New Approach to Identify the Most Sustainable Supplier Based on IFS

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Abstract—To meet the expectations of consumers, who are increasingly demanding products that respect the concept of sustainable development (SD), companies are called upon to engage in an SD approach that begins with the selection of suppliers, taking into consideration the environmental, social and economic criteria. In this paper, we present a new model of selecting the best sustainable supplier. We have developed a hybrid model, which is built by extending the fuzzy set (FS) to the intuitionistic fuzzy set theory (IFS) and with the Decision Making Trial and Evaluation Laboratory (DEMATEL) method. Our model presented, allows us to measure the weight of the selected criteria of SD, to present an approach for defining the SD strategy within companies and finally to choose among the suppliers, the best supplier who respects the concept of SD by taking into consideration the links between the axe of SD. The results of the application of our approach have shown that our model can be easily used in all companies wishing to select sustainable suppliers.

Keywords—Sustainable supplier selection; sustainable development; criteria; DEMATEL; intuitionistic fuzzy set; supply chain management.

I. INTRODUCTION

The emergence towards the new concept of SD nowadays, customers have become more demanding of products that respect SD. This change in national and international markets has forced industrial companies to integrate the concept of SD into the management of their supply chains. This change is mandatory for companies to remain competitive, to open up to new national and international markets and to face the various pressures (NGOs, the media, the State, civil society and other economic actors who demand economic development that is more respectful of the environment and society).

The integration of the SD concept into the logistics chain begins with the selection of sustainable suppliers, in view of the positioning of the supplier selection process upstream of the logistics chain.

The purchase of environmentally friendly raw materials for industrial companies is important for the continuity of existence, improvement and competitiveness of the company. We can cite the example of Sony who used hazardous materials in the manufacture of PlayStation consoles and Mattel who used a material contaminated with lead to paint toys [1], these companies risked losing their image as brand in the market. Therefore, to avoid this kind of problem, it is necessary to choose the partners upstream "suppliers" by determining the right SD criteria in the selection process.

During the last five years, in the literature we find several studies [2, 3, 4] which have started to discuss the problem of selection of sustainable suppliers (SSS), but all these studies do not really study the interrelation between the SD criteria in the supplier selection process.

In this paper, we will present a model, which allows us to calculate the performance index of suppliers, by taking into consideration the interrelation between the different SD criteria in the calculation (see next section). Our model is based on the combination of:

- The extension of FS: The theory of fuzzy sets FS developed by [5], is used to answer the problems of uncertainties and imprecision of choice. FS is based on the principle that all these elements belong to the bounded interval of zero to one, but it is not true in all time that the degree of non-membership of an element of FS equals 1 minus the degree of membership, there is always a degree of hesitation. To solve this hesitation problem, Atanassov proposed a generalization of FS, an IFS [6,7]. IFS is used to address the weakness the FS [8, 9].
- The DEMATEL method presented by Gabus and Fontela in Battelle Memorial Institute [10], it is used to build the interrelationships between the criteria and also to analyze and visualize the interactions between these criteria on the diagram cause and effect.

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In the literature, we find that IF DEMATEL has been used recently by several authors [2, 11, 12, 13, 14], which shows their efficiency and flexibility elaborate uncertainty and vagueness opinion involved in decision making (DM) by manager for calculate of the weights of the criteria.

The originality of our developed model allows us to measure and classify suppliers according to their sustainability performance indices, taking into account the interdependence between the three dimensions of SD (see the next section).

Our article is made up as follows: The first part introduces the concept of sustainable suppliers. The second part presents our developed model, which allows us to measure the sustainability performance index of suppliers. The third part shows the application of the developed model. The fourth part discusses the results obtained and the results. The last part contains the conclusion. In the following section we present the originality of our work

II. LITERATURE REVIEW

In the literature, quite a few studies deal with the subject of selecting sustainable suppliers. We find the study by Amiri and al in 2020, who proposed a fuzzy model based on the Best-Worst Method (BWM) [15]. Lit and al in 2019, who develop an approach that uses the method Technique for Order Performance by Similarity to Ideal Solution [16]. Giannakis and al in 2019, who used the Analytical Network Process (ANP) for the evaluation and selection of suppliers [17]. Abdel-Baset and al in 2019, who used a combination of two method ANP and ViseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) for supplier selection [18]. Chen and al in 2019, propose a framework to select suppliers by using rough-fuzzy approach [19].

Analysing recent work on the issue of selecting sustainable suppliers, we find that all the researchers in the review literature have studied this issue without taking into consideration the intersection between the three dimensions of sustainable development. All the approaches developed in the review literature, list the supplier selection criteria by the dimension and integrate them into a model that allows the selection of suppliers, without studying the relationship between the dimensions.

III. SUSTAINABLE SUPPLIER

The SD concept appeared in 1987, in the report entitled "Our Common Future" [20].

We considered a sustainable supplier, if he respects the conditions of the three following interdependencies between dimensions of SD:

- Suppliers will have to link the two dimensions: environmental and economic. This is what you call being viable. Viable is the state where the environment provides natural resources that are exploitable and essential to the survival of the economy ... and in the long term. In another way, for the economy to be sustainable and beneficial for future generations, natural resources will need to be properly harnessed and managed.
- Suppliers will have to achieve the intersection between the two dimensions: environmental and social. This is what you call being livable. Livable is the healthy environment that provides food, clean water, quality air, shelter and jobs for a society ... an environment in which we can live.
- Suppliers will have to join the economic dimension to the social dimension. This is called being equitable. Equitable is the case where all members of a society can have fair incomes, long-term jobs, and quality goods and services, thanks to an economy that is well managed and sustainable.

Graphically, these three conditions refer to the intersections between the social, environmental and economic dimensions, commonly called the "interfaces". In addition, the "sustainable" is at the confluence of these three interfaces as shown in Figure 1.

FIGURE 1 THE INTERSECTIONS BETWEEN SD DIMENSION

IV. THE THEORETICAL CONCEPT AND PROPOSED
METHODOLOGY

A. Preliminary of IFS

Let X a nonempty set.

An IFS A in X is presented as follows:

$$A = \{(x, \mu_A(x), \nu_A(x)) : x \in X\} \quad (1)$$

Where $\mu_A(x), \nu_A(x) : X \rightarrow [0,1]$, And

$$0 \leq \mu_A(x) + \nu_A(x) \leq 1 \quad \forall x \in X \quad (2)$$

$\mu_A(x)$ and $\nu_A(x)$ represent the degree of membership and non-membership respectively of $x \in X$ to the set A .

Another concept related to IFS represent the hesitancy degree:

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x) \quad (3)$$

$\pi_A(x)$ represent the degree of uncertainty of $x \in X$ to the IFS A .

B. Proposed methodology

In this part, we will present our approach to selecting the best sustainable suppliers who respect the three pillars of sustainable development.

Step 1: Identification the economic, environmental and social criteria for sustainable development:

These criteria are derived from the analysis of literature reviews since the first articles (Dickson, 1966) which published a list of supplier selection criteria. Also the result of the analysis of national and international standards such as the Supply-Chain Operations Reference (SCOR), the GRI (Global Reporting Initiative), the Organisation for Economic Co-operation and Development (OECD) and the International Organization for Standardization (ISO) 26000 ... In our paper [21], we presented the most criteria used in literature reviews from 1966 to 2016.

Step 2: Determination of the linguistic terms for the IF-DEMATEL approach:

Table I shows these linguistic terms in IFS.

TABLE I
LINGUISTIC TERMS FOR IF-DEMATEL

Definition of Linguistic Terms	IFS
NI : No Influence	(0.00, 1.00, 0.00)
LI : Low Influence	(0.35, 0.60, 0.05)
MI : Medium Influence	(0.50, 0.45, 0.05)
HI : High Influence	(0.75, 0.20, 0.05)
VHI : Very High Influence	(0.90, 0.10, 0.00)

Step 3: Calculate the weight of DM:

To define the importance of DM relative to their experience and knowledge, we use the linguistic scale as shown in Table II. We take $D_k = [\mu_k, \nu_k, \pi_k]$ as an IF number for weighting the kth DM. The priority value of the DM is obtained as follows:

$$\lambda_k = \frac{\mu_k + \pi_k \left(\frac{\mu_k}{\mu_k + \nu_k} \right)}{\sum_{k=1}^l \left(\mu_k + \pi_k \left(\frac{\mu_k}{\mu_k + \nu_k} \right) \right)} \quad (4)$$

TABLE II
Linguistic terms for calculate the weight of DM

Definition of Linguistic Terms	IFS
VU : Very Unimportant	(0.10, 1.80, 0.10)
U : Unimportant	(0.25, 0.60, 0.15)
MI : Medium Important	(0.50, 0.40, 0.10)
I : Important	(0.75, 0.20, 0.05)
VI : Very Important	(0.90, 0.05, 0.05)

Step 4: Calculation of the weights of the different SD criteria:

In this step, we calculate the weight of the different criteria of each axe of SD. We use the extension of the Fuzzy DEMATEL to Intuitionistic Fuzzy DEMATEL as follow to calculate the weight:

- Calculate the Aggregated IF Decision Matrix according to the DM opinions

Let $A^k = (a_{ij}^k)_{m \times n}$ is an IF decision matrix for each DM, and $\lambda = \{\lambda_1, \lambda_2, \dots, \lambda_l\}$ DM weights, where $\sum_{k=1}^l \lambda_k = 1$, $\lambda_k \in [0,1]$. The group selection procedure is based on the grouping of all the single opinions of the MD; we use IFWA (IF Weighted Averaging) function [23] to group the indices of importance of all criteria.

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With $A_{ij}^{(k)} = \{\mu_{ij}^{(k)}, v_{ij}^{(k)}, \pi_{ij}^{(k)}\}$ as IFS that used by the kth DM with a_{ij} .

a_{ij} : Represent the criteria.

Using IFWA, we can calculate the aggregated intuitionistic fuzzy relation as following:

$$\begin{aligned} a_{ij} &= IFWA_{\lambda}(a_{ij}^{(1)}, a_{ij}^{(2)}, \dots, a_{ij}^{(l)}) \\ &= \lambda_1 a_{ij}^{(1)} \oplus \lambda_2 a_{ij}^{(2)} \oplus \dots \oplus \lambda_l a_{ij}^{(l)} \\ &= [1 - \prod_{k=1}^l (1 - \mu_{ij}^{(k)})^{\lambda_k}, \prod_{k=1}^l (v_{ij}^{(k)})^{\lambda_k}, \prod_{k=1}^l (1 - \mu_{ij}^{(k)})^{\lambda_k} - \prod_{k=1}^l (v_{ij}^{(k)})^{\lambda_k}] \end{aligned} \quad (5)$$

Where:

$$\begin{aligned} a_{ij}^{(k)} &= (\mu_{Ai}(x_j), v_{Ai}(x_j), \pi_{Ai}(x_j)) \\ (i &= 1, 2, \dots, m; j = 1, 2, \dots, n) \end{aligned}$$

- *Construct the Direct Relation IF Matrix A:*

In this step, DM are called to answer a questionnaire to give the values of non-membership, membership and hesitancy proposed between the criteria. We use these variables, we obtain a non-negative matrix (n x n), which represents the Direct Relation IF Matrix $\tilde{A}_z^{(k)}$.

$z = (\mu_{ij}, v_{ij}, \pi_{ij})$: Represent the impact relation of the criterion i to the criterion j.

$$\tilde{A}_z^{(k)} = \begin{bmatrix} 0 & \tilde{A}_{z_{12}}^{(k)} & \dots & \tilde{A}_{z_{1n}}^{(k)} \\ \tilde{A}_{z_{21}}^{(k)} & 0 & \dots & \tilde{A}_{z_{2n}}^{(k)} \\ \vdots & \vdots & 0 & \vdots \\ \tilde{A}_{z_{n1}}^{(k)} & \tilde{A}_{z_{n2}}^{(k)} & \dots & 0 \end{bmatrix} \quad (6)$$

- *Defuzzify the Direct Relation IF Matrix X:*

We calculate the defuzzify value of the aggregated intuitionistic fuzzy relation by using the equation bellow:

$$\bar{r}_{ij} = \mu_{ij} - v_{ij} + (2\beta - 1)\pi_{ij} \quad (7)$$

β represent the risk neutral, where ($\beta = 0.5$).

We obtain defuzzify the Direct Relation Intuitionistic Fuzzy Matrix X as follow:

$$X = \begin{bmatrix} 0 & \dots & \bar{r}_{1n} \\ \vdots & \ddots & \vdots \\ \bar{r}_{n1} & \dots & 0 \end{bmatrix} \quad (8)$$

- *Construct the Normalized Direct Relational IF Matrix N:*

$\tilde{N}_z^k$ is given by:

$$N = \frac{X}{\min \left[\frac{1}{\max \sum_{j=1}^n |\bar{r}_{ij}|}, \frac{1}{\max \sum_{i=1}^n |\bar{r}_{ij}|} \right]} \quad i, j \in (1, 2, \dots, n) \quad (9)$$

- *Construct the Total Relation IF Matrix T:*

We obtain T like as:

$$T = N(1 - N)^{-1} \quad (10)$$

- *Calculate the Cause/Effect groups:*

We construct the impact digraph map by using the horizontal ($r_i + c_i$) and vertical ($r_i - c_i$) axes.

r_i : Sum of the jth row

c_i : Sum of the ith column.

$$\tilde{T}_z = [\tilde{t}_{zij}]_{n \times n} \quad (11)$$

$$r_i = \left[\sum_{j=1}^n \tilde{t}_{ij} \right]_{n \times 1} \quad (12)$$

$$c_i = \left[\sum_{i=1}^n \tilde{t}_{ij} \right]_{1 \times n} \quad (13)$$

If the vertical axis are positive, the indicate a causal factor, else the indicate the effect in the group.

- *Obtain the weights of criteria:*

We obtain the weights of different criteria of SD by the following equation:

$$w_i = \frac{\sqrt{(r_i + c_i)^2 + (r_i - c_i)^2}}{\sum_i^n \sqrt{(r_i + c_i)^2 + (r_i - c_i)^2}} \quad (14)$$

Step 5: Calculates values of selected criteria

In this step we calculate the values of each criterion selected in step 1 by using the equation developed in our article [22].

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The values of the criteria are bounded between zero and one.

For example, we take the reactivity criteria of the economic dimension:

Reactivity: It is the capability to respond quickly and easily to fluctuating needs in the market.

The equation for calculating the criteria value (C) of reactivity is show as follow:

$$C = \frac{1}{C_{\text{Re activity}}} , \quad C_{\text{Re activity}} = \begin{cases} 1 \text{ if Good} \\ 2 \text{ if Average} \\ 3 \text{ if Low} \end{cases}$$

Step 6: Choice of scenario for SD strategy:

In this step we choose a scenario for define the weight of SD dimensions according to the strategy followed by the company, as shown in the Table III. We calculate the weight in such a way that:

$$W_{\text{economic}} + W_{\text{environmental}} + W_{\text{social}} = 1$$

$$W_{\text{economic}} > 0, W_{\text{environmental}} > 0, W_{\text{social}} > 0$$

$W_{\text{economic}}, W_{\text{environmental}}$ and W_{social} : Weight of economic, environmental and social dimension successively.

TABLE III

DIFFERENT SCENARIO TO DEFINE THE WEIGHT OF SD DIMENSIONS

Different scenario possible
$W_{\text{economic}} = W_{\text{environmental}} = W_{\text{social}}$
$W_{\text{economic}} > W_{\text{environmental}} > W_{\text{social}}$
$W_{\text{economic}} > W_{\text{social}} > W_{\text{environmental}}$
$W_{\text{environmental}} > W_{\text{economic}} > W_{\text{social}}$
$W_{\text{environmental}} > W_{\text{social}} > W_{\text{economic}}$
$W_{\text{social}} > W_{\text{economic}} > W_{\text{environmental}}$
$W_{\text{social}} > W_{\text{environmental}} > W_{\text{economic}}$

Step 7: Calculate the social, environmental and economic index:

In this step we calculate the economic, environmental and social index of each supplier, such as:

$$I_{\text{economique}} = \sum_{i=1}^n W_i C_i \quad (15)$$

$$I_{\text{environmental}} = \sum_{i=1}^m W_i C_i \quad (16)$$

$$I_{\text{social}} = \sum_{i=1}^k W_i C_i \quad (17)$$

$I_{\text{economique}}, I_{\text{environmental}}$ and I_{social} represent the economic, environment and social index successively.

n, m and k : Number of economic, environment and social criteria successively.

W_i : Weight of criteria i.

C_i : Numeric value of the criteria i, where $C_i \in [0,1]$.

Step 8: Calculate the index of tree interfaces de SD:

In this step we calculate the tree index of interfaces of SD as follow:

- Index of viable interface: precaution/prevention, empowerment, robustness of choices, adaptability, etc.

$$I_{\text{viable}} = I_{\text{economique}} \times I_{\text{environmental}} \times 10 \quad (18)$$

- Index of the livable interface: the living environment, the effects on health and safety, acceptance of the population, lifestyle, etc.

$$I_{\text{vivable}} = I_{\text{environmental}} \times I_{\text{social}} \times 10 \quad (19)$$

- Index of the equitable interface: accessibility to the greatest number, intergenerational and intergenerational equity, sharing of wealth, compensation for prejudices, etc.

$$I_{\text{equitable}} = I_{\text{economique}} \times I_{\text{social}} \times 10 \quad (20)$$

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Step 9: Calculate the supplier sustainability performance index:

In this step we calculate supplier sustainability performance index:

$$I_{sustainability} = I_{viable} \times I_{vivable} \times I_{equitable} \quad (21)$$

V. APPLICATION

In this step, we will apply our developed method to choose between five suppliers. We calculate the performance index of each supplier. Then we choose the one between them, which most respects the concept of SD.

A. The calculation of the sustainability performance index of the supplier¹

Step 1: Identification the criteria:

For illustration example of the developed method we use some criteria from our work [22], as shown in Table IV.

TABLE IV
THE CRITERIA OF SD

Criteria		
Economic	Environmental	Social
Cost (C ₁)	Recycling (C ₆)	Human rights (C ₁₁)
Delivery (C ₂)	Use of Resources (C ₇)	Health and security at work (C ₁₂)
Quality (C ₃)	Environmental label (C ₈)	Training, support and education (C ₁₃)
Flexibility (C ₄)	Pollution (C ₉)	Condition of work (C ₁₄)
Technical and technological Capacity (C ₅)	Program (C ₁₀)	Jobs and wealth (C ₁₅)

Step 2: We use Table 1 for to fix IF-DEMATEL:

Step 3: Calculate the weight of DM:

For this study, we have three managers of different years of experience to evaluate the selected criteria. We apply Equation (4) we obtain the importance weight of each manager, as shown in Table V.

TABLE V
DM WEIGHT

DM	Number of experience	Importance values	DM weight
Manager1	20 year	VI	0,413265306
Manager2	15 year	I	0,344387755
Manager3	10 year	MI	0,242346939

Step 4: Calculation of criteria weights:

In this step, DM are asked to compare between the criteria selected in each dimension to indicate the relationships of influence.

For example, the intuitionistic judgments for economic dimension given by manager1 is shown in Table VI.

TABLE VI
MANAGER1 INTUITIONISTIC JUDGMENTS FOR ECONOMIC DIMENSION

Manager ¹	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	NI	HI	HI	HI	MI
C ₂	VHI	NI	HI	HI	LI
C ₃	VHI	LI	NI	LI	VHI
C ₄	HI	HI	HI	NI	LI
C ₅	HI	HI	HI	HI	NI

For example, the intuitionistic judgments for environmental dimension given by manager1 is shown in Table VII.

TABLE VII
MANAGER¹ INTUITIONISTIC JUDGMENTS FOR ENVIRONMENTAL DIMENSION

Manager ¹	C ₆	C ₇	C ₈	C ₉	C ₁₀
C ₆	NI	VHI	HI	HI	VHI
C ₇	HI	NI	VHI	HI	LI
C ₈	VHI	HI	NI	HI	HI
C ₉	LI	HI	HI	NI	HI
C ₁₀	HI	VHI	MI	HI	NI

For example, the intuitionistic judgments for social dimension given by manager1 is shown in Table VIII.

TABLE VIII
MANAGER¹ INTUITIONISTIC JUDGMENTS FOR SOCIAL DIMENSION

Manager ¹	C ₁₁	C ₁₂	C ₁₃	C ₁₄	C ₁₅
C ₁₁	O	HI	LI	LI	VHI
C ₁₂	MI	O	LI	HI	MI
C ₁₃	HI	HI	O	HI	HI
C ₁₄	HI	VHI	MI	O	MI
C ₁₅	HI	LI	MI	LI	O

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- Construct the Direct Relation IF Matrix A:

We applied an IFWA operator, for calculated the aggregated IF Decision Matrix according to the manager1 opinions by using Equation (5), we obtain the Table IX:

TABLE IX

THE AGGREGATED IF RELATION MATRIX FOR ECONOMIC DIMENSION

A	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	(0.00,1.00 ,0.00)	(0.68,0.26 ,0.06)	(0.85,0.13 ,0.02)	(0.59,0.36 ,0.05)	(0.81,0.18 ,0.01)
C ₂	(0.90,0.10 ,0.00)	(0.00,1.00 ,0.00)	(0.62,0.32 ,0.06)	(0.59,0.36 ,0.05)	(0.40,0.51 ,0.09)
C ₃	(0.90,0.10 ,0.00)	(0.35,0.60 ,0.05)	(0.00,1.00 ,0.00)	(0.51,0.41 ,0.08)	(0.90,0.10 ,0.00)
C ₄	(0.82,0.16 ,0.02)	(0.75,0.20 ,0.05)	(0.75,0.20 ,0.05)	(0.00,1.00 ,0.00)	(0.51,0.41 ,0.08)
C ₅	(0.85,0.13 ,0.02)	(0.60,0.35 ,0.05)	(0.75,0.20 ,0.05)	(0.60,0.35 ,0.05)	(0.00,1.00 ,0.00)

- Construct the Defuzzify the Direct Relation IF Matrix A:

To construct A, we use the Equation (7). We obtain the Table X as follow.

TABLE X

THE DEFUZZIFIED AGGREGATED IF RELATION MATRIX FOR ECONOMIC DIMENSION

X	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	-1	0.42	0.72	0.23	0.63
C ₂	0.8	-1	0.30	0.23	-0.11
C ₃	0.8	-0.25	-1	0.1	0.8
C ₄	0.66	0.50	0.55	-1	0.1
C ₅	0.72	0.25	0.55	0.25	-1

- Construct the Normalize the Direct Relation IF Matrix N:

With the Equation (9), we get N, as shown in Table XI.

TABLE XI

THE NORMALIZED MATRIX FOR ECONOMIC DIMENSION

N	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	-0.51	0.21	0.37	0.12	0.32
C ₂	0.41	-0.51	0.15	0.12	-0.07
C ₃	0.41	-0.13	-0.51	0.05	0.41
C ₄	0.34	0.26	0.28	-0.51	0.05
C ₅	0.38	0.13	0.28	0.13	-0.51

- Construct the Total Relation IF Matrix T:

We use the Equation (10) to construct T, as follow in Table XII.

TABLE XII

THE TOTAL RELATION IF MATRIX T FOR ECONOMIC DIMENSION

N	C ₁	C ₂	C ₃	C ₄	C ₅
C ₁	-0.13	0.14	0.30	0.11	0.26
C ₂	0.28	-0.29	0.17	0.09	0.07
C ₃	0.31	0.01	-0.19	0.08	0.29
C ₄	0.31	0.16	0.25	-0.28	0.15
C ₅	0.33	0.11	0.26	0.11	-0.20

- Calculate the cause and effect groups:

To calculate R and C, we use the Equations (12) and (13) respectively. The result is showed in Table XIII as follow.

TABLE XIII

THE CAUSE AND EFFECT GROUPS

	R	C	R+C	Rank	R-C	Rank	Group
C ₁	1.10	0.68	1.78	1	0.42	1	Cause
C ₂	0.13	0.32	0.45	5	-0.19	4	Effect
C ₃	0.79	0.50	1.29	2	0.29	2	Cause
C ₄	0.11	0.60	0.71	4	-0.49	5	Effect
C ₅	0.58	0.61	1.19	3	-0.03	3	Effect

- Calculate the weights of criteria:

Table XIV shows the result of calculating the weights of the criteria selected with Equation (14) as follows.

TABLE XIV

THE WEIGHTS OF CRITERIA

Dimension					
Economic		Environmental		Social	
Criteria	Weight	Criteria	Weight	Criteria	Weight
C ₁	0.32	C ₆	0.32	C ₁₁	0.15
C ₂	0.09	C ₇	0.09	C ₁₂	0.21
C ₃	0.23	C ₈	0.23	C ₁₃	0.23
C ₄	0.15	C ₉	0.15	C ₁₄	0.22
C ₅	0.21	C ₁₀	0.21	C ₁₅	0.19

Step 5: Calculates values of selected criteria

We follow the equation developed in our article [17], we get the Table XV:

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TABLE XV
THE VALUES OF THE CRITERIA

Dimension		Economic		Economic	
Criteria	Value	Criteria	Value	Criteria	Value
C ₁	0.32	C ₆	0.32	C ₁₁	0.15
C ₂	0.09	C ₇	0.09	C ₁₂	0.21
C ₃	0.23	C ₈	0.23	C ₁₃	0.23
C ₄	0.15	C ₉	0.15	C ₁₄	0.22
C ₅	0.21	C ₁₀	0.21	C ₁₅	0.19

Step 6: Calculate the weight of SD dimensions:

We select a scenario where the dimension weights are equal as follow:

$$W_{\text{economic}} = W_{\text{environmental}} = W_{\text{social}} = 1/3$$

Step 7: Calculate the index of dimension of SD:

Using the values of the criteria calculated by the equation cited in our work [17], and the Equations (15), (16) and (17), we can calculate the index of the three dimensions of SD of supplier¹. The Table XVI showed the values of the criteria calculated for the supplier¹.

TABLE XVI
THE VALUES OF THE CRITERIA CALCULATED FOR THE SUPPLIER¹

Dimension		Economic		Economic	
Criteria	Criterion value	Criteria	Criterion value	Criteria	Criterion value
C ₁	0.66	C ₆	0.77	C ₁₁	0.87
C ₂	0.75	C ₇	0.71	C ₁₂	0.45
C ₃	0.56	C ₈	0.69	C ₁₃	0.76
C ₄	0.78	C ₉	0.56	C ₁₄	0.56
C ₅	0.67	C ₁₀	0.45	C ₁₅	0.76

The index calculated of supplier¹ are:
 $I_{\text{economique}} = 0.67$, $I_{\text{environmental}} = 0.65$ and
 $I_{\text{social}} = 0.67$.

Step 8: Calculate Index of interfaces of SD:

By using the Equations (18), (19) and (20) we can calculate the index of the viable, livable and equitable interface of SD for the supplier¹, as follow respectively:

$$I_{\text{viable}} = 4.31, I_{\text{vivable}} = 4.44 \text{ and } I_{\text{equitable}} = 4.32$$

Step 9: Calculate the supplier sustainability performance index:

To calculate the supplier sustainability performance index for the supplier¹, we use the Equation (21).

The calculi gave as result: $I_{\text{sustainability}} = 82.63\%$.

VI. RESULTS AND DISCUSSION

From the Table 13, we obtain the importance between criteria of the economic dimension as follow: According to the axe (R+C): $C_1 > C_3 > C_5 > C_4 > C_2$ and According to the axe (R-C): $C_1 > C_3 > C_5 > C_2 > C_4$.

The Figures II, III and IV showed respectively the diagram of cause-effect relationships between economic, environmental and social criteria, as follow:

FIGURE II THE CAUSAL DIAGRAM OF ECONOMIC DIMENSION

FIGURE III THE CAUSAL DIAGRAM OF ENVIRONMENT DIMENSION

FIGURE IV THE CAUSAL DIAGRAM OF SOCIAL DIMENSION

We apply the same steps to calculate the sustainability performance index of the supplier¹ on the other suppliers, the Table XVII shows these calculi as follow:

TABLE XVII
THE SUSTAINABILITY PERFORMANCE INDEX

Supplier	Sustainability performance index	Rank
Supplier ¹	82.63%	2
Supplier ²	70.23%	4
Supplier ³	75.03%	3
Supplier ⁴	30.98%	5
Supplier ⁵	87.10%	1

From the Table XVII, the best supplier who respects the concept of the sustainable of development is the supplier number 5.

The results obtained show that our developed model makes it possible to classify and select the best suppliers.

VII. CONCLUSIONS

This paper develops a decision making model based on IFS DEMATEL model to choice the best supplier in terms of respect for SD. We use IFS to result the problem of hesitation in uncertain problem, and the DEMATEL to obtain the weight of SD criteria selected.

Our contribution and innovation of this article are as follows:

- It takes into consideration the link between the economic and environmental dimension. This is what we call to be viable.

- It takes into consideration the link between the economic and social dimension. This is what we call equality.
- It takes into consideration the link between the environmental and economic dimension. This is what we call to be livable.
- It presents a simple model that can be adopted to calculate and assess the sustainability performance of suppliers to companies operating in any sector.

In our next work, we will take more criteria in the process of calculating the weight of decision-makers depending on the number of years of experience.

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