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CODAS HFLTS Method to Appraise Organizational Culture of Innovation and Complex Technological Changes Environments

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Abstract: Sustainable development implies establishing principles, objectives and strategies within organizations that impact the organizational culture in innovation. However, a method needs to be defined in order to know the critical factors that allow the strengthening of the organizational culture in innovation with emphasis on Industry 4.0 and sustainable development in a highly changing environment for a specific organization. In this sense, the paper identifies the set of factors that are documented through reviews and analysis of the literature, subsequently proposes a Multi-Criteria Decision Making (MCDM) methodology using hesitant fuzzy linguistic term sets (HFLTS) and combinative distance-based assessment (CODAS), where factors are evaluated to obtain a score and hierarchy value. Weight values were calculated using the ambiguity reduction method, which incorporates the knowledge acquired by researchers in organizational culture of innovation and expert judgment under the Saaty scale used in analytic hierarchy process (AHP). Finally, a model of organizational culture in innovation is proposed that can be used by organizations to focus strategies on the factors of greater hierarchy and thereby optimize their resources considering the sustainable development and the Industry 4.0 approach.

Keywords: Organizational culture; innovation; sustainable development; Industry 4.0; MCDM; CODAS; HFLTS.

1. Introduction

The fourth industrial revolution, known as Industry 4.0, beginning around 2011, stands out for highly complex technological changes with short life spans. The three revolutions that precede it have historically been defined by: (a) the steam engine, the first industrial revolution, from 1784 to 1870, (b) electricity, second revolution, from 1870 to 1969, and (c) mass production, third industrial revolution, from 1969 to 2011 [1].

The technological advances generated by Industry 4.0 have created an ever-changing environment that has pushed for the establishment of programs whose purpose is to give incentives and create innovations within themselves. In this sense, a great variety of factors and aspects exist such as attitudes, values, knowledge and processes that stand out during the innovation management. Many of these changes have been driven by the development of the Internet of things, big data, cyber physical systems, artificial intelligence, virtual reality, robotization, cyber security etc. [2–4].

In correlation to this, the organizational culture tailored to innovation in Industry 4.0 is a key element and implies a paradigm shift in the way the processes and activities have been administrated in the organizations; this allows to identify the different venues to performing certain tasks, thus, conventional methods become obsolete. This in turn allows for process simulation [5], realizing more precise and accurate prediction analysis and obtaining a greater wealth of information about the population through social media in order to create more personalized products [6], which in turn makes it necessary to establish strategies to maintain both leadership and competitiveness within the organizations.

In addition, technologies, techniques and methods involve changes throughout the organization and relationships between companies that support it [1]. Among the new challenges of the implementation of the tools, techniques, methods, processes of Industry 4.0 are the creation of value from the point of view of corporate social responsibility [2,3,7]. The sustainability of the Industry 4.0 under an economic approach implies an improvement in productivity and product quality, in the environmental aspect with the application of energy consumption controls and finally in the social aspect by reducing workloads [4,7].

The impact of Industry 4.0 on sustainable development is evident in the reduction of production cycles, the design of products to improve natural ecosystems [3,8] and in the reduction of waste by the efficient use of resources, as in the case of increase the measurement precision of processes to reduce the use of materials, allowing them to be recycled and reused, generating a positive impact on environmental sustainability [7] and with the implementation of process simulation tools such as artificial intelligence [9].

However, the characteristics of the organizations influence the opportunities and challenges for the implementation of Industry 4.0 and the organizations have the problem of how to encourage the strengthening of the organizational culture of innovation in the Industry 4.0 and sustainable development, from an administrative point of view, in specific about critical factors identification aligned to the objectives of the organization [3,4,7].

For this reason, the factors identification is relevant, a task that several researchers have focused on. However, there is a gap regarding the lack of a method to identify the critical dimensional factors for a specific organization. Being the contribution of this paper, presenting a methodology that allows organizations to identify the critical factors presented in a revised literary compendium, with the next research aims to: (a) propose a Multi-Criteria Decision Making (MCDM) methodology to obtain the highest ranking factors identified in a literature review that incorporates the combinative distance-based assessment (CODAS) and hesitant fuzzy linguistic term sets (HFLTS) analysis; (b) propose a weighting calculation alternative that incorporates the acquired knowledge in the research found in the literature review and experts judgment used in AHP, called Ambiguity Reduction Weight; (c) present a visual model that shows the hierarchical factors, as well as their corresponding scoring values, that can be used to establish concrete strategies for each factor. The following research questions are addressed:

- How can the MCDM tool be used to identify the relevant factors?
- How is it possible to use an equation to calculate the weighting values for each criterion incorporating the acquired knowledge and the expert judgment evaluation?
- Can the results obtained be considered reliable and aligned to other ways to calculate weighting values?

In this manner, the CODAS HFLTS and the criteria weight methodology proposed in this research will be evaluated under the hypothesis: (a) The Ambiguity Reduction Weight, based on acquired knowledge and AHP, provides Cronbach's alpha coefficient equal or greater than 0.900; (b) the scoring values obtained, using CODAS and HFLTS under different weight calculation methods, provides Pearson correlation coefficient values equal or greater than 0.800, allowing to verify that the methodology can be used to determine critical factors by different organizations and researchers in the context of problems they are dealing with and taking into account the environment uncertainties towards the criterions under evaluation.

2. Literature Review

2.1. Definition of Organizational Culture

The organizational culture is defined by [10] as the set of values, principles and beliefs that distinguish an organization, as well as the set of procedures and management behaviors that serve as examples and reinforcements for these basic principles, these principles being the deep truths which express fundamental values.

2.2. Organizational Culture in Innovation and Sustainable Development

Currently, business sustainability is becoming a pre-requisite for competitiveness. For this, organizations have to adapt to a more sustainable oriented environment by using sustainable process and technology; implying the integration of sustainability thinking into the entire organization, in relation with the innovation dimensions. This integration implies aligning the organizational culture with sustainable development principles and the objectives [11].

It is an active strategic asset of noted potential in all organizations [12]; the base factor for innovation management [13]; the importance to reinforce the behavior related to management related actions in communicating the importance of innovation [14], a necessary element for the adaptation and performance of innovation in companies [15], as well as a factor that stimulates or restricts innovation in the companies [16,17]. Although there are opinions related with a negative impact, the organizations must generate an environment to innovation encourage considering the highly changing context derived from Industry 4.0 [18]. Figure 1 presents the classification of factors that encompass the individual elements identified in the literature review, as well as the dimensional criteria. The organizational culture factors in innovation were defined based on the group of elements identified in the literature review emphasizing the management that promote innovation in the different dimensions proposed by the OECD [19].

Figure 1. Factors classification and innovation dimensions.

2.2.1. Knowledge Management

Knowledge management is of vital importance in the context of sustainable development and Industry 4.0 given the complexity of the production processes and new businesses [20]; additionally, his strategies and practices have a positive impact on innovation [21]. The new environment implies taking advantage of the tacit and explicit knowledge generated from different internal and external sources, to apply them in an interconnected and digitized production environment in the generation of the integrated value chain [22], in addition to the knowledge for waste reduction and resources optimization in manufacturing processes to increase the competitive level (efficiency) of the organization [8,9]. Knowledge management is a dynamic process that shifts with the usage of new technologies such as the interaction of automated prototypes, additive manufacturing, simulation processes and information management [20]. Interaction with information to generate more knowledge about consumer needs, which in turn contributes to an increase in learning to operate in a digital environment, requiring skills related to industrial communication, big data, analytics, interface design, robot maintenance and three-dimensional (3D) design, all linked to Industry 4.0 [22,23] and environmental skills and expertise [24]. The factors identified within the context of knowledge management are listed in Table 1.

Table 1. Knowledge management items.

Code	Knowledge Management Items
KM01	Use external sources innovation-contest [25].
KM02	Adoption of information management in the cloud [22].
KM03	Continuous learning [16,22].
KM04	Exploratory learning [20,26].
KM05	Exploitative learning [20,26].
KM06	Search for innovation in universities [14].
KM07	Employees absorption capacity to generate knowledge [27,28].
KM08	Context of innovation-sources of innovation [14].
KM09	Value creation [29–32].
KM10	Creativity, initiative [16].
KM11	Generation of patents [33].
KM12	Knowledge skills encoded in technology [19].
KM13	Value capture [31,34,35].

2.2.2. Financial Management

Financial management is a key aspect of innovation, as part of strategic planning, planning and control. According to [36] companies must allocate adequate and sufficient resources for technological infrastructure, establish personnel management and production, an understanding of the benefits of digitalization. Among other important aspects of financial management include the transfer of technologies [37], the development of new technology and investment in contributions to sustainable development [38] in research and development for incremental or radical innovation; the acquisition of complementary assets, as well as aspects related to staff incentives and rewards [39], require forecasts and budgets and relevant information for decision-making [39,40]. Table 2 shows the factors identified for financial management.

Table 2. Financing management items.

Code	Financing Management Items
FM01	Financing activities for technology transfer [19,37,40].
FM02	Financial aspects [19,33–35,40,41].
FM03	Financing activities for innovation [14].

2.2.3. Organizational Management

Organizational management is an essential part for the generation of innovation and technology. Among the relevant aspects related to innovation are the structure, incentive systems, values and performance, in terms of technological aspects, there are competencies, decision-making and communication skills. Organizational innovation favors the development of technological innovation capabilities [42,43] allows to create, deliver and capture value [42], as well as to establish an awareness with focus on the environment and sustainable development [38] and the considerations to the total quality environmental strategies [44].

Organizational management implies a system of values and beliefs, interactions and relationships within the organization [10], focused on stakeholders aims to obtain financial performance and reputation results through an appropriate organizational culture [45], considering management procedures and behaviors as tools to strengthen it. An efficient organizational management system allows communicating the importance and reinforces a behavior for innovation [14] and focuses on the environment [9,46], which is a reflection of the development that the organization can have in intangible aspects since it favors the development of technological innovation and process capabilities, which can lead to a superior performance of the company [42], The factors identified within the context of organizational management are listed in Table 3.

Table 3. Organizational management items.

Code	Organizational Management Items
OM01	Structure of the high technology industry [19].
OM02	Structure for innovation [19].
OM03	Appreciation, reward system, incentives [39].
OM04	Search for innovation-clients [47].
OM05	Eco-innovation search-suppliers [25].
OM06	Search for innovation-competitors [25].
OM07	External capacities (relations and negotiation) [39].
OM08	Capabilities for decision making generated from data [23,36,48].
OM09	Capacities-content [23,48].
OM10	Training [29,35].
OM11	Competence and professionalism [39].
OM12	Commitment to innovation [19].
OM13	External communication-interaction other media virtual connections [16,17].
OM14	Internal communication [39,49–54].
OM15	Communication [35].
OM16	Trust suppliers, to keep them [39].
OM17	Cooperation between functions [39,51,55–58].
OM18	Development of human talent [39,49,54,59].
OM19	Market focus [25,60].
OM20	Entrepreneurial spirit [16].
OM21	Establishment of innovation/eco-innovations policies [19].
OM22	Innovation strategy generation of spin off [35].
OM23	Structure of the low technology industry [31].
OM24	Structure of the media technology industry [31].
OM25	Success-orientation to achievement [39,55,61–66].
OM26	Ways to access the markets [39].
OM27	Innovation management [27].
OM28	Identification of tacit needs online customers [48].
OM29	Interaction with suppliers-value chain [67].
OM30	Interaction with customers-value chain [31].
OM31	Involvement [10,68].
OM32	Loyalty [39].
OM33	Freedom autonomy [16,69].
OM34	Level of education of the personnel [19].
OM35	Strategic orientation towards the client [16].
OM36	Participation of the workers [16].
OM37	Responsibility [39,50,51,64].
OM38	Sufficiency of resources [16].
OM39	Decision making [31].
OM40	Risk aversion to new projects, acquisition and development of new technology [39]
OM41	Risk taking [16,39,51,65,70,71].
OM42	Teamwork [16,39,51–58].
OM43	Linking private research and development agencies [72,73]
OM44	Linking public research and development agencies [69]
OM45	Links between universities [74]
OM46	The coalignment between TQM and research and development [75,76].

2.2.4. Process Management

The processes have had a radical change in the last decade; the use of augmented reality, artificial intelligence, big data and the internet of things [23], have generated more complex processes [77]. This, in turn, implies the need for personnel with digital skills and talent and digital experience

[78] that allows them to innovate in smart manufacturing processes [79], generate value for their products or services, reduce waste and improve efficiency. They need to be trained in sustainable engineering methods [8] and clean production [38]. Table 4 shows the items identified within process management.

Table 4. Process management items.

Code	Processes Management Items
PM01	Adaptability flexibility for new sustainable processes [39].
PM02	Capacities-automation [80].
PM03	Capacities-connectivity [80].
PM04	Technological capabilities for process automation [67,81,82].
PM05	Technological capabilities use of the cloud [81,83].
PM06	Technological capabilities data mining [22].
PM07	Programing and software development [22].
PM08	Digital marketing and design [22].
PM09	Human digital physical interaction [81].
PM10	Artificial intelligence [22].
PM11	Machine learning [22].
PM12	Process of exploration of innovation [84].
PM13	Generation of innovation [35].
PM14	Innovate in sustainable processes, products, business [31,33].
PM15	Robotics [22].
PM16	Process of exploitation of innovation [32].

2.2.5. Intellectual Property Management

Intellectual property management is the generation of patents, the use of licenses and the registration of trademarks that provides organizations with a competitive advantage [33] for the commercialization of their products or services [32]. Protecting the intellectual property is part of both radical and incremental innovation processes, given the constant evolution of technology, provides legal protection to safeguard the technological, knowledge and identity developments of organizations. Table 5 shows the items identified within intellectual property management.

Table 5. Intellectual property management items.

Code	Intellectual Property Management Items
IPM01	Acquisition of patents [35].
IPM02	Copyright [33].
IPM03	Innovation strategy-sale of intellectual property rights [33].
IPM04	Management of intellectual property [27,33].
IPM05	Licensing [32,33].
IPM06	Trademarks [32,33].

2.2.6. Technology Management

The productive processes in the context of Industry 4.0 are modified throughout the industrial phase of value creation through the digital interconnection of people, machines and objects, which offers numerous possibilities to increase production efficiency [3,4,22], as well as the costs reduction, optimization of energy consumption and product life cycle management improvement [14,85]. These processes are complex given the constant evolution of technology. The management of technology that can be incremental or radical requires skills and capabilities for research and development from the organizational and human component, so that organizations can visualize the importance of using their own or external laboratories, to constantly monitor the technologies cycle to be proactive in the changes of the technologies and conducting eco-design on product [24]. Production processes are modified throughout the industrial phase of value creation through the digital interconnection of people, machines and objects, which offers numerous possibilities to positively impact production efficiency [7]. Table 6 presents the factors identified within the technology management.

Table 6. Technology management items.

Code	Technology Management Items
TM01	Acquisition of complementary assets [25,37].
TM02	Ambidexterity (move to radical innovation or disruptive innovation) [84].
TM03	Internal research and development capabilities [31,82].
TM04	Information technology architecture capabilities [80].
TM05	External research and development capabilities [31].
TM06	Technological capabilities [37,80].
TM07	Capacities-information technology [37,80].
TM08	Focus on incremental innovation [29].
TM09	Flexibility to the production of new methodologies [16,29].
TM10	Open innovation [74].
TM11	Closed innovation [74].
TM12	External laboratories [86].
TM13	Internal laboratories [73].
TM14	Surveillance of innovation-life cycles of technology [84].
TM15	Use external sources innovation-open source software [25,26].

2.3. *Definition of Multi-Criteria Decision Making (MCDM) Problem*

From a theoretical viewpoint, MCDM is a powerful component of operations research that encompasses some analytical tools and techniques to appraise the strengths and weaknesses of a set of m competing alternatives $A = \{a_1, a_2, \dots, a_m\}$ evaluated on a family of n criteria of different nature $C = \{c_1, c_2, \dots, c_n\}$, with the objective of making an accurate decision regarding the preference judgment of the decision-maker. An MCDM problem can be generally represented by a decision matrix as that shown in Table 7 [87].

Table 7. Multi-criteria matrix structure.

	Dimensional Criterions				
A_i/C_j	c_1	c_2	c_3	$\cdots$	c_n
A_1	a_{11}	a_{12}	a_{13}	$\cdots$	a_{1n}
A_2	a_{21}	a_{22}	a_{23}	$\cdots$	a_{2n}
A_3	a_{31}	a_{32}	a_{33}	$\cdots$	a_{3n}
$\vdots$	$\vdots$	$\vdots$	$\vdots$		$\vdots$
A_m	a_{m1}	a_{11}	a_{11}	$\cdots$	a_{mn}

From the reviewed literature, MCDM can be applied to solve several problems, such as credit granting decision problem [87], a sustainability performance measure of a Brazilian oil and gas company [88], a supplier selection analysis [89] and a personnel selection process [90].

2.3.1. Analytic Hierarchy Process (AHP)

The AHP methodology, a tool for multicriteria decision making used to solve quantitative and qualitative problems, allows for complex hierarchy decisions. The main axioms considered are [91]:

Axiom 1. Reciprocal judgments, where if A is a matrix of paired comparisons, $a_{ij} = 1/a_{ij}$.

Axiom 2. Condition of homogeneity of the elements; the elements are compared in the same order of magnitude.

Axiom 3. Condition of hierarchical structure or reuse dependent.

Axiom 4. Condition of rank order expectations, which are structured in alternatives and criteria.

The steps for hierarchical analysis are: (a) define decision criteria, considering the structure at different levels; (b) evaluation of the different criteria, sub-criteria and alternatives according to their importance at each level. These quantitative or qualitative criteria are compared using informal judgments to obtain the respective weights and priorities. The rating scale is based on Saaty's linguistic terms [91].

Table 8. Linguistic terms.

Linguistic Terms	Code	Value
Excellent	L8	8
Very strong	L7	7
Strong	L6	6
Fine	L5	5
Middle good	L4	4
Unbiased	L3	3
Medium insignificant	L2	2
Insignificant	L1	1
Null	L0	0

2.3.2. Combinative Distance-based Assessment (CODAS)

Multicriteria methods are useful and reliable for solving problems with multiple uncertain criteria and inaccurate situations. The CODAS method is used in multiple disciplines and fields, for decision making where there is not too much information and knowledge [92]. This method uses the Euclidean distance as the main distance and the Taxicab distance as a secondary measure, which are calculated according to the negative ideal distance. The alternative with the greatest distance is the most desirable outcome [93].

The CODAS method, presented by Ghorabaee [93], where the original terms have been modified, is described below:

Step 1. Construction of the decision matrix as shown below.

$$L = [L_{ij}]_{n\times m} = \begin{bmatrix} L_{11} & L_{12} & \cdots & L_{1m} \\ L_{21} & L_{22} & \cdots & L_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ L_{n1} & L_{n2} & \cdots & L_{nm} \end{bmatrix} \quad (1)$$

where L_{ij}, shows the value of the i alternative in the criterion j, $i \in \{1,2,\ldots,n\}$ and $j \in \{1,2,\ldots,m\}$.

Step 2. Calculate the normalized decision matrix.

$$n_{ij} = \begin{cases} \frac{L_{ij}}{\max_i L_{ij}} & if\ j \in N_b \\ \frac{\min_i L_{ij}}{L_{ij}} & if\ j \in N_c \end{cases} \quad (2)$$

where N_b y N_c are a set of significant dimensional criteria.

Step 3. Calculate the normalized weight in the decision matrix with the following formula:

$$r_{ij} = w_j n_{ij} \quad (3)$$

where w_j is the weight value of the criterion j, with $0 < w_j < 1$ and $\sum_{j=1}^{m} w_j = 1$.

Step 4. Determining the ideal negative solution:

$$ns = \lceil ns_j \rceil_{1xm} \quad (4)$$

$$ns_j = \min_i r_{ij} \quad (5)$$

Step 5. Calculate the Euclidean distance (E_i) and Taxicab distance (T_i) of the negative idea solution alternatives:

$$E_i = \sqrt{\sum_{j=1}^{m} (n_{ij} - ns_j)^2} \quad (6)$$

$$T_i = \sum_{j=1}^{m} |n_{ij} - ns_j| \quad (7)$$

Step 6. Preparation of the relative evaluation matrix:

$$R_a = \lceil h_{ik} \rceil_{nxn} \quad (8)$$

$$h_{ik} = (E_i - E_k) + (\varphi(E_i - E_k) \times (T_i - T_k)) \quad (9)$$

where $i\epsilon\{1,2,\dots,n\}$ and τ shows a threshold function to recognize the equality of the distances of the two alternatives defined by:

$$\tau(x) = \begin{cases} 1 & if\ |x| \geq r \\ 0 & if\ |x| < r \end{cases} \quad (10)$$

The value of r can be set by the decision maker, with a parameter range between 0.01 and 0.05. The Taxicab distance calculation formula can be used to compare the difference between distances. For the purposes of the present study $r = 0.03$.

Step 7. Determination of the evaluation of the score of each alternative:

$$L_i = \sum_{k=1}^{n} l_{ik} \quad (11)$$

Step 8. Classify the alternatives according to the decreasing values of the evaluation score (L_i). The alternative with the highest value of L_i is the best choice among the alternatives.

2.3.3. Hesitant Fuzzy Linguistic Term Sets (HFLTS)

The concept of HFLTS serves as a basis to increase the flexibility of obtaining linguistic information through linguistic expressions. This allows different expressions to be used to represent the knowledge and/or preferences of the decision maker.

If an expert can consider several values to define a membership function in the qualitative context, experts can doubt between values to determine a linguistic variable; the HFLTS method meets the needs and requirements when there are doubts in the assignment of values [94]. Below are the basic terms and operations necessary for its application.

Definition 1. Let L be a linguistic term set, $L = \{L_0, \dots L_g\}$; an HFLTS, H_L, is an ordered finite subset of the consecutive linguistic term of L. When $H_L(\tau) = \{\}$ the HFLTS is called an empty set; in the case of $H_L(\tau) = L$ the set is denominated a full HFLTS, and when $H_L(\tau) = \{\gamma: \gamma \subseteq \tau\}$, γ is a subset of L.

Definition 2. Let L be a linguistic term set, $L = \{L_0, \dots L_g\}$, and H_L, H_L^1 and H_L^2 be the three HFLTS. The H_{L+} (upper bound) and H_{L-} (lower bound) are defined as:

$$H_{L+} = \max(l_i) = l_j, l_i \in H_L \text{ and } l_i \leq l_j \forall i \quad (12)$$

$$H_{L-} = \min(l_i) = l_j, l_i \in H_L \text{ and } l_i \geq l_j \forall i \quad (13)$$

Definition 3. The complement of an HFTLS, H_L, is defined as:

$$H_L^c = L - H_L = \{l_i: l_i \in L \text{ } and \text{ } l_i \notin H_L\} \quad (14)$$

In addition, the evolutive complement of H_L is $(H_L^c)^c = H_L$, due $H_L^c = L - H_L$ then $(H_L^c)^c = L - H_L^c = L - (L - H_L) = H_L$.

Definition 4. The union between H_L^1 and H_L^2 is defined as:

$$H_L^1 \cup H_L^2 = \{l_i: l_i \in H_L^1 \text{ } or \text{ } l_i \in H_L^2\} \quad (15)$$

In other words, the union of two HFTLS is the set of elements included in both (H_L^1 and H_L^2).

Definition 5. The intersection between H_L^1 and H_L^2 is defined as:

$$H_L^1 \cap H_L^2 = \{l_i: l_i \in H_L^1 \text{ } or \text{ } l_i \in H_L^2\} \quad (16)$$

In other words, the intersection of two HFTLS is the set that contains the elements included in H_L^1 and also included in H_L^2.

Definition 6. The linguistic interval with upper bound and lower bound limits obtained from maximum and minimum linguistic term are called envelope of HFTLS, $Env(H_L)$, and is defined as:

$$Env(H_L) = [H_{L+}, H_{L-}] \quad (17)$$

Definition 7. The comparison between H_L^1 and H_L^2 is defined as:

$$H_L^1(\tau) > H_L^2(\tau)\ if\ Env(H_L^1(\tau)) > Env(H_L^2(\tau)) \quad (18)$$

$$H_L^1(\tau) = H_L^2(\tau)\ if\ Env(H_L^1(\tau)) = Env(H_L^2(\tau)) \quad (19)$$

3. Methodology and analysis

3.1. Aggregated Matrix and Ideal Negative Vector

Figure 2 presents the flow chart used in order to rank the factors and thereby identify the ones that most influence to foster an organizational culture in innovation with emphasis on Industry 4.0, including the assignment of linguistic terms (HFLTS), the steps of the CODAS methodology, where they use the weights obtained by AHP, acquired knowledge and ambiguity reduction.

Using three experts, the factors obtained from the literature review (Table 1–6) were evaluated using the linguistic terms set out in Table 8. Table 9 displays the aggregate matrix under the maximum value criteria (12, 13, 17), where the resulting ideal negative vector is R&D = L2, P = L1, Q = L1, M = L1, O = L1 and F = L1 (4, 5).

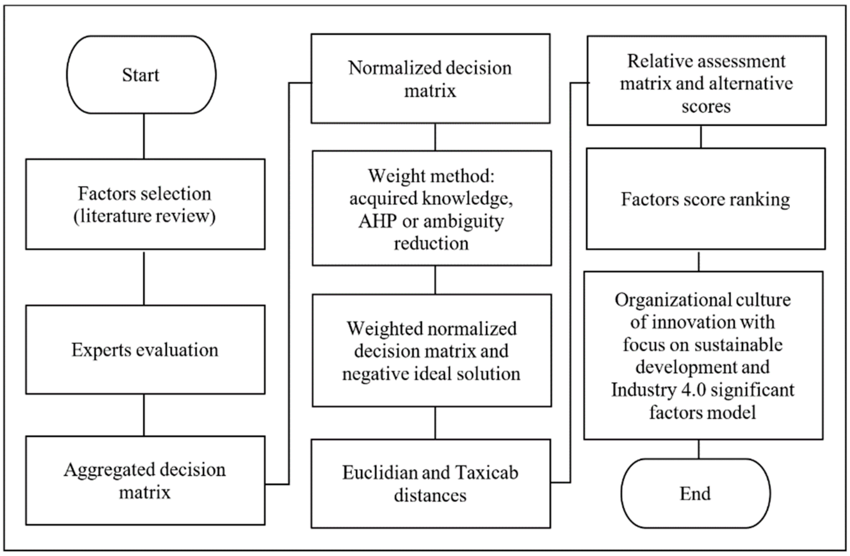

Figure 2. Flow diagram.

Table 9. Aggregated and normalized matrix.

ID	CODE	R&D	P	Q	M	O	F
1	KM01	L8	L2	L5	L3	L6	L6
2	KM02	L6	L8	L6	L6	L5	L4
3	KM03	L8	L7	L5	L5	L7	L2
4	KM04	L8	L4	L5	L3	L6	L4
5	KM05	L4	L6	L1	L2	L8	L5
6	KM06	L8	L5	L5	L3	L8	L3
7	KM07	L6	L6	L5	L6	L8	L6
8	KM08	L8	L4	L2	L1	L1	L2
9	KM09	L8	L7	L6	L6	L7	L6
10	KM10	L8	L8	L8	L6	L6	L5
11	KM11	L8	L6	L3	L6	L6	L6
12	KM12	L8	L6	L6	L6	L8	L4
13	KM13	L8	L8	L8	L8	L6	L5
14	FM01	L6	L6	L5	L4	L5	L8
15	FM02	L6	L4	L4	L4	L4	L8
16	FM03	L7	L7	L8	L6	L6	L8
17	OM01	L7	L4	L5	L2	L8	L7

18	OM02	L7	L4	L2	L4	L8	L3
19	OM03	L5	L8	L7	L3	L8	L8
20	OM04	L6	L6	L3	L5	L8	L2
21	OM05	L6	L5	L7	L8	L8	L2
22	OM06	L7	L6	L6	L5	L8	L4
23	OM07	L8	L6	L6	L6	L8	L2
24	OM08	L5	L8	L8	L1	L6	L8
25	OM09	L3	L8	L8	L1	L2	L7
26	OM10	L8	L8	L8	L8	L8	L8
27	OM11	L8	L8	L7	L6	L8	L6
28	OM12	L8	L7	L8	L6	L8	L7
29	OM13	L8	L8	L8	L6	L6	L1
30	OM14	L8	L8	L8	L8	L7	L8
31	OM15	L8	L8	L8	L8	L8	L8
32	OM16	L2	L8	L8	L5	L8	L1
33	OM17	L8	L8	L8	L8	L8	L7
34	OM18	L8	L8	L4	L5	L5	L2
35	OM19	L8	L8	L4	L4	L4	L7
36	OM20	L6	L1	L2	L8	L8	L4
37	OM21	L8	L8	L4	L2	L7	L1
38	OM22	L8	L7	L5	L4	L4	L4
39	OM23	L5	L7	L5	L6	L8	L7
40	OM24	L6	L7	L5	L5	L8	L8
41	OM25	L8	L8	L8	L8	L8	L5
42	OM26	L8	L2	L7	L8	L8	L6
43	OM27	L8	L8	L5	L6	L3	L2
44	OM28	L8	L2	L4	L8	L8	L4
45	OM29	L4	L6	L5	L4	L8	L8
46	OM30	L8	L6	L4	L5	L8	L2
47	OM31	L4	L8	L7	L4	L8	L6
48	OM32	L7	L6	L6	L7	L8	L1
49	OM33	L8	L2	L8	L8	L8	L8
50	OM34	L8	L8	L8	L8	L8	L5
51	OM35	L5	L8	L8	L8	L3	L3
52	OM36	L8	L8	L8	L5	L8	L3
53	OM37	L8	L8	L8	L8	L8	L8
54	OM38	L8	L7	L4	L2	L8	L8
55	OM39	L8	L4	L4	L8	L8	L5
56	OM40	L8	L8	L8	L1	L8	L5
57	OM41	L8	L5	L7	L4	L8	L2
58	OM42	L8	L8	L8	L8	L8	L7
59	OM43	L8	L2	L6	L2	L8	L3
60	OM44	L8	L2	L4	L4	L8	L7
61	OM45	L8	L3	L3	L3	L3	L6
62	OM46	L8	L7	L8	L4	L5	L1
63	PM01	L8	L8	L8	L1	L8	L4
64	PM02	L8	L8	L8	L4	L5	L3
65	PM03	L8	L8	L8	L5	L8	L4
66	PM04	L8	L8	L8	L4	L7	L4
67	IPM5	L8	L4	L2	L7	L4	L2
68	IPM6	L8	L2	L5	L3	L1	L8
69	TM01	L8	L8	L8	L6	L8	L7
70	TM02	L8	L7	L8	L4	L3	L7
71	TM03	L8	L8	L3	L3	L3	L3
72	TM04	L6	L8	L8	L1	L5	L7
73	TM05	L8	L6	L4	L4	L7	L3
74	TM06	L8	L8	L8	L2	L3	L2
75	TM07	L8	L8	L8	L6	L6	L2

76	TM08	L8	L8	L8	L8	L6	L3
77	TM09	L8	L6	L7	L6	L7	L4
78	TM10	L8	L5	L8	L3	L5	L7
79	TM11	L8	L5	L6	L3	L4	L7
80	TM12	L8	L8	L8	L4	L7	L8
81	TM13	L8	L8	L8	L5	L7	L2
82	TM14	L8	L5	L5	L4	L6	L4
83	TM15	L8	L2	L3	L2	L8	L8
84	PM05	L8	L8	L8	L6	L5	L7
85	PM06	L8	L8	L8	L5	L8	L8
86	PM07	L8	L8	L8	L5	L7	L7
87	PM08	L8	L8	L8	L5	L5	L6
88	PM09	L8	L8	L8	L7	L5	L1
89	PM10	L5	L6	L7	L7	L3	L1
90	PM11	L7	L8	L5	L4	L2	L3
91	PM12	L7	L5	L6	L2	L1	L1
92	PM13	L8	L8	L4	L3	L4	L3
93	PM14	L8	L4	L5	L8	L4	L2
94	PM15	L8	L5	L1	L2	L8	L2
95	PM16	L8	L5	L8	L8	L5	L3
96	IPM1	L8	L8	L1	L2	L1	L7
97	IPM2	L8	L3	L2	L6	L4	L4
98	IPM3	L8	L7	L5	L8	L8	L5
99	IPM4	L8	L6	L4	L2	L4	L1

R&D = Research and Development, P = Product, Q = Quality, M = Marketing, O = Organizational and F = Financial

3.2. Weight Calculation

For the calculation of the w_j weighting, it is proposed to consider the AHP methodology, as well as the acquired knowledge obtained by the literature review, obtaining a third weighting called ambiguity reduction.

3.2.1. Weight Based on Acquired Knowledge (WAK)

It incorporates the knowledge acquired from documentary research that identifies the criteria related to organizational culture in innovation with emphasis on Industry 4.0, which are grouped in critical dimensions to obtain a table of frequencies whose values allow to determine the weighting value of each dimension. Table 10 displays the frequencies and weighting values obtained by analyzing Tables 1, 2, 3, 4, 5 and 6.

Table 10. Weight assessment of literature review.

	Dimensions					
General factors	**R&D**	**P**	**Q**	**M**	**O**	**F**
Knowledge	9	7	0	3	2	3
Financial	1	1	0	0	0	0
Organizational	11	17	14	9	34	9
Process	4	12	2	2	0	2
Intellectual property	4	2	0	2	0	2
Technology	24	12	4	1	16	1
WAK	0.2677	0.2576	0.1010	0.0859	0.2626	0.0253

3.2.2. Weight Based on AHP

The rating scale is based on the Saaty judgment scale [81], which uses ambiguous values to obtain the respective weights and priorities (Table 11).

Table 11. Saaty judgment scale.

Dimension	Saaty Judgment Scale
R&D	1
O	3
P	5
F	6
Q	7
M	8

Based on the matrix of judgments, the standardized autovector is generated, and with this, the normalized average values w_j are obtained, as shown in Table 12.

Table 12. AHP weights.

Dimension	Ahp Weight
R&D	0.4596
O	0.2010
P	0.1576
F	0.0833
Q	0.0654
M	0.0331

Having obtained the above, it is possible to evaluate the congruence of the judgments using the consistency index, $CI = (\lambda max - n)/(n-1)$ and the acceptability index, $IR = CI/RI$, which must not be greater than 10% to be considered as acceptable judgment. The CI and IR obtained were 0.1074 and 9%, respectively, which demonstrates the consistency in the weights determined by the AHP methodology for the different dimensions for innovation.

3.2.3. Weight Based on Ambiguity Reduction (WAHP-AK)

To reduce the ambiguity of the weighted values obtained through AHP, it is proposed to incorporate the weights determined as a result of the analysis of the factors identified in the literature review with the categorized critical dimensions, using $w_j = \delta w_j^{AK} + (1-\delta) w_j^{AHP}$, where δ is the impact that the weighting of the dimensional criteria defined by the decision maker will have, w_i^{AK} is the weighting obtained by reviewing literature for the critical dimension j and w_j^{AHP} is the weighting obtained by AHP for the critical dimension j.

The foregoing implies not only the use of a limited number of experts to assign the weighting values, but also incorporates into the modeling n additional experts who have conducted documented research regarding the organizational culture in innovation with emphasis on Industry 4.0; Table 13 displays the resulting weighting values.

Table 13. Assessment by weight ambiguity reduction.

Dimensions	WAHP-AK Weight
R&D	0.3637
O	0.2318
P	0.2076
F	0.0292
Q	0.0922
M	0.0757

3.3. Normalized Weighted Matrix

Based on the weights obtained by the ambiguity reduction method, the normalized weighted matrix is calculated, using (3), see Table 14.

Table 14. Weighted normalized decision matrix.

ID	CODE	R&D	P	Q	M	O	F
1	KM01	2.9092	0.4152	0.4608	0.2269	1.3908	0.1751
2	KM02	2.1819	1.6606	0.5530	0.4539	1.1590	0.1167
3	KM03	2.9092	1.4530	0.4608	0.3782	1.6226	0.0584
4	KM04	2.9092	0.8303	0.4608	0.2269	1.3908	0.1167
5	KM05	1.4546	1.2454	0.0922	0.1513	1.8544	0.1460
6	KM06	2.9092	1.0379	0.4608	0.2269	1.8544	0.0876
7	KM07	2.1819	1.2454	0.4608	0.4539	1.8544	0.1751
8	KM08	2.9092	0.8303	0.1843	0.0756	0.2318	0.0584
9	KM09	2.9092	1.4530	0.5530	0.4539	1.6226	0.1751
10	KM10	2.9092	1.6606	0.7373	0.4539	1.3908	0.1459
11	KM11	2.9092	1.2454	0.2765	0.4539	1.3908	0.1751
12	KM12	2.9092	1.2454	0.5530	0.4539	1.8544	0.1167
13	KM13	2.9092	1.6606	0.7373	0.6051	1.3908	0.1459
14	FM01	2.1819	1.2454	0.4608	0.3026	1.1590	0.2335
15	FM02	2.1819	0.8303	0.3686	0.3026	0.9272	0.2335
16	FM03	2.5455	1.4530	0.7373	0.4536	1.3908	0.2335
17	OM01	2.5455	0.8303	0.4608	0.1513	1.8544	0.2043
18	OM02	2.5455	0.8303	0.1843	0.3026	1.8544	0.0876
19	OM03	1.8182	1.6606	0.6451	0.2269	1.8544	0.2335
20	OM04	2.1819	1.2454	0.2765	0.3782	1.8544	0.0584
21	OM05	2.1819	1.0379	0.6451	0.6051	1.8544	0.0584
22	OM06	2.5455	1.2454	0.5530	0.3782	1.8544	0.1167
23	OM07	2.9092	1.2454	0.5530	0.4539	1.8544	0.0584
24	OM08	1.8182	1.6606	0.7373	0.0756	1.3908	0.2335
25	OM09	1.0909	1.6606	0.7373	0.0756	0.4636	0.2043
26	OM10	2.9092	1.6606	0.7373	0.6051	1.8544	0.2335
27	OM11	2.9092	1.6606	0.6451	0.4539	1.8544	0.1751
28	OM12	2.9092	1.4530	0.7373	0.4539	1.8544	0.2043
29	OM13	2.9092	1.6606	0.7373	0.4539	1.3908	0.0292
30	OM14	2.9092	1.6606	0.7373	0.6051	1.6226	0.2335
31	OM15	2.9092	1.6606	0.7373	0.6051	1.8544	0.2335
32	OM16	0.7273	1.6606	0.7373	0.3782	1.8544	0.0292
33	OM17	2.9092	1.6606	0.7373	0.6051	1.8544	0.2043
34	OM18	2.9092	1.6606	0.3687	0.3782	1.1590	0.0584
35	OM19	2.9092	1.6606	0.3687	0.3026	0.9272	0.2043
36	OM20	2.1819	0.2076	0.1843	0.6051	1.8544	0.1167
37	OM21	2.9092	1.6606	0.3686	0.1513	1.6226	0.0292
38	OM22	2.9092	1.4530	0.4608	0.3026	0.9272	0.1167
39	OM23	1.8182	1.4530	0.4608	0.4539	1.8544	0.2043
40	OM24	2.1819	1.4530	0.4608	0.3782	1.8544	0.2335
41	OM25	2.9092	1.6606	0.7373	0.6051	1.8544	0.1459
42	OM26	2.9092	0.4152	0.6451	0.6051	1.8544	0.1751
43	OM27	2.9092	1.6606	0.4608	0.4539	0.6954	0.0584
44	OM28	2.9092	0.4152	0.3686	0.6051	1.8544	0.1167
45	OM29	1.4546	1.2454	0.4608	0.3026	1.8544	0.2335
46	OM30	2.9092	1.2454	0.3686	0.3782	1.8544	0.0584
47	OM31	1.4546	1.6606	0.6451	0.3026	1.8544	0.1751
48	OM32	2.5455	1.2454	0.5530	0.5295	1.8544	0.0292
49	OM33	2.9092	0.4152	0.7373	0.6051	1.8544	0.2335
50	OM34	2.9092	1.6606	0.7373	0.6051	1.8544	0.1459
51	OM35	1.8182	1.6606	0.7373	0.6051	0.6954	0.0876
52	OM36	2.9092	1.6606	0.7373	0.3782	1.8544	0.0876
53	OM37	2.9092	1.6606	0.7373	0.6051	1.8544	0.2335
54	OM38	2.9092	1.4530	0.3686	0.1513	1.8544	0.2335
55	OM39	2.9092	0.8303	0.3686	0.6051	1.8544	0.1459
56	OM40	2.9092	1.6606	0.7373	0.0756	1.8544	0.1459
57	OM41	2.9092	1.0379	0.6451	0.3026	1.8544	0.0584

58	OM42	2.9092	1.6606	0.7373	0.6051	1.8544	0.2043
59	OM43	2.9092	0.4152	0.5530	0.1513	1.8544	0.0876
60	OM44	2.9092	0.4152	0.3686	0.3026	1.8544	0.2043
61	OM45	2.9092	0.6227	0.2765	0.2269	0.6954	0.1751
62	OM46	2.9092	2.5455	2.9092	1.4546	1.8182	0.3637
63	PM01	2.9092	2.9092	2.9092	0.3637	2.9092	1.4546
64	PM02	2.9092	2.9092	2.9092	1.4546	1.8182	1.0909
65	PM03	2.9092	2.9092	2.9092	1.8182	2.9092	1.4546
66	PM04	2.9092	2.9092	2.9092	1.4546	2.5455	1.4546
67	PM05	2.9092	2.9092	2.9092	2.1819	1.8182	2.5455
68	PM06	2.9092	2.9092	2.9092	1.8182	2.9092	2.9092
69	PM07	2.9092	2.9092	2.9092	1.8182	2.5455	2.5455
70	PM08	2.9092	2.9092	2.9092	1.8182	1.8182	2.1819
71	PM09	2.9092	2.9092	2.9092	2.5455	1.8182	0.3637
72	PM10	1.8182	2.1819	2.5455	2.5455	1.0909	0.3637
73	PM11	2.5455	2.9092	1.8182	1.4546	0.7273	1.0909
74	PM12	2.5455	1.8182	2.1819	0.7273	0.3637	0.3637
75	PM13	2.9092	2.9092	1.4546	1.0909	1.4546	1.0909
76	PM14	2.9092	1.4546	1.8182	2.9092	1.4546	0.7273
77	PM15	2.9092	1.8182	0.3637	0.7273	2.9092	0.7273
78	PM16	2.9092	1.8182	2.9092	2.9092	1.8182	1.0909
79	IPM01	2.9092	2.9092	0.3637	0.7273	0.3637	2.5455
80	IPM02	2.9092	1.0909	0.7273	2.1819	1.4546	1.4546
81	IPM03	2.9092	2.5455	1.8182	2.9092	2.9092	1.8182
82	IPM04	2.9092	2.1819	1.4546	0.7273	1.4546	0.3637
83	IPM05	2.9092	1.4546	0.7273	2.5455	1.4546	0.7273
84	IPM06	2.9092	0.7273	1.8182	1.0909	0.3637	2.9092
85	TM01	2.9092	2.9092	2.9092	2.1819	2.9092	2.5455
86	TM02	2.9092	2.5455	2.9092	1.4546	1.0909	2.5455
87	TM03	2.9092	2.9092	1.0909	1.0909	1.0909	1.0909
88	TM04	2.1819	2.9092	2.9092	0.3637	1.8182	2.5455
89	TM05	2.9092	2.1819	1.4546	1.4546	2.5455	1.0909
90	TM06	2.9092	2.9092	2.9092	0.7273	1.0909	0.7273
91	TM07	2.9092	2.9092	2.9092	2.1819	2.1819	0.7273
92	TM08	2.9092	2.9092	2.9092	2.9092	2.1819	1.0909
93	TM09	2.9092	2.1819	2.5455	2.1819	2.5455	1.4546
94	TM10	2.9092	1.8182	2.9092	1.0909	1.8182	2.5455
95	TM11	2.9092	1.8182	2.1819	1.0909	1.4546	2.5455
96	TM12	2.9092	2.9092	2.9092	1.4546	2.5455	2.9092
97	TM13	2.9092	2.9092	2.9092	1.8182	2.5455	0.7273
98	TM14	2.9092	1.8182	1.8182	1.4546	2.1819	1.4546
99	TM15	2.9092	1.8182	1.8182	1.4546	2.1819	1.4546
Negative Vector		0.7273	0.2076	0.0922	0.0756	0.2318	0.0292

R&D = Research and Development, P = Product, Q = Quality, M = Marketing, O = Organizational and F = Financial.

3.4. Euclidean and Taxicab Distances, Score and Ranking

Once the normalized weighted matrix was obtained, the Euclidean (6) and Taxicab (7) distances were calculated, the relative matrix determined was calculated (8, 9). Table 15 presents the results of the scores obtained and the hierarchy of the elements (11) that contribute most to the strengthening of organizational culture in innovation with emphasis on Industry 4.0 and sustainability development.

Table 15. Euclidean and Taxicab distances, score and ranking.

				Assessment weight	
ID	**CODE**	**Ei = Euclidean distance**	**Ti = Taxicab distance**	**Score**	**Ranking**

1	KM01	0.07899	4.21427	0.66147	27
2	KM02	0.07331	4.76134	1.21856	15
3	KM03	0.09142	5.51849	-0.58007	67
4	KM04	0.08103	4.57105	0.44915	33
5	KM05	0.06480	3.58011	2.14178	5
6	KM06	0.09017	5.21304	-0.46206	62
7	KM07	0.07773	5.00779	0.77116	25
8	KM08	0.07132	2.92594	1.49537	11
9	KM09	0.09222	5.80302	-0.65278	68
10	KM10	0.09309	5.93393	-0.73533	72
11	KM11	0.08531	5.08717	0.01827	44
12	KM12	0.09334	5.76888	-0.76223	74
13	KM13	0.09382	6.08521	-0.80183	77
14	FM01	0.06498	4.21948	2.08445	7
15	FM02	0.05580	3.48038	3.08212	3
16	FM03	0.08190	5.45025	0.35178	35
17	OM01	0.08006	4.68291	0.54531	31
18	OM02	0.07938	4.44099	0.61738	29
19	OM03	0.07885	5.07504	0.65813	28
20	OM04	0.07662	4.63110	0.89161	22
21	OM05	0.07708	5.01909	0.83477	23
22	OM06	0.08501	5.32959	0.04740	42
23	OM07	0.09330	5.71051	-0.75999	73
24	OM08	0.07094	4.55232	1.46506	12
25	OM09	0.05202	2.86865	3.53394	1
26	OM10	0.10051	6.63635	-1.42140	97
27	OM11	0.09918	6.33455	-1.30783	88
28	OM12	0.09697	6.24831	-1.09933	85
29	OM13	0.09302	5.81720	-0.73077	71
30	OM14	0.09702	6.40455	-1.09915	84
31	OM15	0.10051	6.63635	-1.42140	97
32	OM16	0.07197	4.02327	1.38288	14
33	OM17	0.10045	6.60717	-1.41750	95
34	OM18	0.08827	5.17031	-0.27439	54
35	OM19	0.08608	5.00878	-0.05853	48
36	OM20	0.07054	3.78637	1.53949	10
37	OM21	0.09362	5.37780	-0.79903	76
38	OM22	0.08303	4.80582	0.24636	38
39	OM23	0.07487	4.88090	1.05908	20
40	OM24	0.08049	5.19809	0.49406	32
41	OM25	0.10037	6.54881	-1.41204	93
42	OM26	0.08907	5.24039	-0.35262	56
43	OM27	0.08523	4.87451	0.02600	43
44	OM28	0.08771	4.90555	-0.22074	53
45	OM29	0.06638	4.18758	1.94424	8
46	OM30	0.09230	5.45056	-0.66801	69
47	OM31	0.07466	4.72867	1.08517	19
48	OM32	0.08562	5.39333	-0.01334	45
49	OM33	0.08979	5.39092	-0.42206	59
50	OM34	0.10037	6.54881	-1.41204	93
51	OM35	0.06448	4.24051	2.13386	6
52	OM36	0.09939	6.26352	-1.33007	89
53	OM37	0.10051	6.63635	-1.42140	97
54	OM38	0.09457	5.60630	-0.88596	78
55	OM39	0.08966	5.34988	-0.41003	58
56	OM40	0.09898	6.01931	-1.30069	87
57	OM41	0.09124	5.44382	-0.56358	66
58	OM42	0.10045	6.60717	-1.41750	95

59	OM43	0.08690	4.60684	-0.14118	52
60	OM44	0.08655	4.69053	-0.10512	50
61	OM45	0.07179	3.54213	1.42059	13
62	OM46	0.08680	5.22654	-0.12879	51
63	PM01	0.09895	5.99013	-1.29894	86
64	PM02	0.08994	5.49248	-0.43588	60
65	PM03	0.09941	6.29270	-1.33094	90
66	PM04	0.09567	5.98526	-0.98293	79
67	PM05	0.09059	5.76049	-0.49574	64
68	PM06	0.09958	6.40943	-1.34243	91
69	PM07	0.09600	6.14845	-1.00942	82
70	PM08	0.09026	5.65567	-0.46484	63
71	PM09	0.09077	5.66104	-0.51419	65
72	PM10	0.05434	3.59920	3.22252	2
73	PM11	0.06446	3.18496	2.20174	4
74	PM12	0.07472	4.15697	1.09697	18
75	PM13	0.08576	4.81641	-0.02663	46
76	PM14	0.07724	4.42730	0.83437	24
77	PM15	0.08932	4.73958	-0.38239	57
78	PM16	0.08314	5.17233	0.23201	39
79	IPM01	0.08254	3.88563	0.30416	36
80	IPM02	0.07415	3.85034	1.16540	17
81	IPM03	0.09615	6.06476	-1.02663	83
82	IPM04	0.07947	4.26726	0.61212	30
83	IPM05	0.07594	4.07519	0.97573	21
84	IPM06	0.07025	3.11365	1.59951	9
85	TM01	0.09978	6.45589	-1.35959	92
86	TM02	0.08323	4.93804	0.22483	40
87	TM03	0.08395	4.49245	0.15570	41
88	TM04	0.07387	4.65499	1.16613	16
89	TM05	0.08829	5.17230	-0.27606	55
90	TM06	0.08606	4.84842	-0.05605	47
91	TM07	0.09303	5.84638	-0.73061	70
92	TM08	0.09377	6.02685	-0.79800	75
93	TM09	0.09008	5.62924	-0.44811	61
94	TM10	0.08177	4.91085	0.37119	34
95	TM11	0.07819	4.49473	0.73652	26
96	TM12	0.09585	6.10199	-0.99647	80
97	TM13	0.09584	6.00254	-0.99894	81
98	TM14	0.08302	4.85427	0.24716	37
99	TM15	0.08611	4.47627	-0.06108	49

3.5. Sensitivity Analysis

In order to perform an analysis of the rankings obtained, the scores and rankings were calculated using the acquired knowledge weight and AHP weight. Table 16 displays the results obtained where Cronbach's alpha coefficient is 0.9574 for the APH weight, 0.9870 for acquired knowledge weight and 0.9090 for the ambiguity reduction which is indicative of a high internal consistency between the data, as well as a similar standard deviation value between the three methods, indicative of a minimum error difference between them.

Table 16. Cronbach’s alpha analysis.

Omitted Variable	Adjusted Total Mean	Adjusted Total Standard Deviation	Item-Adjusted Total Correlation	Squared Multiple Correlation	Cronbach’s Alpha
WAHP	99.90	56.10	0.9228	0.9734	0.9574
WAK	99.90	56.91	0.8813	0.9177	0.9870

WAHP-AK	99.90	54.84	0.9884	0.9864	0.9090

Regarding the correlation values calculated between the three weighting methods, Table 17, there is a high correlation between the weighting calculation methodologies considered in the investigation, graphically observed in Figure 3.

Table 17. Correlation matrix.

	WAHP	WAK	WAHP-AK
WAHP	1.00	0.83	0.97
WAK	0.83	1.00	0.92
WAHP-AK	0.97	0.92	1.00

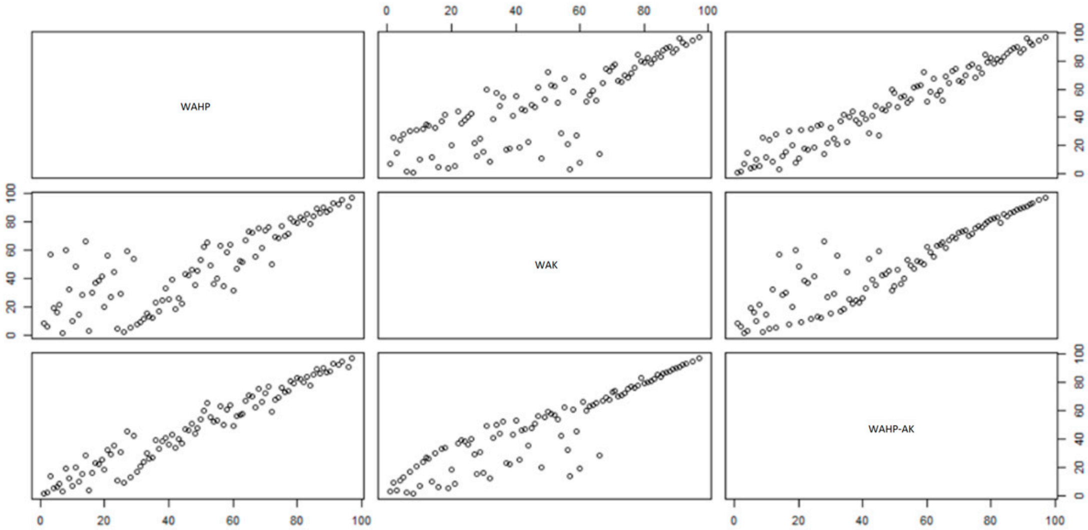

Figure 3. Correlation analysis.

4. Discussion

The multicriteria analysis CODAS HFLTS and an expert's opinion provide a tool to identify the 30 highest scoring factors, establishing a methodological strategy that promotes an organizational culture in innovation with an Industry 4.0 and sustainability development emphasis.

To obtain these factors, the knowledge acquired during 30 years of research related to organizational culture in innovation was used, which allowed complementing the judgment of the experts of the AHP methodology, whose value of square multiple correlation obtained (0.9864) was higher than values obtained using AHP (0.9734) and acquired knowledge (0.9177). In addition, the Table 17 shows high correlation values between the scoring values calculated under the ambiguity reduction weigh and AHP (0.97), same situation with the observed correlation between ambiguity reduction and acquired knowledge weight (0.92). The above endorses the compliance of the statement: the scoring values obtained, using CODAS and HFLTS under different weight calculation methods, provide correlation coefficient values equal or greater than 0.800, which is aligned with the established aims and research questions.

In a similar view, the ambiguity reduction weight, based on acquired knowledge and AHP, providing a Cronbach's alpha coefficient equal or greater than 0.900. By this, the paper probes the results in Table 16 as an indicative of the reliability of the proposed methodology, in accordance to the aims and research questions established in this paper.

Finally, the identify factors in the MCDM analysis presented in Figure 4 includes the score values and ranking that are aligned with the promoted management established in Figure 1. This model facilitates the identification of the type of management required to establish specific strategies according to the enterprises' needs. Figure 4 presents the factors of each dimension, two financial management factors, two technology management factors, four process management factors, four intellectual property management factors, five knowledge management factors and 13 organizational management factors, which indicates that organizational management contributes to a greater extent to generate an organizational culture in innovation with an emphasis on sustainability development and Industry 4.0, since it develops and promotes a work environment that encourages innovation, the above without diminishing importance to the other steps. These factors are described in the following sections.

4.1. Organizational Management

- Capacities-content [23,48], score 3.53, allows the organization to establish or consider basic aspects related to what and how to produce in a complex context derived from hyperconnectivity and digitalization, as well as to the speed with which products must be modified or the new products presented for marketing, according the customer requirements.
- Strategic orientation towards the client [16], score 2.13, establishes that the focus in the new environment is towards the client, unlike the past decades, with the starting point for the generation of innovation in the production of new products services or business models and developing and managing a company green image [24], which allow their competitiveness.
- Interaction with suppliers-value chain [67], score 1.94. In the value chain, it is important to be well integrated with suppliers, so that there are no deficiencies, no aspects of raw material specifications that can delay the innovation process, alerts about future changes that may allow to modify processes, products can be generated with higher quality, better supply conditions can be obtained, lower failures in the provision of the elements occur and a reduction of the use of natural resources in production.

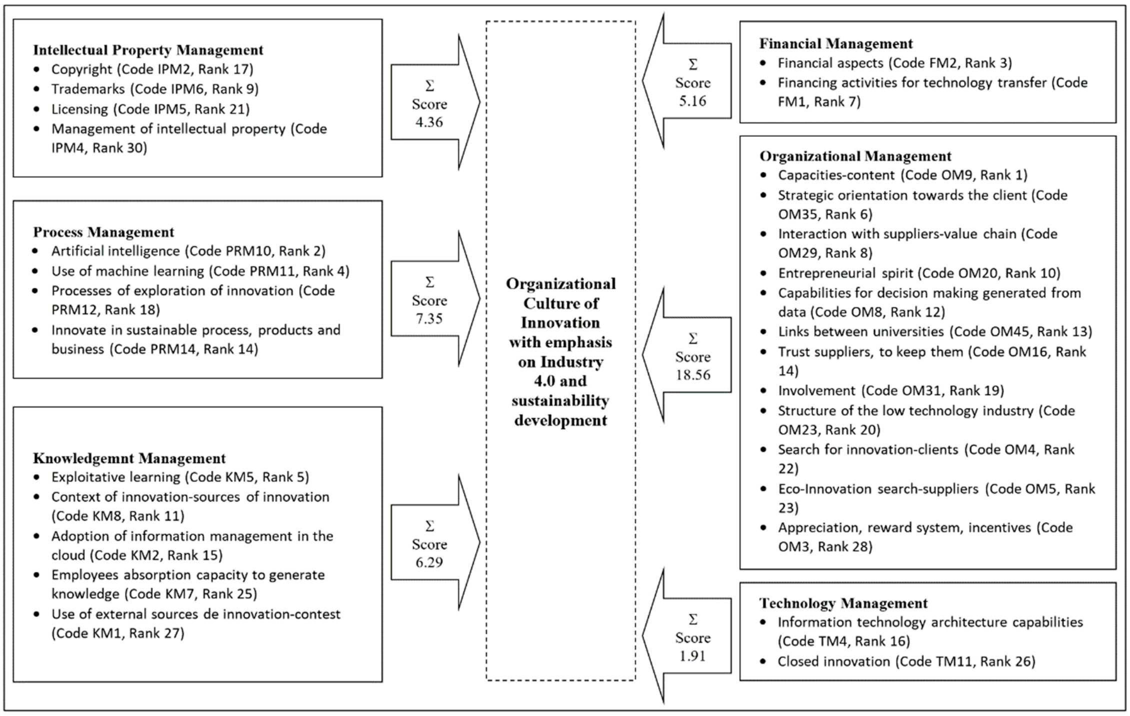

Figure 4. Organizational culture in innovation model with an Industry 4.0 and sustainability development emphasis.

- Entrepreneurial spirit [16], score 1.54, allows companies to consider incremental or radical changes within the organization and focus on clean production as a generator of environmental and economic benefits for companies and consumers.
- Capabilities for decision making generated from data [23,36,48], score 1.47, in the context of Industry 4.0, information increases exponentially, and this information must be used by the organization, for the improvement and management of business innovation.

- Links between universities [74], score 1.42. Linking allows generating research and development activities for new products, processes and product improvements in environments where universities provide new solutions to traditional methods or processes followed by organizations.
- Trust suppliers [39], score 1.38. This is a strategic aspect that is possibly not often considered in organizations, but relevant in innovation, since the perception of lack of trust can generate unfinished innovation projects when related to licensing and issues of intellectual property, which can interfere with innovation and the management.
- Involvement [10,68], score 1.09. This concerns the issues of attitudes, values, abilities, skills and performance of personnel to establish internal and external relationships and relationships that contribute to streamline the process of innovation development and environmental consciousness.
- Structure of the low technology industry [31], score 1.06. High technology is related to economic resources, which are often limited; innovation is not necessarily related to disruptive technological changes, but to the proper use of them.
- Search for innovation-clients [47], score 0.89. The relevance of this factor lies in the search and use of information to generate innovation in new products, when existing products do not meet the functionality expectations specified by customers. It also applies to manufacturing processes, when the existing ones do not present added value in compliance with the process or product specifications.
- Eco-innovation search-suppliers [25], score 0.83, promote the search and development of production equipment suppliers to generate opportunities in process innovation with emphasis in sustainable development.
- Appreciation, reward system and incentives [39], score 0.66. This element establishes reward plans for recognition of employee achievements as an incentive for innovation.
- Structure for innovation [19], score 0.6, involves establishing the conditions to operate in the new environment of digitalization and hyperconnection.

4.2. Process Management

- Artificial intelligence [22], score 3.22, allows the simulation of the most precise production processes, to establish product life cycles, to identify periods of failures, make adaptations in virtual fields before being manufactured or marketed and to carry out product innovations existing or generate new products.
- Use of machine learning [22], score 2.20, provides more information for the development of innovation by integrating it with mathematical algorithms.
- Processes of exploration of innovation [84], score 1.10, strengthens the company's position in terms of competitiveness by establishing search processes and innovation analysis.
- Innovating in sustainable process, products and business [31,33], score 0.83, allows to establish innovation cycles according to the life cycles of the technology and the products themselves.

4.3. Knowledge Management

- Exploitative learning [20,26], score 2.14, involves the potentializing of knowledge derived from the generation of technology, through technology transfers, staff mobility, informal contacts, relationships, information exchanges and the training of human capital to generate new innovations.
- Context of innovation-sources of innovation [14], score 1.50. The sources of innovation derived from competitions allow companies to get new ideas from the prototypes generated in a particular topic for innovation.
- Adoption of information management in the cloud [22], score 1.22, recognizes that information is an intangible asset that produces great changes in organizations, in the new context of digitalization, this promotes more agile processes and more information to gain competitive

advantage over aspects, characteristics, problems, improvements etc., which lead to information and for the generation of innovation.

- Employees absorption capacity to generate knowledge [27,28], score 0.77. This is an intangible asset in companies and is difficult to measure. It allows the organization to implement, adapt and decode tacit knowledge to make it explicit, with the intention of transferring it into innovative products and processes and developing a corporate environmental culture.

4.4. Financial Management

- Financial aspects [19,33–41], score 3.08, include resources that are involved in innovation, costs related to training, updates, payments to professionals for legal aspects related to patenting, licensing, registration and the investment in contributions to sustainable development, as well as those related to human capital.
- Financing activities for technology transfer [19,37,40], score 2.08, refers to significant activities in strategic planning and involves the allocation of financial resources to carry out the generation and implementation of innovation by transferring additional technology to equipment or machinery, including transport and complementary costs for such transfers.

4.5. Intellectual Property Management

- Trademarks [32,33], score 1.60, provide a corporate identity and prestige; the brand is the recognition of innovative research and development of products or services.
- Copyright [33], score 1.17, corresponds to the legal value of the reserved rights that protect ideas for innovation and part of the competitiveness of companies.
- Licensing [32,33], score 0.98, corresponds to the rights for the use of intellectual property that allows you to use and generate income by marketing innovations that include intellectual property of others.
- Management of intellectual property [27,33], score 0.61, involves the legal aspects related to intellectual property rights, licensing and trademark registration, or the use of intellectual property by third parties. As a complement to innovations generated in the organization, this allows to protect the innovation and above all to commercialize the products.

4.6. Technology management

- Information technology architecture capabilities [80], score 1.17, includes the capabilities in the management of information technologies, hardware management for information storage, data synchronization programming and simulation capabilities for the virtual creation of innovation, for its subsequent development of physical way, such as business strategies.
- Closed innovation [74], score 0.74, uses the resources available within the organization, human and technological, to carry out innovative research and development activities.

Finally, from a comparative analysis of the factors of greater hierarchy calculated using the different weighting methodologies, it is observed in Figure 5 that the organizational management is the most important when all the individual factors under the general classifications are analyzed.

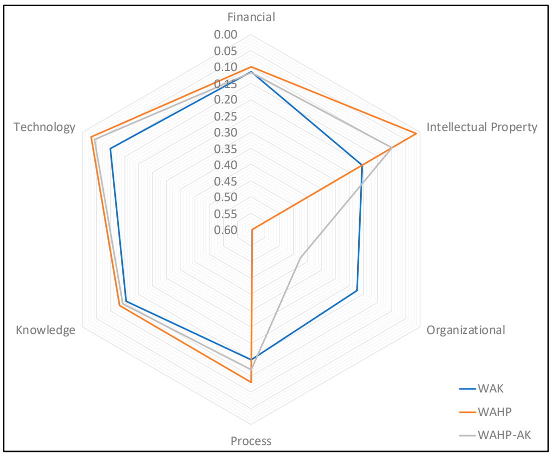

Figure 5. Total score by general factor.

5. Conclusions

Using the CODAS HFLTS methodology, it was possible identify 30 factors with highest hierarchy that influence the cultural organization in the field of innovation, with an emphasis for Industry 4.0 and sustainable development, identified through a literature review from relevant research within the same area of knowledge.

A multicriteria analysis was carried out using weighting values that included the AHP methodology, the knowledge acquired from previous research and the dimensional criteria recommended by the OECD, with the objective of reducing the subjectivity and the impact of a limited number of experts assigning weighting values.

Once the results were obtained, it was observed that organizational management is of great relevance to boost innovation within organizations, continuing with process management, knowledge management, intellectual property management and, finally, technology management.

The above makes sense because it is the human resource that must be strengthened (knowledge and skills) to generate the synergy that encourages innovation activities, since historically it has been observed that organizations that do not adapt to new environments tend to disappear. This is even more true in a complex and changing context such as the environment of Industry 4.0, where the cycles of innovation are becoming shorter and the relevance of the sustainable development and green technologies are more popular.

The main contribution of this research, from the point of view of organizational culture, sustainable development and industry 4.0, is providing a methodology to companies and researchers for relevant factors identification for a specific organization and allow focus resources on establishment of strategies that increase the competitiveness, avoiding the resources waste assigned to not relevant factors.

Here, the expert judgment used is key since it allows to assign greater importance to relevant criteria, which could be undervalued by methodological tools proposed by other researchers. In addition, the ambiguity reduction weight calculation allows varying the magnitude of the impact of expert judgment and the results of previous research present in the literature review. However, an important limitation of the study is the expert opinion, used to establish the weighting values of each criterion. This is considered by some researchers as lacking statistical representativeness, a topic not considered in this paper but considered in [95].

Proposal for future works are: (a) using the entropy method to calculate the weighting values through expert judgment [96], and subsequently, a contrast analysis of the scoring and ranking values obtained; (b) implement the use of machine learning to analyze the factors found in the literary review and contrast them with the factors actually used by organizations; (c) expand the proposed MCDM methodology other case of studies, such as horizontal collaboration [97,98], analysis of critical factors for supplier selection [99] and implementation of lean education [100], among others.

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