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A novel plithogenic TOPSIS- CRITIC model for sustainable supply chain risk management

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A R T I C L E I N F O

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A B S T R A C T

The trend of considering supply chain sustainability with an absence of attention to sustainability risks may disturb the business future. The role of risk management is concentrated in identifying and analyse the influence of loss to business, social and environment, get ready by coverage budget, and derive strategies to protect supply chain sustainability against these risks. Risk management assists the company's performance to be more confident in supply chain sustainability decisions. The extent of the risk is based on the organization's magnitude, so the sustainable supply chain risk management strategies of large firms require to be more advanced. The purpose of this research is the estimation of sustainable supply chain risk management (SSCRM). The proposed methodology in this paper is a combination of plithogenic multi-criteria decision-making approach based on the Technique in Order of Preference by Similarity to Ideal Solution (TOPSIS) and Criteria Importance Through Inter-criteria Correlation (CRITIC) methods. In order to evaluate the proposed model, we present a real-world case study of the Telecommunications Equipment Company. The results show the importance of each criterion to evaluate SSCRM and the ranking of the three telecommunications equipment categories.

1. Introduction

Recently, organizations are more considered in the environmental and social outcomes as well as the economic and financial aspects in order to keep on a sustainable supply chain. In addition, with growing knowledge of the impact to perform sustainable goals, sustainable supply chain management became a major interest in recent years. Because of competition increasing, the impact of globalization, diversity of technological solutions and unlimited customer expectations, the uncertainties and risks of the organization's supply chain were increased (Valinejad and Rahmani, 2018). That's why, attention to risk management has been increased to consider. uncertainty and unexpected issues in sustainable supply chain domain. Because of this large amount of uncertainty in many phases of supply chain management, any organization that focuses on outcomes and effectiveness with disregard risks that may influence its sustainability will face real instability issues (Dong and Cooper, 2016).

In order to achieve the financial and commercial developments, considering the environmental aspects is sufficient as considering of social and economic aspects, which is the aim of studying sustainable development (Valinejad and Rahmani, 2018). A more general description of sustainable supply chain could be: the management of supply chain activities in order to advance the profitability by taking in concern the environmental impacts and social aspects (Abdel-BassetMohamedet al., 2019). Thus, the supply chain sustainability ensure success and improvement of the whole supply chain management in the long term. That's why evaluation of the supply chain sustainability become a major interest to every successful business. In order to guarantee a sustainability of the supply chain, consideration of the risk management is a sufficient point.

There are many studies in this field that focus on risk management to obtain a sustainable supply chain. Behzadi, Golnar, et al. (2018) considered robustness and resilience as two main techniques for managing risk in the field of agricultural supply chain (Behzadi et al., 2018). Kara, M. E., et al. (2018) were employed a data mining framework for measuring different types of supply chain risks (Kara et al., 2018). Shojaei et al. (2019) proposed a comprehensive supply chain risk management approach for construction projects using grounded theory (GT) and fuzzy cognitive map (FCM) by considering the uncertain environment

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(Shojaei and Seyed Amin Seyed Haeri, 2019). Yang et al. (2019) focused on financial risk in the internet supply chain using data science analysis methods (Yang et al., 2019). Oliveira, Josenildo Brito, Et al. (2018) Improved that a combination of simulation-based optimization (S&O) models for supply chain risk management could advance the decision-making process (Oliveira et al., 2019). Xu, Ming, Et al. (2019) represented the supply chain sustainability risk management in two different views they are the deep-structure supply chain derived by simple products and the broad-structure supply chain derived by complex products (Xu et al., 2019).

In order to have better quality information for decision making to improve the supply chain sustainability, the uncertainty and risk factors must be defined and monitored. Sustainable supply chain risk management benefits the organization in different ways: Avoids resource consumption and reduce the costs by detecting the ensure steps, ability to have great responsiveness to an unexpected event, competence to satisfy customer satisfaction, and guarantee that the business will keep operating effectively. There are a lot of challenges and difficulties that facing the sustainable supply chain risk management such as deficiency of resource and tools that assist gathering and analyse the supply chain risks, organizations may have variant challenges that confuse define its risk factors, and sometimes the strong connections of supply chain may prevent the organization from detecting the points of risk that have.

Vagueness and uncertainty in the evaluation process are one of the major problems that may face decision-makers. Recent studies of evaluating sustainable supply chain risk management have some deficiency in the point of considering uncertain factors that prevent decision-making as desired. Also, there is an absence of considering the decision maker's priorities and contradiction degree between risk factors, which leads to inaccurate results. So, in this research, the proposed approach improved the level of consideration to uncertainty and provide high accuracy degree in decision-making problems. Plithogenic set is a generalization of neutrosophic set that deals with uncertainty and inconsistency of information, its more powerful in handling uncertain judgments by considers the truth-membership function, falsity-membership function, and indeterminacy-membership function.

Integrated plithogenic approach based on TOPSIS-CRITIC methods reinforce considering uncertainty and provide a great consistent and accurate measure of sustainability supply chain risk management. Our contribution of this paper is to construct a framework of sustainability supply chain risk management and the plithogenic TOPSIS-CRITIC method is used to focus on uncertainty environment as there's no other application used this technique in the field of SSCRM. In order to evaluate the accuracy and reliability of the proposed approach, it's applied to evaluate the sustainability of the supply chain risk management in telecommunication industry.

1.1. Objective

The main objective of this paper is to evaluate the sustainability supply chain risk management based on plithogenic set theory to define the most important risk factors and to rank the business alternatives based on these factors. To recognize this goal, we propose a combined plithogenic approach based on the TOPSIS-CRITIC method to measure the SSCRM factors. Using features of the plithogenic set operations improve the accuracy of assessment based on decision maker's evaluations. Plithogenic set is a generalization of a neutrosophic set that has a high level of uncertainty consideration which is very efficient in defines uncertain risk factors.

1.2. Organization

The remainder of the paper is organized as follows: Section 2, represents a literature review and related works on sustainability supply chain risk management. Information and definitions about methods and principles that used is described in Section 3. The proposed approach and its features and steps are clearly defined in Section 4. Section 5 presents the application of the proposed approach and discusses its results. Finally, the summarization of the work is presented in Section 6.

2. Related works

2.1. Supply Chain sustainability

Sustainable supply chain (SSC) is a large and interesting research field. In supply chain articles, sustainability was defined in different ways. Ahi, Payman, and Cory Searcy (2015) defines that three scopes of sustainability are measured in the supply chain, derived from customer and stakeholder desires, which are economic, environmental and social dimension to manage raw materials, information and finance flows (Ahi and Searcy, 2015). Closs, David J., Cheri Speier, and Nathan Meacham (2011) united in the opinion that SSC is the integration of economic, social, and environmental aspects of organization based on business process coordination in order to keep it sustainable at the long term (Closs and SpeierNathan, 2011). Jadhav et al. (2018) represent a literature review analysis that shows the function of supply chain orientation (SCO) in reaching supply chain sustainability (Jadhav et al., 2018). Chen et al. (2015) combined the fuzzy set theory, Delphi method, and discrete multi-criteria method to evaluate the sustainability of the minerals industry supply chain in China (Chen et al., 2015). The sustainable supply chain was improved based on customer awareness by Gong, 2019 and how much it has a significant impact on sustainability performance (Gong, 2019).

The supply chain sustainability evaluation is not enough to measure the performance without taking on consideration sustainability risk factors, that's why considering the risk management with supply chain sustainability performance is significant. The main phases of supply chain risk management are: identify the risk, risk assessment, investigation, handling, and monitoring (Giannakis and Papadopoulos, 2016). In this scope, Valinejad (2018) proposed a framework for managing the sustainability risks of the supply chain in the field of telecommunications supply chain (Valinejad and Rahmani, 2018). Deng Et al. explore risk countermeasures that improve supply chain sustainability for perishable products (Deng, 2019). Cunha et al. (2019) conducted a systematic literature review that considering the social risks that threat supply chain sustainability and their consequences to the organization and supply chain (Cunha et al., 2019).

2.2. Plithogenic set

Plithogeny refers to the generating, development, and evolution of new entities from the arrangement of contradictory or non-contradictory multiple old entities (Smarandache, 2017). It's a generalization of neutrosophy introduced by Smarandache (2017). A set of elements that characterization described by attribute values called plithogenic set. The contradiction degree $c(v_j,v_D)$ is one of the two main features of plithogenic set that compares between the attribute value v_j and the dominant (most important) attribute value v_{D}. The aim of the contradiction degree is to improve the accuracy of the results. This is the contribution of this study that considering the risk factors in the high level of uncertainty.

2.3. Multi-Criteria decision-making

Multi-criteria decision making (MCDM) is a popular crucial topic that aims to identify the most qualified alternative from a group of alternatives based on a set of criteria. It's a useful group of techniques that used in a wide decision-making problem types in the field of business, economics, management, social and others. MCDM has two types of techniques; the first one is human techniques that depend on human preferences like Analytic Hierarchy Process (AHP) and Best-Worst Method (BWM). The second is mathematical techniques based on mathematical operations such as Technique in Order of Preference by Similarity to Ideal Solution (TOPSIS). TOPSIS method is based on comparing the alternative solutions by the negative ideal solution (least preferred solution) and a positive ideal solution (most preferred solution) in order to select the optimal solution. Kwok Et al. (2019) proposed an efficient model that helps the traveller in decision making in accommodation selection problems based on the TOPSIS method (Kwok and Lau, 2019). In the field of supply chain management, dos Santos et al. (2019) proposed a model based on a hybrid Entropy-TOPSIS-F to evaluate and select a green supplier in the furniture industry (dos Santos et al., 2019). Yazdi (2018) hybrid TOPSIS method with intuitionistic fuzzy to assessing risks to improve the safety performance of organizations (Yazdi, 2018).

CRITIC is a useful method that identifies the objective weight of MCDM problems based on contrast intensity and the conflicting character of the evaluation criteria proposed by Diakoulaki et al. (1995) (Diakoulaki et al., 1995). Kozarević (2018) proposed a methodology that shows how to measure the practices and performance of the supply chain based on the fuzzy CRITIC method (Kozarević and Puška, 2018). To aggregate the benefits of plithogenic set features, TOPSIS and CRITIC method, this paper proposes integrated plithogenic TOPSIS-CRITIC approach to evaluate sustainable supply chain risk management, which will be discussed in more details in Section 4.

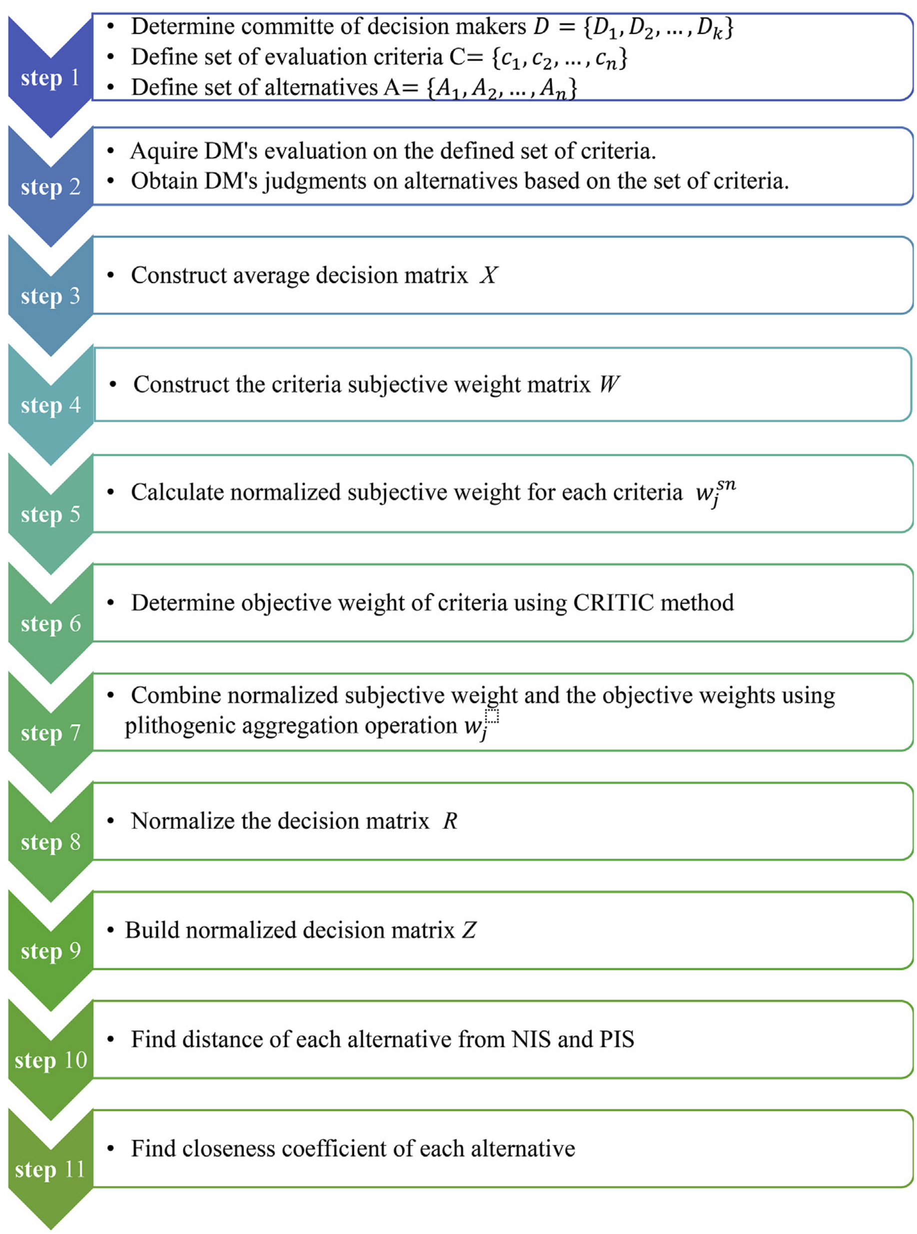

Fig. 1. Steps of the proposed model.

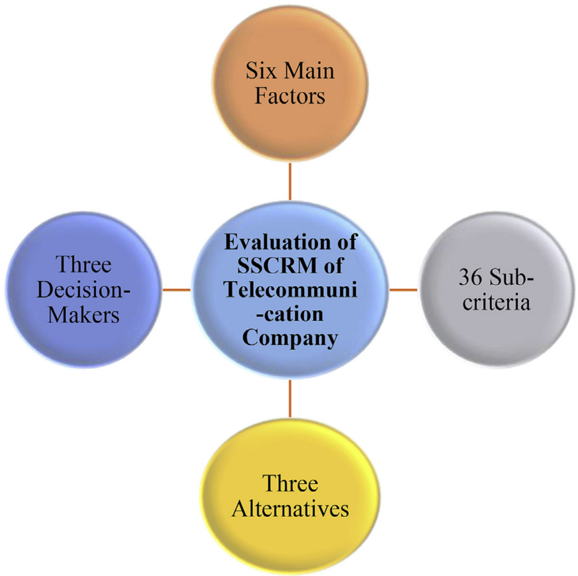

Fig. 2. Aspects of evaluation of SSCRM of telecommunication company.

3. Methods

3.1. Neutrosophic set

Neutrosophic is a new branch of philosophy introduced by Florentin Smarandache (1980) in order to study the origin and the nature of entities and their interaction with different intellectual visions. Neutrosophic set definitions are clearly stated in the following:

- **Definition 1.** Let *X* be a set of elements and $x \in X$. A neutrosophic set *A* in *X* is known by a truth-membership function TN(x), an indeterminacy-membership function IN(x) and a falsity-membership function FN(x), where TN(x), IN(x) and FN(x) are subsets of $]^-0, 1^+[$. TN (x): $X \rightarrow]^-0, 1^+[$, IN (x): $X \rightarrow]^-0, 1^+[$ and FN (x): $X \rightarrow]^-0,1^+[$. There is no restriction on summation of membership functions. Therefore, $0^- \leq$ sup TN(x) + sup IN(x) + sup FN(x) $\leq 3^+$.
- **Definition 2.** Let $\tilde{a} = (a1, a2, a3); \alpha, \theta, \beta$ be a single valued triangular neutrosophic set, with truth membership $T_a(x)$, indeterminate membership $I_a(x)$, and falsity membership function $F_a(x)$ as follows:

$$T_a(x) = \begin{cases} \alpha_a \left(\dfrac{x - a_1}{a_2 - a_1} \right) & if\ a_1 \leq x \leq a_2 \\ \alpha_a & if\ \ x = a_2 \\ o & otherwise \end{cases} \tag{1}$$

$$I_a(x) = \begin{cases} \dfrac{(a_2 - x + \theta_a(x - a_1))}{(a_2 - a_1)} & if\ a_1 \leq x \leq a_2 \\ \theta_a & if\ \ x = a_2 \\ \dfrac{(x - a_2 + \theta_a(a_3 - x))}{(a_3 - a_2)} & otherwise \end{cases} \tag{2}$$

$$F_a(x) = \begin{cases} \dfrac{(a_2 - x + \beta_a(x - a_1))}{(a_2 - a_1)} & if\ a_1 \leq x \leq a_2 \\ \beta_a & if\ \ x = a_2 \\ \dfrac{(x - a_2 + \beta_a(a_3 - x))}{(a_3 - a_2)} & if\ a_2 < x \leq a_3 \\ 1 & otherwise \end{cases} \tag{3}$$

where α_a, θ_a, $\beta_a \in [0,1]$, and they represent the highest truth membership degree, the lowest indeterminacy membership degree, and lowest falsity membership degree, respectively.

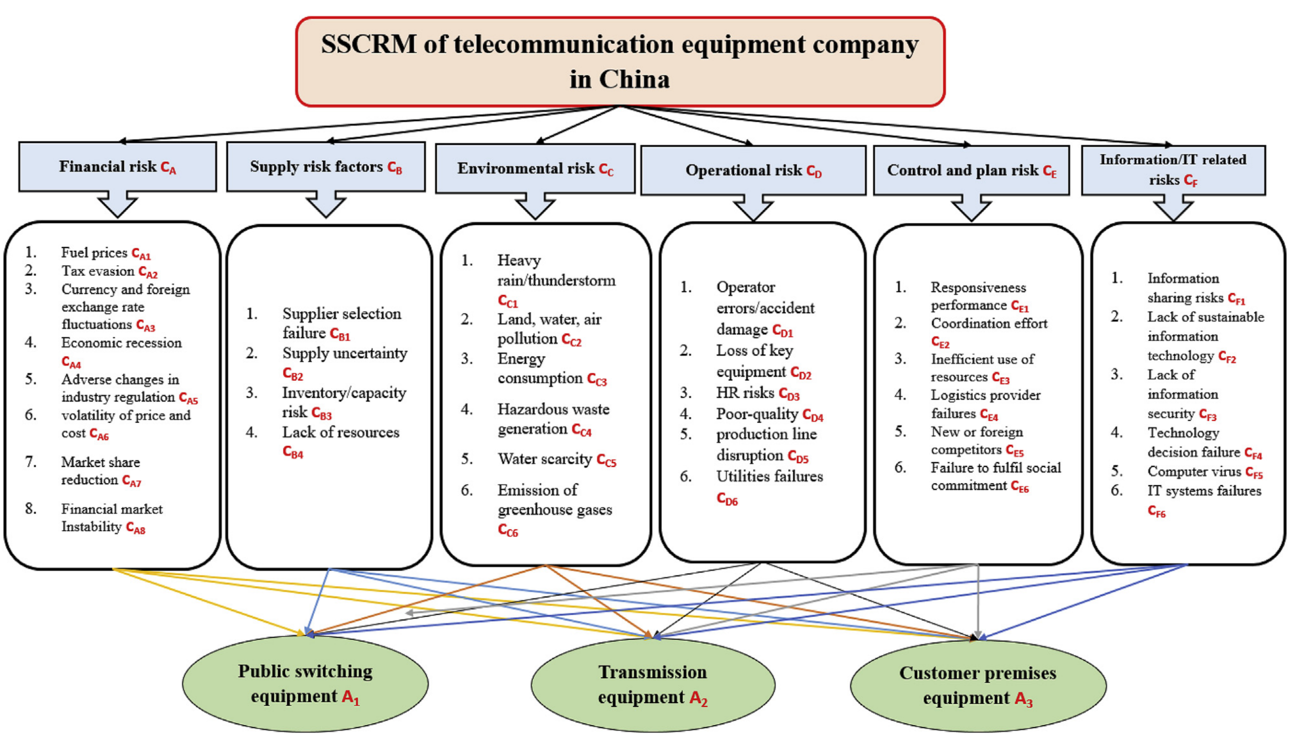

Fig. 3. Hierarchy of H company.

Table 1
Linguistic scale.

Importance Linguistic variable	Triangular neutrosophic scale	Rating Linguistic variable
Very Weakly important (VWI)	((0.10, 0.30,0.35), 0.1,0.2,0.15)	Nothing (N)
Weakly important (WI)	((0.15,0.25,0.10), 0.6,0.2,0.3)	Very Low (VL)
Partially important (PI)	((0.40,0.35,0.50), 0.6,0.1,0.2)	Low (L)
Equal important (EI)	(0.65,0.60,0.70),0.8,0.1,0.1)	Medium (M)
Strong important (SI)	((0.70,0.65,0.80),0.9,0.2,0.1)	High (H)
Very strongly important (VSI)	((0.90,0.85,0.90),0.7,0.2,0.2)	Very high (VH)
Absolutely important (AI)	((0.95,0.90,0.95),0.9,0.10,0.10)	Absolute (A)

Table 2
DMs judgment on the criteria.

Criteria	DM_1	DM_2	DM_3
C_{A1}	PI	EI	PI
C_{A2}	SI	EI	EI
C_{A3}	WI	WI	SI
C_{A4}	SI	SI	VSI
C_{A5}	WI	WI	WI
C_{A6}	SI	EI	EI
C_{A7}	EI	PI	PI
C_{A8}	VSI	VSI	EI
C_{B1}	AI	AI	SI
C_{B2}	VSI	VSI	SI
C_{B3}	PI	PI	EI
C_{B4}	WI	EI	WI
C_{C1}	WI	EI	EI
C_{C2}	SI	SI	EI
C_{C3}	EI	EI	SI
C_{C4}	SI	VSI	SI
C_{C5}	WI	VWI	EI
C_{C6}	VSI	SI	SI
C_{D1}	AI	VSI	SI
C_{D2}	VSI	AI	AI
C_{D3}	EI	SI	EI
C_{D4}	VSI	SI	SI
C_{D5}	EI	WI	EI
C_{D6}	AI	SI	AI
C_{E1}	EI	PI	PI
C_{E2}	WI	VWI	PI
C_{E3}	WI	PI	WI
C_{E4}	WI	EI	PI
C_{E5}	SI	EI	SI
C_{E6}	VSI	SI	SI
C_{F1}	EI	EI	SI
C_{F2}	SI	SI	VSI
C_{F3}	SI	PI	PI
C_{F4}	WI	EI	WI
C_{F5}	EI	PI	EI
C_{F6}	SI	EI	SI

- **Definition 3.** Let $\tilde{a} = (a1, a2, a3); \alpha_a, \theta_a, \beta_a$ and $\tilde{b} = (b1, b2, b3); \alpha_b, \theta_b, \beta_b$ be two single valued neutrosophic numbers. Then,

≻ Addition of two triangular neutrosophic numbers:

$$\tilde{a} + \tilde{b} = (a1 + b1, a2 + b2, a3 + b3); \alpha_a \cap \alpha_b, \theta_a \cup \theta_b, \beta_a \cup \beta_b \tag{4}$$

≻ Subtraction of two triangular neutrosophic numbers:

$$\tilde{a} - \tilde{b} = (a1 - b3, a2 - b2, a3 - b1); \alpha_a \cap \alpha_b, \theta_a \cup \theta_b, \beta_a \cup \beta_b \tag{5}$$

≻ Inverse of two triangular neutrosophic numbers:

$$\tilde{a}^{-1} = \left(\frac{1}{a3}, \frac{1}{a2}, \frac{1}{a1}\right); \alpha_a, \theta_a, \beta_a, \ Where\ (\tilde{a} \neq 0) \tag{6}$$

≻ Multiplication of two triangular neutrosophic numbers

$$\tilde{a}\tilde{b} = \begin{cases} (a1b1, a2b2, a3b3); \alpha_a \cap \alpha_b, \theta_a \cup \theta_b, \beta_a \cup \beta_b \ if \ (a3 > 0, b3 > 0) \\ (a1b3, a2b2, a3b1); \alpha_a \cap \alpha_b, \theta_a \cup \theta_b, \beta_a \cup \beta_b \ if \ (a3 < 0, b3 > 0) \\ (a3b3, a2b2, a1b1); \alpha_a \cap \alpha_b, \theta_a \cup \theta_b, \beta_a \cup \beta_b \ if \ (a3 < 0, b3 < 0) \end{cases} \tag{7}$$

≻ Division of two triangular neutrosophic numbers

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \left(\frac{a1}{b3}, \frac{a2}{b2}, \frac{a3}{b1}\right); \alpha_a \cap \alpha_b, \theta_a \cup \theta_b, \beta_a \cup \beta_b \ if \ (a3 > 0, b3 > 0) \\ \left(\frac{a3}{b3}, \frac{a2}{b2}, \frac{a1}{b1}\right); \alpha_a \cap \alpha_b, \theta_a \cup \theta_b, \beta_a \cup \beta_b \ if \ (a3 < 0, b3 > 0) \\ \left(\frac{a3}{b1}, \frac{a2}{b2}, \frac{a1}{b3}\right); \alpha_a \cap \alpha_b, \theta_a \cup \theta_b, \beta_a \cup \beta_b \ if (a3 < 0, b3 < 0) \end{cases} \tag{8}$$

3.2. Plithogenic set

A Plithogenic set *(P, A, V, d, c)* is a set that comprises various elements defined by a number of attributes A = {α_1, α_2, …, α_m}, $m \geq 1$, each attribute has a values V = {v_1, v_2, …, v_n}, for $n \geq 1$ (Smarandache, 2018a). Contradiction degree and appurtenance degree are the two main features that distinguish plithogenic set. The appurtenance degree function of element *x*, with respect to set of given criteria is noted as *d(x,v)* (Smarandache, 2018b). Contradiction (dissimilarity) degree function *c(v,D)*, which distinguishes between each attribute value and the dominant attribute value. Plithogenic set operations are intersection, union, complement, inclusion, and equality.

Let A be a non-empty set of uni-dimensional attributes A = {α_1, α_2, …, α_m}, $m \geq 1$, and let $\alpha \in A$ be an attribute with its value spectrum the set *S*, where S can be defined as a finite discrete set, $S = \{s_1, s_2, \ldots, s_l\}$, $1 \leq l < \infty$, or infinitely countable set $S = \{s_1, s_2, \ldots, s_\infty\}$, or infinitely uncountable (continuum) set $S =]a,b[$, $a < b$, with the range of all attributes values defined by experts based on the application, $V = \{v_1, v_2, \ldots, v_n\}$ for $n \geq 1$ (Smarandache, 2018). Based on the evaluation and the nature of the problem, decision-maker defines the dominant attribute value In the set *V* which represents the most important value.

The appurtenance degree *d(x,v)* of attribute value *v* is: $\forall x \in P$, $d: P \times V \rightarrow$ P $([0,1]^z)$, so *d(x, v)* is a subset of $[0,1]^z$, and P$([0,1]^z)$ is the power set of $[0,1]^z$, where z = 1, 2, 3, for fuzzy, intuitionistic fuzzy, and neutrosophic degrees of appurtenance respectively (Cunha et al., 2019).

The attribute value contradiction degree function $c(v_1, v_2)$ is *c:*

Table 3
Judgment of DMs on the alternatives based on the main criteria.

Criteria	DM_1			DM_2			DM_3		
	A_1	A_2	A_3	A_1	A_2	A_3	A_1	A_2	A_3
C_{A1}	L	M	M	L	VL	L	M	M	L
C_{A2}	L	L	M	M	L	M	L	H	M
C_{A3}	VL	L	VL	L	M	L	L	VL	L
C_{A4}	M	H	H	VH	H	H	VH	M	H
C_{A5}	L	L	VL	VL	L	VL	VL	L	L
C_{A6}	M	M	L	M	L	L	L	M	M
C_{A7}	L	L	M	M	M	L	L	M	M
C_{A8}	H	H	M	H	VH	H	VH	H	H
C_{B1}	H	VH	VH	A	H	H	VH	VH	VH
C_{B2}	H	M	VH	VH	H	VH	M	H	H
C_{B3}	L	M	M	M	L	L	M	M	L
C_{B4}	M	L	L	L	VL	L	M	L	L
C_{C1}	VL	L	L	L	M	M	L	L	M
C_{C2}	H	M	M	M	M	H	H	M	H
C_{C3}	M	M	H	H	H	M	H	H	H
C_{C4}	VH	VH	H	H	VH	H	H	VH	VH
C_{C5}	L	L	VL	L	L	L	VL	L	L
C_{C6}	H	H	H	VH	H	H	VH	H	H
C_{D1}	VH	VH	A	VH	A	A	H	VH	VH
C_{D2}	H	VH	VH	VH	A	A	VH	VH	VH
C_{D3}	M	H	H	H	M	M	M	H	H
C_{D4}	H	H	VH	VH	H	H	H	VH	VH
C_{D5}	L	L	L	M	L	L	L	M	L
C_{D6}	H	VH	VH	H	H	VH	VH	VH	VH
C_{E1}	L	L	M	M	L	L	M	L	L
C_{E2}	L	L	VL	VL	VL	L	L	L	VL
C_{E3}	VL	VL	L	L	L	L	VL	L	L
C_{E4}	L	L	M	L	M	L	VL	M	M
C_{E5}	M	L	L	M	M	L	L	L	M
C_{E6}	H	H	H	VH	H	H	VH	H	H
C_{F1}	M	L	L	M	M	L	L	L	M
C_{F2}	H	H	VH	VH	VH	H	H	H	VH
C_{F3}	L	L	M	M	L	H	M	M	M
C_{F4}	M	L	L	L	VL	L	M	L	L
C_{F5}	L	L	M	M	L	L	M	L	L
C_{F6}	H	H	M	M	H	M	M	H	M

$V \times V \rightarrow [0, 1]$, and satisfying the following axioms:

$c(v_1, v_1) = 0$, contradiction degree between the attribute values and itself is zero.
$c(v_1, v_2) = c(v_2, v_1$, representing the dissimilarity between two attribute values v_1 and v_2.

Contradiction degree function can be fuzzy C_F, intuitionistic attribute value contradiction function (C_{IF}: $V \times V \rightarrow [0, 1]^2$), or a neutrosophic attribute value contradiction function (C_N: $V \times V \rightarrow [0, 1]^3$).

3.3. Technique in Order of Preference by similarity to ideal solution (TOPSIS)

TOPSIS is a great mathematical MCDM technique used to solve decision-making problems in various fields and achieved impressive results in many researches. The main goal of this approach is to find the optimal solution through a set of defined criteria by measuring the distance of each alternative to a positive and negative ideal solution (Salih, 2018). The steps of TOPSIS is clearly defined as follows:

- Step 1: Define the problem that you need to know the optimal solution based on a set of alternatives and the set of criteria that alternatives will be judged based on them. Then conduct the decision matrix to evaluate each alternative based on defined criteria.
- Step 2: Normalize the decision matrix using TOPSIS vector normalization formula as shows in Equation (9).

$$R = (r_{ij})_{m \times n} = x_{ij} \Big/ \left(\sqrt{\sum_{i=1}^{m} x_{ij}^2} \right) \tag{9}$$

where x_{ij} is the score of alternative i under criterion j.

- Step 3: Build a weighted normalized decision matrix using Equation (10):

$$V = (v_{ij})_{m \times n} = w_j \times r_{ij} \text{ where } w_j \text{ is the weight of each criterion.} \tag{10}$$

- Step 4: Identify the positive ideal solution (PIS) and negative ideal solution (NIS) using the following equations 11–14:

Table 4
Average decision matrix.

Criteria	A_1	A_2	A_3
C_{A1}	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.48,0.48,0.5),0.73,0.13,0.17)	((0.48,0.43,0.57),0.67,0.1,0.17)
C_{A2}	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.5,0.23,0.6),0.7,0.13,0.17)	((0.65,0.6,0.7),0.8,0.1,0.1)
C_{A3}	((0.32,0.32,0.37),0.6,0.13,0.23)	((0.4,0.4,0.43),0.67,0.13,0.6)	((0.32,0.32,0.37),0.6,0.13,0.23)
C_{A4}	((0.82,0.77,0.83),0.73,0.17,0.17)	((0.68,0.63,0.77),0.87,0.17,0.1)	((0.7,0.65,0.80),0.9,0.2,0.1)
C_{A5}	((0.23,0.28,0.23),0.6,0.17,0.27)	((0.4,0.35,0.5),0.6,0.1,0.2)	((0.23,0.28,0.23),0.6,0.17,0.27)
C_{A6}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.57, 0.52,0.63),0.73,0.1,0.13)	((0.48,0.43,0.57),0.67,0.1,0.17)
C_{A7}	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.57,0.52,0.63),0.73,0.1,0.13)
C_{A8}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.68,0.63,0.77),0.87,0.17,0.1)
C_{B1}	((0.85,0.8,0.88),0.83,0.17,0.13)	((0.83,0.78,0.87),0.77,0.2,0.17)	((0.83,0.78,0.87),0.77,0.2,0.17)
C_{B2}	((0.73,0.68,0.77),0.77,0.13,0.13)	((0.68,0.63,0.77),0.87,0.17,0.1)	((0.83,0.78,0.87),0.77,0.2,0.17)
C_{B3}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.48,0.43,0.57),0.67,0.1,0.17)
C_{B4}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.32,0.32,0.37),0.6,0.13,0.23)	((0.40,0.35,0.5),0.6,0.1,0.2)
C_{C1}	((0.32,0.32,0.37),0.6,0.13,0.23)	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.57,0.52,0.63),0.73,0.1,0.13)
C_{C2}	((0.68,0.63,0.77),0.87,0.17,0.1)	((0.65,0.60,0.70),0.8,0.1,0.1)	((0.68,0.63,0.77),0.87,0.17,0.1)
C_{C3}	((0.68,0.63,0.77),0.87,0.17,0.1)	((0.68,0.63,0.77),0.87,0.17,0.1)	((0.68,0.63,0.77),0.87,0.17,0.1)
C_{C4}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.9,0.85,0.9),0.7,0.2,0.2)	((0.77,0.72,0.83),0.83,0.2,0.13)
C_{C5}	((0.32,0.32,0.37),0.6,0.13,0.23)	((0.4,0.35,0.50),0.6,0.1,0.2)	((0.32,0.32,0.37),0.6,0.13,0.23)
C_{C6}	((0.83,0.78,0.87),0.77,0.2,0.17)	((0.7,0.65,0.8),0.9,0.2,0.1)	((0.7,0.65,0.8),0.9,0.2,0.1)
C_{D1}	((0.83,0.78,0.87),0.77,0.2,0.17)	((0.92,0.87,0.92),0.77,0.17,0.17)	((0.93,0.88,0.93),0.83,0.13,0.13)
C_{D2}	((0.83,0.78,0.87),0.77,0.2,0.17)	((0.92,0.87,0.92),0.77,0.17,0.17)	((0.92,0.87,0.92),0.77,0.17,0.17)
C_{D3}	((0.46,0.26,0.73),0.83,0.13,0.1)	((0.68,0.63,0.77),0.87,0.17,0.1)	((0.68,0.63,0.77),0.87,0.17,0.1)
C_{D4}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.83,0.78,0.87),0.77,0.2,0.17)
C_{D5}	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.4,0.35,0.5),0.6,0.1,0.2)
C_{D6}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.83,0.78,0.87),0.77,0.2,0.17)	((0.9,0.85,0.9),0.7,0.2,0.2)
C_{E1}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.4,0.35,0.5),0.6,0.1,0.2)	((0.48,0.43,0.57),0.67,0.1,0.17)
C_{E2}	((0.32,0.32,0.37),0.6,0.13,0.23)	((0.32,0.32,0.37),0.6,0.13,0.23)	((0.23,0.28,0.23),0.6,0.17,0.27)
C_{E3}	((0.23,0.28,0.23),0.6,0.17,0.27)	((0.32,0.32,0.37),0.6,0.13,0.23)	((0.40,0.35,0.50),0.6,0.1,0.2)
C_{E4}	((0.32,0.32,0.37),0.6,0.13,0.23)	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.57,0.52,0.63),0.73,0.1,0.13)
C_{E5}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.48,0.43,0.57),0.67,0.1,0.17)
C_{E6}	((0.83,0.78,0.87),0.77,0.2,0.17)	((0.70,0.65,0.80),0.90,0.2,0.1)	((0.70,0.65,0.8),0.9,0.2,0.1)
C_{F1}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.48,0.43,0.57),0.67,0.1,0.17)
C_{F2}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.83,0.78,0.87),0.77,0.2,0.17)
C_{F3}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.67,0.62,0.73),0.83,0.13,0.1)
C_{F4}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.32,0.32,0.37),0.6,0.13,0.23)	((0.40,0.35,0.50),0.6,0.1,0.2)
C_{F5}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.40,0.35,0.50),0.6,0.1,0.2)	((0.48,0.43,0.57),0.67,0.1,0.17)
C_{F6}	((0.67,0.62,0.73),0.83,0.13,0.1)	((0.70,0.65,0.80),0.9,0.2,0.1)	((0.65,0.60,0.70),0.8,0.1,0.1)

$$A^+ = \{v_1^+, v_2^+, \ldots, v_n^+\} \quad (11)$$

$$v^+ = (max_i\ v_{ij}\ |j \in J_b), (min_i\ v_{ij} | J \in J_{nb})|\ \ \in [1 \ldots m]\ \} \quad (12)$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\} \quad (13)$$

$$v^- = (min_i v_{ij}\ |j \in J_b),\ (max_i\ v_{ij} | J \in J_{nb})|\ \ \in [1 \ldots m]\ \} \quad (14)$$

where J_b is a set of beneficial criteria, and J_{nb} is a set of non-beneficial criteria.

- Step 5: Use the formula of Euclidean distance to compute the distance of each alternative to the PIS and NIS to measure the separation of alternative i performance of to the PIS and NIS using Equations (15) and (16):

$$D_i^+ = \left[\sum_{j=1}^{m} \left(V_i - V_j^+ \right)^2 \right]^{0.5} \quad (15)$$

$$D_i^- = \left[\sum_{j=1}^{m} \left(V_i - V_j^- \right)^2 \right]^{0.5} \quad (16)$$

- Step 6: Find the closeness coefficient of each alternative based on Equation (17).

$$cc_i = \frac{S_i^-}{S_i^+ - S_i^-} \quad (17)$$

- Step 7: Rank alternatives based on the alternative with the highest closeness coefficient represents the optimal alternative.

3.4. Criteria Importance Through Inter-criteria Correlation (CRITIC)

CRITIC is a useful multi-criteria decision-making method that focuses on the objective weight of criteria, which signify the amount of information contained in each of them. This method is measuring the objective weight based on two dimensions of information emitted by criteria in the multi-criteria analysis. The first is the contrast intensity that illustrates each criterion separately. For quantifying the contrast intensity, the standard deviation is computed. The second dimension is the conflict between criteria, which is the main concept in MCDM that considered the core of each decision making, which measured by the linear correlation coefficient between criteria. The steps of the CRITIC method in details are:

- Step 1: Define a membership function x_j mapping the value of the criteria C_i to the interval $[0, 1]$. This step expresses the degree of how the alternative a is close to the ideal value f_j^*, which is the best performance of criterion j, and far from the anti-ideal value f_j^- which is the worst performance of criterion j. If the criteria j is beneficial, $f_j^* = max_i(C_j)$ and $f_j^- = min_i(C_j)$, and if j is non-

Table 5
Subjective weights, normalized subjective weights, and objective weights.

Criteria	Subjective weights	Normalized subjective weights	Objective weights
C_{A1}	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.022,0.021,0.025),0.025,0.018,0.031)	((0,0.007,0.02),0.02,0,0)
C_{A2}	((0.67,0.62,0.73),0.83,0.13,0.1)	((0.03,0.03,0.03),0.031,0.02,0.018)	((0.188,0.368,0.069),0.085,0.053,0)
C_{A3}	((0.33,0.38,0.33),0.7,0.2,0.23)	((0.015,0.018,0.014),0.026,0.036,0.04)	((0.007,0.007,0.005),0.016,0,0.332,0.0039)
C_{A4}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.036,0.035,0.036),0.031,0.036,0.023)	((0.034,0.023,0.030),0.068,0,0.062)
C_{A5}	((0.15,0.25,0.10), 0.6,0.2,0.3)	((0.007,0.012,0.004),0.022,0.036,0.054)	((0,0,0),0,0,0)
C_{A6}	((0.67,0.62,0.73),0.83,0.13,0.1)	((0.03,0.03,0.032),0.031,0.024,0.02)	((0.095,0.063,0.035),0.041,0,0)
C_{A7}	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.02,0.021,0.025),0.025,0.018,0.031)	((0.02,0.013,0.018),0.022,0,0.042)
C_{A8}	((0.82,0.77,0.83),0.73,0.17,0.17)	((0.038,0.037,0.036),0.027,0.031,0.031)	((0.019,0.013,0.019),0.027,0.024,0.026)
C_{B1}	((0.87,0.82,0.9),0.9,0.13,0.1)	((0.041,0.04,0.039),0.03,0.024,0.018)	((0.004,0.003,0.003),0,0.053,0)
C_{B2}	((0.83,0.78,0.87),0.77,0.2,0.17)	((0.039,0.038,0.038),0.028,0.036,0.031)	((0.035,0.023,0.065),0.037,0,0.053)
C_{B3}	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.022,0.021,0.025),0.025,0.018,0.031)	((0.02,0.014,0.019),0.022,0,0.041)
C_{B4}	((0.32,0.37,0.30),0.67,0.17,0.23)	((0.015,0.018,0.013),0.025,0.031,0.041)	((0.024,0.019,0.027),0.047,0.030,0.039)
C_{C1}	((0.48,0.48,0.5),0.73,0.13,0.17)	((0.022,0.023,0.022),0.027,0.024,0.031)	((0.029,0.019,0.035),0.043,0.017,0.05)
C_{C2}	((0.68,0.63,0.77),0.87,0.17,0.1)	((0.032,0.031,0.033),0.032,0.031,0.018)	((0.033,0.022,0.058),0.069,0.185,0)
C_{C3}	((0.67,0.62,0.73),0.83,0.13,0.1)	((0.03,0.03,0.032),0.031,0.024,0.018)	((0,0,0),0,0,0)
C_{C4}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.036,0.035,0.036),0.031,0.036,0.023)	((0.001,0,0.001),0.001,0,0.001)
C_{C5}	((0.3,0.38,0.38),0.5,0.17,0.18)	((0.014,0.018,0.016),0.018,0.031,0.032)	((0.006,0.02,0.028),0,0,0.016)
C_{C6}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.036,0.035,0.036),0.031,0.036,0.023)	((0.034,0.023,0.046),0.047,0,0.062)
C_{D1}	((0.85,0.80,0.88),0.83,0.17,0.13)	((0.04,0.039,0.038),0.031,0.031,0.023)	((0.002,0.001,0.032),0,0.118,0)
C_{D2}	((0.93,0.88,0.93),0.83,0.13,0.13)	((0.043,0.043,0.04),0.031,0.024,0.023)	((0.002,0.001,0.07),0,0.053,0)
C_{D3}	((0.67,0.62,0.73),0.83,0.13,0.1)	((0.031,0.03,0.032),0.031,0.024,0.018)	((0.008,0.012,0.026),0.032,0.079,0)
C_{D4}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.036,0.035,0.036),0.031,0.036,0.023)	((0.015,0.01,0.023),0.021,0,0.035)
C_{D5}	((0.48,0.48,0.5),0.73,0.13,0.17)	((0.022,0.023,0.022),0.027,0.024,0.031)	((0.008,0.007,0.005),0.025,0,0.013)
C_{D6}	((0.87,0.82,0.9),0.9,0.13,0.1)	((0.041,0.04,0.039),0.033,0.024,0.018)	((0.026,0.017,0.025),0,0,0)
C_{E1}	((0.48,0.43,0.57),0.67,0.1,0.17)	((0.022,0.021,0.025),0.025,0.018,0.031)	((0.031,0.021,0.035),0.041,0,0.052)
C_{E2}	((0.22,0.3,0.32),0.43,0.17,0.22)	((0.01,0.015,0.014),0.016,0.031,0.04)	((0.017,0.032,0.061),0,0.082,-0.023)
C_{E3}	((0.23,0.28,0.23),0.6,0.17,0.27)	((0.012,0.014,0.01),0.022,0.031,0.049)	((0.004,0.002,0.005),0,0.061,0.004)
C_{E4}	((0.4,0.4,0.43),0.67,0.13,0.2)	((0.019,0.019,0.019),0.025,0.024,0.036)	((0.005,0.035,0.003),0.060,0.017,0.007)
C_{E5}	((0.68,0.63,0.77),0.87,0.17,0.1)	((0.032,0.031,0.033),0.032,0.031,0.018)	((0.09,0.06,0.034),0.041,0,0)
C_{E6}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.036,0.035,0.036),0.031,0.036,0.023)	((0.034,0.023,0.045),0.047,0,0.062)
C_{F1}	((0.67,0.62,0.73),0.83,0.13,0.1)	((0.031,0.03,0.032),0.031,0.024,0.018)	((0.09,0.06,0.034),0.041,0,0)
C_{F2}	((0.77,0.72,0.83),0.83,0.2,0.13)	((0.036,0.035,0.036),0.031,0.036,0.023)	((0.015,0.01,0.023),0.021,0,0.035)
C_{F3}	((0.5,0.45,0.6),0.7,0.13,0.17)	((0.023,0.022,0.026),0.026,0.024,0.031)	((0.038,0.025,0.029),0.035,0.052,0.01)
C_{F4}	((0.32,0.37,0.30),0.67,0.17,0.23)	((0.015,0.018,0.013),0.025,0.031,0.04)	((0.024,0.019,0.027),0.047,0.03,0.039)
C_{F5}	((0.57,0.52,0.63),0.73,0.1,0.13)	((0.027,0.025,0.027),0.027,0.018,0.023)	((0.031,0.021,0.035),0.041,0,0.052)
C_{F6}	((0.68,0.63,0.77),0.87,0.17,0.1)	((0.032,0.0.031,0.033),0.03,0.031,0.018)	((0.019,0.006,0.012),0.001,0.145,0)

beneficial criterion then, $f_j^* = min_i(C_j)$ and $f_j^- = max_i(C_j)$. And generate a vector x_j for each criterion.

$$x_{aj} = \frac{Cj - f_j^-}{f_j^* - f_j^-} \tag{18}$$

- Step 2: Find the standard deviation σ_j to evaluate each criterion separately for each vector x_j.
- Step 3: Conduct a symmetric matrix with dimension $m \times m$ that represents the linear correlation coefficient between x_j and $x_{j'}$ which is noted as $r_{jj'}$.
- Step 4: To measure the conflict of criteria apply Equation (19).

$$\sum_{j'=1}^{m} (1 - r_{jj'}) \tag{19}$$

- Step 5: As mentioned before, this method is based in both contrast intensity and conflict of decision criteria, so compose them as Equation (20) shows:

$$C_j = \sigma_j \sum_{j'=1}^{m} (1 - r_{jj'}) \tag{20}$$

- Step 6: Normalize the value of information transmitted by each criterion according to the following equation:

$$w_j = \frac{C_j}{\sum_{j'=1}^{m} C_{j'}} \tag{21}$$

4. Proposed approach

In this paper, we propose a plithogenic CRITIC-TOPSIS approach to evaluate sustainable supply chain risk management. The importance of this approach lies in the high level of uncertainty consideration and improves the accuracy of the evaluation process. Plithogenic set aggregation features such as contradiction degree function to ensure more accurate results that excel on other researchers at the same point. TOPSIS basically focuses on evaluation of the set of criteria by comparing the alternatives with the best and worst solutions to find the optimal decision. CRITIC method identifies the objective weight based on contrast intensity and conflict character of the criteria. This approach combines the advantages of plithogenic aggregation operator, TOPSIS and CRITIC method to provide a sturdy model. Fig. 1 shows the phases of the proposed approach and its details will be mentioned in this section:

- ❖ Step 1: Based on the scope of the MCDM problem, determine committee of decision-makers to assist in the evaluation process $D = \{D_1, D_2, \ldots, D_k\}$. Define a set of criteria $C = \{c_1, c_2, \ldots, c_n\}$ and alternative $A = \{A_1, A_2, \ldots, A_n\}$.
- ❖ Step 2: Define the linguistic scale to evaluate the criteria and alternatives by DMs. In this approach, the triangular

Table 6
Results of plithogenic aggregation operation.

Criteria	Contradiction degree	aggregation	Crisp value
C_{A1}	0	((0,0.014,0.0445),0.0005,0.009,0.031)	0.014336
C_{A2}	0.028	((0.0114,0.2,0.094),0.006,0.037,0.0175)	0.074335
C_{A3}	0.056	((0.0013,0.0125,0.018),0.003,0.184,0.04)	0.007043
C_{A4}	0.083	((0.0068,0.029,0.06),0.01,0.018,0.08)	0.022839
C_{A5}	0.11	((0.0008,0.006,0.004),0.002,0.02,0.05)	0.002517
C_{A6}	0.14	((0.02,0.047,0.057),0.011,0.012,0.017)	0.030622
C_{A7}	0.17	((0.007,0.017,0.035),0.008,0.009,0.06)	0.014416
C_{A8}	0.19	((0.011,0.025,0.044),0.011,0.028,0.046)	0.019473
C_{B1}	0.22	((0.01,0.022,0.033),0.007,0.039,0.014)	0.015678
C_{B2}	0.25	((0.019,0.031,0.076),0.017,0.018,0.062)	0.030428
C_{B3}	0.28	((0.012,0.018,0.031),0.013,0.009,0.051)	0.014874
C_{B4}	0.31	((0.012,0.019,0.027),0.023,0.031,0.055)	0.014095
C_{C1}	0.33	((0.017,0.021,0.038),0.023,0.021,0.054)	0.018512
C_{C2}	0.36	((0.024,0.027,0.058),0.037,0.108,0.012)	0.026119
C_{C3}	0.39	((0.012,0.015,0.02),0.012,0.012,0.011)	0.011492
C_{C4}	0.42	((0.016,0.018,0.021),0.013,0.018,0.014)	0.013499
C_{C5}	0.44	((0.004,0.019,0.025),0.008,0.016,0.027)	0.011572
C_{C6}	0.47	((0.033,0.029,0.043),0.037,0.018,0.045)	0.025988
C_{D1}	0.5	((0.021,0.02,0.035),0.016,0.075,0.012)	0.01833
C_{D2}	0.53	((0.024,0.022,0.052),0.016,0.039,0.011)	0.024027
C_{D3}	0.56	((0.022,0.021,0.026),0.035,0.052,0.008)	0.0169
C_{D4}	0.58	((0.029,0.023,0.025),0.03,0.018,0.024)	0.019107
C_{D5}	0.61	((0.018,0.015,0.011),0.032,0.012,0.017)	0.010967
C_{D6}	0.64	((0.043,0.029,0.023),0.021,0.012,0.006)	0.02363
C_{E1}	0.67	((0.035,0.021,0.02),0.044,0.009,0.028)	0.01916
C_{E2}	0.69	((0.019,0.024,0.024),0.011,0.057,0.005)	0.015997
C_{E3}	0.72	((0.011,0.008,0.004),0.016,0.046,0.015)	0.005797
C_{E4}	0.75	((0.018,0.027,0.006),0.063,0.021,0.011)	0.01282
C_{E5}	0.78	((0.094,0.046,0.015),0.056,0.016,0.004)	0.039313
C_{E6}	0.81	((0.056,0.029,0.016),0.062,0.018,0.017)	0.025679
C_{F1}	0.83	((0.099,0.045,0.012),0.059,0.012,0.003)	0.039734
C_{F2}	0.86	((0.043,0.023,0.009),0.044,0.018,0.009)	0.018871
C_{F3}	0.89	((0.054,0.024,0.007),0.054,0.038,0.005)	0.02105
C_{F4}	0.92	((0.036,0.019,0.003),0.065,0.031,0.008)	0.014588
C_{F5}	0.94	((0.054,0.023,0.005),0.063,0.009,0.006)	0.020826
C_{F6}	0.97	((0.049,0.019,0.002),0.03,0.088,0.001)	0.016775

neutrosophic scale is defined (Table 1). Based on this scale, DMs evaluate the defined set of criteria and alternatives.

❖ Step 3: Construct the average decision matric (X) that integrates the DMs judgments of defined alternatives using Equations (22) and (23).

$$X = [x_{ij}]_{n\times m} \quad \text{where,} \tag{22}$$

$$x_{ij} = x_{ij}^{p} \Big/ k \tag{23}$$

where x_{ij}^{p} is the performance value of alternative A_i in regard to criteria C_j evaluated by decision-maker p.

❖ Step 4: Construct the subjective criteria weight's matrix (W) as shown in Equations (24) and (25).

$$W = \left[w_j^s\right]_{1\times m} \text{ where,} \tag{24}$$

$$w_j^s = w_{jp}/k \tag{25}$$

The weight of criteria C_j which is evaluated by DM p is denoted by w_{jp}.

❖ Step 5: Calculate normalized subjective weight for each criteria w_j^{sn} using Equation (26):

$$w_j^{sn} = w_j^s \Big/ \sum\nolimits_{j=1}^{m} w_j^s \tag{26}$$

❖ Step 6: Using CRITIC method, determine objective weight of criteria

- Define a membership function x_j using Equation (18) based on ideal and anti-ideal values.
- Find the standard deviation σ_j for each vector x_j.
- Compute the linear correlation coefficient between x_j and $x_{j'}$ which is denoted as $r_{jj'}$.
- Based on Equation (20), calculate the information from each criterion.
- Normalize the value of each criterion according to Equation (21).

❖ Step 7: To improve the accuracy of the aggregation, use plithogenic aggregation operation to combine normalized subjective weight results from Step 5 and the objective weights results from Step 6 w_j .

- Define contradiction degree c of each criterion with respect to the dominant.
- Plithogenic Neutrosophic Set intersection is defined as following in Equation (27):

$$((a_{i1}, a_{i2}, a_{i3}), 1 \le i \le n) \wedge_p ((b_{i1}, b_{i2}, b_{i3}), 1 \le i \le n) = \left(\left(a_{i1} \wedge_F b_{i1}, \frac{1}{2}(a_{i2} \wedge_F b_{i2}) + \frac{1}{2}(a_{i2} \vee_F b_{i2}), a_{i2} \vee_F b_{i3}\right)\right), 1 \le i \le n. \tag{27}$$

where $\wedge_F$ and $\vee_F$ are fuzzy t-norm and t-conorm respectively.

❖ Step 8: Normalize the decision matrix based on Equation (28):

Table 7
Normalization of decision matrix.

Criteria	A_1	A_2	A_3
C_{A1}	((0.21,0.23,0.18),0.15,1,0.59)	((0.21,0.23,0.18),0.15,1,0.59)	((0.21,0.23,0.18),0.15,1,0.59)
C_{A2}	((0.21,0.23,0.18),0.15,1,0.59)	((0.2,0.43,0.17),0.14,0.77,0.59)	((0.15,0.16,0.13),0.11,0.59,1)
C_{A3}	((0.41,0.41,0.35),0.22,1,0.57)	((0.33,0.33,0.3),0.19,1,0.22)	((0.41,0.41,0.35),0.22,1,0.57)
C_{A4}	((0.12,0.13,0.12),0.14,0.59,0.59)	((0.15,0.16,0.13),0.11,0.59,1)	((0.14,0.15,0.13),0.11,0.5,1)
C_{A5}	((0.43,0.36,0.43),0.17,0.59,0.37)	((0.25,0.29,0.2),0.17,1,0.5)	((0.43,0.36,0.43),0.17,0.59,0.37)
C_{A6}	((0.18,0.19,0.16),0.14,1,0.77)	((0.18,0.19,0.16),0.14,1,0.77)	((0.21,0.23,0.18),0.15,1,0.59)
C_{A7}	((0.21,0.23,0.18),0.15,1,0.59)	((0.18,0.19,0.16),0.14,1,0.77)	((0.18,0.19,0.16),0.14,1,0.77)
C_{A8}	((0.17,0.18,0.16),0.16,0.65,1)	((0.17,0.18,0.16),0.16,0.65,1)	((0.15,0.16,0.13),0.11,0.59,1)
C_{B1}	((0.15,0.16,0.15),0.16,0.76,1)	((0.16,0.17,0.15),0.17,0.65,0.76)	((0.16,0.17,0.15),0.17,0.65,0.76)
C_{B2}	((0.14,0.15,0.13),0.13,0.77,0.77)	((0.15,0.16,0.13),0.11,0.59,1)	((0.12,0.13,0.12),0.14,0.59,0.59)
C_{B3}	((0.18,0.19,0.16),0.14,1,0.77)	((0.18,0.19,0.16),0.14,1,0.77)	((0.21,0.23,0.18),0.15,1,0.59)
C_{B4}	((0.18,0.19,0.16),0.14,1,0.77)	((0.31,0.31,0.27),0.17,0.77,0.43)	((0.25,0.29,0.2),0.17,1,0.5)
C_{C1}	((0.31,0.31,0.27),0.17,0.77,0.43)	((0.21,0.23,0.18),0.15,1,0.59)	((0.18,0.19,0.16),0.14,1,0.77)
C_{C2}	((0.15,0.16,0.13),0.11,0.59,1)	((0.15,0.16,0.13),0.11,0.59,1)	((0.15,0.16,0.13),0.11,0.59,1)
C_{C3}	((0.15,0.16,0.13),0.11,0.59,1)	((0.15,0.16,0.13),0.11,0.59,1)	((0.15,0.16,0.13),0.11,0.59,1)
C_{C4}	((0.17,0.18,0.16),0.16,0.65,1)	((0.14,0.15,0.14),0.19,0.65,0.65)	((0.17,0.18,0.16),0.16,0.65,1)
C_{C5}	((0.31,0.31,0.27),0.17,0.77,0.43)	((0.25,0.29,0.2),0.17,1,0.5)	((0.31,0.31,0.27),0.17,0.77,0.43)
C_{C6}	((0.12,0.13,0.12),0.14,0.59,0.59)	((0.14,0.15,0.13),0.11,0.5,1)	((0.14,0.15,0.13),0.11,0.5,1)
C_{D1}	((0.16,0.17,0.15),0.17,0.65,0.76)	((0.14,0.15,0.14),0.17,0.76,0.76)	((0.14,0.15,0.14),0.16,1,1)
C_{D2}	((0.2,0.22,0.2),0.22,0.85,1)	((0.18,0.20,0.18),0.22,1,1)	((0.18,0.20,0.18),0.22,1,1)
C_{D3}	((0.22,0.38,0.14),0.12,0.77,1)	((0.15,0.16,0.13),0.11,0.59,1)	((0.15,0.16,0.13),0.11,0.59,1)
C_{D4}	((0.17,0.18,0.16),0.16,0.65,1)	((0.17,0.18,0.16),0.16,0.65,1)	((0.16,0.17,0.15),0.17,0.65,0.76)
C_{D5}	((0.21,0.23,0.18),0.15,1,0.59)	((0.21,0.23,0.18),0.15,1,0.59)	((0.25,0.29,0.2),0.17,1,0.5)
C_{D6}	((0.17,0.18,0.16),0.16,0.65,1)	((0.12,0.13,0.12),0.14,0.59,0.59)	((0.14,0.15,0.14),0.19,0.65,0.65)
C_{E1}	((0.18,0.19,0.16),0.14,1,0.77)	((0.25,0.29,0.2),0.17,1,0.5)	((0.21,0.23,0.18),0.15,1,0.59)
C_{E2}	((0.41,0.41,0.35),0.22,1,0.57)	((0.41,0.41,0.35),0.22,1,0.57)	((0.57,0.46,0.57),0.22,0.76,0.48)
C_{E3}	((0.43,0.36,0.43),0.17,0.59,0.37)	((0.31,0.31,0.27),0.17,0.77,0.43)	((0.25,0.29,0.2),0.17,1,0.5)
C_{E4}	((0.41,0.41,0.35),0.22,1,0.57)	((0.18,0.19,0.16),0.14,1,0.77)	((0.18,0.19,0.16),0.14,1,0.77)
C_{E5}	((0.18,0.19,0.16),0.14,1,0.77)	((0.21,0.23,0.18),0.15,1,0.59)	((0.21,0.23,0.18),0.15,1,0.59)
C_{E6}	((0.12,0.13,0.12),0.14,0.59,0.59)	((0.14,0.15,0.13),0.11,0.5,1)	((0.14,0.15,0.13),0.11,0.5,1)
C_{F1}	((0.18,0.19,0.16),0.14,1,0.77)	((0.21,0.23,0.18),0.15,1,0.59)	((0.21,0.23,0.18),0.15,1,0.59)
C_{F2}	((0.17,0.18,0.16),0.16,0.65,1)	((0.17,0.18,0.16),0.16,0.65,1)	((0.16,0.17,0.15),0.17,0.65,0.76)
C_{F3}	((0.18,0.19,0.16),0.14,1,0.77)	((0.21,0.23,0.18),0.15,1,0.59)	((0.15,0.16,0.14),0.12,0.77,1)
C_{F4}	((0.18,0.19,0.16),0.14,1,0.77)	((0.41,0.41,0.35),0.22,1,0.57)	((0.25,0.29,0.2),0.17,1,0.5)
C_{F5}	((0.18,0.19,0.16),0.14,1,0.77)	((0.25,0.29,0.2),0.17,1,0.5)	((0.21,0.23,0.18),0.15,1,0.59)
C_{F6}	((0.15,0.16,0.14),0.12,0.77,1)	((0.14,0.15,0.13),0.11,0.5,1)	((0.15,0.16,0.13),0.11,0.59,1)

$$R = [r_{ij}]_{n\times m} \tag{28}$$

❖ Step 9: Build the matrix of weighted normalized decisions based on aggregated weights results from step 7 and the normalized decision matrix from step 8 using Equation (29).

$$Z = [z_{ij}]_{n\times m}$$

$$z_{ij} = w_j \times r_{ij} \tag{29}$$

❖ Step 10: Find the distance of each alternative from a negative ideal solution and a positive ideal solution.

- Transform the neutrosophic number into a crisp number using Equation (30):

$$S\left(a\right) = \frac{1}{8}\left(a_1 + b_1 + c_1\right) \times \left(2 + \alpha - \theta - \beta\right. \tag{30}$$

- Identify the PIS and NIS using Equations 11–14.
- Find the distance using the Euclidian distance formula as shown in Equations (15) and (16).

❖ Step 11: Find the closeness coefficient of each alternative using Equation (17).

5. Application of proposed approach and discussion

5.1. Application setup

In this section, the proposed approach will be examined in a real-world case study in the field of the telecommunications industry. Company H in China is a large multinational company that produces different telecommunications equipment and exports them all over the world. There are many reasons and risks that may threaten the sustainability of this supply chain such as competition increasing in this sector of manufacturing, unstable demand, stakeholders' needs, and other outside and inside uncertain issues. That's why, Company H decided to obtain a sustainable supply chain risk management. There are six major criteria that this company SSCRM will be evaluated based on them: Financial risk C_A, supply risk factor C_B, environmental risks C_C, operational risk C_D, control and plan risk C_E, and information technology risks C_F. Fig. 2 shows the main aspects of the telecommunication company evaluation. These main criteria derive a thirty-six sub-criteria that are shown in Fig. 3. Telecommunications equipment in H Company is categorized into three main parts: public switching equipment A_1 that consists of analogue and digital switches, transmission equipment A_2 such as transmission lines and communication satellites, and customer premises equipment like mobile phones, routers and private switches A_3.

6. Results and discussion

Applying the proposed approach on H Company case to evaluate

Table 8
Weighted normalized decision matrix.

Criteria	A_1	A_2	A_3
C_{A1}	((0,0.003,0.008),0.0001,0.009,0.018)	((0,0.003,0.008),0.0001,0.009,0.0183)	((0,0.0032,0.008),0.0001,0.009,0.018)
C_{A2}	((0.0024,0.0458,0.0170),0.0009,0.037,0.01)	((0.0023,0.086,0.016),0.0008,0.03,0.01)	((0.002,0.032,0.012),0.0006,0.022,0.02)
C_{A3}	((0.0005,0.005,0.006),0.0006,0.184,0.024)	((0.0004,0.004,0.0054),0.0005,0.18,0.009)	((0.0005,0.005,0.006),0.0006,0.18,0.02)
C_{A4}	((0.0008,0.0038,0.0072),0.001,0.011,0.045)	((0.001,0.005,0.008),0.001,0.011,0.077)	((0.001,0.004,0.008),0.0011,0.009,0.08)
C_{A5}	((0.0003,0.002,0.0015),0.0004,0.012,0.018)	((0.0002,0.002,0.0007),0.0004,0.0.2,0.024)	((0.0003,0.002,0.0015),0.0004,0.01,0.02)
C_{A6}	((0.0035,0.009,0.009),0.0015,0.012,0.0132)	((0.0035,0.009,0.009),0.0015,0.012,0.013)	((0.004,0.011,0.01),0.002,0.012,0.0101)
C_{A7}	((0.0015,0.004,0.006),0.0012,0.009,0.0354)	((0.0013,0.0032,0.0056),0.001,0.009,0.05)	((0.001,0.0032,0.006),0.001,0.009,0.05)
C_{A8}	((0.002,0.0045,0.007),0.0018,0.018,0.046)	((0.0020,0.0045,0.007),0.002,0.018,0.046)	((0.002,0.004,0.006),0.0012,0.017,0.05)
C_{B1}	((0.0015,0.0035,0.005),0.001,0.03,0.014)	((0.002,0.004,0.005),0.0012,0.025,0.011)	((0.002,0.004,0.005),0.0012,0.025,0.01)
C_{B2}	((0.003,0.0046,0.01),0.002,0.014,0.048)	((0.003,0.005,0.01),0.02,0.011,0.062)	((0.0023,0.004,0.009),0.002,0.01,0.037)
C_{B3}	((0.002,0.0034,0.005),0.002,0.009,0.039)	((0.0022,0.0034,0.005),0.002,0.009,0.04)	((0.0025,0.004,0.006),0.002,0.009,0.03)
C_{B4}	((0.0022,0.0036,0.0043),0.003,0.03,0.042)	((0.004,0.006,0.0073),0.004,0.024,0.024)	((0.003,0.006,0.0054),0.004,0.031,0.028)
C_{C1}	((0.0053,0.007,0.01),0.004,0.016,0.023)	((0.004,0.005,0.007),0.0034,0.021,0.032)	((0.003,0.004,0.006),0.0032,0.02,0.042)
C_{C2}	((0.004,0.004,0.008),0.004,0.064,0.012)	((0.004,0.0043,0.0075),0.004,0.064,0.012)	((0.004,0.004,0.0075),0.004,0.064,0.012)
C_{C3}	((0.002,0.0024,0.003),0.001,0.007,0.011)	((0.002,0.0024,0.003),0.0013,0.007,0.011)	((0.002,0.0024,0.0026),0.0013,0.007,0.01)
C_{C4}	((0.003,0.003,0.003),0.002,0.018,0.014)	((0.0022,0.003,0.003),0.0025,0.012,0.009)	((0.003,0.0032,0.0034),0.002,0.012,0.014)
C_{C5}	((0.0012,0.006,0.007),0.0014,0.012,0.012)	((0.001,0.006,0.005),0.0014,0.016,0.014)	((0.0012,0.006,0.007),0.0014,0.012,0.012)
C_{C6}	((0.004,0.004,0.005),0.005,0.011,0.027)	((0.005,0.0043,0.006),0.0041,0.009,0.045)	((0.005,0.0043,0.006),0.004,0.009,0.045)
C_{D1}	((0.0034,0.0034,0.005),0.003,0.049,0.009)	((0.003,0.003,0.005),0.003,0.057,0.0091)	((0.003,0.003,0.005),0.0026,0.075,0.012)
C_{D2}	((0.005,0.005,0.01),0.004,0.033,0.011)	((0.0043,0.0044,0.009),0.004,0.04,0.011)	((0.004,0.0044,0.0094),0.0035,0.04,0.01)
C_{D3}	((0.005,0.008,0.004),0.004,0.04,0.008)	((0.0033,0.0034,0.0034),0.004,0.03,0.008)	((0.0033,0.0034,0.003),0.004,0.03,0.008)
C_{D4}	((0.005,0.004,0.004),0.005,0.018,0.024)	((0.005,0.004,0.004),0.005,0.012,0.024)	((0.005,0.004,0.004),0.005,0.012,0.018)
C_{D5}	((0.004,0.0034,0.002),0.005,0.012,0.01)	((0.004,0.0034,0.002),0.005,0.012,0.010)	((0.0045,0.004,0.002),0.0054,0.012,0.009)
C_{D6}	((0.007,0.005,0.004),0.003,0.008,0.006)	((0.005,0.004,0.003),0.003,0.007,0.004)	((0.006,0.0043,0.003),0.004,0.008,0.004)
C_{E1}	((0.006,0.004,0.003),0.006,0.009,0.022)	((0.009,0.006,0.004),0.0075,0.009,0.014)	((0.0074,0.005,0.004),0.004,0.009,0.017)
C_{E2}	((0.008,0.01,0.008),0.002,0.06,0.003)	((0.008,0.01,0.0084),0.0024,0.057,0.0028)	((0.011,0.011,0.014),0.0024,0.043,0.0024)
C_{E3}	((0.005,0.003,0.002),0.003,0.03,0.006)	((0.0034,0.0025,0.001),0.003,0.035,0.007)	((0.003,0.0023,0.0008),0.003,0.05,0.008)
C_{E4}	((0.0074,0.01,0.002),0.014,0.02,0.00630)	((0.003,0.005,0.001),0.009,0.021,0.009)	((0.0032,0.005,0.001),0.009,0.02,0.0085)
C_{E5}	((0.017,0.009,0.0024),0.008,0.016,0.003)	((0.02,0.012,0.003),0.0084,0.016,0.0024)	((0.02,0.011,0.003),0.0084,0.02,0.0024)
C_{E6}	((0.007,0.004,0.002),0.009,0.011,0.01)	((0.008,0.0043,0.002),0.007,0.009,0.017)	((0.008,0.0043,0.002),0.007,0.009,0.017)
C_{F1}	((0.018,0.009,0.002),0.0083,0.012,0.0023)	((0.021,0.01,0.0022),0.009,0.012,0.002)	((0.021,0.01,0.0022),0.009,0.012,0.0018)
C_{F2}	((0.0073,0.004,0.0014),0.007,0.012,0.009)	((0.007,0.004,0.0014),0.007,0.012,0.009)	((0.007,0.004,0.0013),0.008,0.012,0.007)
C_{F3}	((0.01,0.005,0.0011),0.008,0.04,0.004)	((0.011,0.006,0.0013),0.008,0.04,0.003)	((0.008,0.004,0.001),0.0065,0.03,0.005)
C_{F4}	((0.0065,0.004,0.0005),0.009,0.03,0.0062)	((0.015,0.008,0.001),0.014,0.03,0.005)	((0.009,0.0055,0.0006),0.01,0.03,0.004)
C_{F5}	((0.01,0.0044,0.0008),0.009,0.009,0.0046)	((0.014,0.007,0.001),0.011,0.009,0.003)	((0.011,0.0053,0.0009),0.01,0.009,0.0035)
C_{F6}	((0.0073,0.003,0.0003),0.004,0.068,0.001)	((0.007,0.003,0.0003),0.0033,0.044,0.001)	((0.0073,0.003,0.0003),0.003,0.052,0.001)

the SSCRM will be as following:

✓ As described in step 1, the objective, criteria and alternatives of this supply chain was defined. A group of three decision makers who has experience in the field of finance, quality management and risk management were selected.
✓ Based on the linguistic scale in Table 1, the three DMs obtain their judgments on criteria and alternatives as show in Table 2 and Table 3 respectively.
✓ Based on Table 3, convert it to the average decision matrix using Equations (22) and (23), and the results of this step shows in Table 4.
✓ Table 5 shows subjective weights, normalized subjective weights, and objective weights calculated using CRITIC method.
✓ To aggregate normalized subjective weights with objective weights, plithogenic aggregation operation is used based on the contradiction degree of the criteria. In this step, the accuracy of aggregation will increase. Then, convert the result of aggregation to crisp values using Equation (30) as shown in Table 6.

✓ Normalization of decision matrix and the weighted normalized decision matrix were shown in Table 7 and Table 8, respectively.
✓ The distance of each alternative to the PIS and NIS is calculated using Equations (15) and (16). That's help to measure the performance of the alternatives based on the PIS and the NIS as shown in Table 9.
✓ Based on the highest closeness coefficient is represents the optimal alternative, ranks the three alternatives as shown in Table 10.

- As the results show in Fig. 4, the financial risk criteria is the most important main criteria with a weight of 0.186. The importance order of the other criteria as the following: information technology risks (0.132); control and plan risks (0.119); operational risks (0.113); environmental risks (0.107); supply risk factors (0.075).

- The order of sub-criteria importance in regard to the main criteria is summarized in Table 11.
- The customer premises equipment is the best alternative that C Company must consider, the next public switching equipment and transmission equipment is the last.
- Financial risks criteria are the most criteria that must be sustainable to improve the supply chain sustainability, while supply risk factor is the least important. In the level of sub-criteria, the most important seven criteria are: volatility of price and cost, supply uncertainty, energy consumption, poor-quality, inefficient use of resources, and information sharing risks.
- The analysis of the evaluation results is shown in Fig. 5. While Fig. 6 shows a comparison between the sub-criteria according to results in Table 6. In financial risks $\mathbf{C_A}$ group of criteria, the volatility of price and cost (C_{A6}) in the top of importance order with weight 0.074335 and economic recession (C_{A4}) is the last with 0.00252. In supply risk factor (C_B), the supply uncertainty (C_{B2}) is the highest weight 0.03043 and lack of resource (C_{B4}) is the lowest with 0.014095. According to environmental risks (C_C) the energy consumption (C_{C3}) is most important with weight 0.0261 and heavy rain/thunderstorm (C_{C1}) is the least with 0.0115. Operational risks criteria (C_D) has the highest sub-

Table 9
NIS and PIS, and the distance of alternatives to them.

Criteria	NIS	PIS	D_i^-			D_i^+		
			A_1^-	A_2^-	A_3^-	A_1^+	A_2^+	A_3^+
C_{A1}	0.002762	0.002762	0	0	0	0	0	0
C_{A2}	0.025487	0.01123	0.009561	0	0.014257	0.004696	0.014257	0
C_{A3}	0.002667	0.002237	0	0.000431	0	0.000431	0	0.000431
C_{A4}	0.003182	0.00287	0.000312	0	6.92E-05	0	0.000312	0.000243
C_{A5}	0.000986	0.000636	0	0.00035	0	0.00035	0	0.00035
C_{A6}	0.006186	0.005287	0.000899	0.000899	0	0	0	0.000899
C_{A7}	0.002862	0.002457	0	0.000405	0.000405	0.000405	0	0
C_{A8}	0.003245	0.002738	0	0	0.000507	0.000507	0.000507	0
C_{B1}	0.00253	0.002447	8.33E-05	0	0	0	8.33E-05	8.33E-05
C_{B2}	0.004269	0.003764	9.63E-05	0	0.000505	0.000409	0.000505	0
C_{B3}	0.002993	0.002588	0.000405	0.000405	0	0	0	0.000405
C_{B4}	0.004133	0.002436	0.001696	0	0.000753	0	0.001696	0.000944
C_{C1}	0.005427	0.003202	0	0.001721	0.002225	0.002225	0.000504	0
C_{C2}	0.003712	0.003712	0	0	0	0	0	0
C_{C3}	0.001686	0.001686	0	0	0	0	0	0
C_{C4}	0.002298	0.001932	0	0.000365	0	0.000365	0	0.000365
C_{C5}	0.003436	0.002835	0	0.000601	0	0.000601	0	0.000601
C_{C6}	0.003535	0.003198	0.000336	0	0	0	0.000336	0.000336
C_{D1}	0.002942	0.002586	0	0.000327	0.000355	0.000355	2.83E-05	0
C_{D2}	0.004899	0.00442	0	0.000479	0.000479	0.000479	0	0
C_{D3}	0.00401	0.002481	0	0.001529	0.001529	0.001529	0	0
C_{D4}	0.0032	0.003012	0	0	0.000188	0.000188	0.000188	0
C_{D5}	0.002729	0.00228	0.000449	0.000449	0	0	0	0.000449
C_{D6}	0.004029	0.002939	0	0.00109	0.000667	0.00109	0	0.000423
C_{E1}	0.004688	0.003334	0.001355	0	0.000776	0	0.001355	0.000579
C_{E2}	0.008683	0.006313	0.002369	0.002369	0	0	0	0.002369
C_{E3}	0.00229	0.001413	0	0.000575	0.000877	0.000877	0.000303	0
C_{E4}	0.005115	0.002301	0	0.002815	0.002815	0.002815	0	0
C_{E5}	0.008209	0.00696	0.001248	0	0	0	0.001248	0.001248
C_{E6}	0.003516	0.003082	0.000434	0	0	0	0.000434	0.000434
C_{F1}	0.008329	0.007054	0.001275	0	0	0	0.001275	0.001275
C_{F2}	0.003178	0.003008	0	0	0.00017	0.00017	0.00017	0
C_{F3}	0.004451	0.00318	0.000667	0	0.001271	0.000604	0.001271	0
C_{F4}	0.005837	0.002613	0.003224	0	0.002107	0	0.003224	0.001117
C_{F5}	0.005297	0.003716	0.00158	0	0.000928	0	0.00158	0.000652
C_{F6}	0.002584	0.002448	2.07E-05	0.000136	0	0.000116	0	0.000136

Table 10
Closeness coefficient of alternatives.

Alternatives	A_1	A_2	A_3
CC_i	0.588214	0.337978	0.698307
Rank	2	3	1

criteria is poor-quality (C_{D4}) with 0.024 and the lowest is loss of key equipment (C_{D2}) with 0.01097. In control and plan risks (C_E), inefficient use of resources (C_{E3}) is the top with 0.0393 and coordination effort (C_{E2}) is the last with 0.0058. In the last main criteria information/IT related risks (C_F), the most important is

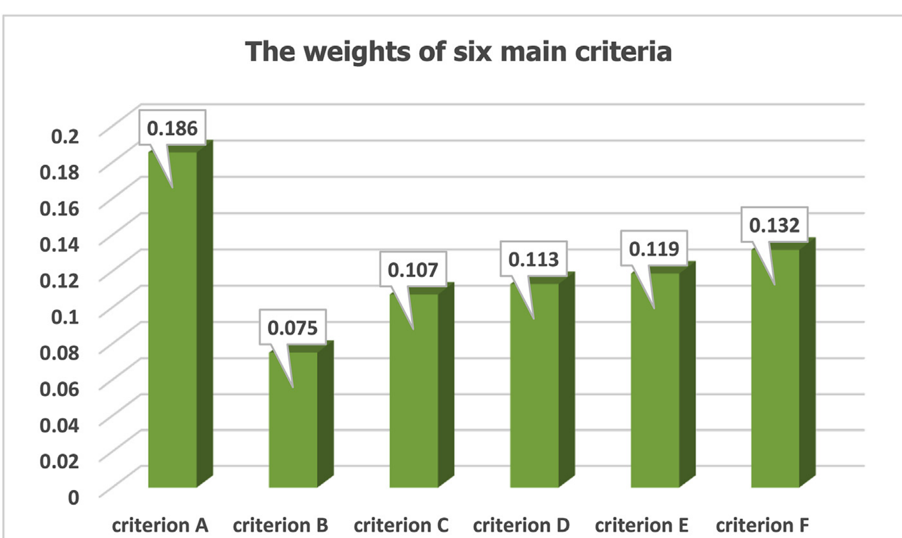

Fig. 4. Weights of the main criteria.

Table 11
Rank of main criteria and sub-criteria.

Main criteria	Rank	Sub-criteria	Rank
Financial risk C_A	1	Fuel prices C_{A1}	2
		Tax evasion C_{A2}	6
		Currency and foreign exchange rate fluctuations C_{A3}	4
		Economic recession C_{A4}	8
		Adverse changes in industry regulation C_{A5}	7
		volatility of price and cost C_{A6}	1
		Market share reduction C_{A7}	3
		Financial market Instability C_{A8}	5
Supply risk factors C_B	6	Supplier selection failure C_{B1}	2
		Supply uncertainty C_{B2}	1
		Inventory/capacity risk C_{B3}	3
		Lack of resources C_{B4}	4
Environmental risk C_C	5	Heavy rain/thunderstorm C_{C1}	6
		Land, water, air pollution C_{C2}	2
		Energy consumption C_{C3}	1
		Hazardous waste generation C_{C4}	4
		Water scarcity C_{C5}	5
		Emission of greenhouse gases C_{C6}	3
Operational risk C_D	4	Operator errors/accident damage C_{D1}	2
		Loss of key equipment C_{D2}	6
		HR risks C_{D3}	4
		Poor-quality C_{D4}	1
		production line disruption C_{D5}	3
		Utilities failures C_{D6}	5
Control and plan risk C_E	3	Responsiveness performance C_{E1}	5
		Coordination effort C_{E2}	6
		Inefficient use of resources C_{E3}	1
		Logistics provider failures C_{E4}	2
		New or foreign competitors C_{E5}	4
		Failure to fulfil social commitment C_{E6}	3
Information/IT related risks C_F	2	Information sharing risks C_{F1}	1
		Lack of sustainable information technology C_{F2}	3
		Lack of information security C_{F3}	5
		Technology decision failure C_{F4}	2
		Computer virus C_{F5}	6
		IT systems failures C_{F6}	4

Information sharing risks (C_{F1}) with 0.0397 and the least important is computer virus (C_{F5}) with 0.01459.

- From the side of alternative evaluation, the results in Fig. 7 shows that the ranking as follows: customer premises equipment A_3, public switching equipment A_1, and transmission equipment A_2.

7. Conclusion and future works

The importance of studying management of risk in the field of supply chain operations encouraged the researchers to consider the uncertain risk factors that threaten the sustainability of the supply chain. There is enough awareness in companies of the importance of considering risk management in order to ensure a sustainable supply chain. The main problem in evaluation of the sustainability of the supply chain risk management is considering the inconsistent and uncertain information. In order to identify and rank the important risk factors that may have a negative influence on supply chain sustainability under uncertainty, we proposed an integrated plithogenic TOPSIS-CRITIC approach that measured the uncertainty of the risk significantly. This approach has all the advantages of plithogenic operations, TOPSIS and CRITIC method. Firstly, plithogenic aggregation features increase the accuracy and consistency of the evaluation results. Second, TOPSIS method basically depends on the distance of the alternatives to the positive and negative ideal solutions in order to specify the optimal solution. Finally, CRITIC is evaluating the information amount in the evaluation criteria based on the contrast intensity of each criterion and the conflict between them.

In order to test the efficiency and accuracy of the proposed approach, a real-world case study was evaluated, which is a telecommunications equipment company in china. This company has three main categories of equipment that need to be evaluated, public switching equipment A_1, transmission equipment A_2, and customer premises equipment A_3. The evaluation was based on a set of thirty-six risk criterion under six main factors: Financial risk, supply risk factor, environmental risks, operational risk, control and plan risk, and information technology risks. There are three decision-makers that assist in this evaluation process based on their experience in this field. The DMs' opinions were aggregated using plithogenic aggregation operation in order to have more accurate aggregation result, and the weights of the criteria were identified based on the TOPSIS-CRITIC method.

The results shows that the financial risk criteria is the most important main criteria. The importance order of the other criteria as the following: information technology risks; control and plan risks; operational risks; environmental risks; supply risk factors. The rank of alternatives as follows: customer premises equipment, public switching equipment, and transmission equipment A_2. The contributions of this study are:

- This paper shows the utmost importance of risk management regarding guarantee sustainable supply chain operations.
- The objective and subjective weights of the risk criteria were evaluated by a committee of decision-makers, and these weights were aggregated by plithogenic operator that conceders

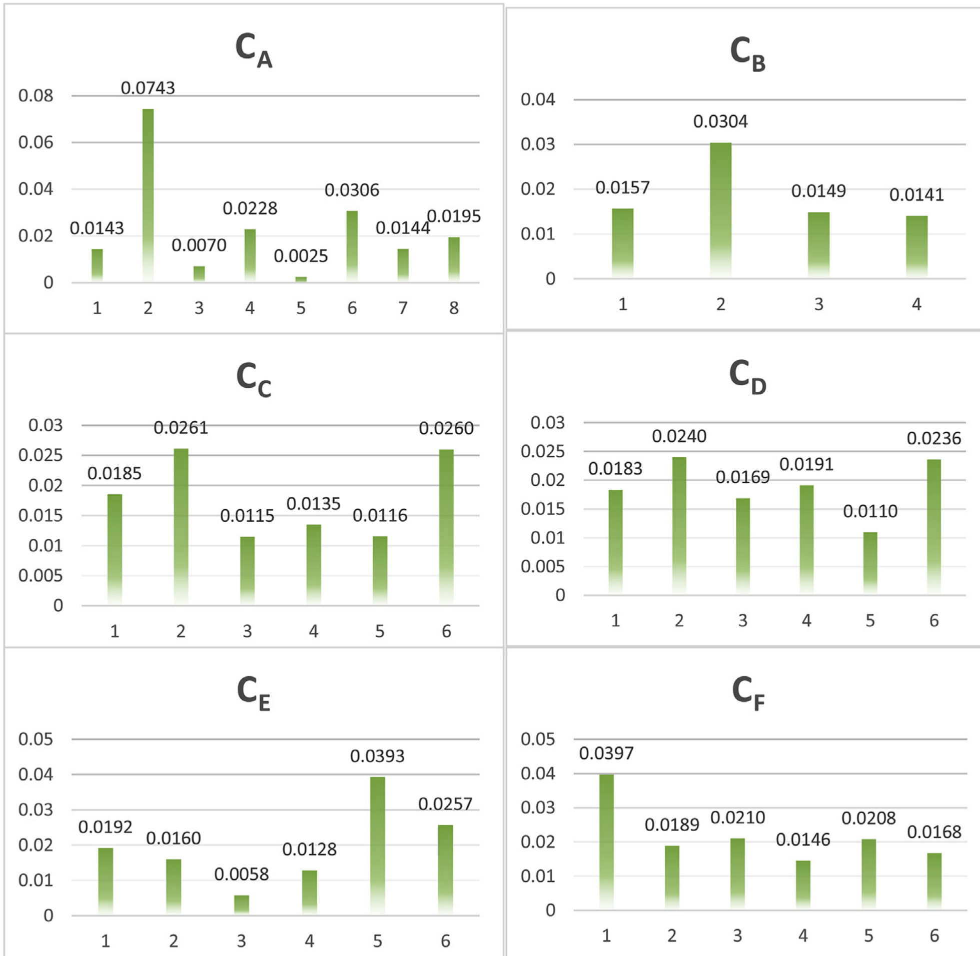

Fig. 5. Analysis of the evaluation.

the contradiction degree of each criteria to improve the accuracy of aggregation results.

- The using of the TOPSIS-CRITIC method allows the decision-maker to take into account the importance of evaluation based on the amount of information in each criterion (from CRITIC method) and the performance of alternatives in regards to best and worst solutions (from TOPSIS method).
- The linguistic scale that used to evaluate the criteria in this approach was presented in triangular neutrosophic numbers, which increase the consideration of uncertainty.

The supply chain sustainability has many tools and aspects that must be considered to maintain sustainability operations; thus risk management is the point that measured in this study. In future

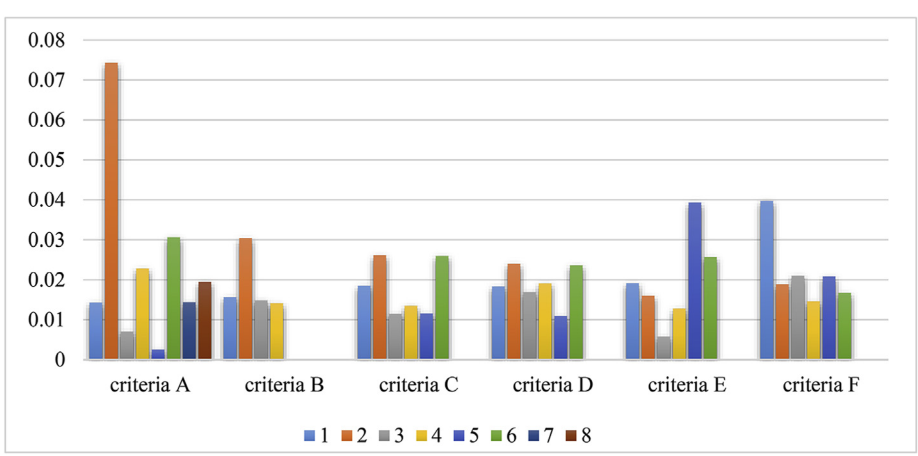

Fig. 6. Comparison between criteria evaluation.

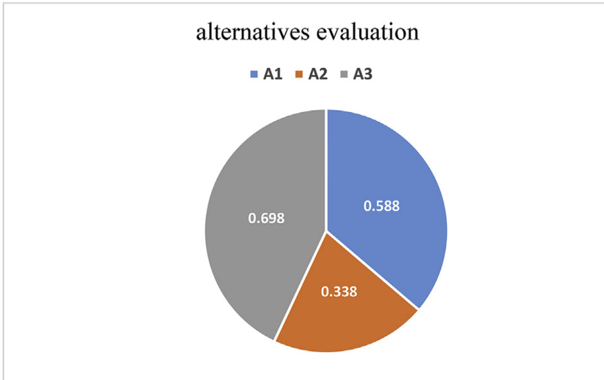

Fig. 7. Alternatives evaluation.

researches, other aspects to improve sustainability may be assessed using the proposed approach. Moreover, other scopes of supply chains rather than the telecommunications industry may be evaluated by this study. Finally, plithogenic operation may be combined with other methods and techniques to evaluate sustainable supply chain risk management.

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Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Declaration of competing interest

This is hereby certify that the paper is original, neither the paper nor a part of it is under consideration for publication anywhere else. Also, we have no conflicts of interest to disclose.

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