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Innovative method to evaluate quality management system audit results' using single value neutrosophic number

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Abstract

Using Quality Management System (QMS) enables the organization to fulfil its purpose and mission to meet customers and regulatory requirements and improve its effectiveness and efficiency on a continuous basis, Quality Audit is very critical tool to ensure that the standards, policies and/or procedures are applied in the organization as planned in QMS, in real world applications, the results of the Quality Audit process depend on the auditors' human judgments that characterized with doubts sometimes, estimating values another times, and using general impressions in his judgment, which motivate to introduce for the first time the Neutrosophic Quality Audit (NQA) model which can be extended to manage and audit in the future. NQA will be used to enhance the way of evaluating the quality audit results while many uncertainty aspects and indeterminacy do exist, the proposed model using Single Value Neutrosophic Numbers (SVNN) which is an instance of neutrosophic set, to overcome the weakness of using a crisp value to present the result of the audit findings, in addition, using Simplified Neutrosophic Weighted Geometric Average Operator (SNWGAO), and cosine similarity degree, an illustrative example is provided to validate the proposed model.

Keywords: Neutrosophic sets; Quality management system; Quality audit; Single value neutrosophic number; Neutrosophic weighted geometric average operator; Cosine similarity

1. Introduction

The quality was defined by Quality Management and Quality Assurance – Vocabulary (ISO 8402, 1994) as "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs", also it defined by BS EN ISO 9000:2015 (The British Standards Institution, 2015) as "The quality of products and services includes not only their intended function and performance, but also their perceived value and benefit to the customer", from the above definitions we can consider quality from business point of view as the way of satisfying customers' needs to achieve the organization goals, therefore, to apply quality the Quality Management System (QMS) has to be implemented in the organization to emphasize that needed level of quality can be achieved.

According to BS EN ISO 9000:2015 (The British Standards Institution, 2015) we can conclude a definition for QMS as "QMS can be considered as a set of Policies, Procedures, Processes and resources used to achieve the organization objectives and desired results, by manages the interacting processes, resources required and inter-related parts of the business, which enables top

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management to best use the available resources considering the long and short term consequences".

To evaluate the effectiveness of the QMS audit activities have to be applied, to gather information about working processes and how the organization accurately applies the policies and procedures and evaluate the effectiveness of the system, to identify opportunities for improvements, which are critical to the success of an organization, During the audit tangible and intangible evidence needs to be collected, in addition, corrective actions and preventive active can be taken according to the evidence gathered, therefore the quality audit can be consider as a key element and an important part of applying QMS.

We can define quality audit as systematic, independent and documented process of examining the QMS, these processes carried out by an internal or external quality auditor or could be by an audit team according to the organization size, during the audit process there are some of tasks such as gather information about the organization and the surrounding environment, plus reviewing records about the work activities, also the auditor can talk to employees and doing an analysis for process key process data or even observing the process in action, the auditor doing all these activities to gather objective evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled and the process is functioning as planned in the QMS.

According to International Organization for Standardization (ISO) (International Organization for Standardization, 2015), as shown in Fig. 1 there are seven Quality Management Principles (QMP) which are: QMP1: Customer focus QMP2: Leadership QMP3: Engagement of people QMP4: Process approach QMP5: Improvement QMP6: Evidence-based decision making QMP7: Relationship management, These principles are not listed in priority order. The relative importance of each principle will vary from organization to organization and can be expected to change over time, the relationships between QMS principles are shown in Fig. 2.

Fig. 1. Quality management principles.

According to BS EN ISO 9000:2015 (The British Standards Institution, 2015) there are some basic definitions about the audit process have to be clear before moving toward explaining the proposed model:

- **Audit Criteria**: the reference against which objective evidence is compared with such as policies, procedures or requirements.
- **Objective Evidence**: everything the auditor can collect during the audit which are relevant to the audit criteria and verifiable, such as records, statements of fact or other information.
- **Audit Findings**: audit evidence collected against the audit criteria where the findings of the audit indicate conformity or nonconformity, it can show that opportunities for improvement may be exist or recording good practices, finally, audit finding can be called compliance if the audit criteria are selected from statutory requirements or it can be called non-compliance if audit criteria are selected from regulatory requirements, in general we can summarize the audit findings in four categories as shown in Fig. 3 using like "traffic lights" as visually communicate the risk posed by the audit finding, and the expected actions.
- **Audit Conclusion**: audit outcome, consideration all audit findings and audit objectives.

Also, the following verbal forms are used in ISO International Standard:

- "shall": means a requirement
- "should": means a recommendation
- "may": means a permission
- "can": means a possibility or a capability.

The proposed model can be applied even the audit is an internal audit (first party), or an external audit (second party or third party), or it is a combined audit or a joint audit.

Quality auditor may use an audit checklist (like the sample checklist shown in Fig. 4) to facilitate and document the audit process, it is one of the common tools used by auditors, it is a key element during planning for carrying out audit process, the checklist composed of a set of questions derived from the quality management system standard requirements and any process documentation prepared by the organization, mostly the checklist designed with closed-ended questions that are answered by a simple "yes" or "no" or not applicable in addition to fewer open-ended questions, obviously, answering closed-ended questions in uncertainty, ambiguous and indeterminacy environment is very difficult task.

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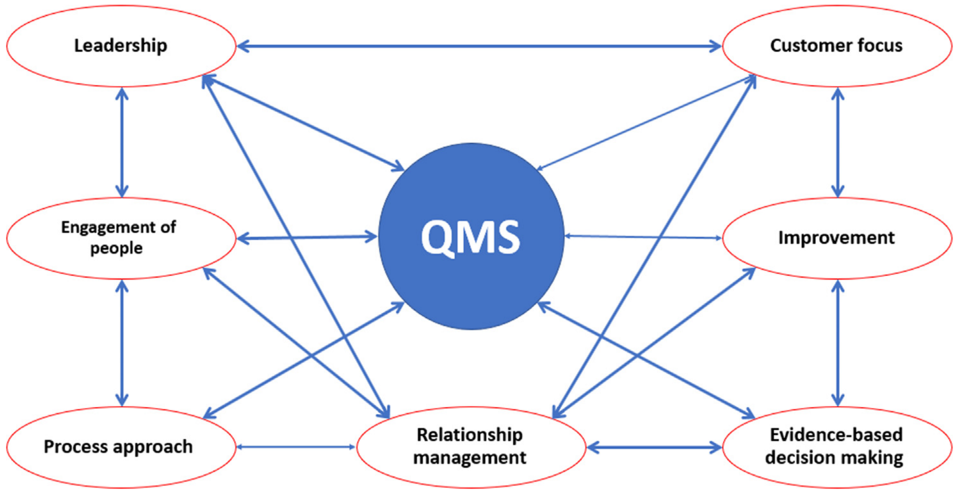

Fig. 2. Quality management principles and its relationship.

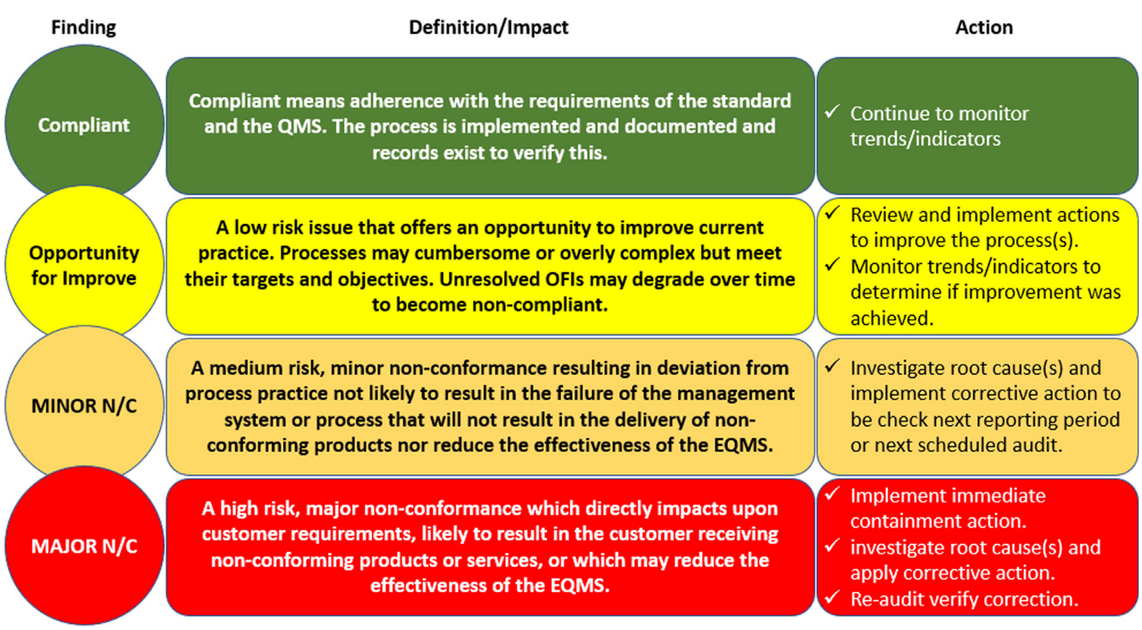

Fig. 3. Audit finding categories.

After explaining the purpose of QMS and how it affects achieving the organization its goals, and how critical is the audit as a process ensuring the proper implementation of QMS, meanwhile, the audit finding totally depend on the auditor human judgment and it is the only way to evaluate the quality audit result and the final audit conclusion, whereas, the real life has many uncertainty and indeterminacy aspects, the auditor cannot always provide exact values when determining a fact or auditing organization against QMS, therefore, there is a need to approximate the values (auditor judgment) that has resulted in emerging various approaches to handle uncertainty and indeterminacy in QMS quality audit, because of that, Neutrosophic logic has been used to overcome the uncertainty of concepts that are associated with human expert judgments.

The concepts "Neutrosophy" which is the study of neutralities as an extension of dialectics and its derivative "Neutrosophic", such as "Neutrosophic Logic", "Neutrosophic Set", "Neutrosophic Probability", and "Neutrosophic Statistics" and thus opening new ways of research in four fields: philosophy, logics, set theory, and probability/statistics was introduced by F. Smarandache in 1995 (published in 1998) (Smarandache, 2007), where the word <*philosophy*> (From Latin "neuter" – neutral, Greek "sophia" – skill/wisdom) A branch of philosophy, which studies the origin, nature, and scope of neutralities, as well as their interactions with different ideational spectra, Neutrosophy is the basis of neutrosophic logic, neutrosophic probability, neutrosophic set, and neutrosophic statistics.

Neutrosophic Logic (or "Smarandache logic") is a generalization of fuzzy logic based on Neutrosophy, and

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Clause	Ref	Audit Question	Audit Findings (Score '1' per box)				Audit Evidence	Opportunities for Improvement (OFI)
			COMPLIANT	OFI	MINOR N/C	MAJOR N/C	Provide reference to documented information to justify the finding	Provide suggestions for process improvement
4.1	1	Has your organization determined external and internal issues relevant to its purpose and its strategic direction that affect its ability to achieve the intended result(s) of its QMS?						
4.1	2	Does your organization monitor and review information about these external and internal issues?						
4.2	3	Does the organisation determine the interested parties that are relevant to the QMS?						
4.2	4	Does the organisation determine the requirements of these interested parties that are relevant to the QMS?						
4.2	5	Does your organization monitor and review information about these interested parties and their relevant requirements?						

Fig. 4. Audit checklist sample.

Neutrosophic Set is a generalization of the intuitionistic set, classical set, fuzzy set, paraconsistent set, dialetheist set, paradoxist set, tautological set based on Neutrosophy, where Neutrosophic theory considers every entity <A> together with its opposite or negation <antiA> and with their spectrum of neutralities <neutA> in between them, the <neutA> and <antiA> ideas together are referred to as <nonA> , in neutrosophic logic a proposition has a degree of truth (T), a degree of indeterminacy (I), and a degree of falsity (F), where T, I, F are standard or non-standard subsets of $^{-}]0,1[^{+}$ (Smarandache, 2014);

Neutrosophic set, neutrosophic logic has many scientific applications in many fields such as Bera and Mahapatra (2018) have been introduced the concept of neutrosophic soft completely prime ideals, neutrosophic soft completely semi-prime ideals and neutrosophic soft prime k–ideals, Muhiuddin, Bordbar, Smarandache, and Jun (2018) and others discussed neutrosophic subalgebra in a BCK-algebra, Kim, Song, and Jun (2018) studied neutrosophic subalgebras of several types in BCK/BCI-algebras by using the notion of neutrosophic points, Pramanik, Dey, and Smarandache (2018) introduced for first time the definition of correlation coefficient, and weighted correlation coefficient measures of interval bipolar neutrosophic sets, Broumi et al. (2017) propose some computing procedures in Matlab for neutrosophic operational matrices, Sebastian and Smarandache (2017) generalize the definition of Neutrosophic sets and present a method for extending crisp functions on Neutrosophic sets and study some properties of such extended functions, Dhavaseelan, Parimala, Jafari, and Smarandache (2017) introduce and investigate a new class of sets and functions between topological space called neutrosophic semi-supra open set and neutrosophic semi-supra open continuous functions respectively.

Neutrosophic best fit in representing indeterminacy and uncertainty which is the typical case of Quality Audit, where the auditor is responsible to determine a crisp value for each question in the checklist as shown in audit check list sample in Fig. 4, while the auditor in the real life has a lot of uncertainty regarding each question.

The remainder of this research is structured as follows:

A literature review about the single value neutrosophic number and cosine similarity degree, Neutrosophic Weighted Average Operator in Section 2, Section 3 illustrates the basic definitions of neutrosophic sets, the proposed algorithm is presented in Section 4, a numerical example is illustrated in Section 5. Finally, Section 6 concludes the paper with future work.

2. Literature review

In this section, we present an overview of the single value neutrosophic number and cosine similarity degree, Neutrosophic Weighted Average Operator which are used across various domains, Smarandache present Neutrosophy as a branch of philosophy (Smarandache, 2007, 2015) to studies the origin and scope of neutralities, neutrosophic models have been studied by many authors. it has been used in various applications to solve various problems as an influential criterion in the selection (Abdel-Basset, Mohamed, & Smarandache, 2018), Multi-criteria decision making (Abdel-Basset, Mohamed, & Smarandache, 2018; Abdel-Basset, Mohamed, Zhou, & Hezam, 2017; Deli, 2014, 2014; Ye, 2014; Chang, Abdel-Basset, & Ramachandran, 2018; Abdel-Basset, & Manogaran, 2018; Abdel-Basset, Mohamed, & Chang, 2018; Abdel-Basset, Manogaran, Mohamed, & Chilamkurti, 2018; Abdel-Basset, Gunasekaran, Mohamed, & Smarandache, 2018), obtaining PERT three times in project management

(Mohamed, Abdel-Baset, Zaied, & Smarandache, 2017), studying the effect of Internet of Things (IoT) and how it impact on supply chain (Abdel-Basset, Manogaran, & Mohamed, 2018), many researchers have developed a variety of aggregation operators (Kanika & Kajla, 2018; Liu, 2016; Ye, 2014). Jiang and Shou (2017) propose a new method to measure the similarity between single-valued neutrosophic sets, also Ye and Du (2017) propose some distances, similarity and entropy measures for interval-valued neutrosophic sets and their relationship, Pramanik and Mondal (2015) define a rough cosine similarity measure between two rough neutrosophic sets, said (Broumi and Smarandache, 2014) define a new cosine similarity between two interval valued neutrosophic sets based on Bhattacharya's distance, Ye (2014) propose some aggregation operators, including a simplified neutrosophic weighted arithmetic average operator and a simplified neutrosophic weighted geometric average operator. Based on the two aggregation operators and cosine similarity measure for SNSs,

3. Preliminaries

In this section, the basic definitions involving neutrosophic set, single valued neutrosophic set SVNS, single valued neutrosophic number SVNN, and operations on single valued neutrosophic number are outlined.

Definition 1. According to Smarandache (2017) neutrosophic set characterized by a single attribute value (appurtenance) which has three values (membership, indeterminacy, and non-membership), (Abdel-Basset et al., 2017; Smarandache, 2015) Let x be a space of points (objects) and $x \in X$. A neutrosophic set A in X is defined by a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$ and a falsity-membership function $F_A(x)$, where $T_A(x)$, $I_A(x)$ and $F_A(x)$ are real standard or real non-standard subsets of $]^{-}0, 1^{+}[$ That is $T_A(x)$: $X \to]^{-}0, 1^{+}[$, $I_A(x)$:$X \to]^{-}0, 1^{+}[$ and $F_A(x)$:$X \to]^{-}0, 1^{+}[$. There is no restriction on the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, so $^{-}0 \le \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \le 3^{+}$.

As non-standard unit interval is mostly used in philosophy in cases where one needs to make distinction between "absolute truth" (which is a truth in all possible worlds) and "relative truth" (which is a truth in at least one world, but not in all possible worlds), and similarly for distinction between "absolute indeterminacy" and "relative indeterminacy", and respectively distinction between "absolute falsehood" and "relative falsehood". But for other scientific and technical applications one uses standard subsets, and the standard classical unit interval [0, 1].

Therefore, for the sake of simplicity we will use the standard classical unit interval $T_A(x)$:$X \to [1, 0]$, $I_A(x)$:$X \to [1, 0]$ and $F_A(x)$:$X \to [1, 0]$. There is no restriction on the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, so $0 \le \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \le 3$.

Definition 2. (Abdel-Basset & Mohamed, 2018; Abdel-Basset, Mohamed, Smarandache, & Chang, 2018; Liu, 2016) In this section, we present the notion of single valued neutrosophic set (SVNS). SVNS is an instance of neutrosophic set which can be used in real scientific and engineering applications Let X be a universe of discourse. A single valued neutrosophic set A over X is an object having the form of

$$A = \{\langle x, T_A(x), I_A(x), F_A(x)\rangle : x \in X\} \tag{1}$$

where $T_A(x)$:$X \to [1, 0]$, $I_A(x)$:$X \to [1, 0]$ and $F_A(x)$:$X \to [1, 0]$ with $0 \le T_A(x) + I_A(x) + F_A(x) \le 3$ for all $x \in X$. The intervals $T_A(x)$, $I_A(x)$ and $F_A(x)$ denote the truth-membership degree, the indeterminacy-membership degree and the falsity membership degree of x to A, respectively.

For convenience, the SVNS can be simplified as $A = \langle T_A, I_A, F_A\rangle$ and can call it a single-valued neutrosophic number (SVNN).

The SVNS attribute is $\alpha =$ "*appurtenance*"; set of attribute values $V = \{$*membership, indeterminacy, non-membership*$\}$, whose cardinal $|V| = 3$; The notations for Neutrosophic set: union ($\bigvee_{N(tconorm)}$), intersection ($\bigwedge_{N(tnorm)}$), complement ($\neg_N$), less than or equal to ($\le_N$), greater than or equal to ($\ge_N$), and equal to ($=_N$); the SVNS aggregation operators (Intersection, Union, Complement etc.), according to Smarandache (2017) when applying the t_{norm} *(intersection)* on membership, then the t_{conorm} *(Union)* has to be applied on non-membership (and reciprocally), while on indeterminacy one applies the average of t_{norm} and t_{conorm}.

Definition 3. (Smarandache, 2017) F. Smarandache introduce the "Plithogenic Set" for a first time as a generalization of crisp, fuzzy, intuitionistic fuzzy, and neutrosophic sets, Plithogenic Set elements are characterized by many attributes' values. An attribute value v has a degree of appurtenance function $d(x, v)$ of the element x to the set P; corresponding to fuzzy, intuitionistic fuzzy, or neutrosophic, with respect to some given criteria, the attribute value appurtenance degree function is:

$$\forall x \in P,\ d:\ P \times V \to P([0,\ 1]^z) \tag{2}$$

so, $d(x, v)$ is a subset of $[0, 1]^z$, where P $([0, 1]^z)$ is the power set of the $[0, 1]^z$, where z = 1 (for fuzzy degree of appurtenance), z = 2 (for intuitionistic fuzzy degree of appurtenance), or z = 3 (for neutrosophic degree of appurtenance), The functions $d(\cdot, \cdot)$ is defined according to the application where the experts solving.

Definition 4. The Contradiction Degree Function c is used to enhance plithogenic aggregation operator's accuracy for the plithogenic set, Neutrosophic set has one attribute ("appurtenance" to the set), which attribute has three attribute-values: T (membership), I (indeterminacy), and F (nonmembership). the attribute value contradiction degree function is designed in each field where plithogenic logic is

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used in accordance with the application to solve. If it is ignored, the aggregations still work, but the result may lose accuracy as defined by Smarandache (2017).

The attribute value contradiction degree is calculated between each attribute value with respect to the dominant attribute value (denoted v_D), in general, attribute value contradiction degree function between any two attribute values v_1 and v_2, denoted by $c(v_1, v_2)$, where the contradiction degree between the same attribute values is zero $c(v_1, v_1) = c(v_2, v_2) = 0$; and $c(v_1, v_2) = c(v_2, v_1)$ commutativity,

$$\begin{aligned} &c : V \times V \to [0,1],\\ &c(T,F) = c(F,T) = 1,\\ &c(T,T) = c(I,I) = c(F,F) = 0,\\ &c(T,I) = c(I,T) = c(F,I) = c(I,F) = 0.5 \end{aligned} \tag{3}$$

"c" stands for "c_N" when dealing with neutrosophic degree of contradiction between attribute values respectively. The functions c (•,•) is defined according to the application where the experts solving.

$$x(d(x,V)), where\, d(x,V) = \{d(x,v), for\, all\, v \in V\}, \forall x \in P \tag{4}$$

a neutrosophic attribute value contradiction function (c_N: $V \times V \to [0,1]^3$) could increase the calculation complexity of but it will increase the accuracy as well, contradiction degree is calculated between uni-dimensional attribute values. Therefore, to calculate contradiction degree for multi-dimensional attribute values first we split them into corresponding uni-dimensional attribute values then calculate the contradiction degree between each two attribute values.

Using he attribute value contradiction degree function helps the plithogenic aggregation operators but ignoring it will cause less accuracy result for the aggregations operators.

Definition 5. As presented by Smarandache (2017) the plithogenic number operations are extensions of the fuzzy, intuitionistic fuzzy, and neutrosophic number operations.

Let $A = (a_1, a_2, \cdots, a_n)$ and $B = (b_1, b_2, \cdots, b_n)$ be two single-valued uni-attribute plithogenic numbers, where $a_1, a_2, \cdots, a_n,\ b_1, b_2, \cdots, b_n \in [0,1]$, $n \geq 1$, $0 \leq \sum_{i=1}^{n} a_i \leq n$, and $0 \leq \sum_{i=1}^{n} b_i \leq n$.

Let α be the attribute that has n values: $V = \{v_1, v_2, \cdots, v_n\}$, where the attribute dominant value $v_D \equiv v_1$, the single valued contradiction fuzzy degree $c(v_D, v_1) = c_i \in [0,1]$ *for* $i \in \{1, 2, \cdots, n\}$, such that $0 = c_1 \leq c_2 \leq \cdots \leq c_n \leq 1$

Plithogenic Single-Value Number Summation

$$\begin{aligned} A \oplus B = \{&(1 - c_i) \cdot [a_i + b_i - a_i \cdot b_i] + c_i \cdot [a_i \cdot b_i],\\ &i \in \{1, 2, 3, \cdots ., n\}\} \end{aligned} \tag{5}$$

Plithogenic Single-Value Number Multiplication

$$\begin{aligned} A \otimes B = \{&(1 - c_i) \cdot [a_i \cdot b_i] + c_i \cdot [a_i + b_i - a_i \cdot b_i],\\ &i \in \{1, 2, \cdots, n\}\} \end{aligned} \tag{6}$$

One-Attribute-Value Plithogenic Single-Valued Neutrosophic Set Intersection

$$\begin{aligned} &(a_1, a_2, a_3) \bigwedge\nolimits_p (b_1, b_2, b_3)\\ &\quad = (a_1 \bigwedge\nolimits_p b_1, \frac{1}{2}(a_2 \bigwedge\nolimits_f b_2 + a_2 \bigwedge\nolimits_f b_2), a_3 \bigvee\nolimits_p b_3 \end{aligned} \tag{7}$$

One-Attribute-Value Plithogenic Single-Valued Neutrosophic Set Union

$$\begin{aligned} &(a_1, a_2, a_3) \bigvee\nolimits_p (b_1, b_2, b_3)\\ &\quad = (a_1 \bigvee\nolimits_p b_1, \frac{1}{2}(a_2 \bigwedge\nolimits_f b_2 + a_2 \bigvee\nolimits_f b_2), a_3 \bigwedge\nolimits_p b_3). \end{aligned} \tag{8}$$

Definition 6. (Ye, 2014) let A is SVNN numbers $A = \langle T_A, I_A, F_A \rangle$ the simplified neutrosophic weighted geometric average operator is defined by:

$$\begin{aligned} &SNWGAO(x_1, x_2, \cdots, x_n)\\ &\quad = \left(1 - \prod_{j=1}^{n} \left(1 - T_{x_j}\right)^{w_j}, 1 - \prod_{j=1}^{n} \left(1 - I_{x_j}\right)^{w_j}, 1 - \prod_{j=1}^{n} \left(1 - F_{x_j}\right)^{w_j}\right) \end{aligned} \tag{9}$$

where w_j is the weight vector of x_j , $j = 1, 2, \ldots$, n, $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$

Definition 7. (Gayyar, 2016) The Null (empty) neutrosophic set 0_N and the absolute (universe) neutrosophic set 1_N are defined as follows:

$$\begin{aligned} 0_N &=< x, 0, 0, 1 > x \in X\\ 0_N &=< x, 0, 1, 1 > x \in X\\ 1_N &=< x, 1, 1, 0 > x \in X\\ 1_N &=< x, 1, 0, 0 > x \in X \end{aligned}$$

Definition 8. (Mohamed, Abdel-Basset, Nasser, & Smarandache, 2017; Surapati, Rumi, Tapan, & Florentin, 2018) The complement (Negations) of a single valued neutrosophic set $A = \{\langle x, T_A(x), I_A(x), F_A(x) \rangle : x \in X\}$*is denoted by*:

$$\neg(A) = \{x, T_{c(A)}, I_{c(A)}, F_{c(A)} \rangle : x \in X\} \tag{10}$$

where $T_{c(A)}(x) = F_A(x)$**,** $I_{c(A)}(x) = 1 - I_A(x)$**,** $F_{c(A)}(x) = T_A(x)$

while Smarandache (2017) extend the definition of one-Attribute-Value Plithogenic Single-Valued Neutrosophic Set Complements (Negations) as**:**

$$\neg p(a_1, a_2, a_3) = (a_3, a_2, a_1) \tag{11}$$

$$\neg p(a_1, a_2, a_3) = (a_3, 1 - a_2, a_1) \tag{12}$$

$$\neg p(a1, a_2, a_3) = (1 - a_1, a_2, 1 - a_3) \tag{13}$$

Definition 9. (Liu, 2016) *Algebraic single-valued neutrosophic number-weighted averaging operator* ($ASVNNWA$).

$$ASVNNWA(x_1,x_2,\cdots,x_n)=\left(1-\prod_{j=1}^{n}(1-T_{x_j})^{w_j},\prod_{j=1}^{n}I_{x_j}^{w_j},\prod_{j=1}^{n}F_{x_j}^{w_j}\right) \tag{14}$$

where w_j is the weight vector of x_j, $j = 1, 2, \ldots, n$, $w_j \in [0, 1]$ and $\sum_{j=1}^{n} w_j = 1$.

The Algebraic single-valued neutrosophic number-weighted averaging is not efficient to calculate the weighted average for SVNN that any presented absolute (universe) neutrosophic set 1_N will lead the indeterminacy-membership degree and the falsity membership degree to be 0 that $0^x x \in R, x > 0 = 0$ that will affect all over the result.

Definition 10. In order to compare two SVNNs, Ye (2014) proposed a method based on the cosine similarity measure for a SVNN $x = (T, I, F)$ to ideal solution $(1, 0, 0)$. The cosine similarity degree $COS(x)$ is defined as:

$$COS(x)=\frac{T}{\sqrt{T^2+I^2+F^2}} \tag{15}$$

Suppose $x = (T_1, I_1, F_1)$ and $y = (T_2, I_2, F_2)$ are two SVNNs if $S(x) \leq S(y)$ then $x \leq y$.

Smarandache (2017) extend the definition of cosine Similarity Plithogenic Number Measure

$$COS(A,B)=\frac{\sum_{i=1}^{n}a_i b_i}{\sqrt{\sum_{i=1}^{n}a_i^2}\cdot\sqrt{\sum_{i=1}^{n}b_i^2}} \tag{16}$$

The cosine similarity of 1 means that the SVNN is an absolute (universe) neutrosophic set 1_N as explained above and the nearest SVNN cosine similarity to 1 is better.

While humans may prefer using words by means of linguistic labels or terms to articulate their preferences, the ratings of each alternative with respect to each attribute are given as linguistic variables characterized by SVNN in the evaluation process as shown in Table 1, domain experts can replace its values according to the terms used in Quality Audit, in the same time the auditor has the ability to write the value of SVNN form that reflect the corresponding value.

Table 1
Linguistic terms and SVNN environment values.

Linguistic terms	prefix	Equivalent SVNN values
Extremely good	EG	(1, 0, 0)
Very very good	VVG	(0.9, 0.1, 0.1)
Very good	VG	(0.8, 0, 15, 0.20)
Good	G	(0.70, 0.25, 0.30)
Medium good	MG	(0.60, 0.35, 0.40)
Medium	M	(0.50, 0.50, 0.50)
Medium bad	MB	(0.40, 0.65, 0.60)
Bad	B	(0.30, 0.75, 0.70)
Very bad	VB	(0.20, 0.85, 0.80)
Very very bad	VVB	(0.10, 0.90, 0.90)
Extremely bad	EB	(0, 1, 1)

4. Proposed algorithm

In this section we conclude the proposed algorithm as follows:

Step 1. We consider each question in NQA checklist as SVNS "as explained in definition 2" using Eq. (1) $Q_i = \{\langle x_i, T_A(x_i), I_A(x_i), F_A(x_i)\rangle : x_i \in X\}$, $i \epsilon [1, z]$ where $z =$ total number of NQA questions.
Step 2. The expert detriment the weight of for each NQA checklist questions, considering that the total weight must be equal one as explained in Eq. (9).
Step 3. The auditor has to determines the value of $T_A(x_i)$a truth-membership,$I_A(x_i)$ an indeterminacy-membership, and $F_A(x_i)$a falsity-membership for each question in NQA checklist during the audit.
Step 4. The auditor can use the linguistics terms presented by the expert in Table 1 otherwise write the value of SVNN that reflect the corresponding value.
Step 5. If the auditor determining the linguistic term, then we replace each linguistic term with its equivalent SVNN value using Table 1.
Step 6. Calculate a cosine similarity measure using Eq. (15) for each question in NQA checklist.
Step 7. For each question any cosine similarity less than one (or less than the predefined target defined by the experts) means either non-conformity, opportunities for improvement, or non-compliance detected in that specific question and action needed according to cosine similarity calculated value.
Step 8. Then calculate the *Simplified Neutrosophic Weighted Geometric Average Operator SNWGAO* using Eq. (9) which refer to the overall result of the audit.
Step 9. Calculate cosine similarity measure for *SNWGAO* using Eq. (9).
Step 10. If the cosine similarity measure for *SNWGAO* which represent the overall result of the audit less than one (or less than the predefined target defined by the experts) means that the organization fail to pass the audit, otherwise it indicate that the overall performance regarding the audit is accepted with respect to the finding in step no Step 7.

Fig. 5 present a step-by-step procedure and schematic diagram for evaluating NQA result.

5. Illustrative example

To explain the proposed approach in a better way, we solved a numerical example, steps of solution are determined clearly, for simplicity we select only five questions listed below:

1. Has your organization determined external and internal issues relevant to its purpose and its strategic direction that affect its ability to achieve the intended result(s) of its QMS? (x_1).

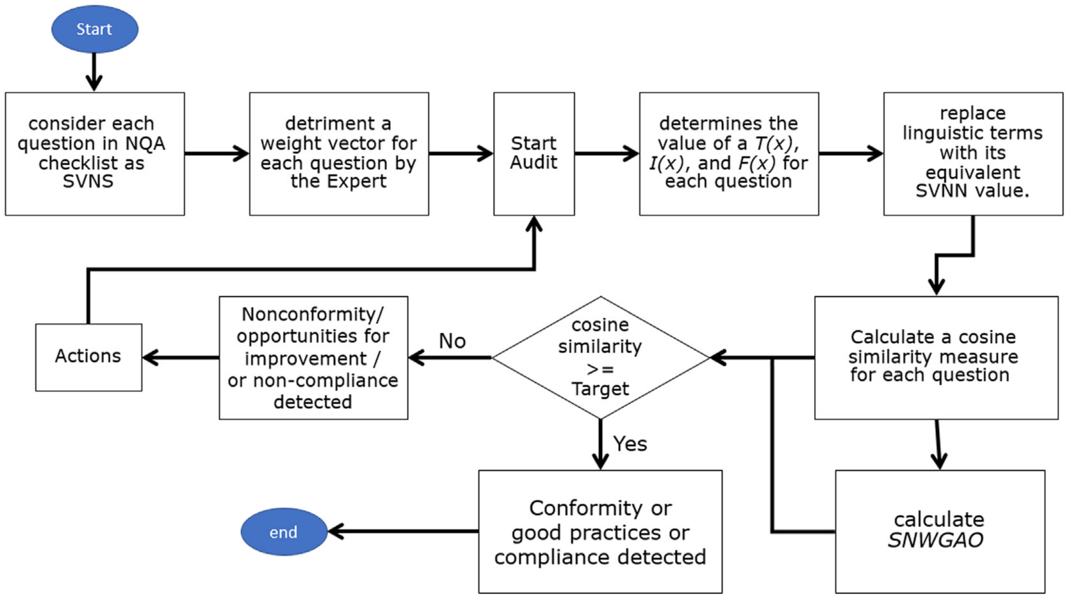

Fig. 5. Schematic diagram for NQA.

2. Does your organization monitor and review information about these external and internal issues? (x_2).
3. Does the organisation determine the interested parties that are relevant to the QMS? (x_3).
4. Does the organisation determine the requirements of these interested parties that are relevant to the QMS? (x_4).
5. Does your organization monitor and review information about these interested parties and their relevant requirements? (x_5).

Applying the proposed algorithm:

1. The first step we consider each question as SVNN and ask the auditor for his/her corresponding value for each question.
2. The second step is to ask the auditor to detriment a weight for each NQA checklist questions weight, considering that the total weight must be equal one (see Table 2).
3. The next step is to gather the auditor judgments either it was as linguistics or numeric values as shown in Table 3.
4. After that we use the linguistic terms and its SVNN corresponding values in Table 1 to replace each linguistic team in Table 3 with its equivalent neutrosophic value as shown in Table 4.
5. The next step is calculating a cosine similarity measure using Eq. (15) for each question.
6. Compare cosine similarity with the expert predefined values presented in Table 6.
7. From Tables 5 and 6 its obviously that, the issues covered by Question_4(x_4) is compliant with no needs for corrective nor preventive actions, while the issues covered by question_5 (x_5) has a similarity of 0.381000381reflect a major non-conformance which is in need for an intervention, implement immediate containment action, investigate root cause(s), and apply corrective action meanwhile, the issues covered by question_1, question_3 (x_1),(x_3) seems good enough with opportunities for improvement, for question_2 a minor non-conformance detected Investigate root cause(s) and implement corrective action to be check next reporting period or next scheduled audit.

Table 2
NQA checklist Question Weight.

	Question	weight	Question weight
(x_1)	Has your organization determined external and internal issues relevant to its purpose and its strategic direction that affect its ability to achieve the intended result(s) of its QMS?	w_1	0.20
(x_2)	Does your organization monitor and review information about these external and internal issues?	w_2	0.20
(x_3)	Does the organization determine the interested parties that are relevant to the QMS?	w_3	0.20
(x_4)	Does the organization determine the requirements of these interested parties that are relevant to the QMS?	w_4	0.20
(x_5)	Does your organization monitor and review information about these interested parties and their relevant requirements?	w_5	0.20
	Total weight		**1.00**

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Table 3
checklist questions and auditor corresponding judgments.

	Question	Auditor judgments
(x_1)	Has your organization determined external and internal issues relevant to its purpose and its strategic direction that affect its ability to achieve the intended result(s) of its QMS?	Very good
(x_2)	Does your organization monitor and review information about these external and internal issues?	Good
(x_3)	Does the organization determine the interested parties that are relevant to the QMS? *auditor comment: there are 7 determined parties, one totally not determined, while there are 2 parties they have a doubt if it totally related or not. → like this comment can easily translated into Single Value Neutrosophic number (0.70, 0.2, 0.1).*	(0.70, 0.2, 0.1)
(x_4)	Does the organization determine the requirements of these interested parties that are relevant to the QMS?	Very very good
(x_5)	Does your organization monitor and review information about these interested parties and their relevant requirements?	(0.30, 0.2, 0.70)

Table 4
Equivalent SVNN.

Question	SVNN
(x_1)	(0.8, 0, 15, 0.20)
(x_2)	(0.70, 0.25, 0.30)
(x_3)	(0.70, 0.2, 0.1)
(x_4)	(0.9, 0.1, 0.1)
(x_5)	(0.30, 0.2, 0.70)

Table 5
Calculated cosine similarity.

Question	cosine similarity
(x_1)	0.954479978
(x_2)	0.873296006
(x_3)	0.952579344
(x_4)	0.98787834
(x_5)	0.381000381

Table 6
Expert predefined cosine similarity.

Expected decision	Predefined cosine similarity
Compliant	0.97
Opportunity for Improve	0.90
Minor non-conformance	0.80
Major non-conformance	0.60

8. using equation no. (9), to calculate $SNWGAO = (0.73693, 0.18157, 0.32894)$.
9. Using equation no. (15) to calculate cosine similarity for the $SNWGAO = 0.927147818$ for overall the questions in NQA checklist that means the overall performance regarding the audit is accepted with respect to the finding for each question separately.

6. Conclusion and future work

In this paper we propose an Innovative Method to Evaluate Quality Management System Audit Results' using single value neutrosophic number to handle Neutrosophic Quality Audits to improve the audit process by enhancing the way of judging the audit finding, for dragging the Quality Audits to be more effective through using neutrosophic concept and applying cosine similarity as a measuring tool and using a Simplified Neutrosophic Weighted Geometric Average Operator for aggregation, we also give numerical examples to show the efficiency of the proposed method. As far as future directions are concerned, this research should be extended by employing more enhancement for the NQA in Neutrosophic environment, using different way for measuring the distance and similarity, also using the interval valued neutrosophic number to benefit from the "rang from" it can handle, that it one of the cases already facing the auditor in the real-life that the auditor may want assign a value to a question this value characterized as a form of range with effectively deal with vagueness and handle the interdependencies, in addition, maxing different forms of neutrosophic numbers such as single valued neutrosophic number, e single valued triangular neutrosophic number, interval valued neutrosophic number,... could be another case need to be addressed to have a way for measuring the distance, similarity and calculate the aggregation for a mixture of different neutrosophic numbers shapes.

Conflicts of interest

The authors declare no conflict of interest.

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