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New Framework for Detecting the suitable Supplier of Smart Systems Based on the effect of Internet of Things

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Abstract: Nowadays, there are many organizations and institutions have realized the significant effect of the Internet of Things (IoT). The IoT technologies can enhance the quality of processes and services that make organizations seek to integrate these technologies to their products especially their smart devices. The IoT can be considered as one of the most important requirements that influences on detecting the best supplier. Therefore, every organization should take into account the effect of IoT on detecting the best supplier. So that, there is a need to a framework to help organizations for detecting the suitable supplier based on the effect of IoT. This work aims to introduce a proposed framework using trapezoidal neutrosophic numbers to detect the suitable supplier for purchasing smart systems based on the effect of IoT. The proposed framework consists of six phases. The proposed framework integrates the values and ambiguities index method with Single Valued Trapezoidal Neutrosophic Numbers (SVTN-numbers) which generalized fuzzy set and intuitionistic fuzzy to give more accurate results. The proposed framework is applied with a case study and the results concluded that the proposed framework can handle unclear information which exists in the purchasing process for detecting the suitable supplier of smart devices based on the effect of IoT. Also, the proposed framework can handle uncertainty in decision making and link between customers and suppliers which can improve Supply Chain Management (SCM).

Index Terms: Internet of Things (IoT), Single Valued Trapezoidal Neutrosophic Numbers (SVTN-numbers), Supply Chain Management (SCM)

1. Introduction

The IoT is not only a network of computers, but it has evolved into a network of device of all type and sizes [2]. The IoT services can help companies to come into direct contact with potential customers and build new relationships [3]. Companies integrated these technologies in their products to achieve more competitive advantage. According to [11] “the internet of things consists of things that are connected to the Internet, anytime, anywhere. As [6] pointed out “The basic idea is that the IoT connects objects around us (electronic, electrical, and non-electrical) to provide communication and services”. The IoTis applied in many applications such as smart cities, education, agriculture, and industry [1]. The main characteristics of the IoT involve [4]: interconnectivity, things-related services, heterogeneity, dynamic changes, enormous scale, and safety connectivity. IoT can improve services that make companies need to embed IoT to their products so that has effect on supplier selection. According to [21] companies can enhance their work through the use of IoT. Many companies have observed the significant benefits of using IoT technology. Therefore, IoT has effect on decision making process in various phases of selling and buying [3].

According to [27] IoT can be considered a powerful technology for operational efficiency, improved decision-making processes, overall productivity that can support Supply Chain Management (SCM). As [26] pointed out the benefits of IoT in SCM include: enhance decision making, improve inventory management, predictive maintenance, and decreases costs, increasing customer satisfaction, increasing sales, and reducing risks.

Although, there are different types of the same product, IoT became one of the most important elements that distinguish a product from others. So that, there is a need to a framework to recommend customers with the suitable supplier based on IoT. This motivated us to propose a new mathematical model based on the effect of IoT to help customers to detect the best supplier. Therefore, the proposed framework can be considered as a comprehensive model that links between customers and suppliers for detecting the best suppliers based on the effect of IoT using trapezoidal neutrsophic numbers. Also, the results concluded that the consideration of the IoT for determining the suitable supplier of smart systems during the purchasing phase of SCM can achieve the benefits of IoT which improve the SCM.

This paper is arranged as the following: the first section gives the introduction; the second section introduces IoT components, characteristics, and application; the third section introduces benefits **of** IoT in Supply Chain Management (SCM), the fourth section introduces the concept of neutrsophic; the fifth section describe the proposed framework to detect the best supplier for building smart systems based on the effect of IoT; the sixth section provides conclusion and future work; finally gives references.

2. The Iot Components, Characteristics, and Application

The concept of IoT has evolved since it was conceived in the late 1990s. According to [16] the IoT enables things or objects to communicate with each. According to [20] "The expression 'Internet of Things' is wider than a single concept or technology. It is rather a new paradigm that involves a wide set of technologies, applications and visions. As [8] pointed out "the IoT make use of intelligent interfaces. It can focus on the virtual identity of the smart objects and their capabilities to interact intelligently with other objects, humans and environments".

According to [5] there are three IoT layers; the following figure represents the three main IoT layers

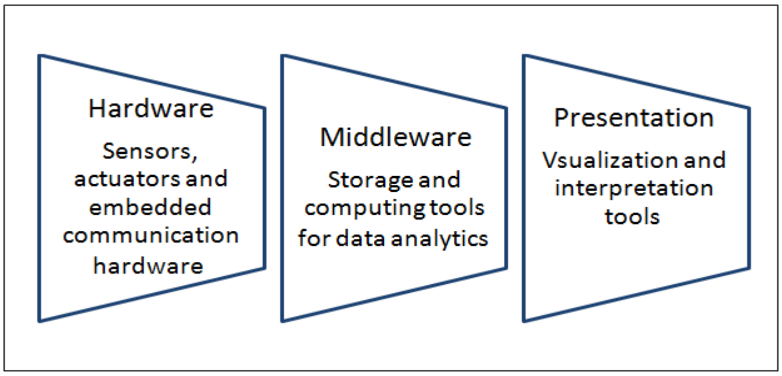

Fig. 1. The three main IoT layers

The infrastructure and technology of IoT involved sensors, processors, cloud computing, and wireless connectivity. As [8] pointed out IoT involves the following elements that are summarized in figure 2:

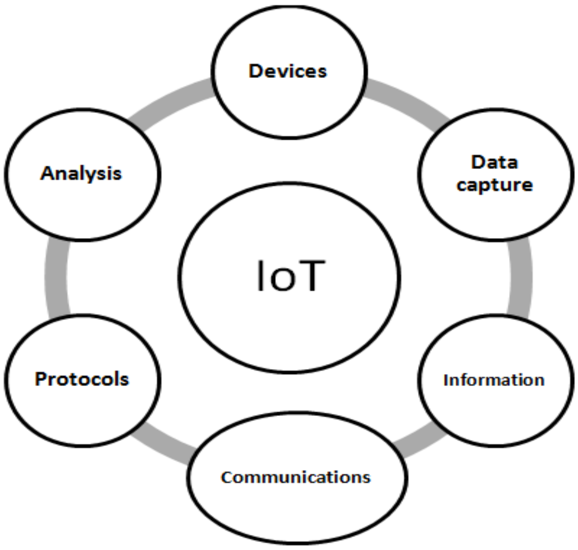

Fig. 2. The main IoT elements

The application of IoT can enhance many services and improve the quality of life in society. As [15] pointed out the applications of IoT include:

1. Home automation,
2. Fitness tracking,

3. Monitoring,
4. Environment protection,
5. Smart cities, and
6. Industrial

IoT applications can be classified based on the type of network availability, coverage, scale, heterogeneity, repeatability, user involvement and impact [15]. According to [12] IoT characteristics have effect on its functions. As [3] pointed out the concept of IoT can enhance many operational processes. As [14] pointed out IoT could improve businesses processes and proactively provide solutions. As [13] stated IoT can improve service delivery by ensuring timely and introduce efficient delivery to customers. According to [10, 25] the use of IoT services can be considered as one of the important elements of service quality. The IoT can be applied in business, transport, home, energy, and other [2].

3. Benefits of IoT in Supply Chain Management (SCM)

Supply Chain Management (SCM) consists of suppliers, factories, distributors and retailers for supporting customer satisfaction. The SCM aims to have the correct item at the correct time. As [26, 28] pointed out the integration of IoT in supply chain management leads to many improvements that can be summarized in the following figure:

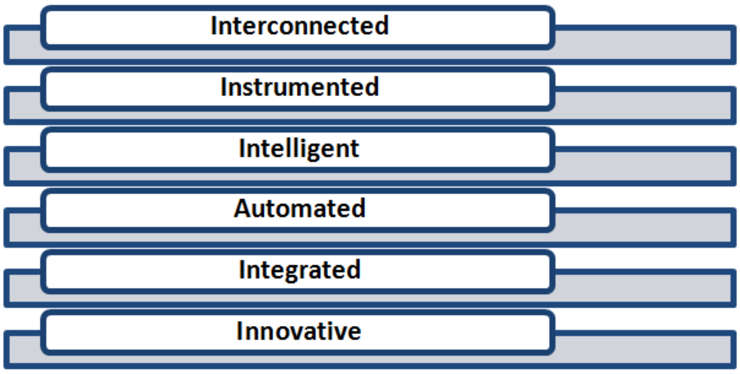

Fig. 3. Improvements in SCM based on IoT

According to [27, 29] the IoT can introduce many benefits for SCM as shown in the following figure

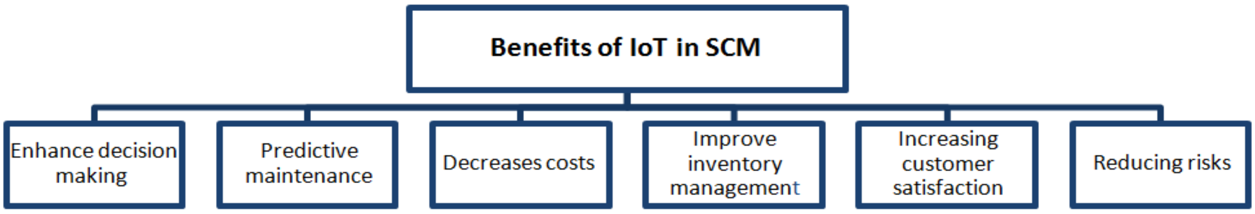

Fig. 4. Benefits of IoT in SCM

4. The Concept of Neutrosophic

The concepts of neutrosophic can provide a generalization of fuzzy set and intuitionistic fuzzy set (Smarandache, 2005) and it can handle indeterminate and inconsistent information [18]. Fuzzy set is characterized by its membership function between zero and one[7]. According to [24]]the neutrosophicnumbers are best fit in manipulating indeterminacy and inconsistent data. As [23] pointed, neutrosophic numbers that can support decision making. According to [17] the weighted value and ambiguity of neutrosophic numbers provides more importance to uncertainty. Deli and Şubaş [9] generalized new method based on Single Valued Neutrosophic-numbers and show effective results.

4.1 Single Valued Trapezoidal Neutrosophic Numbers (SVTN-numbers)

SVTN-numbers can manipulate ill-known quantity in data. The SVTN-numbers have beenintroduced in many applications [22] as medical diagnosis,and fault diagnosis.

Definition 1: Based on [19] the SVTN-numbers $\bar{a}$ can be represented as: $\bar{a} = ((a, b, c, d); w_{\bar{a}}, u_{\bar{a}}, y_{\bar{a}})$ and its (truth $\mu_{\bar{a}}(x)$, indeterminacy$\upsilon_{\bar{a}}(x)$ and falsity$\lambda_{\bar{a}}(x)$) membership functions are defined as:

$$\mu_{\bar{a}}(x) = \begin{cases} \frac{(x-a)w_{\bar{a}}}{b-a}, & a \le x < b \\ w_{\bar{a}}, & b \le x \le c \\ \frac{(d-x)w_{\bar{a}}}{d-c}, & c \le x \le d \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

$$\upsilon_{\bar{a}}(x) = \begin{cases} \frac{(b-x+u_{\bar{a}}(x-a))}{b-a}, & a \le x < b \\ u_{\bar{a}}, & b \le x \le c \\ \frac{(x-c+u_{\bar{a}}(d-x))}{d-c}, & c \le x \le d \\ 0 & , \text{otherwise} \end{cases} \quad (2)$$

$$\lambda_{\bar{a}}(x) = \begin{cases} \frac{(b-x+y_{\bar{a}}(x-a))}{b-a}, & a \le x < b \\ y_{\bar{a}}, & b \le x \le c \\ \frac{(x-c+y_{\bar{a}}(d-x))}{d-c}, & c \le x \le d \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

4.2. The Values and Ambiguities for SVTN –Numbers

Consider ā= ((a, b, c, d); wā, uā, yā); then the cut sets, ambiguities, and weighted values can be introduced as:

1- α-cut set of the SVTN-number ā for truth-membership is represented as:

$$[L\bar{a}(\alpha), R\bar{a}(\alpha)]=[\frac{(w_{\bar{a}}-\alpha)a+\alpha b}{w_{\bar{a}}}, \frac{(w_{\bar{a}}-\alpha)d+\alpha c}{w_{\bar{a}}}]$$

If f(α) =α, where f(α)∈ [0, 1] and is monotonic and non-decreasing of αα ∈ $[0, w_{\bar{a}}]$

$$V_{\mu}(\bar{a}) = = \frac{(a+2b+2c+d)(w_{\bar{a}})^2}{6} \quad (4)$$

$$A_{\mu}(\bar{a}) = \frac{(d-a+2c-2b))(w_{\bar{a}})^2}{6} \quad (5)$$

2- β-cut set of the SVTN-number ā for indeterminacy membership is:

$$[\acute{L}\bar{a}(\beta), \acute{R}\bar{a}(\beta)] = [\frac{(1-\beta)b+(\beta-u_{\bar{a}})a}{1-u_{\bar{a}}}, \frac{(1-\beta)c+(\beta-u_{\bar{a}})d}{1-u_{\bar{a}}}]$$

If g(β)=1−β, whereg(β) ∈ [0, 1] and g(β)is monotonic and non-increasing of β ∈ $[u_{\bar{a}}, 1]$, the value and ambiguity of the SVTN-number ā can berepresented as:

$$V_{\upsilon}(\bar{a}) = \frac{(a+2b+2c+d)(1-u_{\bar{a}})^2}{6} \quad (6)$$

$$A_{\upsilon}(\bar{a}) = \frac{(d-a+2c-2b)(1-u_{\bar{a}})^2}{6} \quad (7)$$

3- γ - cut set of the SVTN-number a for falsity-membership is

$$[\acute{\acute{L}}\bar{a}(\gamma), \acute{\acute{R}}\bar{a}(\gamma)] = [\frac{(1-\gamma)b+(\gamma-y_{\bar{a}})a}{(1-y_{\bar{a}})}, \frac{(1-\gamma)c+(\gamma-y_{\bar{a}})d}{(1-y_{\bar{a}})}]$$

Where γ ∈ $[y_{\bar{a}}, 1]$.If h(γ)=1- γ , where h(γ) ∈ [0, 1] and h(γ)is non-increasing of γ ∈ $[y_{\bar{a}}, 1]$, the value and ambiguity of the SVTrN-numberā are;

$$V_{\lambda}(\bar{a}) = \frac{(a+2b+2c+d)(1-y_{\bar{a}})^2}{6} \quad (8)$$

$$A_{\lambda}(\bar{a}) = \frac{(d-a+2c-2b)(1-y_{\bar{a}})^2}{6} \quad (9)$$

3.2 The Values and Ambiguities Index of the SVTN-numbers

Consider $\bar{a} = ((a, b, c, d); w_{\bar{a}}, u_{\bar{a}}, y_{\bar{a}})$, then the values and ambiguities index method can be adapted and generalized for [0, 1] as following:

$$V(\bar{a}, \lambda) = \frac{(a + 2b+2\,c+d)}{6}\,[\lambda w_{\bar{a}}2 + (1-\lambda)(1-u_{\bar{a}})\,2 + (1-\lambda)(1-y_{\bar{a}})\,2] = V\mu(\bar{a})\,\lambda + V\upsilon(\bar{a})\,(1-\lambda) + V\lambda(\bar{a})\,(1-\lambda) \tag{10}$$

And

$$A(\bar{a}, \lambda) = \frac{(d-a+2c-2b)}{6}[\lambda w_{\bar{a}}\,2+ (1-\lambda)(1-u_{\bar{a}})\,2+ (1-\lambda)\,(1-y_{\bar{a}})\,2] = A\mu(\bar{a})\,\lambda + A\upsilon(\bar{a})\,(1-\lambda) + A\lambda(\bar{a})(1-\lambda) \tag{11}$$

Where $\lambda \in [0, 1]$ and λ is a weight which represents the decision maker's preference information.

$\lambda \in [0,.5]$ shows that the decision maker has pessimistic feeling; $\lambda \in [.5,1]$ shows that the decision maker has optimistic feeling; $\lambda = .5$ shows that the decision maker is between positive and negative feeling.

Let $G = ((a, b, c, d); w_G, u_G, y_G)$, $H= ((a, b, c, d); w_H, u_H, y_H)$ be two SVTN-numbers.

5. The Proposed Framework

The proposed framework consists of six steps as shown in the follows figure:

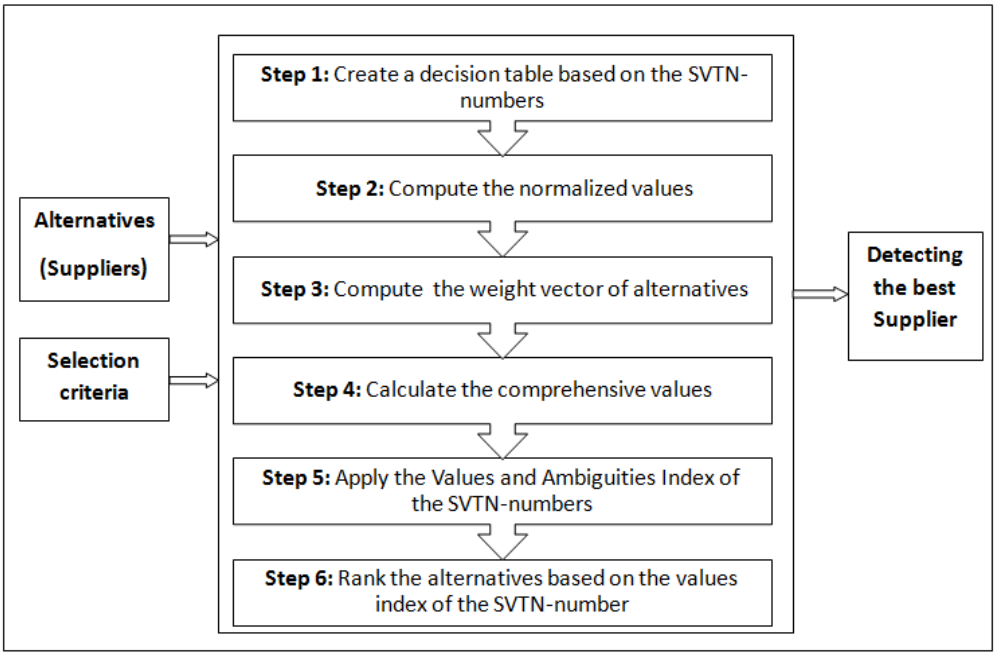

Fig. 5. The proposed framework

The proposed framework integrates the SVTN-numbers with the Values and Ambiguities Index method. The proposed framework consists of six steps; the outputs and deliverables of each step represent the inputs for next step as the follows:

Step 1: Create a decision table based on the SVTN-numbers

Step 2: Compute the normalized values, where $R= ((a_{ij}/\bar{a}^+, b_{ij}/\bar{a}^+, c_{ij}/\bar{a}^+, d_{ij}/\bar{a}^+); w_{\bar{a}ij}, u_{\bar{a}ij}, y_{\bar{a}ij})$, such that

$$\bar{a}^+ = \max \{r_{ij}.\ i \in I_{row},\ j \in I_{columns}\}$$

Step 3: Compute $u_{ij} = \omega_i r_{ij}$ (for $i \in I_{rows}$, $j \in I_{columns}$) , where $\omega = (\omega_1, \omega_2 \ldots \omega_{row})$ be the weight vector of alternatives

$$U = \sum_{i=1}^{row} u_{ij} = ((\sum_{i=1}^{row} a\,\omega_i r_{ij}, \sum_{i=1}^{row} b\,\omega_i r_{ij}, \sum_{i=1}^{row} c\,\omega_i r_{ij}, \sum_{i=1}^{row} d\,\omega_i r_{ij});\ \text{Min}\ w_{\bar{a}ij}, \text{Max}\ u_{\bar{a}ij}, \text{Max}\ y_{\bar{a}ij})$$

Step 4: calculate the comprehensive values

This step computes comprehensive values by finding the sum of each column

Step 5: Apply the Values and Ambiguities Index of the SVTN-numbers

$$V(S_j, \lambda) = \frac{(a + 2b+2c+d)}{6} [\lambda w_{Sj}^{2} + (1-\lambda)(1-u_{Sj})^{2} + (1-\lambda)(1-y_{Sj})^{2}]$$

Step 6: Rank the alternatives based on the values index of the SVTN-number

5.1 The Proposed framework with numerical example

An export and import organization wants to buy new smart devices for its employees. This organization need to choose the suitable supplier of the new smart devices according to three characteristics of IoT as the following

- Response time
- Scalability
- Price

The proposed framework can be applied for the selection process as follows:

Table 1.The linguistic term and corresponding Linguistic values

linguistic term	**Linguistic values**
Very poor	((0.1, 0.1, 0.1, 0.1); 0.5, 0.3, 0.3)
Poor	((0.2, 0.3, 0.4, 0.5); 0.6, 0.2, 0.2)
Fairly poor	((0.3, 0.4, 0.5, 0.6); 0.7, 0.1, 0.1)
Medium	((0.4, 0.5, 0.6, 0.7); 0.8, 0.0, 0.1)
Fairly good	((0.5, 0.6, 0.7, 0.8); 0.7, 0.3, 0.3)
Good	((0.7, 0.8, 0.9, 1.0); 0.8, 0.2, 0.2)
Very good	((1.0, 1.0, 1.0, 1.0); 0.9, 0.1, 0.1)

Step 1: Create a decision table based on the SVTN-numbers
Create table such that rows represent decision criteria and columns represent alternatives as the follows:

Table 2. Decision table

Criteria	**Alt1**	**Alt2**	**Alt3**
Response time	((0.2, 0.3, 0.4, 0.5); 0.6, 0.2, 0.2)	((0.7, 0.8, 0.9, 1.0); 0.8, 0.2, 0.2)	((0.4, 0.5, 0.6, 0.7); 0.8, 0.0, 0.1)
Scalability	((0.7, 0.8, 0.9, 1.0); 0.8, 0.2, 0.2)	((1.0, 1.0, 1.0, 1.0); 0.9, 0.1, 0.1)	((0.3, 0.4, 0.5, 0.6); 0.7, 0.1, 0.1)
Price	((0.4, 0.5, 0.6, 0.7); 0.8, 0.0, 0.1)	((0.4, 0.5, 0.6, 0.7); 0.8, 0.0, 0.1)	((0.5, 0.6, 0.7, 0.8); 0.7, 0.3, 0.3)

Step 2: Compute the normalized values
$R= ((a_{ij}/\bar{a}^{+}, b_{ij}/\bar{a}^{+}, c_{ij}/\bar{a}^{+}, d_{ij}/\bar{a}^{+}); w_{\bar{a}ij}, u_{\bar{a}ij}, y_{\bar{a}ij})$, such that $\bar{a}^{+} = \max \{r_{ij}.\ i \in I_{row}, j \in I_{columns}\}$

Table 3.The normalized values

Criteria	**Alt1**	**Alt2**	**Alt3**
Response time	((0.2, 0.3, 0.4, 0.5); 0.6, 0.2, 0.2)	((0.7, 0.8, 0.9, 1.0); 0.8, 0.2, 0.2)	((0.4, 0.5, 0.6, 0.7); 0.8, 0.0, 0.1)
Scalability	((0.7, 0.8, 0.9, 1.0); 0.8, 0.2, 0.2)	((1.0, 1.0, 1.0, 1.0); 0.9, 0.1, 0.1)	((0.3, 0.4, 0.5, 0.6); 0.7, 0.1, 0.1)
Price	((0.4, 0.5, 0.6, 0.7); 0.8, 0.0, 0.1)	((0.4, 0.5, 0.6, 0.7); 0.8, 0.0, 0.1)	((0.5, 0.6, 0.7, 0.8); 0.7, 0.3, 0.3)

Step 3: Compute $u_{ij}=\omega_i r_{ij}$(for $i \in I_{rows}$, $j \in I_{columns}$),

$$U = \sum_{i=1}^{row} u_{ij} = ((\sum_{i=1}^{row} a\, \omega_i r_{ij}, \sum_{i=1}^{row} b\, \omega_i r_{ij}, \sum_{i=1}^{row} c\, \omega_i r_{ij}, \sum_{i=1}^{row} d\, \omega_i r_{ij});\ \text{Min } w_{\bar{a}ij}, \text{Max } u_{\bar{a}ij}, \text{Max } y_{\bar{a}ij})$$

$\omega = (\omega_1, \omega_2 \ldots \omega_{row})$ be the weight value of alternatives,
Where $\omega_i \in [0,1]$, $i \in I_{row}$, and $\sum_{i=1}^{row} \omega_i = 1$ $\omega = (.35, .40, .25)$

Table 4. The weighted values

Criteria	**Alt1**	**Alt2**	**Alt3**
Response time	((0.07, 0.105, 0.14, 0.175); 0.6, 0.2, 0.2)	((0.245, 0.28, 0.315, .350); 0.8, 0.2, 0.2)	((0.14, 0.175, 0.210, 0.245); 0.8, 0.0, 0.1)
Scalability	((0.28, 0.32, 0.36,.40); 0.8, 0.2, 0.2)	((.40, .40, .40, .40); 0.9, 0.1, 0.1)	((0.12, 0.16, 0.2, 0.24); 0.7, 0.1, 0.1)
Price	((0.1, 0.125, 0.15, 0.175); 0.8, 0.0, 0.1)	((0.1, 0.125, 0.15, 0.175); 0.8, 0.0, 0.1)	((0.125, 0.15, 0.175, 0.2); 0.7, 0.3, 0.3)

Step 4: Calculate the comprehensive values

Table 5.The comprehensive values

Criteria	**Alt1**	**Alt2**	**Alt3**
Response time.	((0.07, 0.105, 0.14, 0.175); 0.6, 0.2, 0.2)	((0.245, 0.28, 0.315, .350); 0.8, 0.2, 0.2)	((0.14, 0.175, 0.210, 0.245); 0.8, 0.0, 0.1)
Scalability	((0.28, 0.32, 0.36,.40); 0.8, 0.2, 0.2)	((.40, .40, .40, .40); 0.9, 0.1, 0.1)	((0.12, 0.16, 0.2, 0.24); 0.7, 0.1, 0.1)
Price	((0.1, 0.125, 0.15, 0.175); 0.8, 0.0, 0.1)	((0.1, 0.125, 0.15, 0.175); 0.8, 0.0, 0.1)	((0.125, 0.15, 0.175, 0.2); 0.7, 0.3, 0.3)
The sum of each column	S1= ((0.45, 0.55, 0.65, 0.75); 0.6, 0.2, 0.2)	S2= ((0.745, 0.805, 0.865, 0.925); 0.8, 0.2, 0.2)	S3= ((0.645, 0.485, 0.585, 0.685); 0.7, 0.3, 0.3)

Step 5: Apply the Values and Ambiguities Index of the SVTN-numbers
The values and ambiguities index method can be adapted and calculated for λ[0, 1] as following:

$$V\,(S_j, \lambda) = \frac{(a + 2b+2\ c+d)}{6}\,[\lambda w_{Sj}{}^{2\,+}\ (1-\lambda)(1-u_{Sj})^{2} +\ (1-\lambda)(1-y_{Sj})^{2}]$$

Table 6.The Values index of the SVTN-numbers V (Sj, λ) of the three alternatives

	S1 V (S1, λ)	**S2 V (S2, λ)**	**S V (S3, λ)**
V_μ	.216	.534	.283
V_υ	.384	.534	.283
V_λ	.384	.534	.283
V (S, λ)	V (S1, λ) = .216λ +.284(1- λ) + 384(1- λ)	V (S2, λ) = .534λ + .534 (1- λ) + .534(1- λ)	V (S3, λ) = .283λ + .283 (1- λ) + .283 (1- λ)

Step 6: Rank the alternatives based on the values index of the SVTN-number

Table 7.The ranking results of the three alternatives based on the values index of the SVTN-numbers

λ	**V** $_{(S1,\ \lambda)}$	**V** $_{(S2,\ \lambda)}$	**V** $_{(S3,\ \lambda)}$	**ranking**
0	.668	1.068	.566	S2>S1>S3
.1	.7128	1.014	.5377	S2>S1>S3
.4	.5472	.8544	.4528	S2>S1>S3
.6	.4368	.7476	.3962	S2>S1>S3
.7	.3516	.6942	.3679	S2>S3>S1
.8	.3264	.6408	.3396	S2>S3>S1
.9	.2712	.5874	.3113	S2>S3>S1
1	.216	.534	.283	S2>S3>S1

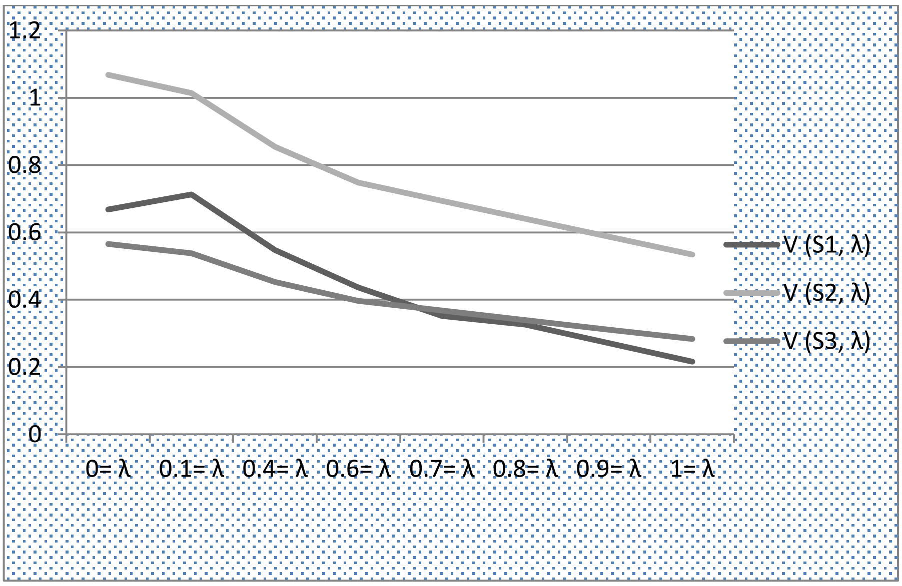

Fig.6. Te ranking results of the three alternatives based on the values index of the SVTN-numbers

Figure 6 represents the interrelationship between the three alternatives based on the value of λ that reflects the decision maker's subjectivity attitude to the SVTN- numbers.Table (7) gives different values forλ as follows:

Forvalues: 0, .1, .4 and .6 where λ∈ [0, .6], the results show that the rank of the three alternatives is S2>S1>S3 and the best supplier based on the effect of IoT is thesecond alternative S2. Secondly, for values: .7, .6, .8, .9 and 1 where λ∈ [.7, 1], where the decision maker prefers positive feeling the results show that the rank of the three alternatives is S2>S3>S1, the best supplier based on the effect of IoT is the second alternative S2. The results indicated that the proposed framework by using trapezoidal neutrosophic numbers can handle unclear and conflicting information which exist in the purchasing process for detecting the best supplier. Also the proposed framework can introduce a new method to detect the best supplier based on the effect of IoT and it can reflect the decision maker's subjectivity attitude to the SVTN- numbers.

The main findings of the proposed framework can be the summarized as the following:

1- The proposed framework incorporated the IoT characteristics as main factor during purchasing smart systems that enable the decision makers to determine the suitable supplier and enhance the purchasing process
2- The proposed framework enable the decision maker to express unclear data with the trapezoidal neutrosophic numbers that involves four dimensions to manipulate the ill known quantities
3- The proposed framework uses SVTN-numbers that handles uncertainty and gives more accurate results rather than the traditional methods that applied fuzzy numbers
4- The integration of the IoT technologies can enhance the efficiency of smart devices which make the purchasing process more effective
5- The consideration of IoT for determining the suitable supplier of smart systems during the purchasing phase of SCM can achieve the benefits of IoT to improve supply chain management

6. Conclusion and Future Work

This work intended to introduce a new framework based on SVTN-numbers for detecting and building smart systems the best supplier based on the effect of IoT. The proposed framework integrates the values and ambiguities index method with SVTN-numbers which generalized fuzzy set and intuitionistic fuzzy to give more accurate results. The results concluded that the proposed framework can manipulate unclear and conflicting data which exist in the purchasing process of selecting the best supplier. Also, the proposed framework can be considered as a comprehensive framework that links between customers and suppliers to detect the best suppliers based on the effect of IoT which can improve supply chain management. Moreover, the results represented that the proposed framework introduces a flexible method that take into account the IoT technologies for determining the suitable supplier of smart systems during the purchasing phase of SCM to achieve the benefits of IoT for enhancing the SCM. For future work, SVTN-numbers can be applied widely for more real practical applications with adapting existing ranking methods to give more efficient results.

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