Dynamics of stakeholder relations with multi-person aggregation

Abstract

Purpose: The primary aim of this paper is to develop a novel method to analyse dynamic interactions of stakeholders to explain how a set of agents can act by considering the power/influence positions.

Design/methodology/approach: A novel mathematical application uses the importance of characteristics algorithm in combination with composition max-min to compare, group and order information according to the importance of its characteristics. The mathematical application is focused on a strategic analysis, evaluating stakeholder dynamics through power relationships.

Findings: The results show a comparison of the relationships among each of the stakeholders to obtain the relative intensity and importance of relationships between them, given by the fuzzy matrix $FRIn_M$ and the fuzzy matrix FRI_M, respectively. This application provides a useful tool for a dynamic analysis of stakeholders in a complex environment, where the best approach to performing a strategic analysis process is sought.

Limitations/Implications: the main implication of the proposed approach is taking into account the importance of information to establish the boundaries and relationships of each characteristic according to its intensity. However, limitations are due to the nature of this research, based on theoretical assumptions regarding stakeholders and the use of a hypothetical example to show the operation of algorithms.

Original/value: The primary advantage of this proposition is that it takes into account the importance of information to establish the relationships among the characteristics according to their intensity. Additionally, it performs multiple comparisons among each characteristic of the information. The interests and opinions of decision makers can be parameterised. A mathematical application shows how each interest group could be classified and related according to subjective information.

Keywords: Decision-making, Strategy, Fuzzy relation, Stakeholder, Power/Influence.

Paper type: Research paper

1. Introduction

The stakeholder theory has helped researchers to understand the dynamics of the interaction between a firm and its environment. This theory has tried to explain and predict how organisations should act by considering the influences of stakeholders (Wagner et al., 2011) on planning and decision-making. The stakeholder analysis is essentially descriptive, normative and instrumental (Donaldson and Preston, 1995; Friedman and Miles, 2002). Accordingly, numerous authors have proposed various analysis methods that explain relations between stakeholders (Friedman and Miles, 2006; Frooman, 1999; Jones, 1995; Savage et al., 2011; Wagner et al., 2012). Such methods analyse stakeholders' relationships via visual diagrams that can help comprehend, simplify and aggregate complex information (Fassin, 2007). A widely accepted graphical representation is Freeman's stakeholder model. Freeman (1984, 2004, 2011) has proposed an approach for obtaining an aggregate view of the relationships between a firm and a set of actors around it. Nonetheless, Freeman's model has been criticised for being a static representation that does not consider changes over time and heterogeneity of factors (Fassin, 2009; Friedman and Miles, 2002).

Several approaches have been suggested to remedy the above deficiencies by considering networks and interactions. One of them is a network approach to explaining interactions among stakeholders. This approach suggests a broader perspective, going beyond the dyadic linkages between the firm and each stakeholder (Rowley, 1997). Furthermore, it focuses on the firm's response to the influence of its stakeholders and considers multiple and interdependent interactions that simultaneously exist in stakeholder environments (Rowley, 1997). However, this approach does not explain how relationships within the network could vary in the context of threats and opportunities created by changes in the environment (Friedman and Miles, 2002). Thus, dynamic and changing relationships among stakeholders are complex due to changes in the environment.

Indeed, the dynamics and changes in stakeholder's relationships have critical impacts on an entity's chain of responsibility, the importance and status of stakeholders (Fassin, 2010). Furthermore, the subjectivity of the observer performing the stakeholder analysis directly influences the results. Considering the above, several theories, e.g., dynamic capabilities, game theory and cooperation theory, are being used to model stakeholder dynamics and improve strategic analysis and decision-making processes in business and economics (Windsor, 2011). Thus, by relying on a descriptive analysis of stakeholders, it is possible to develop a methodological perspective using fuzzy techniques of decision-making under uncertainty. Such techniques could help improve the dynamic analysis of stakeholder theory, as they are capable of representing the importance of information and established relationships.

The literature on decision-making under uncertainty includes a wide range of methods capable of processing subjective and objective information, personal preferences, attitudes and the resulting data (Gil-Lafuente and Merigó, 2007; Gil-Lafuente *et al.*, 2013; Herrera et al. 1995; Martinez and Herrera, 2000; Wei, 2009), which are being applied to economics and business management (Gil-Aluja, 2000; Kaufmann et al., 1994; Kaufmann and Gil-Aluja, 1993, 1995) to improve strategic decision-making within a complex environment. On the one hand, there is an effective technique that can guide a comparison process (Merigó and Gil-Lafuente, 2010, 2011). This technique is related to distance measures, developed in Gil-Aluja, (1999), Gil-Lafuente (2002), Kaufmann and Gil-Aluja (1986, 1987) and Merigó (2009), which enable the decision maker to compare various different aspects of available information. On the other hand, other techniques based on the incidence concept (Kaufmann and Gil-Aluja, 1988) can enable analysis of relationships and their ordering, e.g., to identify causality among relationships, link relationships and order them according to importance of their characteristics (Gil-Aluja, 1999). Indeed, incidence is a subjective concept that is difficult to measure and is rarely properly justified, as it is related to subjective attributes. Accordingly, such techniques can enable analysis of the relevant subjective attributes, i.e., to perform an appraisal of the decision maker according to certain notable characteristics. The opinion of the decision maker is more significant in such an analysis than in other methodologies. The decision maker offers its estimates based on the quality or quantity of data received, statistics, reports and information from surveys, all of which are used to guide its decisions. Hence, such techniques enable decision makers to analyse dynamic relationships between each stakeholder and the firm according to the importance of each and to define strategic courses of action. Furthermore, the firm's relationships are established between individuals (either senior management or a group of employees selected to represent employees' shared interests) and linked through certain characteristics to different levels of importance. Thus, the links between each of them can be strengthened or weakened by variations in the intensity of relations (Blanco-Mesa, 2015).

The above perspective has been used by several authors to apply this methodology in business and economics, e.g., marketing (Gil-Lafuente, 1997; Nicolás and Gil-Lafuente, 2012), customer relationship management (Gil-Lafuente and Luis Bassa, 2011), strategy (Gil-Lafuente and Barcellos de Paula, 2010), stakeholders (Gil-Lafuente and Barcellos de Paula, 2013), corporate social responsibility (Vizuete Luciano *et al.*, 2013), economics (Blanco-Mesa and Gil-Lafuente, 2017; Blanco-Mesa and Gil-Lafuente, 2014; Gil-Lafuente et al., 2012; León-Castro et al., 2016, 2017; Pérez-Arellano et al., 2017), entrepreneurship (Blanco-Mesa et al., 2017; Maqueda Lafuente et al., 2013) and sport business (Gil-Lafuente, 2002, 2008; Gil-Lafuente et al., 2012), showing its utility for decision-making under uncertainty. The above applications have the advantage that the appraisal of the decision maker involves assessments of several alternatives, intensities and the importance of relationships. Thus, this methodology allows subjective attributes to be represented relative to strategic decision-making in business and economics problems.

The primary objective of the paper is to develop a novel method for analysing dynamic interactions of stakeholders to explain how a set of agents can act by considering the power/influence positions. This method applies the importance of characteristics algorithm together with composition max-min to compare, group and order information. A mathematical application is focused on strategic analyses for evaluating stakeholder dynamics through power relationships. The primary advantages of this proposition are that a) it takes into account the importance of information to establish the relationships among the characteristics according to their intensity, b) it performs multiple comparisons among each characteristic of the information, c) the interests and opinions of decision makers can be parameterised, and d) the mathematical application shows how each interest group could be classified and related according to subjective information. This application provides a useful tool for a dynamic analysis of stakeholders in a complex environment, and it provides the best method of performing a strategic analysis process. This paper is organised as follows. Section 2 reviews the basic concepts of comparison indices' representation in a square fuzzy matrix and fuzzy composition. Section 3 develops a strategic analysis technique for evaluating stakeholder dynamics. Section 4 presents a mathematical application focused on the power attribute of stakeholder relationships. Section 5 presents the summary and the primary conclusion.

2. Preliminaries

In this Section, we briefly review several basic concepts related to the distance notion and a fuzzy relation composed of the importance of characteristics representation in a square fuzzy matrix and fuzzy composition.

2.1. The comparison indices' representations in a square fuzzy matrix

Links between relations are used in decision-making under uncertainty to establish the incidence or causality of a relation through the details of relation levels. The levels can be given by subjective attributes that in turn can be parameterised by comparison indices. Therefore, the results obtained by comparison indices can be represented on a square fuzzy matrix.

2.1.1. The ordering according to the importance of characteristics algorithm

The importance of characteristics (Gil-Aluja, 1999) is a useful technique for establishing the relative importance in a causality relation between two objects by considering their characteristics. The importance of characteristics algorithm involves the reciprocal matrix, the dominant eigenvalue and the dominant eigenvector.

Definition 1. The reciprocal matrix $[\tilde{R}]$ collects all comparisons of characteristics performed by the time it has been preferred. A binary comparison is performed for each characteristic C_j, i.e., involving $C_i, C_k;\ i, k = 1, 2, \dots, n$ using a quotient, which determines the time that such characteristic is preferred to the other, such that

$$\mu_{ik} = \frac{f_i}{f_k} \quad , \qquad i, k = 1, 2, \dots, n, \tag{1}$$

where C_i represents the times it is preferred to C_k.

Note that the matrix comprises the collection of all μ_{ik} and is both reciprocal and coherent/consistent. It is reciprocal because it satisfies the following conditions: $\mu_{ii} = 1$; $\mu_{ik} = 1/(\mu_{ki}$, where $\mu_{ik} \in R_o^+, i, k = 1, 2, \dots, n$. It is coherent/consistent because it satisfies the following criteria: $\forall\, i, k, l \in \{1, 2, \dots, n\}$; $f_i/f_k * f_k/f_l = f_i/f_l$, i.e. $\mu_{ik} * \mu_{kl} = \mu_{il}$.

Therefore, the matrix must satisfy the transpose property, given by:

$$\sum_{k=1}^{n} \mu_{ik} * f_k = \sum_{k=1}^{n} \frac{f_i}{f_k} * f_k = n * f_i, \tag{2}$$

and the proportionality property, given by:

$$\frac{\mu_{ik}}{\mu_{lk}} = \frac{f_i/f_k}{f_l/f_k} = \frac{f_i}{f_l}, \tag{3}$$

Additionally:

$$\frac{\mu_{ik'}}{\mu_{lk'}} = \frac{f_i/f_{k'}}{f_l/f_{k'}} = \frac{f_i}{f_l}, \tag{4}$$

Therefore:

$$\frac{\mu_{ik}}{\mu_{lk}} = \frac{\mu_{ik'}}{\mu_{lk'}}\ . \tag{5}$$

Definition 2. The dominant eigenvalue E_{va} of dimension n is a mapping E_{va}: $[0,1]^n x[0,1]^n \rightarrow [0,1]$ that has an associated limit weighting vector $\lambda_1^{(c)}$, with $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j \geq 1$, such that:

$$E_{va}(\langle x_{\mathrm{i}}, y_{\mathrm{k}}\rangle, \dots, \langle x_n, y_m\rangle) = \sum_{k=1}^{n} max w_j(\mu_{ik} * y_{\mathrm{k}}), \tag{6}$$

where x_i and y_k represent the jth largest of sets *X* and *Y*, respectively.

Therefore,

$$\lambda_1^{(c)} = E_{va} max. \tag{7}$$

Definition 3. The dominant Eigenvector $V^{(c)}$ has an associated weighting vector $\lambda_1^{(c)}$, with $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j \leq 1$, such that

$$V^c(\langle x_{\mathrm{i}}, y_{\mathrm{k}}\rangle, \dots, \langle x_n, y_m\rangle) = \sum_{k=1}^{n} \frac{(\mu_{ik} * y_{\mathrm{k}})}{max(\mu_{ik} * y_{\mathrm{k}})}, \tag{8}$$

while the normalised form is defined by:

$$N^{(c)} = \frac{V^{(c)}}{\sum V^{(c)}}\ . \tag{9}$$

Therefore, the relative importance is shown by each characteristic within a representation of the importance matrix $[\tilde{R}]$. This matrix is given by:

$$[\tilde{R}]^* = N^{(c)} * [\tilde{R}], \quad (10)$$

where $[\tilde{R}]$ is the *ith* argument of set X.

Hence, following the above process, a matrix $[\tilde{R}]$ that represents a *square fuzzy matrix* is obtained. This matrix satisfies all of the following properties: being reflexive, transitive, symmetric and fuzzy anti-symmetric.

It is *reflexive* because the relation of elements of set $x \in E$ with itself, i.e., with $x \in E$ is total, while the elements along the main diagonal are all equal to 1. Therefore, it must hold that $\forall\, a_i \in E$, where $i = 1, 2, \dots, n$: $\mu_{ij} = 1, i = j$ and $\mu_{ij} \in [0,1], i \neq j$, where a_i are the *ith* arguments of set E.

It is *transitive* because the indirect relation between three elements of the referential E (a_i, a_j, a_k) can be considered in the same manner, i.e., the indirect relation between a_i and a_k cannot be greater than the direct relation between a_j and a_k. Therefore it must hold that $\forall\, a_{i,} a_j, a_k \in E$: $\mu_{ai\ k} \geq \vee\ (\mu_{ai\ aj} \wedge \mu_{aj\ ak})$.

It is *symmetric* because the intensity of the relation from a_i to a_j is considered to be the same as that from a_j to a_i. Therefore, it must hold that $\forall\, a_i, a_j \in E, a_i \neq a_j$ and $\mu_{ai} = \mu_{aj}$, where a_i and a_j are the ith arguments of set E.

It is *fuzzy anti-symmetric* because the intensity of the relation from a_i to a_j is not considered to be the same as from a_j to a_i. Therefore it must hold that $\forall\, a_i, a_j \in E, a_i \neq a_j$ and $\mu_{ij} \neq \mu_{ji}$ or $\mu_{ij} = \mu_{ji} = 0$ where a_i and a_j are the *ith* arguments of the set E.

2.2. Fuzzy composition

Fuzzy composition or convolution max-min (Gil-Aluja, 1999) is a useful technique for associating physical and mental objects. In decision-making under uncertainty, it is used to represent the degree of belonging or the lack of association and the interaction or interconnection of fuzzy relation between elements of the set itself or two or more fuzzy sets. For elements of the set itself, or two or more fuzzy sets, the convolution max-min can be defined as follows:

Definition 4. A fuzzy composition $R \circ S$ is defined as a fuzzy relation UxW, and it is associated with the respective characteristic functions $\mu_R(x, y)$ and $\mu_S(y, z)$, which are given by the composition max-min, such that

$$\mu_{R \circ S}\,(x, z) = \vee_{y \in V}\,(\mu_{\mathrm{R}}(x, y) \wedge \mu_{\mathrm{s}}(y, z)), \quad (11)$$

where $(x, z) \in (\mathrm{U}, \mathrm{W})$.

Therefore, the relative intensity is established by the convolution of fuzzy matrix $[\tilde{R}]$ with itself. The behaviour of relation can be observed through evolution over time or along the time axis.

Definition 5. The max-min composition of matrix $[\tilde{R}]$ is given by:

$$[\tilde{R}] \circ [\tilde{R}] = [\tilde{R}]^2$$
$$[\tilde{R}] \circ [\tilde{R}] \circ [\tilde{R}] = [\tilde{R}]^3 \circ [\tilde{R}] = [\tilde{R}]^4. \quad (12)$$

Therefore:

$$[\tilde{R}] \circ [\tilde{R}] = [\tilde{R}]^n \circ [\tilde{R}] = [\tilde{R}]^{n+1}, \quad (13)$$

when $[\tilde{R}]^n = [\tilde{R}]^{n+1}$ the process is terminates.

3. A strategic analysis process for evaluating stakeholder dynamics

In this section, we present a rational process for evaluating the stakeholder dynamics. We describe the strategic analysis approach.

The use of ordering according to the importance of characteristics and fuzzy composition max-min in a dynamic relationship analysis of stakeholders within a specific environment allows aggregating, ordering and linking information. The dynamics and changes in relationships of each stakeholder have a crucial impact on an entity's chain of responsibility, the salience and status of stakeholders (Fassin, 2010).

The firm reacts to the influence of its stakeholders and considers multiple and interdependent interactions that simultaneously exist in stakeholder environments (Rowley, 1997). The introduction of importance of characteristics and linking relationships can reflect the dynamics of stakeholders' relations according to the preference of each characteristic. A similar process has been developed by Gil-Lafuente and Barcellos de Paula (2013) and Gil-Lafuente *et al*. (2012a; 2012b), resulting in instruments that can be applied to the comparison, ordering and linking process. The strategic analysis process consists of five steps. They are described as follows:

Step 1. Analyse and determine the salient characteristics for each stakeholder. Theoretically, the result will be represented as $C = \{C_1, C_2, \ldots, C_i, \ldots, C_n\}$, where C_i is the *ith* characteristic of each stakeholder to be considered.

Step 2. Estimate the level of preference for each characteristic to form a reciprocal matrix category (see Tables 3 and 4), where P is the preference condition of stakeholders expressed by a subset, C_i is the *ith* characteristic to be considered and $l_i \in [0, 1]$; $i = 1, 2, \ldots, n$ is the quotient that determines the time of preference for the *ith* characteristic.

Note that the importance of characteristics is assessed through a multi-person analysis, where several experts provide opinions. To this effect, we can use a wide range of aggregation operators including a weighted average, an ordered weighted average (OWA) (Yager, 1988), a weighted ordered weighted average (WOWA) (Merigó, 2011; Torra, 1997; Xu and Da, 2003), a probabilistic weighted average (Merigó, 2013; Merigó et al., 2016) and unified aggregation operators (Merigó et al., 2015).

Definition 6. A weighted average is defined by:

$$WA\,(C_1^i, C_2^i, \ldots, C_n^i) = \sum_{h=1}^{m} v_h C_h^i \,, \tag{14}$$

where C_h^i is the importance given by the *hth* expert about the *ith* characteristic, and v_h is the importance of the *hth* expert with $v_h \in [0, 1]$ with $\sum_{h=1}^{m} v_h = 1$.

Note that if $v_h = 1/m$, all experts are equally important to the analysis, and the multi-person aggregation is performed via an arithmetic average. However, we may encounter scenarios where the experts' importance is unknown. Thus, we need to use a different approach to aggregating data, e.g., with the OWA operator.

Definition 7. The OWA operator considers a parameterised family of aggregation operators between the minimum and the maximum, as follows:

$$OWA\,(C_1^i, C_2^i, \ldots, C_n^i) = \sum_{j=1}^{m} w_j b_j \,, \tag{15}$$

where b_j is the *jth* largest of the C_h^i, and $w_j \in [0, 1]$ with $\sum_{j=1}^{m} w_j = 1$.

Note that a more general approach could be developed by using the WOWA operator (also known as OWAWA operator) in the following way:

Definition 8. WOWA operator is defined as follow:

$$WOWA\,(C_1^i, C_2^i, \ldots, C_n^i) = \sum_{j=1}^{m} \hat{v}_j b_j \;, \tag{16}$$

where b_j is the jth largest of the C_h^i, each characteristic C_h^i has an associated weight v_h with $\sum_{h=1}^{m} v_h = 1$ and $v_h \in [0, 1]$, $\hat{v}_j = \beta w_j + (1-\beta) v_j$ with $\beta \in [0, 1]$, v_j is the weight v_h ordered according to b_j, that is, according to the jth largest of the C_h^i, and $w_j \in [0, 1]$ with $\sum_{j=1}^{m} w_j = 1$, representing the OWA weights.

Note that if $\beta = 1$, the WOWA operator is identical to OWA, while if $\beta = 0$, we obtain a weighted average. Numerous other extensions could be developed in the same manner, following the current developments in the aggregation operator literature (Emrouznejad and Marra, 2014; Yager et al., 2011; Zeng et al., 2012).

Step 3. Determine the criteria levels of importance for each stakeholder and the current environment to form the actual condition of each stakeholder (see Tables 5 and 6), where Q is the level of importance according to a fuzzy subset, C_i is the *ith* characteristic to be considered and $k_i \in [0, 1]$; i = 1, 2, ... , n is the valuation, a number between 0 and 1, of the *ith* characteristic.

Note that in this new approach with a multi-person analysis, the level of importance can be obtained in two different ways. The first is the classical method by which we only add a previous calculation in Step 2 by aggregating the experts' information. This is the common process for all aggregation operators mentioned. However, in case of the weighted average, it is also possible to have all processes analysed by different experts, obtaining a level of importance for each stakeholder and for each expert. Having obtained such information, we aggregate the data of experts, forming a collective level of importance that is equivalent to that of the classical method.

Step 4. Determine eigenvalues and eigenvectors in order to find the dominant eigenvalue and the dominant eigenvector. In this step, the largest eigenvalue and the dominant eigenvector are used to establish a fuzzy relative importance matrix, which is used to define a fuzzy relative intensity matrix.

Step 5. Strategic decisions are made according to results obtained during the preceding steps. In the final step, the decision as to the strategy position of the stakeholder network should be made. It is worth noting that adoption of strategic decisions is based on analysing the position that best fits the firm's interests.

4. A numerical example

In this section, we present an application of the new approach proposed above. The primary advantage of using the ordering importance of characteristics algorithm and linking relationships is being able to parameterise the importance of information for each characteristic and order characteristics according to the intensity of relation. The application is focused on use of attributes, i.e., characteristics, for evaluating stakeholder dynamics. The design of the proposed approach consists of three steps, as follows:

Step 1. The attributes (Mitchell et al. 1997) of each stakeholder category (Fassin, 2009) are determined from the perspective of a group of experts. Based on the specific circumstances of the firm's immediate environment, it is assumed that senior management wants to analyse the relationships with specific stakeholders according to the dominance of the *power/influence* (P) characteristic. Similarly, it is also assumed that senior management wants to consider the importance of the firm's environment (L_{IE}), defined according to stakeholder categories: R_S being the genuine stakeholders, S_W being the stake-watchers and S_K representing the stake-keepers (see Table 1). Each characteristic of the set of stakeholders is considered a property. This first step allows us to make a holistic appraisal of the firm's immediate environment, as it takes into account each category and subset of stakeholders around the firm.

Table 1. Characteristics and categories of each stakeholder group

Category		**Stakeholders**	**Kind of relation**	**Characteristic**
Real Stakeholders	*a*	Firm	Growth business	P
	b	Employees	Labour laws	P
	c	Business	Contracts and agreements	P
	d	Financers	Owners or investors	P
	e	Customers	Users, customers	P
	f	Communities and Society	Local government, Location, community	P
Stakewatchers	*g*	Unions and association	Unions and Safety groups	P
	h	Competitors	Marked, competitors	P
	i	Institutions and Auditors	Institutional investors	P
	j	Customers Associations	Customer advocate group	P
	k	Public interest Public	Public interest group	P
Stakekeepers	*l*	Local and national organization	Business activities control	P
	m	Media and others	Diffuser and observer	P
	n	International Commission	Ranking agencies and security analysts	P
	o	Government state	Legal activities control	P
	p	Civil Society	Civil, environmental and human rights advocates	P

Step 2. The level of preference for each characteristic is determined to define the reciprocal matrix category. Here, each estimate of a characteristic could be composed of a quality- or quantity-related dataset, i.e., statistics, reports and information from surveys, all of which are as guidance by the CEO. It is assumed that senior management suggests the estimates of the power characteristic for each stakeholder (see Table 3) to define the subjective preference matrix for each stakeholder (see Table 4). Note that information is assessed by a group of five experts that gives their opinion about the results. We assume that the five experts are equally important. Thus, we use an arithmetic average to aggregate their information. In other words, following Eq. 14, we use $V = (0{,}2;\ 0{,}2;\ 0{,}2;\ 0{,}2;\ 0{,}2)$. The results are shown in Tables 2 and 3.

Table 2. Estimation of the characteristics according to the opinion given by the experts

Stakeholder	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
Power – Expert 1	0,9	0,3	0,9	0,6	0,5	0,6	0,3	0,6	0,9	0,3	0,6	0,7	0,7	0,5	0,8	0,6
Power – Expert 2	1	0,5	0,7	0,9	0,8	0,7	0,5	0,8	0,7	0,4	0,7	0,8	0,6	0,9	0,8	0,9
Power – Expert 3	0,8	0,6	0,8	0,9	0,7	0,8	0,2	0,8	0,8	0,4	0,3	0,7	0,7	0,8	0,6	0,7
Power – Expert 4	0,8	0,3	0,7	0,7	0,8	0,4	0,5	0,5	0,5	0,3	0,4	0,9	0,8	0,7	0,9	0,6
Power – Expert 5	1	0,3	0,9	0,9	0,7	0,5	0,5	0,8	0,6	0,1	0,5	0,9	0,7	0,6	0,9	0,7

Table 3. Estimation of the characteristics – Collective results

Stakeholder	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
Power	0,9	0,4	0,8	0,8	0,7	0,6	0,4	0,7	0,7	0,3	0,5	0,8	0,7	0,7	0,8	0,7

Table 4. Subjective preference matrix

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
a	1	2,25	1,13	1,13	1,29	1,50	2,25	1,29	1,29	3,00	1,80	1,13	1,29	1,29	1,13	1,29
b	0,44	1	0,50	0,50	0,57	0,67	1,00	0,57	0,57	1,33	0,80	0,50	0,57	0,57	0,50	0,57
c	0,89	2,00	1	1,00	1,14	1,33	2,00	1,14	1,14	2,67	1,60	1,00	1,14	1,14	1,00	1,14
d	0,89	2,00	1,00	1	1,14	1,33	2,00	1,14	1,14	2,67	1,60	1,00	1,14	1,14	1,00	1,14
e	0,78	1,75	0,88	0,88	1	1,17	1,75	1,00	1,00	2,33	1,40	0,88	1,00	1,00	0,88	1,00
f	0,67	1,50	0,75	0,75	0,86	1	1,50	0,86	0,86	2,00	1,20	0,75	0,86	0,86	0,75	0,86
g	0,44	1,00	0,50	0,50	0,57	0,67	1	0,57	0,57	1,33	0,80	0,50	0,57	0,57	0,50	0,57
h	0,78	1,75	0,88	0,88	1,00	1,17	1,75	1	1,00	2,33	1,40	0,88	1,00	1,00	0,88	1,00
i	0,78	1,75	0,88	0,88	1,00	1,17	1,75	1,00	1	2,33	1,40	0,88	1,00	1,00	0,88	1,00
j	0,33	0,75	0,38	0,38	0,43	0,50	0,75	0,43	0,43	1	0,60	0,38	0,43	0,43	0,38	0,43
k	0,56	1,25	0,63	0,63	0,71	0,83	1,25	0,71	0,71	1,67	1	0,63	0,71	0,71	0,63	0,71
l	0,89	2,00	1,00	1,00	1,14	1,33	2,00	1,14	1,14	2,67	1,60	1	1,14	1,14	1,00	1,14
m	0,78	1,75	0,88	0,88	1,00	1,17	1,75	1,00	1,00	2,33	1,40	0,88	1	1,00	0,88	1,00
n	0,78	1,75	0,88	0,88	1,00	1,17	1,75	1,00	1,00	2,33	1,40	0,88	1,00	1	0,88	1,00
o	0,89	2,00	1,00	1,00	1,14	1,33	2,00	1,14	1,14	2,67	1,60	1,00	1,14	1,14	1	1,14
p	0,78	1,75	0,88	0,88	1,00	1,17	1,75	1,00	1,00	2,33	1,40	0,88	1,00	1,00	0,88	1

Step 3. The levels of importance of each stakeholder and the current environment, defining the actual condition of each stakeholder is to be determined. It is assumed that a group of experts suggest the level of importance of each stakeholder and category (see Tables 5 and 6) based on external information and the experts' experience and criteria.

Table 5. Level of importance for each stakeholder

Stakeholder	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
$\mathbf{L_{IS}}$	0,09	0,04	0,08	0,08	0,07	0,06	0,04	0,07	0,07	0,03	0,05	0,08	0,07	0,07	0,08	0,07

Table 6. Level of importance of the environment

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
Category	Real Stakeholders						Stakewatchers						Stakekeepers			
L_{IE}	0,7						0,3	0,7	0,5	0,2	0,7	0,7	0,7	0,2	0,8	0,7

4.1. Results

The primary results of fuzzy matrix calculation that allow establishing the importance and intensity relations among stakeholders are shown as follows: the relative level of importance (RL_I) is obtained by multiplication of each level of importance of each stakeholder (L_{IS}) and the level of importance of the environment (L_{IE}) of each stakeholder category (see Table 7). To determine the dominant eigenvalue (E_{va}) and the dominant eigenvector ($V^{(c)}$), the main fuzzy matrix is multiplied by RL_I (see Table 8). To determine the fuzzy relative importance matrix (FRI_M), the main fuzzy matrix is multiplied by normalised $V^{(c)}$ (see Table 9), while to obtain the fuzzy relative intensity matrix ($FRIn_M$), FRI_M is processed through the max-min composition (see Table 10). Finally, Figures 1 and 2 show visual diagrams of the resulting linking relationship and its intensity.

Table 7. Relative level of importance

	$\mathbf{R_S}$						$\mathbf{S_W}$						$\mathbf{S_K}$			
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
L_{IS}	0,09	0,04	0,08	0,08	0,07	0,06	0,04	0,07	0,07	0,03	0,05	0,08	0,07	0,07	0,08	0,07
L_{IE}	0,7						0,3	0,7	0,5	0,2	0,7	0,7	0,7	0,2	0,8	0,7
RL_I	0,06	0,03	0,05	0,05	0,05	0,04	0,01	0,05	0,03	0,01	0,03	0,05	0,05	0,01	0,06	0,05

Table 8. Eigenvector and Eigenvalue

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
(E_{va})	16,000	7,111	14,222	14,222	12,444	10,667	7,111	12,444	12,444	5,333	8,889	14,222	12,444	12,444	14,222	12,444
($V^{(c)}$)	1	0,444	0,889	0,889	0,778	0,667	0,444	0,778	0,778	0,333	0,556	0,889	0,778	0,778	0,889	0,778
(N)	0,086	0,038	0,076	0,076	0,067	0,057	0,038	0,067	0,067	0,029	0,048	0,076	0,067	0,067	0,076	0,067

N Note that the dominant eigenvector has been normalized (N) to determine the weight of each stakeholder. Notation: Dominant Eigenvalue (E_{va}); Dominant Eigenvector ($V^{(c)}$); Normalizing (N).

Table 9. Fuzzy relative importance matrix

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
a	1	0,193	0,096	0,096	0,11	0,129	0,193	0,11	0,11	0,257	0,154	0,096	0,11	0,11	0,096	0,11
b	0,017	1	0,019	0,019	0,022	0,025	0,038	0,022	0,022	0,051	0,03	0,019	0,022	0,022	0,019	0,022
c	0,068	0,152	1	0,076	0,087	0,102	0,152	0,087	0,087	0,203	0,122	0,076	0,087	0,087	0,076	0,087
d	0,068	0,152	0,076	1	0,087	0,102	0,152	0,087	0,087	0,203	0,122	0,076	0,087	0,087	0,076	0,087
e	0,052	0,117	0,058	0,058	1	0,078	0,117	0,067	0,067	0,156	0,093	0,058	0,067	0,067	0,058	0,067
f	0,038	0,086	0,043	0,043	0,049	1	0,086	0,049	0,049	0,114	0,069	0,043	0,049	0,049	0,043	0,049
g	0,017	0,038	0,019	0,019	0,022	0,025	1	0,022	0,022	0,051	0,03	0,019	0,022	0,022	0,019	0,022
h	0,052	0,117	0,058	0,058	0,067	0,078	0,117	1	0,067	0,156	0,093	0,058	0,067	0,067	0,058	0,067
i	0,052	0,117	0,058	0,058	0,067	0,078	0,117	0,067	1	0,156	0,093	0,058	0,067	0,067	0,058	0,067
j	0,01	0,021	0,011	0,011	0,012	0,014	0,021	0,012	0,012	1	0,017	0,011	0,012	0,012	0,011	0,012
k	0,026	0,06	0,03	0,03	0,034	0,04	0,06	0,034	0,034	0,079	1	0,03	0,034	0,034	0,03	0,034
l	0,068	0,152	0,076	0,076	0,087	0,102	0,152	0,087	0,087	0,203	0,122	1	0,087	0,087	0,076	0,087
m	0,052	0,117	0,058	0,058	0,067	0,078	0,117	0,067	0,067	0,156	0,093	0,058	1	0,067	0,058	0,067
n	0,052	0,117	0,058	0,058	0,067	0,078	0,117	0,067	0,067	0,156	0,093	0,058	0,067	1	0,058	0,067
o	0,068	0,152	0,076	0,076	0,087	0,102	0,152	0,087	0,087	0,203	0,122	0,076	0,087	0,087	1	0,087
p	0,052	0,117	0,058	0,058	0,067	0,078	0,117	0,067	0,067	0,156	0,093	0,058	0,067	0,067	0,058	1

Table 10. Fuzzy relative intensity matrix

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*
a	1	0,193	0,096	0,096	0,110	0,129	0,193	0,110	0,110	0,257	0,154	0,096	0,110	0,110	0,096	0,110
d	0,068	0,152	0,076	1	0,087	0,102	0,152	0,087	0,110	0,203	0,122	0,076	0,087	0,087	0,087	0,087
c	0,068	0,152	1	0,076	0,087	0,102	0,152	0,087	0,087	0,203	0,122	0,076	0,087	0,087	0,087	0,087
l	0,068	0,152	0,076	0,076	0,087	0,102	0,152	0,087	0,087	0,203	0,122	1	0,087	0,087	0,087	0,087
o	0,068	0,152	0,076	0,076	0,087	0,102	0,152	0,087	0,087	0,203	0,122	0,076	0,087	0,087	1	0,087
m	0,068	0,117	0,076	0,076	0,087	0,087	0,117	0,076	0,087	0,156	0,093	0,076	1	0,087	0,087	0,087
e	0,067	0,117	0,067	0,067	1	0,078	0,117	0,067	0,067	0,156	0,093	0,067	0,067	0,067	0,067	0,067
h	0,067	0,117	0,067	0,067	0,067	0,078	0,117	1	0,067	0,156	0,093	0,067	0,067	0,067	0,067	0,067
n	0,067	0,117	0,067	0,067	0,067	0,078	0,117	0,067	0,067	0,156	0,093	0,067	0,067	1	0,067	0,067
p	0,067	0,117	0,067	0,067	0,067	0,078	0,117	0,067	0,067	0,156	0,093	0,067	0,067	0,067	0,067	1
i	0,067	0,117	0,067	0,067	0,067	0,040	0,117	0,067	1	0,156	0,093	0,067	0,067	0,067	0,067	0,067
f	0,049	0,086	0,049	0,049	0,049	1	0,086	0,049	0,049	0,114	0,069	0,049	0,049	0,049	0,049	0,049
k	0,040	0,060	0,040	0,040	0,040	0,040	0,060	0,040	0,040	0,079	1	0,040	0,040	0,040	0,040	0,040
g	0,030	0,038	0,030	0,030	0,030	0,030	1	0,030	0,030	0,051	0,030	0,030	0,030	0,030	0,030	0,030
b	0,030	1	0,030	0,030	0,030	0,030	0,038	0,030	0,030	0,051	0,030	0,030	0,030	0,030	0,030	0,030
j	0,021	0,021	0,021	0,021	0,021	0,021	0,021	0,021	0,021	1	0,021	0,021	0,021	0,021	0,021	0,021

4.2. Analysis of results

Fuzzy matrices show how ambiguity and fuzziness of stakeholders and a subjective appraisal of the decision maker can be managed. Fuzzy matrices of FRI_M and $FRIn_M$ for each stakeholder are obtained from the dominant eigenvalue and eigenvector. Each matrix takes into account that the relationship of each stakeholder with itself is total, i.e., all vertices have loops equals 1.

First, the values, colours and a semantic scale used to show the intensity of relationships, representing the different degrees of intensity, need to be defined. According to the scale, if there is a significantly intense relationship represented by the value of 10, it is highlighted in green colour and implies that the respective stakeholder is very powerful/influential. On the other hand, a moderately intense relationship is represented by values between 6 and 9, is highlighted in colours ranging from greenish yellow to light green, and implies that the stakeholder has substantial power/influence. An equally intense relationship is represented by the value of 5, is highlighted in yellow colour and implies that both parties are equally powerful/influential. Similarly, a relationship of weak intensity could be represented by a value between 4 and 1, is highlighted in colours ranging between light yellow and light orange, and implies a low level of power/influence. Finally, a relationship with an insignificant intensity relationship is represented by the value of 0, is highlighted in orange colour, and implies a negligible level of power/influence. Therefore, a stakeholder shown in a colour nearest to orange possesses the lowest intensity of power. Several intensity relations are shown according to this scale.

Table 11. Scale of intensity degree

Value scale	Colour scale	Semantic scale
10		Huge powerful/influential
9		Practically to be powerful/influential
8		Almost to be powerful/influential
7		Quite to be powerful/influential
6		More to be powerful/influential
5		Equally to be powerful/influential
4		Fewer to be powerful/influential
3		Partly to be powerful/influential
2		Almost without to be powerful/influential
1		Far to be powerful/influential
0		Tiny power/influence

The fuzzy matrix $FRIn_M$ is shown according to the above scale, illustrating the power/influence relationship intensity of each stakeholder (see Figure 1). First, the figure shows the ranking of the intensity of relationships in descending order, where *a* has a significantly and moderately intense relationship, indicating its huge power/influence over others. Similarly, it is seen that stakeholders, *d, c, l, o* and *m* have a moderately intense relationship, indicating a certain amount of influence due to the power exercised. On the other hand, it is seen that stakeholders *e, h, n, p* and *i* have a moderately and weakly intense relationship, indicating a lower power/influence over others. Finally, *f, k, g, b* and *j* have an insignificantly intense relationship, indicating a negligible amount of power/influence. Thus, results show to the differences in the analysis depending on the appraisal by the CEO of the available information.

Figure 1. Depict of relative intensity of the relationships

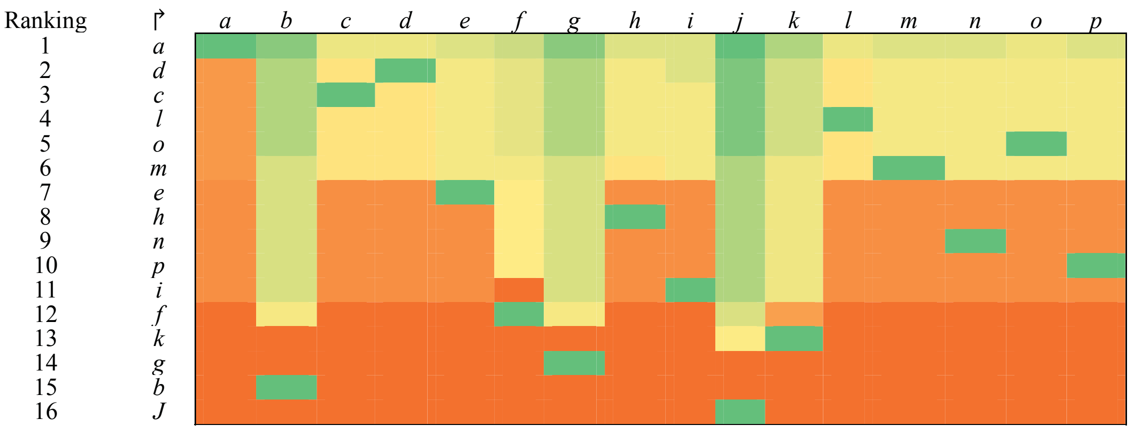
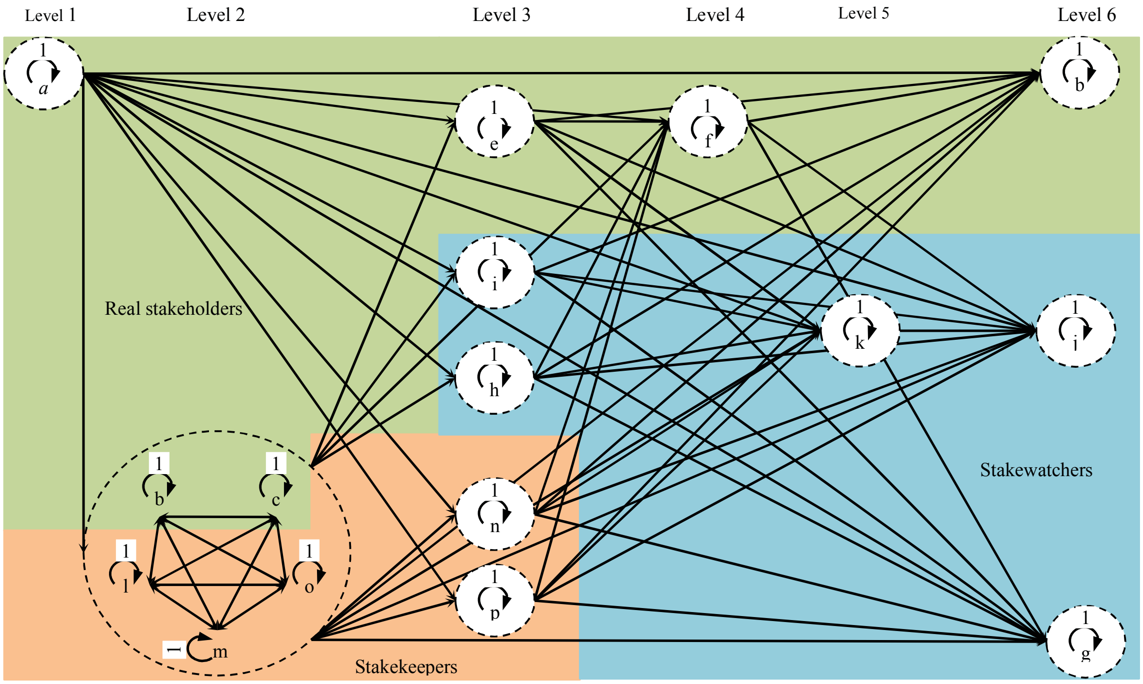


Figure 2 shows ordered relationships of the fuzzy matrix FRI_M to illustrate the dynamic relationships between stakeholders. The ordered relationship is given by $\alpha = 0.07$, considered as the threshold for the desired level of importance. In this case, the importance of grouping of indifferent elements (IE) is highlighted, as there are several groups of IE and a single closed loop. On the one hand, a circuit between several stakeholders *b, c, l, m* and *o* is observed, which is explained as an equivalency class or a set of strongly connected relations (Gil-Aluja, 1999). Indeed, linking relationships and an equivalency class denote the incidence, importance and intensity of relations for each vertex. On the other hand, the figure shows unidirectional relations from *a* and a closed loop, containing *e, i, h, n, p, f, k, b, j* and *g,* which are explained as a relation of significantly stronger influence over others. Furthermore, it shows several levels, where level 1 is the most influential and level 6 is the least influential, in turn, illustrating the position of power of each category within the system. Therefore, the levels of incidence and importance can be weakened and strengthened.

Figure 2. Graph of the relative importance of the relationships



In conclusion, using this tool, we have compared and related each stakeholder to obtain the relative intensity and importance of relationships among them. On the one hand, the relative intensity is given by fuzzy matrix $FRIn_M$, which depicts the relationships among each stakeholder through scale of intensity degree. This scale considers three ways of evaluating intensity, i.e., *value, colour* and *semantic*, allowing a better understanding of the relative intensity relationships. On the other hand, the relative importance is given by fuzzy matrix FRI_M, which shows graphically ordered relationships using the α value as a threshold for the desired level of importance. Additionally, influential levels are shown in descending order.

4.3. Implications and limitations

The proposed mathematical approximation provides a novel tool for the analysis of dynamic and uncertain processes involved in changing relationships between stakeholders. Indeed, other tools have been developed within stakeholder theory to evaluate the environment and identify the relationships between groups of stakeholders (Wagner et al., 2011). Among such tools, particularly prominent are the multi-criteria decision-making tool (Holz et al., 2006), the stakeholder analysis tool (Bourne and Walker, 2005), the network approach to interactions of stakeholders (Rowley and Moldoveanu, 2003; Rowley, 1997), cognitive mapping of stakeholders' mental models (Hjortsø et al., 2005), analysis of conflicts (Memon and Wilson, 2007), the multi-criteria analysis technique (MCAT) (Finn et al., 2009) and the Q methodology (Wolsink and Breukers, 2010). Such tools have difficulty defining boundaries and identifying the relevant stakeholders (Ramirez, 1999).

Accordingly, the main implication of the proposed approach is taking into account the importance of information to establish the boundaries and relationships of each characteristic according to its intensity. Additionally, it performs multiple comparisons between each characteristic of the information. The interests and opinions of decision makers can be parameterised. A mathematical application shows how each interest group could be classified and related according to subjective information. Similarly, relationships established between stakeholders are determined by power/influence and the position of each agent within the relationship network. Furthermore, dynamics of such relationships not only encourage competition but also contribute to improved competitiveness and productivity by fostering cooperation and the transfer of knowledge, and strengthening trust between the interested parties and the ties among them according to power/influence positions. Thus, a position of influence refers to groups or individuals that can affect or be affected by the organization, according to pragmatic aspects of the relationship between the stakeholders and the firm, i.e., a relationship determined by the market (Fassin, 2009; Freeman, 2011). Multiple relationships have a high degree of variation in the intensity of power/influence that can be explained by heterogeneity. Accordingly, the analysis focuses on the dynamics and the intensity of a relationship, which imply how stakeholders can affect or be affected by decisions or actions of an organisation within a dynamic and uncertain environment, resulting from factors such as globalization, improvements in information technology systems and technological changes.

For example, Apple Inc. is an American multinational company in the technology sector that designs and manufactures electronic equipment, software and online services and enjoys a significant presence and prestige worldwide due to the quality of its products and services. At the end of 2017, Apple Inc. faced customer complaints related to a slowdown of mobile devices. In this case, two agents, i.e., the customers and the company, are involved, with the relationship dynamics affected by company's decisions. The interactions also involve the third regulatory agent, namely, the government, which must protect the interests of society. Thus, the power/influence intensity and the dynamics of the relationship among the customers, the company and the government cause their respective positions to change, causing the ties to be in continuous tension and maintaining strong positions among the stakeholders. This situation has short-term effects that are not predictable. Likewise, the intensity of relations between agents is more dynamic from their positions of power where public opinion determines the effect on the reputation. Hence, the intensity and importance of the relationships is relative.

On the other hand, the primary limitations are in the empirical validation of the research itself, due to presenting a methodological proposal with a mathematical application. Similarly, there are methodological limitations, as subsequent to a mathematical proposition, a hypothetical example is shown to illustrate the operation of algorithms and in this case, to show how the subjectivity of decision-makers is parameterized. Additionally, such methodological limitations are clear, as we use as an example the power/influence relationships that exist between stakeholders, studied by the stakeholder theory. Thus, given the stated theoretical assumptions, a methodology has been proposed that tries to capture the impacts of the dynamic interaction between the environment and the companies.

5. Conclusions

We have focused on studying dynamic interactions of stakeholders to explain how a set of agents can act by considering the power/influence positions. We have considered the models of Freeman (1984) , Donaldson and Preston (1995) , Jones (1995) , Frooman (1999) , Friedman and Miles (2006) , Fassin (2009) , Savage et al. (2011) and Wagner et al. (2012) , that present various analysis methods that explain the relations of the stakeholders. Similarly, we have studied the literature on the decision-making under uncertainty, which offers a wide range of methods for processing subjective and objective information, personal preferences, attitudes and the resulting data. Based on the above, we have proposed a novel tool to analyse dynamic interactions for evaluating stakeholder dynamics through power relationships. This application uses the importance of characteristics algorithm in combination with composition max-min to compare, group and order information. Thus, a combination of these techniques can represent a holistic appraisal of the firm's immediate environment according to the relative level of importance. The method is called relative importance and relative intensity of characteristics.

We have developed a hypothetical mathematical example to show the feasibility and usefulness of this tool for evaluating dynamics of stakeholder relationships through power relationships. This tool allows comparing and relating each stakeholder, resulting in the relative intensity and importance of relationships among them. The relative intensity is given by a fuzzy matrix $FRIn_M$ that describes the relationships among all stakeholders in terms of a scale of variable intensity. Such a scale presents three ways of evaluating the intensity, namely, as a *value, a colour* and a *semantic* expression, allowing a better understanding of a relative intensity relationship. The relative importance is represented by the fuzzy matrix FRI_M, showing a graphically ordered relationship from α value as the threshold for the desired level of importance. Additionally, the influential levels are shown in the descending order. Thus, it is noteworthy that the proposed tool determines the boundaries and the relationship between each characteristic according to the intensity through multiple comparisons, taking into account the importance of information. Furthermore, it is shown each interest group could be classified and related according to the subjective information, the interests and opinions of the decision makers. Furthermore, it is noted that the relationships established between stakeholders are determined by power/influence and the position that each agent occupies within the network of relationships.

However, the methodological proposal has limitations due to the nature of this research, based on theoretical assumptions regarding stakeholders and the use of a hypothetical example to show the operation of algorithms. The theoretical assumptions include the focus on the position of influence referring to agents that can affect or be affected by other agents and the environment. A hypothetical mathematical proposition shows the operation of algorithms, which in this case seeks to show how the subjectivity of decision makers is parameterized. Thus, the primary limitation concerns the empirical validation of the research itself.

Finally, the importance of a relation can be shown by different degrees of intensity. Therefore, the proposed method enables us to analyse the firm's immediate environment, according to the appraisal of the CEO. Application of this novel method to strategic problems in business, such as planning management, strategy management, business ethics and corporate responsibility, can be considered. Similarly, in future research, we can explore and develop new extensions of this method by combining it with other techniques, e.g., aggregation operators or distance measures, offering the possibility to aggregate and compare information.

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