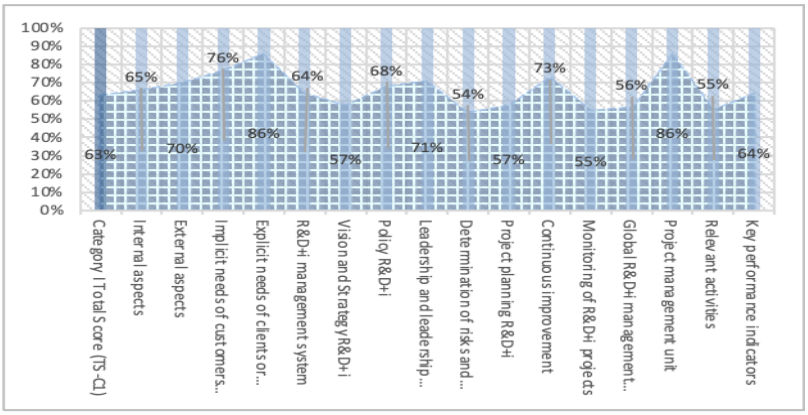
Source: Own elaboration from TMII, applied to some flavors and fragrances industries.

Table 2. Results of the pillars of the system R&D+*i*

	DIMENSION	SCORE	MAX.	% SCORE	% MAX.
	Total Dimensions Score (TDS)	523	833	63%	100%
1	ORGANIZATIONAL CONTEXT	155	224	69%	100%
2	LEADERSHIP	75	112	67%	100%
3	PLANNING	46	77	60%	100%
4	SUPPORT	116	203	57%	100%
5	OPERATIONAL PROCESSES	50	91	55%	100%
6	PERFORMANCE EVALUATION	80	126	64%	100%

Source: Own elaboration from TMII, applied to some flavors and fragrances industries.

Graph 4. Results of the primary categories of the R&D+*i* system



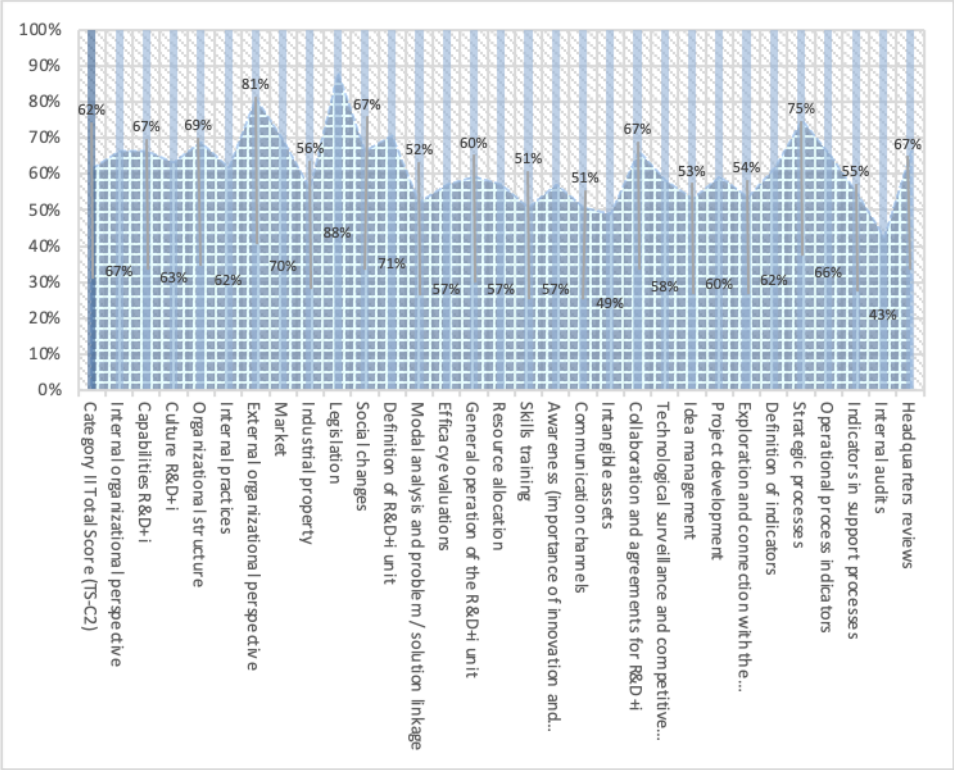
Source: Own elaboration from TMII, applied to some flavors and fragrances industries.

Table 3. Results of the primary categories of the R&D+*i* system

	PRIMARY CATEGORY	SCORE	MAX.	% SCORE	% MAX.
	Category I Total Score (TS-C1)	523	833	63%	100%
1.1.	Internal aspects	55	84	65%	100%
1.2.	External aspects	68	98	70%	100%
1.3.	Implicit needs of customers or users	11	14	76%	100%
1.4.	Explicit needs of clients or users	12	14	86%	100%
1.5.	R&D+i management system	9	14	64%	100%
2.1.	Vision and Strategy R&D+i	16	28	57%	100%
2.2.	Policy R&D+i	19	28	68%	100%
2.3.	Leadership and leadership commitment	40	56	71%	100%
3.1.	Determination of risks and opportunities	15	28	54%	100%
3.2.	Project planning R&D+i	8	14	57%	100%
3.3.	Continuous improvement	15	21	73%	100%
3.4.	Monitoring of R&D+i projects	8	14	55%	100%
4.1.	Global R&D+i management unit	110	196	56%	100%
4.2.	Project management unit	6	7	86%	100%
5.1.	Relevant activities	50	91	55%	100%
6.1.	Key performance indicators	80	126	64%	100%

Source: Own elaboration from TMII, applied to some flavors and fragrances industries.

Graph 5. Results of the secondary categories of the R&D+*i* system



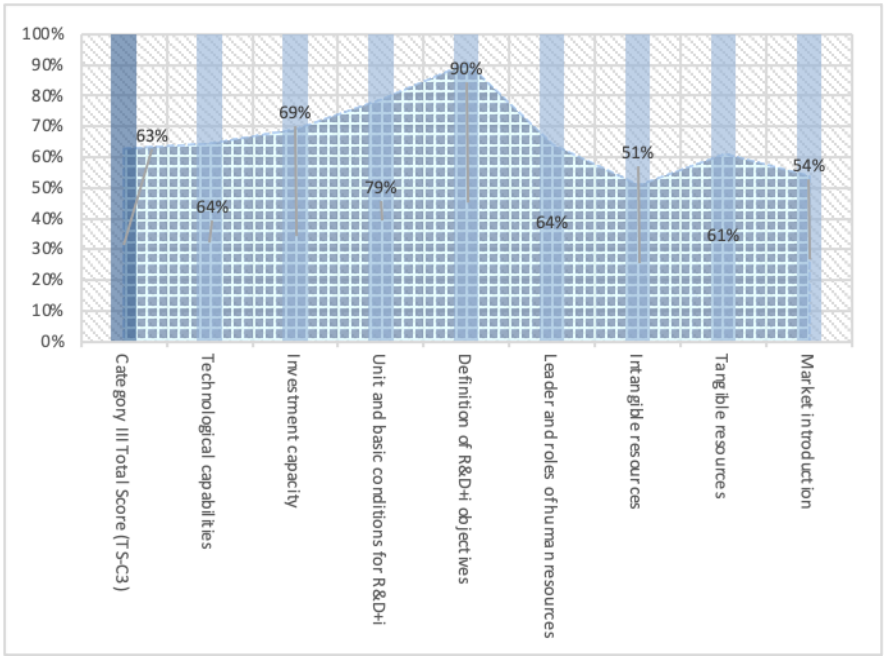
Source: Own elaboration from TMII, applied to some flavors and fragrances industries.

Table 4. Results of the secondary categories of the R&D+*i* system

	SECONDARY CATEGORY	SCORE	MAX.	% SCORE	% MAX.
	Category II Total Score (TS-C2)	419	679	62%	100%
1.1.1.	Internal organizational perspective	5	7	67%	100%
1.1.2.	Capabilities R&D+i	19	28	67%	100%
1.1.3.	Culture R&D+i	13	21	63%	100%
1.1.4.	Organizational structure	10	14	69%	100%
1.1.5.	Internal practices	9	14	62%	100%
1.2.1.	External organizational perspective	17	21	81%	100%
1.2.2.	Market	15	21	70%	100%
1.2.3.	Industrial property	20	35	56%	100%
1.2.4.	Legislation	12	14	88%	100%
1.2.5.	Social changes	5	7	67%	100%
2.3.1.	Definition of R&D+i unit	40	56	71%	100%
3.1.1.	Modal analysis and problem / solution linkage	11	21	52%	100%
3.1.2.	Efficacy evaluations	4	7	57%	100%
4.1.1.	General operation of the R&D+i unit	8	14	60%	100%
4.1.2.	Resource allocation	32	56	57%	100%
4.1.3.	Skills training	11	21	51%	100%
4.1.4.	Awareness (importance of innovation and R&D)	8	14	57%	100%
4.1.5.	Communication channels	11	21	51%	100%
4.1.6.	Intangible assets	10	21	49%	100%
4.1.7.	Collaboration and agreements for R&D+i	14	21	67%	100%
4.1.8.	Technological surveillance and competitive intelligence	16	28	58%	100%
5.1.1.	Idea management	19	35	53%	100%
5.1.2.	Project development	17	28	60%	100%
5.1.3.	Exploration and connection with the environment	15	28	54%	100%
6.1.1.	Definition of indicators	9	14	62%	100%
6.1.2.	Strategic processes	21	28	75%	100%
6.1.3.	Operational process indicators	28	42	66%	100%
6.1.4.	Indicators in support processes	8	14	55%	100%
6.1.5.	Internal audits	6	14	43%	100%
6.1.6.	Headquarters reviews	9	14	67%	100%

Source: Own elaboration from TMII, applied to some flavors and fragrances industries.

Graph 6. Results of the tertiary categories of the R&D+*i* system



Source: Own elaboration from TMII, applied to some flavors and fragrances industries.

Table 5. Results of the tertiary categories of the R&D+*i* system

	TERTIARY CATEGORY	SCORE	MAX.	% SCORE	% MAX.
	Category III Total Score (TS-C3)	105	168	63%	100%
1.1.2.1.	Technological capabilities	9	14	64%	100%
1.1.2.2.	Investment capacity	10	14	69%	100%
2.3.1.1.	Unit and basic conditions for R&D+i	11	14	79%	100%
2.3.1.2.	Definition of R&D+i objectives	6	7	90%	100%
2.3.1.3.	Leader and roles of human resources	22	35	64%	100%
4.1.2.1.	Intangible resources	11	21	51%	100%
4.1.2.2.	Tangible resources	21	35	61%	100%
5.1.3.1.	Market introduction	15	28	54%	100%

Source: Own elaboration from TMII, applied to some flavors and fragrances industries

5. Discussion

5.1. Influence matrix of the variables of the proposed system

The matrix was evaluated with 6% zero influence relationships, 37% low influence relationships, 51% medium influence relationships, 12% high influence relationships and 0% potential relationships (P1, P2, P3). The matrix was repeated 6 times and showed a good compliance rate (26.3%). The counterintuitive variables were around 10% and the stability of the matrix converged towards 100% from the second iteration, giving reliability according to the background of the MICMAC® method, in relation to a matrix of size n=30. All results were taken directly from the software ©Micmac - Analyze the structure [11].

The map 1 orders the variables according to their influence and dependence, differentiating quadrants that encompass the variables type (I) called autonomous (strong influential, but weakly dependent on the rest of the variables), type

(II) called key variables demarcated with a dashed line of color red (strong influencer and strong dependent on the rest of the variables), type (IV) called resulting variables (weak dependent and weak influential) and type (III) variables called evolution variables (strong dependent, but weak influential on the system).

The results of direct influence/dependence of the variables make it possible to determine the key variables of the system and, therefore, they should receive special attention in the flavors and fragrances industry in order to ensure an administrative and management base on which to establish the rest of the system variables (see map 1).

The influence and dependency map of the variables reveals the existence of 10 key variables of the system, of which only the variable "Implicit needs of customers/users" was noted as counterintuitive. The rest of the variables were considered reasonable for the construction of the R&D+*i* management system, in terms of their highly driving role and bibliographic relevance, as they are normally described in the R&D+*i* management systems consulted. For example, the variables: environment, strategy (internal organizational perspective), R&D+*i* policy, internal practices (generation and selection of ideas), leadership and management commitment are variables included in R&D+*i* systems consulted [24, 25, 26, 36].

The 10 key variables (high influence and high dependency) associated with quadrant II are: 1-Internal organizational perspective; 13-R&D+*i* management system; 14-R&D+i vision and strategy; 15-R&D+*i* Policy; 16-Leadership and commitment of the management; 3-Culture of R&D+*i*; 5-Internal practices; 11-Implicit needs of clients/users; 12-Explicit needs of clients/users and 4-Organizational structure.

The strategic diagonal, demarcated on map 1 with an eleptic zone, is developed from the vertex to the end of quadrant II (key variables) to open an instance for the analysis of variables whose motility and dependence generate a strategic group that allows the evolution of the system and future perspective on the variables determining the performance of the system.

The strategic diagonal constitutes a complementary reflection to the subsystems of the cartesian plane (see map 1) and is constructed as a projection of the cloud of variables on an imaginary bisector that, starting from the base, is launched towards the opposite vertex where they are located the key variables.

This projection offers a practical image to identify the variables whose driving force towards the future, and high dependency, allow us to predict an answer to the question: what are the important elements to elaborate the strategic objectives of the system? The map 2 identifies the meeting zone of weakly differentiated variables and with certain neutrality that, on occasions, can be eliminated according to Godet M. et al (2011) [11].

In order to illustrate the holistic and matrix analysis of the study, graphic 1 allows to visualize the large number of relationships and loops of direct and strong influences (red lines) between the isolated variables to form the design proposal, which originate a complex framework of links that, mentally, it is not possible to measure when the number of variables is high as in the present study.

Consistent with classical systems theories, a variable is not only influenced by the direct relationship with other variables in the system, but also by the indirect influence loops that affect its performance (graphic 1 and 2). The new classification originated through the potential multiplication of the matrix, called the Indirect Influence Matrix (IIM), results not displayed, indicates that, both the preliminary evaluation of direct relationships, and the analysis of relationships by feedback loops between variables, (usually not noticed among the variables) are aligned and coherent, since they did not vary significantly in the type, quantity and mobility of the variables between quadrants. This may suggest that the model is preferentially determined by direct relationships and only shows small variations due to feedback loops due to indirect relationships of the system variables.

Using maps of displacement of the variables between the analyzes of direct and indirect influence, it was found that the variables with the greatest tendency to displacement (from quadrants of least to greatest influence and dependence) are the following: organizational structure (Est_org), internal practices (Pract), R&D+*i* culture (Cult) and leadership and management commitment (Lid & comp). However, in none of the cases was the displacement of the variables sufficient to move the variables from one quadrant to another (map and data not shown).

5.2. R&D+*i* management system for the flavors and fragrances industry

The following is a brief description of how the system variables are integrated.

1. The variable "market" located in the sphere furthest from the context; where the organization operates, represents the ecosystem where technological and social changes occur. Market trends (global & local trend), climatic, demographic and cultural changes that give rise to a series of customer/user needs, both explicit (Nec_e) and implicit (Nec_i). As a result of this study, an interesting aspect to take into account is that the variable "Nec_i" is more important to interpret than Nec_e (see map 1).
2. Continuing, the market requirements are related to the most external sphere of the organization, the R&D+*i* culture (Cult), which governs and creates the atmosphere of the organization in which the R&D+*i* processes find leverage to move and direct market requirements towards the functional areas of formulation, development, implementation and evaluation of the R&D+*i* strategy.
3. The scheme of the proposed system shows a sphere circumscribed to the sphere of R&D+*i* culture, where the variable "Internal organizational perspective" has been set in charge of developing the first formal agreements to direct R&D+*i* efforts. This entails starting the preliminary evaluation of the organization to establish an R&D+*i* strategy.
4. The proposed system has framed, under a preliminary strategic perspective, the definition of leadership and management commitment, which, being convinced of the importance of innovation in economic performance, defines a vision and strategy for R&D+*i*.
5. In the proposed model. An R&D+*i* policy consistent with the strategy is framed within the leadership to capture the R&D+*i* objectives, in which the management units, formalized under an organizational structure with job descriptions and roles, develop practices preliminary studies linked to the generation of ideas that allow the development of projects independently of the daily development requirements. This would transform R&D efforts into value offerings; with a high degree of differentiation, inventive level, novelty and industrial application.

Regarding these variables and interaction briefly described above, the organization and industry should adopt type III variables, also called "result variables". According to the structural study of section 4.2. A favorable scenario is observed regarding the performance of the system due to the functional integration of the influence and dependence relationships of the variables.

Finally, the results of section 5.3. reveal how current management systems do not propose an implementation logic, where the key elements of a system have been first identified from a structural analysis for the evolution of the organization. This problem, just described, projects a scenario in which the key variables of a system are subject to the random implementation and almost innate formation of a structure where the considered variables become functional, at the cost of the uncertain disbursement of resources.

5.3. Degree of implementation R&D+*I* and technology management and innovation instruments (TMII)

The flavors and fragrances industry has a SWOT performance at opportunity levels (Strengths≧75%, Weaknesses<25%, Opportunities <75% to ≧50% and Threats<50% to ≧25%) for the 4 dimensions of the system (% score TDS table 2 and graph 3).

However, it is important to note that within each dimension strong performances were obtained in some categories (Table 3, 4 and 5), for example: Explicit needs of clients or users (86%), Project management unit (86%), External organizational perspective (81%), Legislation (88%) and Definition of R&D+*i* objectives (90%). The SWOT analysis of the operational processes have been included in the Opportunity category of the system, which points to a good capacity to optimize R&D+*i* management. This balance between categories makes the flavors and fragrances industry a coherent economic context, in a certain way, a balanced economic group to distribute resources, allocating technical and budgetary investment to projects with good profitability. A comparison between organizations of this economic group, in which the TMII instrument was applied, shows that the strong dimensions differ somewhat, with leadership, planning and support being the best evaluated. Benchmark activities carried out show variations in global compliance of 20 to 30%.

Category TS-C1 (table 3) describes high performance of variables 1.3; 1.4 and 4.2 variables not associated with strong dimensions. Such variables denote a certain capacity to manage innovation in projects and systematically to accommodate and translate the implicit and explicit needs of the market, also capturing opportunities to function under a cycle of continuous improvement (variable 3.3; 73%).

Category TS-C2 (table 4) broadens the strengths of the economic group studied in the variables of External organizational perspective (81%), legislation (88%), Strategic processes(75%), Definition of R&D+*i* unit (71%) and market knowledge (70%).

Finally, category TS-C3 (table 5) describes variable 2.3.1.2 and 2.3.1.1 Definition of R&D+*i* objectives (90%), Unit and basic conditions for R&D+*i* (79%), respectively, as aspects well developed by the leadership (TDS 67%, table 2).

A general appreciation of the graphs of categories TS-C1, TS-C2 and TS-C3 of the implemented system denote a good overall performance, but non-systematic development of the elements of an R&D+*i* system, which is consistent with the lack of Intangible assets (49%), Skills training (51%), Determination of risks and opportunities(54%), Market introduction (54%), Monitoring of R&D+i projects (55%), visionand definition of a R&D+*i* strategy (57%) of global compliance places this industry in a risky profile to meet the demands of a changing and technology-driven economy[1,2,3, 7,48, 49, 50].

Synthesizing, and after analyzing the performance of each dimension, it is possible to deduce an effect-cause relationship from the performance of the system at the most specific levels of the system (TS-C3). The variables 4.1.2.1. Intangible resources and 5.1.3.1. Introduction to the market would be causing dysfunctionality of the sections Intangible assets, Communication channels and Skills training, 4.1.6; 4.1.5 and 4.1.3 respectively, which would be having a negative impact on the management of ideas and exploration and connection with the environment. This ability to interact and manage ideas would be causing a poor performance of the global R&D+*i* management unit (4.1), Relevant activities (5.1.) and, consequently, in dimensions 4. SUPPORT and 5. OPERATIONAL PROCESSES.

Without detriment to the profile obtained in the flavors and fragrances industry. The evaluated organizations show that the degree of development of the variables, be it low or high, only indicates a certain development that is not necessarily useful, since some of the organizations have more than a century in the international market. These observations open the possibility that R&D and its use to generate innovative value offers could do without some elements of a management system as it is known.

6. Conclusions

The bibliographic antecedents reinforce the positive relationship between innovation, economic performance and high levels of well-being, which is why innovation has received special attention in the development of strategies worldwide.

The flavors and fragrances industry in Chile is made up of 8 technology-based organizations that make intensive use of R&D to achieve innovations and their profitability outside the traditional framework. However, these industries lack formal R&D+*i* management systems that allow them to prioritize the key elements for generating value offers.

This study has carried out an unprecedented analysis of the cause-effect relationship between the key variables of an R&D+*i* system, identifying 38 variables, which have been quantified through the TMII, quantifying each variable and the degree of general development of R&D+*i* in some industries associated with the flavors and fragrance industry in Chile. Some of these variables show a moderate and low performance of some factors, even in companies with a global presence with more than a century in the market, which raises the possibility that not all elements of an R&D+*i* system are functional in an organization and even so, it is possible to maintain the R&D+*i* cycles. Some justifications that support these observations can be given by the multiple factors on which an organization depends, which must be evaluated quantitatively and progressively integrated based on an internal reflection of the direct and indirect relationships that the variables maintain, fundamentally, and of experts from the R&D+*i* area.

The R&D+*i* system of the flavors and fragrances industry proposes a deep and initial reflection of its performance, and not only as a study of gaps, but also as a structural analysis that has unraveled the important factors of its performance in I&D+*i* (10 key variables + 02 variables associated with the strategic axis), in addition to a tangible description of the direct and indirect relationships between the variables (graphic 1).

The key variables identified are the following: 1-Internal organizational perspective, 13-R&D+*i* management system, 14-R&D+*i* vision and strategy, 15-R&D+*i* policy, 16-Leadership and management commitment, 3-R&D+*i* culture, 5-Internal practices, 11-Implicit needs of clients/users. 12-Explicit needs of clients/users, 4-Organizational structure, 7-Market and 10-Social changes, these two variables assigned thanks to the strategic axis (see Map 1. Direct Influence-Dependence).

The proposed system would allow obtaining new results from the complete system, thanks to the high influence and dependence between the variables, aiming to mitigate the gaps in the system and optimize R&D+*i* management. Such effects of the system, on the results of the industry, have been validated with good results, both by the reliability of the results of the bibliographic antecedents (93%), and by the expert appointed to evaluate the management system. The R&D+*i* leader of the industry rated the system in the 4th quartile 75% to 100%, through a parameterized qualitative instrument whose descriptor was defined as follows:

> "The proposed system can be considered validated, because it has an R&D+*i* strategy with several key dimensions of an R&D+*i* system. Also, there is good coherence between the external and internal aspects of a formal R&D+*i* management system, and that the organization is also capable of addressing given its reality. Also, the system shows coherence with the team's reflections regarding the elements that would make the current system an optimal ecosystem for managing R&D+*i* ".

The proposed innovation management system represents a preliminary reference for its implementation in the industry, which will be supported during the year 2021-2022 by the creation of a free web platform with the TMII for the quantification, generation of preliminary guidelines and self-diagnosis of companies from various sectors. The TMII designed for a global scope of R&D+*i* management allows feedback from the system without the need to resort to an expert advisor. The aim of this tool is to allow a free and equalized evolution to the frequency of market development thanks to a database that is planned to be drawn up to outline management systems by industrial sectors and specific subsectors of the market.

Finally, some limitations of the study:
- The key variables identified could vary from one country to another and from one period to another. Therefore, updating this structural analysis is a requirement to maintain the validity of the proposed system in the medium and long term.
- The proposed system does not integrate assessment mechanisms to consider changes in the context that allow integrating new scenarios such as: social conflicts, economic crises and pandemics that affect nations.
- The flavors and fragrances industry in Chile must find more open mechanisms for applied research in technological management that allow increasing the degree of analysis of the functional management structures in the sector.

7. List of abbreviations

R&D+*i*: research, development and innovation.
MICMAC®: Matrix Impact Cross-Reference Multiplication Applied to a Classification.
TMII: technology management and innovation instruments.
DIM: Direct Influence Matrix.
DIR: direct influence relationships.
IIM: Indirect Influence Matrix.
IIR: Indirect Influence Relationships.
DID: Direct Influence-Dependence.
TS: Total Score.
TDS: Total Dimensions Score.
SWOT: Strengths, Weaknesses, Opportunities and Threats.

8. Declarations

8.1. Competing interests

The authors declare that there are no conflicts of interest with respect to the research, authorship and / or publication of this article. Also, it should be noted that the results are not related in any way to a particular industry, but rather to an exploratory perspective of the Chilean flavors and fragrances industry. The data and results presented were obtained thanks to the information provided by some members of the ACHISAF union. The data provided is protected by confidentiality agreements.

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8.3. Availability of data and materials

The complete analysis reports of the MICMAC method are available, as well as the instrument (TMII) and the results completed by the companies that participated. Original data is protected by confidentiality but can be managed for its safe distribution under encryption protocols from primary sources.

8.4. Author's contributions

The authors have elaborated the present investigation, sharing equally the author's rights, under the investigation protocols defined by the Technological Faculty of the University of Santiago de Chile and have participated in the validation and application processes of the instrument (TMII) in equal degree of involvement. The writing and synthesis of the study, for publication purposes, have been carried out by the authors.

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