I.J. Information Engineering and Electronic Business, **2025, 1, 1-13**
Published Online on February 8, 2025 by MECS Press (http://www.mecs-press.org/)
DOI: 10.5815/ijieeb.2025.01.01

Framework for Evaluating Business Processes Modeling Techniques under Neutrosophic Environment

Samah Ibrahim Abdel Aal
Lecturer, Faculty of Computers and Informatics, Zagazig University, Egypt
Email: dr.samahibrahim2018@gmail.com; SIAbdelaal@fci.zu.edu.eg
ORCID iD: https://orcid.org//0009-0000-3947-9854

Received: 13 August, 2024; Revised: 12 September, 2024; Accepted: 15 December, 2024; Published: 08 February, 2025

Abstract: In today's, dynamic business environment and complexity of its operations make the need for modeling Business Processes (BP) is a very critical. Modeling BP is a very important task for improving BP and achieving business needs and goals. BP modeling techniques are necessary for making BP more understandable and easily maintainable which lead to successful Business Process Management (BPM). There many types of modeling techniques for expressing and modeling business process. However, each one has its own characteristics and not all modeling techniques are suitable to all parts of the process. Therefore, it is critical to determine the right and suitable modeling technique. The problem of evaluating BP modeling techniques has been addressed by many researches. However, there is need to handle uncertainty and take into account costs and benefits of BP modeling techniques during the evaluation process. This work aims to introduce different types of BP modeling techniques and present different views of characteristics, features and quality criteria of BPmodeling techniques that can help the modeler during the evaluation process. Also, this work aims to adapt and introduce neutrosophic framework to handle uncertainty and remove confusion during evaluating and determining the BP modeling suitable technique. Moreover, the proposed framework utilizes the neutrosophic benefits and costs method with simple way to improve its use and to balance between benefits and costs during the evaluation process. The proposed framework is applied to a real world case study and the results concluded that the proposed framework can be adopted by business organizations and institutes that need for determining the suitable BP modeling technique to improve their business processes. Also, the results concluded that the utilization of proposed framework can be helpful for handling uncertainty during the evaluation process.

Index Terms: Business Processes (BP), Business Process Management (BPM), Single Valued Triangular Neutrosophic Numbers (SVTrN-numbers), Multi-Criteria Decision Making (MCDM)

1. Introduction

Business Processes (BP) is an organization's interrelated operations/tasks for achieving organizational goals [1, 2]. BP combines operations of stakeholders, applications, and data at different departments as accounting and customer service for fulfilling business needs and satisfying customer needs [3]. There are several fields depend BP modeling for designing IT solutions. Business process management (BPM) mainly emphases on applying different methods to model, analyze, improve, and optimize business operations [4]. Modeling of BP has a great effect on the success of BPM. Modeling of BP aim to support the optimization and improve its implementation. Modeling can simplify the documentation of BP to be understandable and easily maintainable [5]. There many types of modeling techniques for expressing and modeling business process. However, each one has its own characteristics and not all modeling techniques are suitable to all parts of the process. Therefore, it is critical to determine the right and suitable modeling technique. The significant impact of evaluating and selecting the suitable BP modeling technique has been addressed by many researches as [17, 15, 19, 27, 28] and concluded that the suitable modeling technique can increase the understandability of business needs which lead to more improvements in business performance and achieve business goals. There are many studies that have been addressed the problem of evaluating BP modeling techniques. However, these researches could not handle uncertainty and confusion during the evaluation process. Also, these researches could not take into account costs and benefits of BP modeling techniques.The purpose of thiswork is to introduce different types of BP modeling techniques and present different views of characteristics, features and quality criteria of modeling

techniques that can help the modeler during the evaluation process. Also, this work aims to adapt and introduce neutrosophic framework to handle uncertainty and remove confusion during evaluating and determining the BP modeling suitable technique. Moreover, the proposed framework utilizes the neutrosophic benefits and costs method with simple way to improve its use and to balance between benefits and costs during the evaluation process. The proposed framework is applied to a real world case study and the results concluded that the proposed framework can be adopted by business organizations and institutes that need for determining the suitable BP modeling technique.Also, the results concluded that the utilization of proposed framework can be helpful for handling uncertainty during the evaluation process which gives more reliable results. This work is divided into five sections as the follows: the first section gives the introduction for this work; the second section discusses the theoretical background and research gap; the third section introduces the business process modeling approaches, techniques and the requirement for evaluating business process modeling techniques; the fourth section describesthe research methodology and introduces the proposed framework and validates it; Also, this section discusses the limitationsofthe proposed frameworkand applies it for a *practical* case study as well as discussing the finding; the fifth section presentsconclusion and future work; finally gives references.

2. Theoretical Background and Research Gap

There are many studies that have been addressed BP modeling techniques and different aspects of it. However, the problem of evaluating and selecting the suitable BP modeling techniqueswas handled mainly using the traditional methods such as fuzzy sets, Analytics Hierarchy Process (AHP), and the statistical methods.Also,these previous studies could not take into account costs and benefits of BP modeling techniques which caused the problem of inability to balance costs and benefits during the evaluation process. These studies can be summarized as the follows: The [11, 26] introduced selection approach for selecting BP modeling language using Analytics Hierarchy Process (AHP) which requires series of pair wise comparisons that is time consuming and difficult to be handled. Abdel-Fattah et al [17] presented an evaluation framework that depended on analyzing business needs and match with the characteristics of BP modeling techniques which are time consuming and required several professionals to manipulate it. Jin et al [18] introduced selection tool for BP Modeling based on fuzzy DEMATEL and TOPSIS method that can handle the problem of selecting suitable tool. However, it is complex method. Pereira and Silva [25] provided a framework which is no more than comparative framework to help modelers during the selection process. Thus, this study indents to handle this problem as the follows:

1. Address different aspects of BP modeling techniques
2. Present different views of characteristics, features and quality criteria of modeling techniques
3. Balance costs and benefits of BP modeling techniques during the evaluation process.
4. Introduce new method based on neutrosophic numbers that overcomes the problems of the traditional methods to handle uncertainty and remove confusion during evaluating and determining the BP modeling suitable technique.

Accoding to [29] the Fuzzy Set (FS), Interval Valued Fuzzy Sets (IVFS), Intuitionistic Fuzzy Sets (IFS), Interval-Valued Intuitionistic Fuzzy Sets (IVIFS) can manipulate incomplete data. However, there is need to handle the complicated real world problems which have inaccurate and inconsistent data, neutrosophic sets can handle these complicated problems and manipulate the inaccurate and inconsistent data.

The motivations of applying SVTrN-numbers over other methods can be summarized as the follows:

- Provide a generalization of other fuzzy methods
- Can handle the indeterminacy , vagueness, and uncertainty
- Solve complicated real world problems with imprecise data
- Introducereliable results for multi-criteria decision-making cases
- Has ability to manipulatedata from different data sources

The proposed framework utilizes these capabilities of SVTrN-numbers which enable the modeler to evaluate the BP modeling and give more suitable and reliable results. In addition to the capabilities of SVTrN-numbers the proposed framework utilizes the benefits and costs method with simple way to improve its use and to balance between benefits and costs during the evaluation process.

2.1 Business Process Management (BPM) Lifecycle

The BPM lifecycle involves various stages to handle different parts of the process-related operations which are required to achieve process goals [4, 5, 6] as shown in the following Figure:

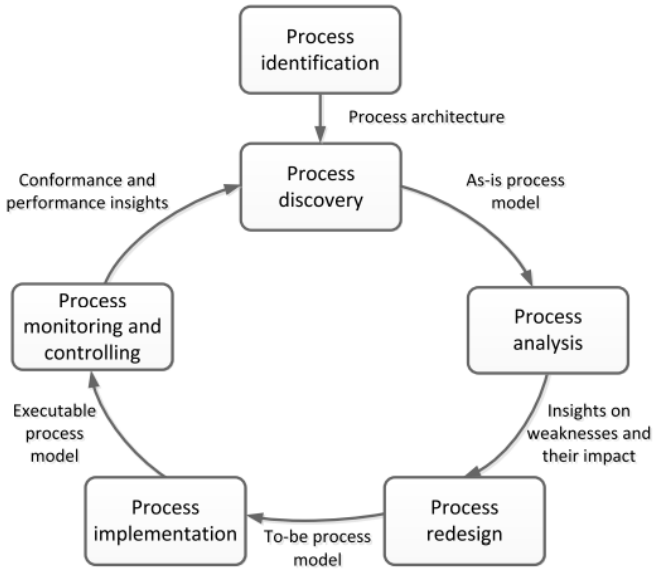

Fig. 1. BPM Lifecycle [6]

1. *Process identification:* Identifies activities/operations with specification of its details and goals.
2. *Process discovery:*Observes and discovers the current practices of business operations.
3. *Process analysis:*Understands existing practices and determines the suitable analytical approach for modeling BP.
4. *Process redesign:* Focuses on remodeling BP and improving practices and workflow.
5. *Process implementation:*aims to apply BP with smooth transitions and provide training for new changes.
6. *Process controlling and monitoring:*This phase aims to determine the key performance indicators related to BP for providing feedback and enhancements.

The deliverables of each is considered as input to the next phase. The following table summarizes theinputs and deliverables of each phase

Table 1. The inputs and deliverables of each phase

Phase	Inputs and actions	Deliverables
Process identification	Business objectives and needs	Processes identification
Process discovery	Discovery of improvements areas and needs for changes	New processes identification
Process analysis	AS-IS analysis	Determines the suitable analytical method for modeling BP. Identification of deficiencies
Process redesign	BP description, objectives, Policies and procedures	Resources allocation TO-BE process model Detailed design model
Process implementation	Detailed design model Execution request	IT services, improved BP. Ready to execute
Process controlling and monitoring	Deficiencies, areas for improvement or changes	Performance evaluation TO-BE process model and identification ofnew changes

2.2 The Importance of Business Process Modeling

Business Process Modeling: is the practice of representing BP. Modeling can enable firms to change their procedures quickly in response to changes according to the new requirements. Business process modeling techniques can provide several advantages as [6, 7, 8]:

- Achieve a standardization of business process model.
- Improve Agility.
- Fulfilling customer requirements
- Increase the efficiency of procedures and workflow.
- Enhancing the presentation of business process.
- Decrease errors and risks

Business Process Modeling involves: Analysis, Enactment, and Description [9] as the follows:

- *Analysis:*Involves simulation of BP for predicting behaviors; and verification of BP models to achieve business goals and satisfy customers.
- *Enactment:* Focuses on Automating BP to convert the manual process into a working application to help stockholders, spend processing time, minimize cost, and reduce mistakes.
- *Description:*provides a graphical representation of the BP to enable the users to understand how the BP is operating.

Zachman framework [10] provides different views of BP to represent and model BP as shown in the following figure.

Fig. 2. Views of business process

BP Modeling techniques depend on one or more of these views. So that, there is need to select the suitable one that can achieve business goals and needs.

2.3 The Elements of Business Process Modeling

Business process modeling defines and document processes and show logical relations between process [11]. Business process modeling has a set of elements to represents business process as the following [12]:

1) *Process*: A combination of activities, events, etc
2) *Activity*: Specific action/operation within an organization.
3) *Service and Product*: The visible outcome reflecting the value of a process.
4) *Role*: The categories of actors or agents.
5) *Goal*: The objectives of a process.
6) *Event*: An action occurs at a specific time for triggering activity or process.
7) *Rule*: Provides procedures for any part of the organization and its activities.

A process model is the final product of BP modeling with activities and its constraints [13]. The suitable BP modeling can help firms in determining problems and redundancies which lead to improvements in processes and workflow.

3. The Business Process Modeling Approaches and Techniques

There are many modeling approachesand techniques formodeling BP which can be summarized as the follows:

3.1 The Business Process Modeling Approaches

Business process has different approaches which have ways for modeling process. According to [14], there are main six approaches as follow:

- *Transformation*: Represents model as input to achieve the desired output.
- *Conversational:* It focuses on how user applies model for coordinating tasks for analyzing and visualization**.**
- *Declarative and Constraint:*It emphases on the goals and activities.
- *Role-Oriented:*Represents the BP as a set of roles and the activities/actions.
- *System Dynamics:*It focuses on understanding the nonlinear behavior of complicated operations over time using flows, feedback, and time delays.
- *Object-Oriented:*It focuses on abstraction of both data structures and processes together.

3.2 The Main Business Process Modeling Techniques

There are several modeling techniques for modeling business process. This work considered the following which techniques are the most influential and standard [11, 15, 16]:

- The Business Process Model and Notation (BPMN)
- The Unified Modeling Language– Activity Diagrams (UML-AD)

- The Event-driven Process Chain (EPC)
- The Integration DEFinition (IDEF)
- The Role Activity Diagram (RAD)
- Petri Net
- Yet Another Workflow Language (YAWL)

The following table provides comparison between these techniques

Table 2. Comparison between BP modeling techniques

BP modeling techniques	Objectives
The Business Process Model and Notation (BPMN)	Provides a notation for the graphical representation of BP in a workflow. The notation of BPMN is readily used by business analysts who create the first process draft for the IT developers. The BPMN can bridges the gap betweenbusiness analysts and IT.
The Unified Modeling Language– Activity Diagrams (UML-AD):	Provides a behavioral diagram with UML, to express the triggering of events according to the states of system.
The Event-driven Process Chain (EPC):	It works as the ordered graphof functions and events Supports the execution of parallelprocesses. It decomposes activities and events tosimplify complex BP
The Integration DEFinition (IDEF)	Provides a family of techniques to support paradigm that is able to address the business BP requirements of various business areas. It include IDFE0, IDFE1, IDFE1X, IDFE2, IDFE3 . . . IDFE13 and IDFE14, and IDEF1X.
The Role Activity Diagram (RAD)	Presents a graphical view of BPs from the perspective of individual roles. It highlights roles, responsibility and interactions.
Petri Net	Provides a mathematical model used to represent various systems.
Yet Another Workflow Language (YAWL)	Extended Petri nets to support multiple instance models of advanced synchronization.

3.2.1 Requirement For Evaluating Business Process Modeling Techniques

Evaluating business process modeling techniques need to determine the requirements and quality criteria that meet business needs and goals. This work aims to introduce different views and types of the requirements, characteristics, features and quality criteria that can help the modeler during the evaluation process. According to [15] the main features of business process modeling techniques include:

1- *Syntax and semantics:* emphases on ensuring that the language is unambiguous and consistent.
2- *Granularity:* emphases on the level of detail and decomposition to supportBP modeling technique.
3- *Enact ability*: emphases on the degree to which a process modeling technique supports automated and dynamic simulation of business processes.
4- *Stability* emphases on how stable and well-accepted.
5- Learn ability: emphases on making the process modeling technique easy to be learned.
6- *Innovation Inducer:* emphases on discovering new solutions and modeling practices.
7- *Standardization* emphases on providing standardized file formatand open-source tools.
8- *Modularity:*emphases on expanding process to the sub processes to make it more understandable and get more simple details.

As [17] pointed out BP modeling requirements include:

- *Hierarchically*

Business processes hierarchicallycan be: *(1) Top-down* which begins with the high-level process to facilitate analysis, (2) *Bottom-up* which begins with lower-level to gives more descriptions of activities.

- *Business Process Environment*

There are two types of processes Static and Dynamic: (1) static business processes unchangeable or change over a long time, (2) *dynamic business environment:* change over time for responding to newrequirements.

- *Business Process complexity*

Business process becomes more complicated which lead to decompose it into small multiple levels of details for simplifying the structure of the process model.

- *Abstraction levels*

There are three classes managerial activities include: (1) the strategic level: combines all activities related to the goals and policies of the organization, (2) the tactical level: combines all activities deal with the efficient use of the resources of the organization, (3) the operational level: focuses on effective execution of specific tasks.

The main quality criteria to evaluate business process modeling techniques [18, 19, 20], which are considered by different authors:

- *Expressiveness*–supports different situations as behavioral, functional, or structural.
- *Readability* – ease for users to understand and interpret.
- *Usability* – emphases on the ease use of the language.
- *User Friendly* – provide attractive tool with friendly GUI.
- *Formality*- minimizes the ambiguities in models to be formal and precise.
- *Versatility*- enables simulation of models.
- *Universality*- disclosure of the language among users.
- *Tools Support*- availability of suitable tools to support use.
- *Flexibility*–provides different scenarios and represents distinct features.
- *Concision*- provides various facets of a business process.
- *Innovation Inducer*- ability to discover new solutions and modeling practices;
- *Evolutionary*– ability to be updatable and improved in the future;
- *Collaborative Work*–support the modeling of collaborative work situations.
- *Operational costs*–cost of modeling tool and the salary of the modelers.
- *Training cost*–costs for users training.
- *Application and installment time*–The time for configuration, and installation

4. The Research Methodology

This work aims to introduce new method that overcomes the problems of the traditional methods to handle uncertainty and remove confusionbased on Single Valued Triangular Neutrosophic Numbers (SVTrN-numbers)**.** SVTrN -Numbers is a neutrosophic set that can handle confusion and indeterminate data in Multi-Criteria Decision Making (MCDM). Neutrosophic set is provides a bigger umbrella of Fuzzy logic [21] as shown in the following figure:

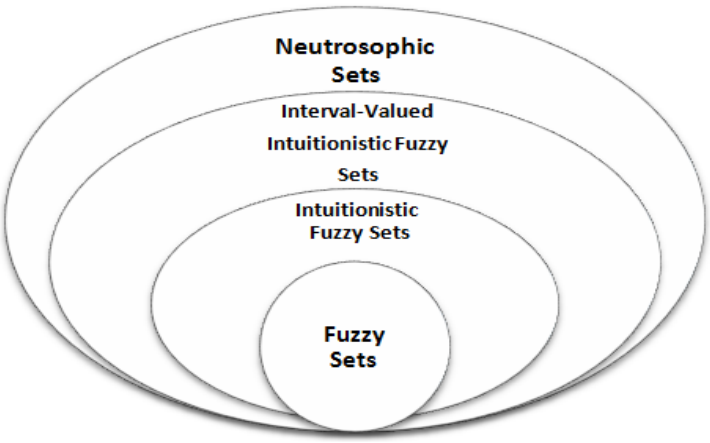

Fig. 3. The umbrella of Neutrosophic sets

Definition 1: According to [22]SVTrN-numbers a can be defined as the follows:

let $\bar{a} = ((a_1, a_2, a_3); T_a, I_a, F_a)$ where is a SVTrN-number whose truth-membership, indeterminacy-membership and falsity-membership functions are respectively defined by:

$$T_a(x) = \begin{cases} T_a \frac{(x-a_1)}{(a_2-a_1)}, & a_1 \le x < a_2 \\ T_a x = a_2 \\ T_a \frac{(a_3-x)}{(a_3-a_2)}, & a_2 \le x < a_3 \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

$$I_a(x) = \begin{cases} \frac{(a_2-x+I_a(x-a_1))}{(a_2-a_1)}, & a_1 \le x < a_2 \\ I_a x = a_2 \\ \frac{(x-a_2+I_a(a_3-x))}{(a_3-a_2)}, & a_2 \le x < a_3 \\ 1, & \text{otherwise} \end{cases} \quad (2)$$

$$F_a(x) = \begin{cases} \frac{(a_2-x+F_a(x-a_1))}{(a_2-a_1)}, & a_1 \le x < a_2 \\ F_a x = a_2 \\ \frac{(x-a_2+F_a(a_3-x))}{(a_3-a_2)}, & a_2 \le x < a_3 \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

The multiplication of triangular neutrosophic number by constant value**,** addition, subtraction, and multiplication of two triangular neutrosophic numbers can be performed as defined by [22].

4.1 The Proposed Framework

The proposed method consists of eight steps the deliverables of each step is considered as input to the next step as shown in the following figure:

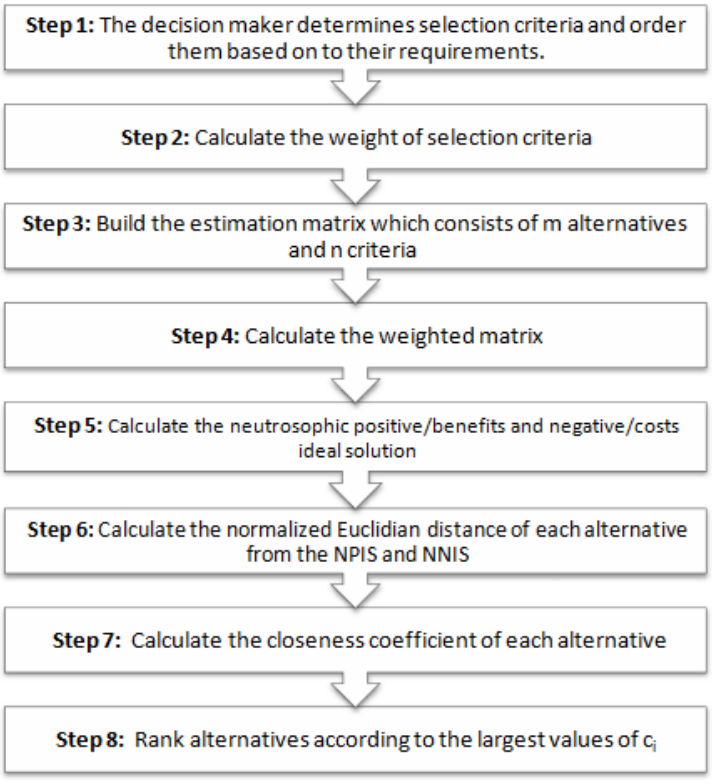

Fig. 4. The proposed framework for evaluating BP modeling techniques

The proposed framework involves eight steps for evaluating BP modeling techniques as the following:

Step 1: The decision maker determines the requirements criteria and orders them according to their requirements.

Step 2: Calculate the weight of selection criteria by using the rank their order as [23]. For a set of ranks of order N, the r_k of the kth rank is given by:

$$r_k = \frac{\sum_{i=k}^{N} \frac{1}{i}}{N} \quad (4)$$

Step 3: Build the estimation matrix which consists of m alternatives and n criteria as the following:

$$[A_{ij}]_{m*n} = \begin{pmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \dots & A_{2n} \\ \vdots & & \ddots & \vdots \\ A_{m1} & A_{m2} & \cdots & A_{mn} \end{pmatrix}$$

Step 4: Calculate the weighted matrix as follows:

$$E^{w} = E*w = \{e_{ij}^{wj}\}_{m*n} = \{L_{ij}^{wj}, M_{ij}^{wj}, U_{ij}^{wj};\ T_{ij}, I_{ij},\ F_{ij}\}_{m*n} \quad (5)$$

Step 5: Calculate the neutrosophictwo types of attributes:positive andnegative ideal solution as the follows.

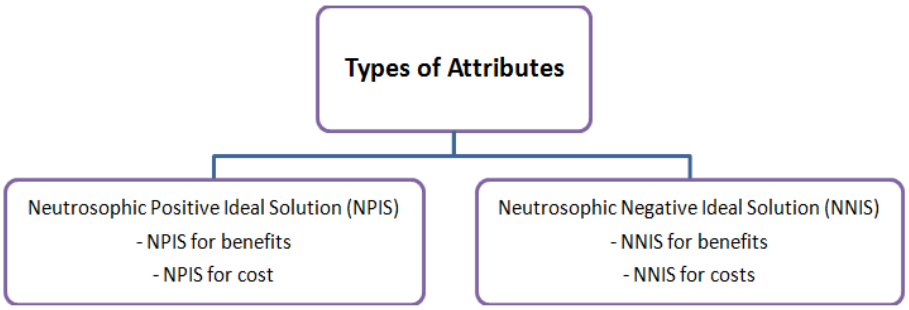

Fig. 5. Types of attributes of the neutrosophic positive and negative

(1)- The Neutrosophic Positive Ideal Solution (NPIS)

Thiswork handles the conflicted that exist in the work that is introduced by [24] where the equations of NPIS are not consistent with the numerical example where the maximum value ,$\max_i \{ M_{ij}^{wj}\}$, $\max_i \{ U_{ij}^{wj}\}$ for $j \in B_1$ at the same time numerical example take the minimum value ,$\min_i \{ M_{ij}^{wj}\}$, $\min_i \{ U_{ij}^{wj}\}$ where $j \in B_1$. This conflict gives inaccurate results for NPIS values.As [24] pointed out, to calculate the NPISand NNISthere is a need to many equations. However equations can be presented with more simple and readable way to calculate the NPISand NNIS as the follows:

1. NPIS for benefits

The estimation of costs can be calculated as the following:
For $V^{+} = [e_1^{w+}, e_2^{w+} \dots e_n^{w+}]$ $\quad e_j^{w+} = [L_{ij}^{wj+}, M_{ij}^{wj+}, U_{ij}^{wj+}; T_j^{+}, I_j^{+}, F_j^{+}]$ where j=1,2,3

$$e_j^{w+} = \{(\text{Max}\{L_{ij}^{wj+}\}, \text{Max}\{M_{ij}^{wj+}\}, \text{Max}\{U_{ij}^{wj+}\}); \text{Max}\{T_{ij}^{+}\}, \text{Min}\{I_{ij}^{+}\}, \text{Min}\{F_{ij}^{+}\} \quad j \in B_1\} \quad (6)$$

2. NPIS for costs

The estimation of costs can be calculated as the following:

$$e_j^{w+} = \{(\text{Min}\{L_{ij}^{wj+}\}, \text{Min}\{M_{ij}^{wj+}\}, \text{Min}\{U_{ij}^{wj+}\}; \text{Min}\{T_{ij}^{+}\}, \text{Max}\{I_{ij}^{+}\}, \text{Max}\{F_{ij}^{+}\} \quad j \in B_2\} \quad (7)$$

(2)- The Neutrosophic Negative Ideal Solution (NNIS)

As [24] pointed out, to calculate the NNIS there is a need to six equations are used calculate the NPIS. This work intended to represent and introducesequations of NNIS in more simple way that make it more readable and applicable as follows:

$v^{-} = [e_1^{w-}, e_2 \dots e_n^{w-}]$ $\quad e_j^{w-} = [L_j^{wj-}, M_j^{wj-}, U_j^{wj}; T_j, I_j, F_j]$ $\quad$ for j=1,2,3

1. NNIS for benefits

$$e_j^{w-} = \{(\text{Min}\{L_{ij}^{wj}\}, \text{Min}\{M_{ij}^{wj}\}, \text{Min}\{U_{ij}^{wj}\}; \text{Min}\{T_{ij}^{-}\}, \text{Max}\{I_{ij}^{-}\}, \text{Max}\{F_{ij}^{-}\} \quad j \in B_1\} \quad (8)$$

2. NNIS for costs

$$e_j^{w-} = \{(\text{Max}\{L_{ij}^{wj}\}, \text{Max}\{M_{ij}^{wj}\}, \text{Max}\{U_{ij}^{wj}\}; \text{Max}\{T_{ij}^{-}\}, \text{Min}\{I_{ij}^{-}\}, \text{Min}\{F_{ij}^{-}\} \quad j \in B_2\} \quad (9)$$

Step 6: Calculate the normalized Euclidian distance of each alternative for the NPIS and NNIS
Calculate the normalized Euclidian distance of each alternative A_i for the NPIS as follows:

$$D_N(A_i,NPIS)=D_N^{i+}(e_{ij}^{wj},e_j^{w+})=\sqrt{\frac{1}{6n}\sum_n^j \begin{matrix}\{\left(L_{ij}^{wj}(X_j)-L_j^{w+}(X_j)\right)^2+\left(M_{ij}^{wj}(X_j)-M_j^{w+}(X_j)\right)^2+\left(U_{ij}^{wj}(X_j)-U_j^{w+}(X_j)\right)^2\\+\left(T_{ij}^{j}(X_j)-T_j^{+}(X_j)\right)^2+\left(I_{ij}^{j}(X_j)-I_j^{+}(X_j)\right)^2+\left(F_{ij}^{j}(X_j)-F_j^{+}(X_j)\right)^2\end{matrix}} \quad (10)$$

Calculate the normalized Euclidian distance of each alternative Ai for the NNIS as follows:

$$D_N(A_i,NNIS)=D_N^{i-}(e_{ij}^{wj},e_j^{w-})=\sqrt{\frac{1}{6n}\sum_n^j \begin{matrix}\left(L_{ij}^{wj}(X_j)-L_j^{w-}(X_j)\right)^2+\left(M_{ij}^{wj}(X_j)-M_j^{w-}(X_j)\right)^2+\left(U_{ij}^{wj}(X_j)-U_j^{w-}(X_j)\right)^2\\+\left(T_{ij}^{j}(X_j)-T_j^{-}(X_j)\right)^2+\left(I_{ij}^{j}(X_j)-I_j^{-}(X_j)\right)^2+\left(F_{ij}^{j}(X_j)-F_j^{-}(X_j)\right)^2\end{matrix}} \quad (11)$$

Step 7: Calculate the closeness coefficient of each alternative

$$c_i=\frac{D_N^{i-}(e_{ij}^{wj},e_j^{w-})}{D_N^{i+}\left(e_{ij}^{wj},e_j^{w+}\right)+D_N^{i-}(e_{ij}^{wj},e_j^{w-})} \quad \text{where} \quad 0\le c_i^*\le 1 \quad (12)$$

Step 8: Rank alternatives according to the largest values of c_i

4.2 Validation of the proposed framework for practical implementation

The proposed framework is applied to several practical cases to validate it according to the following attributes:

- Complexity of equations
- Clarity of equations
- Usability of the proposed framework work

The results of applying the proposed framework for five practical cases can summarized as the follows:

- *Complexity of equations*

The results of applying the proposed framework to practical cases conclude that the proposed framework requires specialists to implement and deal with the complexity of equations.

- Clarity of equations

The implementations of the proposed framework for the practical cases emphasized on the equations are clear to specialists, but it need to more clarifications and explanations for non-specialists.

- *Usability of the proposed framework*

The results of applying the proposed framework to practical cases conclude that the proposed framework is usable for practical cases; however, it requires very precise and accurate calculations to avoid inaccurate results.

4.3 Limitation of the proposed framework

The main limitations/challenges in the practical implementation of the proposed framework can be stated as the follows:

- The eight phases of proposed framework depends on each other and any mistake can cause problems and errors in the final results ;Therefore, each phase requires accurate calculations
- The proposed framework depends mainly on mathematical equations which may require experts and specialists to handle and use it

These limitations can be handled in future work by converting all calculations and equations into computer program to make the proposed framework more applicable.

4.4 Practical Case Study

A business company for electronic devices and services needs to evaluate three BP modeling techniques for selecting one of them to model and enhance its business processes for coping with its competitors. The three BP modeling techniques are: The Role Activity Diagram (RAD), The Event-driven Process Chain (EPC), The Business Process Model and Notation (BPMN). Use the following linguistic scale table:

Table 3. Linguistic scale

Linguistic variables	Neutrosophic numbers
Very Low	(0, 1, 2; 0.10, 0.85, 0.90)
Low	(1, 2, 3; 0.20, 0.75, 0.80)
Medium Low	(2, 3, 4; 0.35, 0.65, 0.60)
Medium	(3, 4, 5; 0.50, 0.50, 0.50)
Medium High	(4, 5, 6; 0.60, 0.35, 0.30)
High	(5, 6, 7; 0.80, 0.20, 0.15)
Very High	(6, 7, 8; 0.90, 0.10, 0.05)
Extremely	(7, 8, 9; 1.00, 0.00, 0.00)

Consideration of the case study

The proposed framework gives flexibility for each case to evaluate BP modeling techniques according to its business requirements and the modeler/the decision maker view points toward a special case. Therefore, we rename andsymbolizeBP modeling technique of the case study as: The Role Activity Diagram (RAD): A, The Event-driven Process Chain (EPC): B, The Business Process Model and Notation (BPMN): C

Step 1: Ask the modeler to determines estimation criteria and order them based on to their requirements from the most to the least important; the modeler determines three estimation criteria as follows:

1- Formality
2- Expressiveness
3- Cost

Step 2: Calculate the weight of estimation criteria (Scalability, Security, Cost) by using the rank order as follows:

1. Weight of Formality = 0.61,
2. Weight of Expressiveness = 0.28
3. Weight of Cost= 0.11.

Step 3: Build the estimation table which consists of BP modeling techniques (A,B,C) and criteria/n=3 according to the linguistic scale which was presented in table 1as the following:

Table 4. Estimation table of alternatives according to estimation criteria

Criteria (m)	BENEFITS (B_1)		COST (B_2)
BP modeling techniques	Formality	Expressiveness	
A	(5, 6, 7; 0.80, 0.20, 0.15)	(5, 6, 7; 0.80, 0.20, 0.15)	(3, 4, 5; 0.50, 0.50, 0.50)
B	(5, 6, 7; 0.80, 0.20, 0.15)	(6, 7, 8; 0.90, 0.10, 0.05)	(5, 6, 7; 0.80, 0.20, 0.15)
C	(7, 8, 9; 1.00, 0.00, 0.00)	(7, 8, 9; 1.00, 0.00, 0.00)	(6, 7, 8; 0.90, 0.10, 0.05)

Step 4: Calculate t the weighted decision matrix via multiplying weights of criteria by the estimation matrix as in the following table

Table 5. The weighted decision matrix table

Criteria (m)	BENEFITS (B_1)		COST (B_2)
BP modeling techniques	Formality	Expressiveness	
A	(3, 4, 4; 0.80, 0.20, 0.15)	(1, 2, 2; 0.80, 0.20, 0.15)	(0, 0, 1; 0.50, 0.50, 0.50)
B	(3, 4, 4; 0.80, 0.20, 0.15)	(2, 2, 2; 0.90, 0.10, 0.05)	(1, 1, 1; 0.80, 0.20, 0.15)
C	(4, 5, 5; 1.00, 0.00, 0.00)	(2, 2, 3; 1.00, 0.00, 0.00)	(1, 1, 1; 0.90, 0.10, 0.05)

Step 5: Calculate the Euclidian distance of each alternative from the NPIS and NNIS
Use eq. (6) and (7) to calculate the NPIS

Table 6. The NPIS

NPIS	Formality	Expressiveness	Cost
	(4, 5, 5; 1.00, 0.00, 0.00)	(2, 2, 3; 1.00, 0.00, 0.00)	(0, 0, 1; 0.50, 0.50, 0.50)

Use eq. (8) and (9) to calculate the NNIS

Table 7. The NNIS

NNIS	Formality	Expressiveness	Cost
	(3, 4, 4; 0.80, 0.20, 0.15)	(1, 2, 2; 0.80, 0.20, 0.15)	(1, 1, 1; 0.90, 0.10, 0.05)

Step 6: Calculate the normalized distance of each alternative from the NPIS and NNIS by using eq. (10), and (11),

Table 8. The normalized Euclidian distance of BP modeling technique for the NPIS and NNIS

BP modeling techniques	$D_N^{i+}(e_{ij}^{wj}, e_j^{w+})$	$D_N^{i-}(e_{ij}^{wj}, e_j^{w-})$
A	.5376	.3742
B	.5974	.2424
C	.3742	.5367

Step 7: Calculate the closeness coefficient of BP modeling technique by using eq. (12)

Table 9. The closeness coefficient of BP modeling techniques

The closeness coefficient of BP modeling techniques	
A	.4103
B	.2886
C	.5896

Step 8: Evaluating the BP modeling techniques according to the largest values of c_i

The most suitable BP modeling technique is the Business Process Model and Notation (BPMN): C. By ranking the three modeling techniques from the most suitable to the least; the rank is C>A>B. the following figure highlights this result.

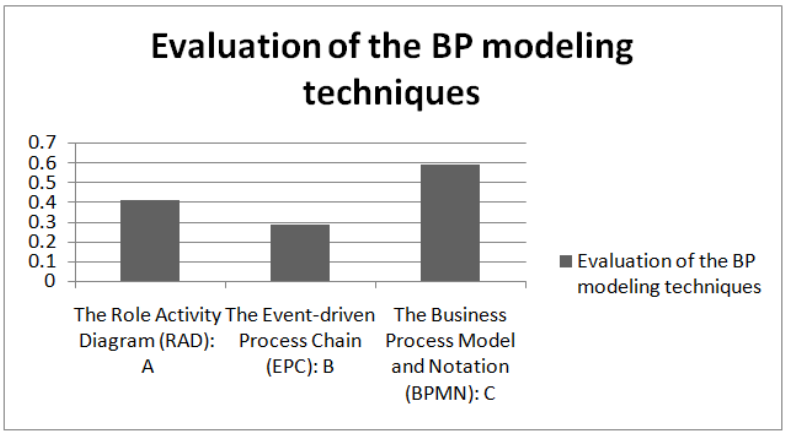

Fig. 6. Evaluating the BP modeling techniques

4.5 Discussion

The significant impact of evaluating and selecting the suitable BP modeling technique has been addressed by many researches and concluded that the suitable modeling technique can increase the understandability of business needs which lead to more improvements in business performance and achieve business goals. Therefore, the determination of the suitable technique by the proposed framework can be considered the first step for achieving business requirements and goals. The proposed framework evaluates each BP modeling technique and enables the modeler to determine the right modeling technique according to their requirements to achieve business goals. According to the case study and its business requirements, the best BP modeling technique is The Business Process Model and Notation (BPMN): C. The proposed framework appliedneutrosophic numbersthat generalized fuzzy sets to gives more dimensions for every neutrosophic number to handle uncertainty and give more accurate results.The findings of the proposed framework can be summarized as the following:

1. In spite of some complexity of SVTrN-numbers, the proposed framework can handle the complicated real world problems which have inaccurate and inconsistent data.
2. The proposed framework uses the neutrosophic numbers to handle confusion and lack of clarity of information during the evaluation processes.
3. The proposed framework can handle costs and benefits with simple equations that can enable the modeler to balance between costs and benefits for detectingthe suitable BP modeling techniques.

4. The proposed framework has a flexibility thatenables the modeler to evaluate business process modeling techniques according to their requirements to achieve business goals and represent their views.

5. Conclusion and Future Work

The competition in business environment causes organizations seek to improve and enhance their BPM. BP modeling has a great impact on the success of BPM. The problem of evaluating BP modeling techniques has been addressed by many researches. However, there is a need to handle uncertainty and confusion during the evaluation process. Also, there is a need to take into account costs and benefits of BP modeling techniques during the evaluation process.This work introduces different types of BP modeling techniques and presented different views of characteristics, features and quality criteria of BP modeling techniques that can help the modeler during the evaluation process. Also, this work aims to adapt and introduce neutrosophic framework to handle uncertainty and remove confusion during evaluating and determining the BP modeling suitable technique. Moreover, the proposed framework utilizes the neutrosophic positive/benefits and negative/costs method with simple way to improve its useand to balance between benefits and costs during the evaluation process. The proposed framework is applied to a real world case study and the results concluded that the proposed framework can be adopted by business organizations and institutes that need for determining the suitable BP modeling technique to improve their business processes. Also, the results concluded that the utilization of proposed framework can be helpful for handling uncertainty and taking into account benefits and costs of BP modeling techniques during the evaluation process. In spite of the capabilities of the proposed framework, it has two limitations: (1) the eight phases of proposed framework depends on each other and any mistake can cause problems and errors in the final results; Therefore, each phase requires accurate calculations; (2) the proposed framework depends mainly on mathematical equations which may require experts and specialists to handle and use it.These limitations can be handled in future work by converting all calculations and equations into computer program to make the proposed framework more applicable. Also; for future work, this work can be improved by different ways as the following: (1) Include new and more BP modeling techniques, (2) include new requirements, features and quality criteria to determine the suitable modeling technique according to new changes in business environment, (3) apply more new mathematical methods under neutrosophic environment to give more accurate results.

References

[1] Recker, J., Rosemann, M., Indulska, M. and Green, P., Business process modeling-a comparative analysis. *Journal of the association for information systems*, 2009,Vol. 10, No. 4.

[2] Aalst V., MP W., Business process simulation survival guide." Handbook on Business Process Management, Springer Berlin Heidelberg, 2015, pp.337-370.

[3] Őri, D. and Szabó, Z., A Conceptual Blueprint for Enterprise Architecture Model-Driven Business Process Optimization. In *Business Process Management: Blockchain and Central and Eastern Europe Forum: BPM 2019 Blockchain and CEE Forum, Vienna, Austria*, Springer International Publishing, *2019* ,pp. 234-248.

[4] Dumas, M., La Rosa, M., Mendling, J. and Reijers, H.A., Fundamentals of business process management, Heidelberg: Springer, 2018, Vol. 2.

[5] Scheer, A.W., Abolhassan, F., Jost, W. and Kirchmer, M., 2002. Business process excellence: ARIS, 2002 practice.

[6] Athanasopoulou, A. and De Reuver, M., How do business model tools facilitate business model exploration? Evidence from action research, Electronic Markets, 2020, vol. 30, pp.495-508.

[7] Olofsson, L. and Farr, R., 2006. Business model tools and definition-a literature review. Vivace Consortium.

[8] Kulkarni, P.P., 2019. A qualitative analysis of the 'experiential learning'of business school students and graduates through their participation in The University of Manchester's annual business start-up competition. Entrepreneurship Education, 2(3-4), pp.149-169.

[9] Mousa A., Shiratuddin N., Bakar M., Evaluation Framework for Business Process Evaluation Approaches, Journal of Computer Science & Computational Mathematics, 2016, Vol 6.

[10] Lapalme, James, Exploring the future of enterprise architecture: A Zachman perspective, Computers in Industry, 2016, vol.79, pp.103-113.

[11] Guizania K, and Ghannouchia S., An approach for selecting a business process modeling language that best meets the requirements of a modeler, International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2020 , Available online at www.sciencedirect.comScienceDirect Procedia Computer Science, 2021, pp. 843–851.

[12] Aldin, L. and De Cesare, S., A comparative analysis of business process modeling techniques, 2009, UK Academy for Information Systems Conference.

[13] Weske, M., Business process management architectures, Springer Berlin Heidelberg, 2007, pp. 305-343.

[14] Krogstie, John. Perspectives to process modeling. Business Process Management. Springer Berlin Heidelberg, 2013. pp.1-39.

[15] Farshidi S., Kwantes I., ·Jansen S.,, Business process modeling language selection for research modelers, Software and Systems Modeling, Springer, 2024, pp. 137–162 https://doi.org/10.1007/s10270-023-01110-8.

[16] Gabryelczyk, R. and Jurczuk, A., The diagnosis of information potential of selected business process modeling notations. Information Systems in Management, 2015. 4(1), pp.26-38.

[17] Abdel-Fattah M, Khedr A., Aldeen Y., An Evaluation Framework for Business Process Modeling Techniques, International Journal of Computer Science and Information Security (IJCSIS), 2017, Vol. 15, No. 5.

[18] Jin G., Jin G., and Huo H., Selection of Business Process Modeling Tool with the Application of Fuzzy DEMATEL and TOPSIS Method, MDPI, Axioms 2022, 11, 601.
[19] Trauer, J., Wöhr, F., Eckert, C., Kannengiesser, U., Knippenberg, S., Sankowski, O., & Zimmermann, M., Criteria for selecting design process modeling approaches. Proceedings of the Design Society, 1(ICED21), 2021), pp.791-800. https://doi.org/10.1017/pds.2021.79
[20] Looy, Van A., Backer M., and Poels G., A conceptual framework and classification of capability areas for business process maturity, Enterprise Information Systems 2014, pp. 188-224.
[21] AboElHamd E., Shamma H, Saleh M., El-Khodary I.,Neutrosophic Logic Theory and Applications, Neutrosophic Sets and Systems, University of New Mexico Vol. 41, 2021, pp.30-51.
[22] Abdel-Basset, M.; Mohamed, M.; Chang, V. NMCDA: A framework for evaluating cloud computing services, Future Gener. Comput. Syst. 2018, 86, 12–29.
[23] McCaffrey, J.D. Using the multi-attribute global inference of quality (MAGIQ) technique for software testing. In Proceedings of the Information Technology: New Generations, Las Vegas, NV, USA, 2009, pp. 27–29.
[24] Abdel-Basset M. , Mohamed M., Victor Chang V., and Smarandache F., IoT and Its Impact on the Electronics Market: A Powerful Decision Support System for Helping Customers in Choosing the Best Product, Symmetry, 2019, vol. 11, 611; doi:10.3390/sym11050611
[25] Pereira J and Silva1 D, Business Process Modeling Languages: A Comparative Framework. In: . Rocha et al. (eds.), New Advances in Information Systems and Technologies, Advances in Intelligent Systems and Computing 444, (2016), Springer International Publishing Switzerland 2016, vol. 444, DOI 10.1007/978-3-319-31232-3_58
[26] Kaschek R, Roman Pavlov R, Shekhovtsov V, and Zlatkin S, Towards Selecting Among Business Process Modeling Methodologies, 2006, Journal of Business Information Systems, pp. 28- 46
[27] Pietroń R, Best Practices In Business Process Modelling, Information Systems in Management (2016) Vol. 5 (4) 551-562
[28] Lopes T and Guerreiro S, Assessing business process models: a literature review on techniques for BPMN testing and formal verification, Business Process Management Journal, Emerald Publishing Limited 1463-7154, Vol. 29 No. 8, 2023 pp. 133-162, DOI 10.1108/BPMJ-11-2022-0557
[29] Tian Z, Zhang H., Wang J. , Wang J., and Chen X., Multi-criteria decision-making method based on a cross-entropy with interval neutrosophic sets, 2015, International Journal of Systems Science, Taylor & Francis

Author's Profile

Samah Ibrahim Abdel Aal is a lecturer at the information systems department, faculty of Computers and Informatics, Zagazig University where graduated and is now a Ph.D., Egypt. She is teaching several courses for information systems management, expert systems, mathematics, cloud computing logic design, programming, information systems, database systems, IoT, big data, data security, quality management, Cloud Computing, business management, and information systems analysis and design.

How to cite this paper: Samah Ibrahim Abdel Aal, "Framework for Evaluating Business Processes Modeling Techniques under Neutrosophic Environment", International Journal of Information Engineering and Electronic Business(IJIEEB), Vol.17, No.1, pp. 1-13, 2025. DOI:10.5815/ijieeb.2025.01.01