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Evaluating the Impact of Blockchain Models for Secure and Trustworthy Electronic Healthcare Records

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ABSTRACT Blockchain technology is among the most significant developments and revolutionary innovations of the Information Technology industry. It corners a crucial space in the present digital era and has already made significant differences in human life. Moreover, it is anticipated that the Blockchain technology will improvise the existing IT facilities in the next several years in many domains. Recent technological developments are allowing for a major advancement in Healthcare sectors. Information security and accessibility are critical considerations for the integration and communication with Electronic Healthcare Record (EHR) systems when sharing private medical information. In this context, selecting the most effective blockchain model for secure and trustworthy EHRs in the healthcare sector requires an accurate mechanism for evaluating the impact of different available blockchain models for its features. The present study uses a scientifically proven approach for evaluating the impact of blockchain technology and provides a novel idea and path to the future researchers. This research analysis garnered the feedback of 56 domain experts in the healthcare management for assessing the impact of different blockchain models. To eliminate the ambiguities that arose due to multiple opinions of these experts and for the externalization and organization of information about the selection context of the blockchain model, the study used a decision model. Fuzzy Analytic Analytical Network Process (F-ANP) method was used to calculate the weights of the criteria as well as the Fuzzy-Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) technique was used to evaluate the effect of alternative solutions. Further, the results obtained through this empirical investigation will be an instrumental reference for choosing the most appropriate Blockchain model for maintaining breach-free EHRs.

INDEX TERMS Blockchain, decision making, fuzzy logic, healthcare blockchain, health and safety.

I. INTRODUCTION

Nowadays several countries are experiencing massive growth in the healthcare challenges, although accessibility to primary physicians or practitioners has become more challenging for patients. Taking into consideration the word “blockchain,” it’s becoming increasingly apparent that such a technology is not only significant but also indispensable in the era of the World Wide Web [1]. Generally, a blockchain is considered as a decentralized record database or a distributed ledger of all transaction processing or electronic activities that have been conducted and exchanged between the involved parties. A blockchain includes a definite and provable documentation of each transaction that has ever been made [2], [3]. A transaction may be carried out in a decentralized manner using blockchain technology. Blockchain can therefore reduce costs considerably as well as increase performance [4].

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The blockchain technology-based modern emerging technological innovations have revolutionized almost every sector, such as energy [5], [6], e-commerce [7], banking [8], government administration [9], medical services [10], [11], education [12], agricultural development [13] and several other industries. A renowned scientific study and market consulting firm, Gartner, estimated investment decisions worth $3.1 trillion in blockchain technology by 2030 [14]. The following Figure 1 shows the blockchain investment growth rate forecast by Gartner.

The blockchain technology's transformative capability has been rapidly recognized by leading companies, identifying it as a turning point in many market use case scenarios including healthcare sectors. Due to this substantial scale of enterprise implementation of blockchain technology, a large amount of work has been conducted in this area. According to the HIPAA Journal report, there were 3,054 data breaches in the healthcare sector affecting over 500 records between 2009 and 2019. Those breaches caused the destruction, theft, disclosure, or unauthorized release of 230,954,151 records in the healthcare sector. This is equal to even more than 69.78 percent of the US population. Breaches of healthcare data were recorded at a rate of 1.4 per day in the year 2019 [82].

The Healthcare industry alone has recently begun to emphasis more on the implementations allowed by blockchain [15]–[20].

The blockchain is a technological innovation now attracting tremendous interest in the healthcare sector. However, blockchain can be seen as the top 5 preferences by 40 percent of health executives. Besides, blockchain technology spending on the worldwide healthcare sector is projected to reach $5.61 billion by 2025, as per a study from BIS Research. As per this report, the implementation of blockchain technology may save up to $100-$150 billion annually by 2025 in costs related to data loss, IT costs, operating costs, assistance structure costs and administration costs, and by the deception and fraudulent products in the healthcare sector [21]. Adoption of EMR (Electronic Medical Record) has now been regarded as a pivotal step in enhancing the knowledge, efficiency, customer experience and associated costs of access to healthcare. Kemkarl *et al.* estimated that, ultimately, the EMR program can save more than billions annually [22]. Transferring health care data would allow us to become more informed, for example, to understand better behavioral patterns in community health and disease in order to guarantee better clinical care [23], better practice of the guidelines instituted by the doctors [24]. However, at the same time it is sensitive to a wide variety of security and privacy risks due to the functionality and design [25], [27]. A big problem for advanced health-care data structures is how to capture, control and interpret patient healthcare data without increasing privacy abuses [26].

Blockchain technology may combine medical and pharmaceutical records of a patient from different websites as well as data providers to create a single, updated record that a physician can refer to while treating patients. There are also major technological barriers to blockchain adoption in healthcare sectors [29], [30]. Therefore, evaluation of the impact of different blockchain technology models for securing web-based electronic healthcare records is a critical as well as a challenging task in general. Evaluating the impact of blockchain technology on the healthcare sector's growth is significant because it is the prerequisite for implementing an effective healthcare policy. In this research paper, we are modeling the effect of different blockchain models on healthcare applications as an issue involving Multiple Criteria Decision Making (MCDM) techniques.

There are several MCDM approaches available for solving this kind of problem [31]. Furthermore, the core challenge is to determine the impact of blockchain technology in the healthcare perspective. In this research paper, the researchers used the Fuzzy-based Analytic Network Process (ANP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approaches [32]. AHP is focused on the structure of the hierarchy whereas the ANP is focused on the structure of the network. Although many authors have used AHP-TOPSIS for this kind of assessment yet, ANP is another extensively used Analytic Hierarchy Process (AHP) tool implemented in MCDM based problems [33]. Many authors presented their work on fuzzy ANP-TOPSIS Multiple-criteria decision-making (MCDM) strategies available for solving problem creating choices of this kind. However, none of them performed study on evaluating the impact of blockchain technology for securing web based electronic healthcare records with the help of fuzzy based decision-making Process.

The rest of the paper is organized as follows: In Section 2, the paper describes the different blockchain technology models. Section 3 defines the methodology for the proposed research study. With the help of Fuzzy ANP-TOPSIS, impact of blockchain models for secure and trustworthy EHR is evaluated in Section 4. Comparisons of the findings and sensitivity analysis have been presented in Section 5 of this paper. Finally, discussion and conclusions are given in Section 6.

II. DIFFERENT BLOCKCHAIN MODELS

If Different types of Blockchain models in this category include: Private Blockchain, Public Blockchain, Hybrid Blockchain, Permissioned Blockchain, Consortium Blockchain, and Decentralized application which are discussed in details in the following sub-sections.

A. PRIVATE BLOCKCHAIN

Private blockchain is a distributed ledger that functions as a closed, secure repository founded on principles of cryptography. It is a blockchain running with limitations or permissions only within a closed network. Private blockchains are typically used by an enterprise or company where users in a blockchain network are only selected participants. Write-permissions are tracked in a completely private ledger through a central vector of decision making while read-permissions may be public or confined [35]. It only enables

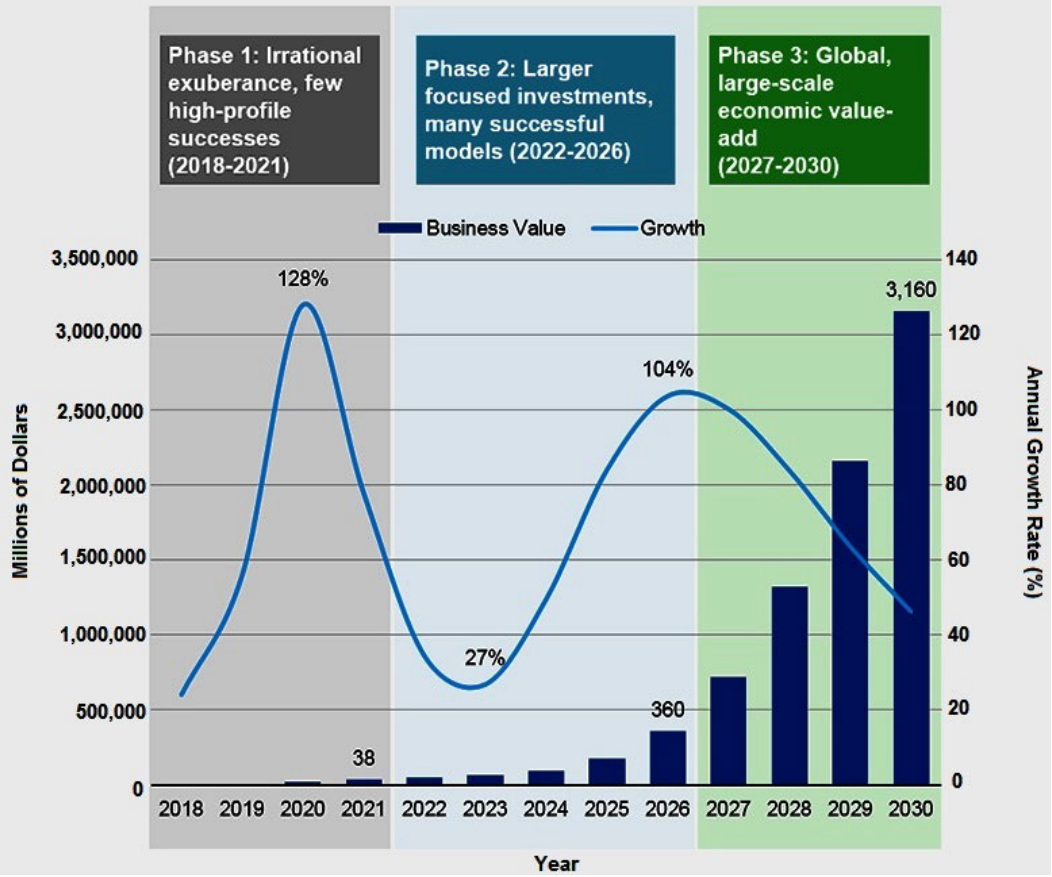

FIGURE 1. Blockchain investment growth rate forecast (2018-2030).

authorized individuals or particular organizations to enter the ledger, access as well as display data. In this, some recognize most of the users' accounts before transacting. A version of the private blockchain is the concept of a decentralized system or cooperative, wherein the blockchain works under community governance. This kind of blockchain is a private network that preserves a public transaction record which can only be accessed by someone who is authorized [36].

B. PUBLIC BLOCKCHAIN

A public blockchain allows everyone to participate. It is indeed a distributed ledger platform which is non-restrictive, with no permission. Everyone who has internet connectivity can enter to become an approved node on a blockchain platform and thus become a component of the blockchain technology network. A node or user that is a member of the public blockchain who is allowed to view recent as well as old records, check transactions, or prove tasks for an upcoming chain, and perform mining activities. Public blockchain technologies enable everyone to communicate with one another participant involved in the transaction. It holds a history of unchangeable transactions. Anybody can report a transaction through conforming to a collection of established standards and participating in the network. The identification between each of the two participants can be either anonymous or completely pseudonymous, i.e., before the exchange, the transacting participants may not recognize one another [37].

C. HYBRID BLOCKCHAIN

Hybrid blockchain is based on a mixture of a private blockchain with a public one. This incorporates the functionality from both kinds of blockchains that someone can have a network dependent on private consent and also a network without public consent. In this kind of decentralized network, users are able to monitor who receives access to the information the blockchain holds. Besides this, a selected portion of blockchain information or documents may be permitted to go public while maintaining the secrecy of the rest of the information in private network as possible. The blockchain hybrid network is versatile, thus making it possible for users to enter a private blockchain alongside numerous public blockchains. Highly controlled businesses as well as governments may take advantage of hybrid blockchain. It allows consistency and flexibility including what information on a public ledger is kept secret or distributed. There are many implementations of hybrid blockchain that exist in the real world. For instance, on *Ethereum* (public blockchain) as well as *Quorum* (private blockchain), *XinFin* is a hybrid blockchain. *XinFin* has accomplished numerous pilots through supply chain logistics, transportation, and foreign trade agreements as well as financial services [38]. Hybrid blockchains are also used as a means of preserving security while providing greater transaction performance. It often takes the form of a public primary chain attaching the primary chain with private or permitted side chains [39].

D. PERMISSIONED BLOCKCHAIN

Anyone else involved in verifying transactions or accessing the information on the network has to get a centralized regulator's authorization. This really is valuable for businesses, financial institutions, and organizations which are confident complying with most of the restrictions as well as very conscious about maintaining full monitoring of the records [34]. Permissioned blockchains may be regarded as an enhanced blockchain protection mechanism since it maintains an authentication layer that allows specific acts to be done only by certain recognizable individuals involved. Permissioned blockchains function remarkably different from the private as well as public blockchains. It is constructed to reap the benefits of blockchains without compromising a centrally controlled system's authority component. A good example of permissioned blockchain is *Ripple.*

E. CONSORTIUM BLOCKCHAIN

The consortium blockchain is based on a semi-decentralized model, in which the blockchain network is operated by more than one enterprise. This is contradictory to a private ledger that only one entity manages. In this type of blockchain, more than one enterprise may function as a node as well as share knowledge, or do mining. The consortium blockchain incorporates elements from the private as well as public chains. At a consensus point, the most significant deviation from either system can be identified. Rather than an open platform in which anybody can verify blocks or even a closed platform in which only one party gets to appoint block suppliers, a consortium chain has a group of similarly powerful entities as validators functioning [40, 56-57].

F. DECENTRALIZED BLOCKCHAIN

Decentralized applications (dApps) are software applications or systems which run and operate on a blockchain as well as P2P database network rather than a single device, and are beyond the influence and authority of a single body. BitTorrent, Popcorn Time and Tor are some examples of a software application running on different computers which are members of a P2P network where there are several members from both sides, some downloading the data, others feeding and maybe even seeding the data, whereas others execute both operations concurrently. The dApps live and operate on a blockchain platform in a public, open-source, decentralized ecosystem in the sense of cryptocurrencies, and are free of any single authority's control and intervention [41]. DApps provide serverless specifications that can be implemented on the client-side and through a blockchain-based distributed network. The client tool handles the front-end and user credentials, while the back end operates inside a network of disbursed machines providing processing as well as storage needs [42].

TABLE 1. Different criteria to evaluate the blockchain models impact on healthcare services.

Criteria	Description
Patient Identity (T1)	In a blockchain based healthcare setting patients may control their public keys, maybe with the help of mobile or wearable devices and also use the public key infrastructure (PKI) to create their unique identity to access their medical data from the blockchain system, and also attach new relevant information. PKI helps to ensure professionals and organizations can believe the data is being created by the specific patient. It ensures proper authentication and authorization features.
Data Security (T2)	Patients receive the option by which they can share their keys essentially puts them in charge of what their health records can do, including different access privileges. In a blockchain setting, integrating keys with smart contracts prohibits illegitimate participants from attaching data to records of a patient, particularly outsiders trying to exploit data for objectives of fraudulent or any other personal reasons. This criterion ensures patient's personal information privacy, proper data management and effective authorization.
Data Monitoring (T3)	The ledger keeps tracking data each step along the way in a healthcare blockchain system, such as who managed it as well as where it was, until it hits the appropriate user. For efficient data monitoring, every patient data is properly controlled and synchronized in a real-time manner to all concerned parties.
Immutability (T4)	Medical data is spread safely throughout various sectors, maintaining confidentiality, reducing the risk of failure, and providing a proper audit trail in the situation of malicious actors. Blockchain model assures full clinical presentation of all professionals with secure access to confidential information with proper implementation of cryptography and hashing functions.
Consensus (T5)	Blockchain technology with its consensus process and decentralized architecture that protects against hacking or abuse eliminates the possibility of data theft in the healthcare system. Electronic healthcare records on the blockchain can be granted proof or evidence and verification of authentication. In blockchain setting several nodes find consensus on Proof-of-Stake and Proof-of-Work.
Value (T6)	Blockchain technology could emerge as a big platform for the healthcare professionals with the potential to deliver significant value in the industry. The value of blockchain technology can be measured by assessing the performance, convenience and demand in healthcare setting.

The Table 1 discusses the different criteria which have been identified to evaluate the impact of blockchain technology on the different healthcare services.

III. MATERIALS AND METHOD

Research methodology included in this analysis aims to evaluate the impact of blockchain technology for Securing Web-based electronic healthcare records. The hierarchical structure of the proposed challenge of evaluating the impact of blockchain technology models for secure web-based electronic healthcare records is shown in Figure 2.

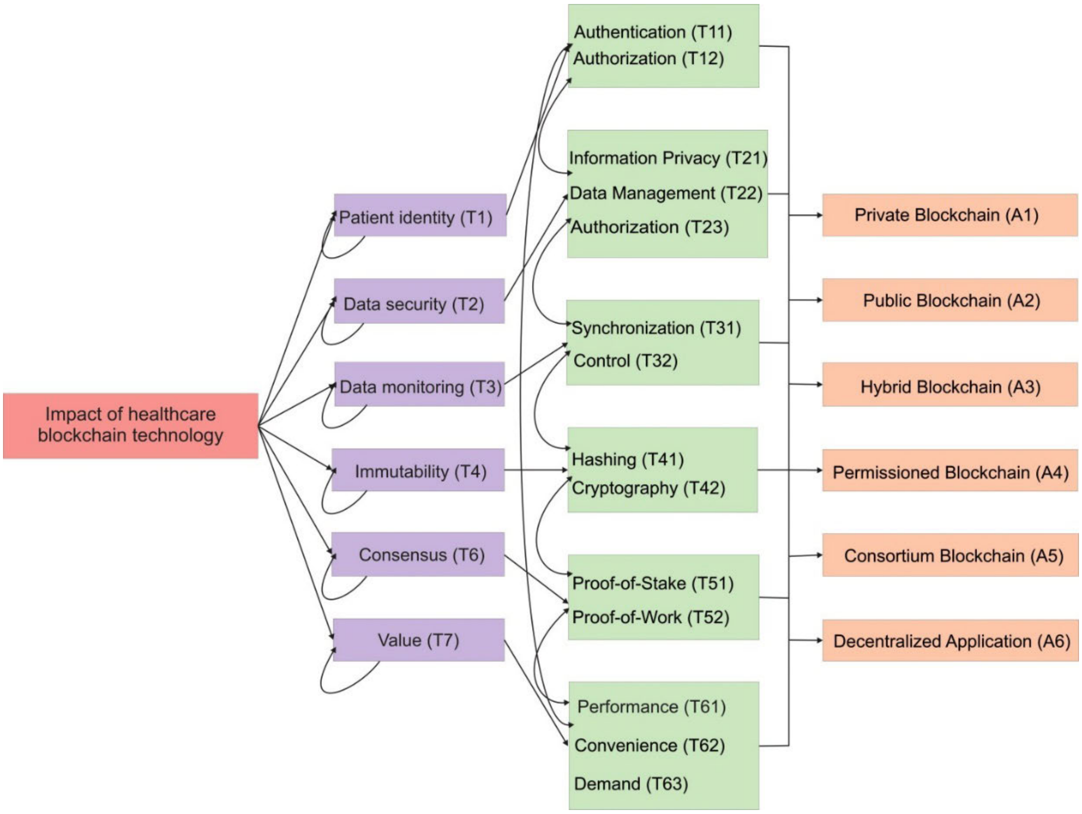

FIGURE 2. ANP Structure for the evaluation of healthcare blockchain technology models.

This is designed to analyze the impact of different blockchain models on different digital healthcare services, and to implement MCDM technique in a fuzzy setting so as to choose the most appropriate solution. To accomplish the stated objective, the researchers of this study have used Fuzzy-ANP to calculate the weights of the factors and their respective interconnectivity with one another. We also used TOPSIS methodology to order the alternates. A comprehensive description of these procedures is provided in the following subsections.

A. FUZZY-ANP

Saaty [43] introduced ANP as a method for decision-making across several criteria. Because of its strengths compared with the previous method for analytical multiple criteria tasks, Saaty [44] coined the name Analytical Hierarchy Process (AHP). ANP is chosen in this research study to solve the problem. AHP evaluates hierarchical relationships between different levels of decision without addressing interconnections between criteria or alternatives, whereas the ANP tests interconnections between criteria including level of decision using network connections. In some cases, the ANP has also been verified as well. ANP also represents inter-dependencies among elements of the same cluster using loops and with other clusters of the same network along with feedback [23], [45]. The fuzzy-ANP methodology is a combination of fuzzy logic with the ANP method to manage inaccurate data, thus aiding in the conduct of reliable and consistent tests.

B. FUZZY-TOPSIS

Yoon and Hwang [46] initially proposed the TOPSIS methodology. They designed the TOPSIS founded on the idea that the selected alternative must have the shortest distance from the ideal-positive solution as well as the longest distance from the ideal-negative. TOPSIS system is one of the popular multiple criteria decision-making strategies for dealing with real-world complex problems. It strengthened the Zelany's [47] conception of the displaced ideal solution [48]. This is one of the strongest MCDM approaches to tackle the problem of ranking reversal that is the shift in alternative ranks whenever a non-optimal alternative is implemented. This approach has already been frequently implemented in several existing works. Besides, the TOPSIS approach has been improved to fix Fuzzy MCDM issues [32].

The researchers have used a hybrid method of fuzzy-ANP and TOPSIS in this study to evaluate the impact of blockchain-oriented technology for securing web-based electronic healthcare records. As per the Figure 3, the step-by-step process for determining weighting as well as priority ranking with the help of Fuzzy ANP-TOPSIS is defined as follows:

Step 1: The linguistic terms were first transformed into straight measurable numeric values, and after that into triangular fuzzy numbers (TFN). In this research study TFN may be defined as $(c1, c2, c3)$, where $(c1\ c2 = c3)$ as well as $c1, c2, c3$ are variables indicating the *smallest, intermediate*, and the *highest* value in the TFN. Assume A is a mischievous number

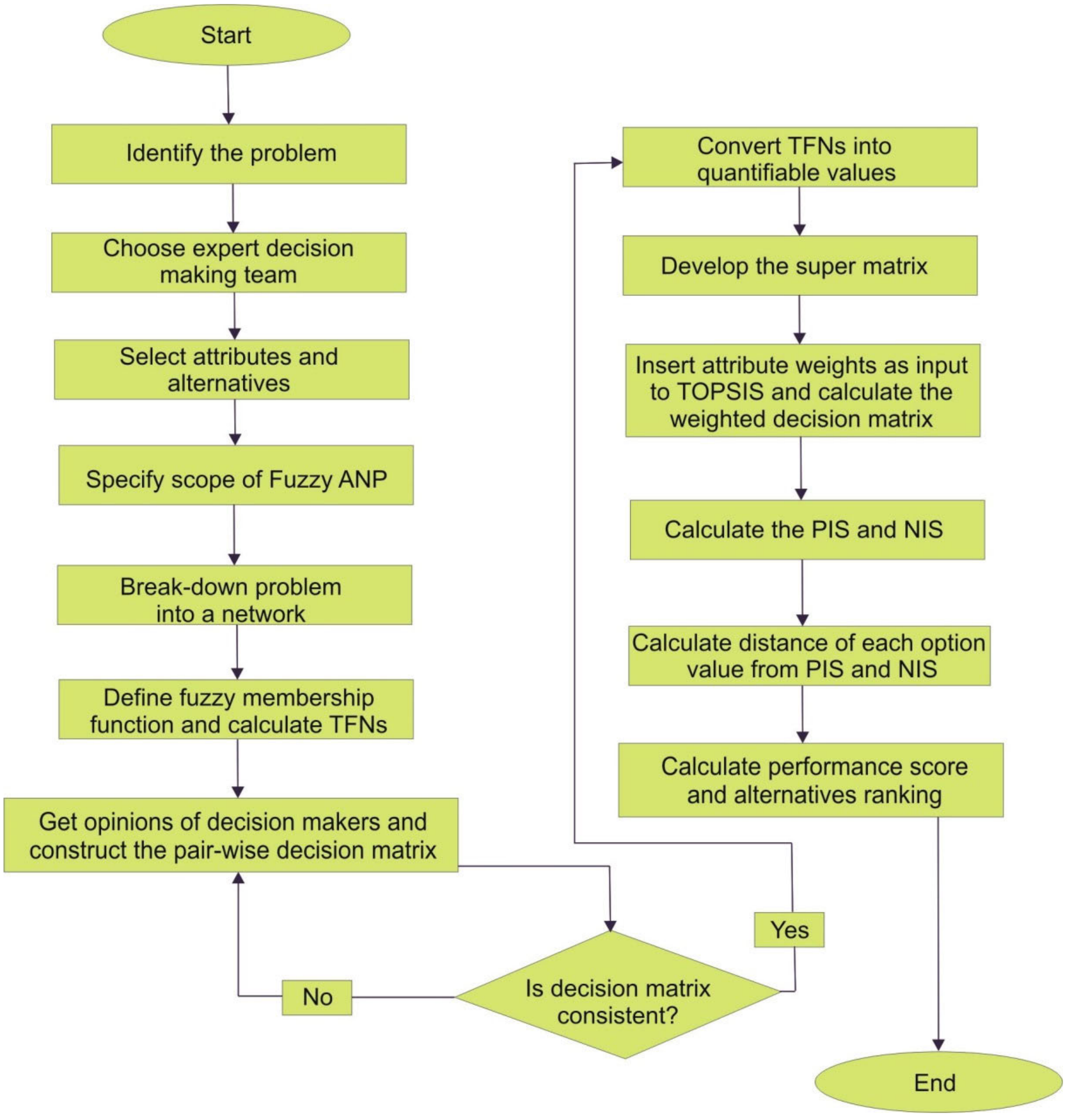

FIGURE 3. Fuzzy-ANP-TOPSIS Procedure.

and can also be represented as in equations (1-2) and can be seen in [48].

$$\mu_A(x) = F \rightarrow [0, 1] \tag{1}$$

$$\mu_A(x) = \begin{cases} \dfrac{x - \mathrm{c1}}{\mathrm{c2} - c1}, & \mathrm{c1} \leq \mathrm{x} \leq \mathrm{c2} \\ \dfrac{c3 - x}{c3 - c2}, & \mathrm{c2} \leq \mathrm{x} \leq \mathrm{c3} \\ 0, & \mathrm{x} > c3 Otherwise \end{cases} \tag{2}$$

First, different views have been taken from 56 academic and Blockchain industry experts, who had a variety of blockchain development and research experience for each attribute set and related data. The experts were requested to collect and analyze their perspectives in a virtual meeting environment and were informed about the scale of the attributes as regards the different groups and the linguistic values.

Thereafter with the help of the collected data, the researchers obtained network structure to assess the weights of the specified attributes about the impact of blockchain technology. Professionals and experts in blockchain research and development are given the answers by assigning ratings to the attributes which affect each other in an observable manner as per the scale shown in Table 2.

Triangular Fuzzy Number (TFN) is derived with the help of crisp numerical value systems by implementing equations (3-6) as well as presented as (*c1ij, c2ij, c3ij*) where, c1ij signifies low value, *c2ij* signifies mean value and c3ij signifies high value. In contrast, the concept of TFN [ηij] is as follows:

$$\eta_{ij} = \left(c1_{ij}, c2_{ij}, c3_{ij}\right) \tag{3}$$

where, $c1_{ij} \leq c2_{ij} \leq c3_{ij}$

$$c1_{ij} = min\left(J_{ijd}\right) \tag{4}$$

TABLE 2. **Saaty Scale with corresponding TFNs.**

Saaty Scale Definition	Fuzzy Triangle Scale	
1	Equally important	(1 ,1, 1)
3	Weakly important	(2 ,3, 4)
5	Fairly important	(4 ,5, 6)
7	Strongly important	(6 ,7, 8)
9	Absolutely important	(9 ,9, 9)
2		(1 ,2, 3)
4	Intermittent values between two adjacent scales	(3 ,4, 5)
6		(5 ,6, 7)
8		(7 ,8, 9)

$$c2_{ij} = (J_{ij1}, J_{ij2}, J_{ij3})^{\frac{1}{x}} \tag{5}$$

$$and \;\; c3_{ij} = max\left(J_{ijd}\right) \tag{6}$$

Jijk describes relative impact of the values among two factors listed according to the above equations; as well as provided through the decision of the experts. Where, I and j indicate a pair of attributes determined by experts. TFN (ηij) is calculated for a specific comparison dependent on the geometric mean of domain expert opinions. Therefore, equation 7 to 9 allows combining TFN values. Two TFNs were A1 and A2, A1= (c11, c21, c31), and A2= (c12, c22, c32). The operating standards for them are as follows:

$$\begin{aligned}(\mathrm{c}1_1, \mathrm{c}2_1, \mathrm{c}3_1) + (\mathrm{c}1_2, \mathrm{c}2_2, \mathrm{c}3_2)\\ = (\mathrm{c}1_1 + \mathrm{c}1_2, \mathrm{c}2_1 + \mathrm{c}2_2, \mathrm{c}3_1 + \mathrm{c}3_2)\end{aligned} \tag{7}$$

$$\begin{aligned}(\mathrm{c}1_1, \mathrm{c}2_1, \mathrm{c}3_1) \times (\mathrm{c}1_2, \mathrm{c}2_2, \mathrm{c}3_2)\\ = (\mathrm{c}1_1 * \mathrm{c}1_2, \mathrm{c}2_1 * \mathrm{c}2_2, \mathrm{c}3_1 * \mathrm{c}3_2)\end{aligned} \tag{8}$$

$$(\mathrm{c}1_1, \mathrm{c}2_1, \mathrm{c}3_1)^{-1} = \left(\frac{1}{\mathrm{c}3_1}, \frac{1}{\mathrm{c}2_1}, \frac{1}{\mathrm{c}1_1}\right) \tag{9}$$

Step 2: The matrix for a pair-wise comparison is developed with the help of the feedback obtained from the decision-makers. Consistency index (CI) evaluation is performed using such a formula present in equation 10 as follows:

$$CI = (\gamma_{max} - t)/(t - 1) \tag{10}$$

From which, CI represents the Consistency Index and t represents the compared number of factors. Next Consistency Ratio (CR) calculation with the help of a Random Index (RI) is as follows:

$$CR = CI/RI \tag{11}$$

If CR < 0.1 therefore the matrix produced is fairly consistent. Where, RI determines the random index taken from the Saaty random index [49].

Phase 3: With the help of the defuzzification process, the TFN values are transformed into measurable value after receiving a remarkably consistent matrix. The technique of defuzzification used in this research work is drawn from [50] as developed in equation (12-14), generally referred to as alpha-cut.

$$\mu_{\alpha,\beta}(\eta_{ij}) = [\beta \cdot \eta\alpha(c1_{ij}) + (1 - \beta) \cdot \eta\alpha(c3_{ij})] \tag{12}$$

where, $0 \leq \alpha \leq 1$ and $0 \leq \beta \leq 1$

Such that,

$$\eta\alpha(c1_{ij}) = (c2_{ij} - c3_{ij})\alpha + c1_{ij} \tag{13}$$

$$\eta\alpha(c3_{ij}) = c3_{ij} - (c3_{ij} - c2_{ij}).\alpha \tag{14}$$

α and β have been used in the previous mathematical formulas for the domain expert choices, α and β also differ among 0 and 1.

Step 4: The ANP method deals with dependency within a cluster as well as between various clusters. The aim of this step is the formulation of the supermatrix resulting from the pairing comparisons among groups like target, factors, sub-factors, as well as alternatives resulting from the preference vector.

Step 5: Evaluating the output rating of any alternative over any fixed factor TOPSIS requires this equation to normalize the entire decision matrix.

$$X_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{15}$$

In this equation, i = 1, 2, …m; and j = 1,2, …n.

Thereafter, the Normalized Weighted-Decision Matrix is calculated.

$$M_{ij} = w_i X_{ij} \tag{16}$$

where, i = 1, 2, …m and j = 1,2, …n.

Step 6: Estimation of I+ matrix positive-ideal solution, and I- matrix negative-ideal solution.

$$\begin{aligned}I^{+} &= z_1^{+}, z_2^{+}, z_3^{+} \ldots\ldots z_n^{+}\\ I^{-} &= z_1^{-}, z_2^{-}, z_3^{-} \ldots\ldots z_n^{-}\end{aligned} \tag{17}$$

In this equation, $\boldsymbol{z_j^{+}}$ is Max zij if j is an advantage factor as well as Max zij if j is a cost factor; $\boldsymbol{z_j^{-}}$ is Min zij if j is an advantage factor and Min zij if j is a cost factor?

Step 7: The next step is to determine the difference between each alternative value and the positive-ideal solution as well as the negative-ideal solution:

The positive-ideal solution:

$$D_i^{+} = \sqrt{\sum\nolimits_{j=1}^{m} (z_i^{+} - z_{ij})^2}; \; i = 1, 2, 3 \ldots .m \tag{18}$$

The Negative-ideal solution:

$$D_i^{-} = \sqrt{\sum\nolimits_{j=1}^{m} (z_{ij} - z_i^{-})^2}; \; where, \;\; i = 1, 2, 3 \ldots .m \tag{19}$$

where, $\boldsymbol{D_j^{\mathcal{C}}}$ Describes Positive-Ideal solution distance for i option and $\boldsymbol{D_i^{-}}$ is the distance from the ideal-negative approach. Measuring the importance of output for each alternative *(Pi)*.

$$P = \frac{D_i^{-}}{D_i^{-} - D_i^{+}} \tag{20}$$

The above-mentioned step-by-step assessment process would be accompanied through the use of the Fuzzy-ANP TOPSIS system with a specific number of alternatives to evaluate the impact of blockchain technology for EHRs. The next

TABLE 3. Aggregated Fuzzy Pair Wise Comparison Matrix at Level 1.

	T1	T2	T3	T4	T5	T6
T1	1.00000, 1.00000, 1.00000	1.75600, 2.35000, 3.03400	1.48300, 1.95800, 2.52900	1.12800, 1.55400, 1.98800	0.22150, 0.28710, 0.41520	0.31460, 0.46100, 0.87050
T2	-	1.00000, 1.00000, 1.00000	0.57000, 0.78600, 1.15600	0.57000, 0.72000, 0.97000	0.26790, 0.35210, 0.51760	0.16630, 0.19690, 0.25310
T3	-	-	1.00000, 1.00000, 1.00000	0.62700, 0.81200, 1.07200	0.30090, 0.43520, 0.80270	0.80270, 0.87050, 1.00000
T4	-	-	-	.00000, 1.00000, 1.00000	0.53860, 0.91430, 1.58360	0.60830, 1.05920, 1.68290
T5	-	-	-	-	1.00000, 1.00000, 1.00000	0.41520, 0.63720, 1.17910
T6	-	-	-	-	-	1.00000, 1.00000, 1.00000

section conducts a case study which provides the quantitative framework for achieving blockchain technology strategies.

Analysis manuscripts documenting large datasets stored in a database that is freely accessible should indicate wherein the data was stored and include the appropriate association agreement numbers. If at the time of request the accession numbers have not been received, it should be specified that they would be issued during the review. The same may be made available before release.

Interventional experiments involving animals or people and other research requiring ethical permission must mention the authority as well as the accompanying code of ethical acceptance.

IV. DATA ANALYSIS AND RESULTS

Estimating the impact of blockchain technology objectively is a qualitative measurement. For evaluation, six criteria of blockchain technology at Level 1, namely *Patients' Identity, Data Security, Data Monitoring, Immutability, Consensus* and *Value* are defined, respectively, as *T1, T2, T3, T4, T5 and T6.*

Regarding blockchain technology impact evaluation for EHRs at Level 2: the attributes of patient identity are *authentication* and *authorization* and are represented as *T11, T12*, respectively. The attributes of data security are *information privacy, data management*, and *authorization* which are represented as *T21, T22, and T23*, respectively. The attributes of data monitoring are *synchronization* and *control,* represented as *T31, T32* respectively. The attributes of immutability are *cryptography* and *hashing* which are represented as *T41, T42,* respectively. The attributes of consensus are *Proof-of-Stake* and *Proof-of-Work* which are represented as *T51, T52,* respectively. The attributes of value are *performance, convenience* and *demand,* represented as *T61, T62* and *T63, respectively,* in the tables specified below. The impact evaluation of blockchain technology for securing electronic healthcare records with the help of fuzzy-ANP-TOPSIS has been measured by using the Equations (1)–(20) as follows:

By using the standardized Saaty scale which can be seen in Table 1 as well as using Equations (1)–(9), we transformed the linguistic-terms into quantitative values and afterwards aggregated triangular fuzzy numeric (TFN) values. Then, the consistency indexes, as well as random index, were determined using Equations (10) and (11). A pair-wise comparison matrix has a random index of less than 0.1 which implies that our matrix is consistent in the pair-wise matrix. Further the pair-wise comparison matrix of the Level-1 parameters is then determined.

With the help of Equations (12)–(14), the defuzzification of pair-wise comparisons matrix was performed to use the alpha-cut process, and uniform values as well as defuzzified local weights of all these sub-attributes are therefore shown in Tables 4, accordingly. Through implementing the very same procedures used through the hierarchy, pair-wise comparison matrixes and local weights were measured accordingly.

TABLE 4. Defuzzified Pair-Wise Comparison Matrix and Local Weight of Attributes at Level 1.

	T1	T2	T3	T4	T5	T6	Weights
T1	1.0000	2.3723	1.9819	1.5564	0.3027	0.5268	0.16032
T2	0.4215	1.0000	0.8243	0.7447	0.3724	0.2033	0.07817
T3	0.5046	1.2132	1.0000	0.8309	0.4935	0.8520	0.11743
T4	0.6425	1.3428	1.2035	1.0000	0.9636	1.1024	0.15778
T5	1.8982	4.9188	1.1737	0.9071	1.0000	0.7172	0.24368
T6	0.8554	1.5397	0.5445	0.7401	1.3943	1.0000	0.24263
CR= 0.064104							

TABLE 5. Weighted Super Matrix.

	Goal	T1	T2	T3	T4	T5	T6	T11	T12	T21	T22
Goal	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T1	0.16032	1.00000	2.57230	1.92190	1.53640	0.25270	0.50680	0.00000	0.00000	0.00000	0.00000
T2	0.07817	0.41050	1.00000	0.85430	0.69470	0.35240	0.18330	0.00000	0.00000	0.00000	0.00000
T3	0.11743	0.48460	1.31320	1.00000	0.83090	0.49350	0.85200	0.00000	0.00000	0.00000	0.00000
T4	0.15778	0.62250	1.14280	1.25350	1.00000	0.96360	1.10240	0.00000	0.00000	0.00000	0.00000
T5	0.24368	1.78820	4.81880	1.17370	0.85710	1.00000	0.71720	0.00000	0.00000	0.00000	0.00000
T6	0.24263	0.80540	1.85970	0.54450	0.74010	1.35430	1.00000	0.00000	0.00000	0.00000	0.00000
T11	0.00000	0.31234	0.00000	0.00000	0.00000	0.00000	0.00000	0.17300	0.19000	0.19200	0.21000
T12	0.00000	0.62766	0.00000	0.00000	0.00000	0.00000	0.00000	0.16900	0.18700	0.18200	0.18400
T21	0.00000	0.00000	0.32986	0.00000	0.00000	0.00000	0.00000	0.13900	0.15800	0.14100	0.16300
T22	0.00000	0.00000	0.17553	0.00000	0.00000	0.00000	0.00000	0.16300	0.17000	0.15300	0.21300
T23	0.00000	0.00000	0.49461	0.00000	0.00000	0.00000	0.00000	0.17300	0.14200	0.19600	0.19200
T31	0.00000	0.00000	0.00000	0.47523	0.00000	0.00000	0.00000	0.19900	0.17700	0.19400	0.22800
T32	0.00000	0.00000	0.00000	0.52477	0.00000	0.00000	0.00000	0.17300	0.19800	0.17400	0.20400
T41	0.00000	0.00000	0.00000	0.00000	0.31323	0.00000	0.00000	0.15200	0.16000	0.18700	0.19300
T42	0.00000	0.00000	0.00000	0.00000	0.68677	0.00000	0.00000	0.19700	0.19000	0.17600	0.16800
T51	0.00000	0.00000	0.00000	0.00000	0.00000	0.23495	0.00000	0.18400	0.19600	0.18200	0.19200
T52	0.00000	0.00000	0.00000	0.00000	0.00000	0.76505	0.00000	0.17300	0.19000	0.19200	0.21000
T61	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.23546	0.16900	0.18700	0.18200	0.18400
T62	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.37517	0.13900	0.15800	0.14100	0.16300
T63	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.38937	0.16300	0.17000	0.15300	0.21300

	T23	T31	T32	T41	T42	T51	T52	T61	T62	T63
Goal	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T11	0.16800	0.16800	0.16800	0.17300	0.13300	0.16800	0.17300	0.19000	0.19200	0.21000
T12	0.17700	0.14900	0.14900	0.16900	0.16800	0.14900	0.16900	0.18700	0.18200	0.18400
T21	0.15900	0.14900	0.14900	0.13900	0.12300	0.14900	0.13900	0.15800	0.14100	0.16300
T22	0.16400	0.16900	0.16900	0.16300	0.15300	0.16900	0.16300	0.17000	0.15300	0.21300
T23	0.20600	0.20000	0.20000	0.17300	0.13200	0.20000	0.17300	0.14200	0.19600	0.19200
T31	0.22900	0.19600	0.19600	0.19900	0.16200	0.19600	0.19900	0.17700	0.19400	0.22800
T32	0.20000	0.17600	0.17600	0.17300	0.14000	0.17600	0.17300	0.19800	0.17400	0.20400
T41	0.20800	0.15500	0.15500	0.15200	0.14000	0.15500	0.15200	0.16000	0.18700	0.19300
T42	0.17800	0.18900	0.18900	0.19700	0.13100	0.18900	0.19700	0.19000	0.17600	0.16800
T51	0.17000	0.20100	0.20100	0.18400	0.17800	0.20100	0.18400	0.19600	0.18200	0.19200
T52	0.16800	0.16800	0.16800	0.17300	0.13300	0.16800	0.17300	0.19000	0.19200	0.21000
T61	0.17700	0.14900	0.14900	0.16900	0.16800	0.14900	0.16900	0.18700	0.18200	0.18400
T62	0.15900	0.14900	0.14900	0.13900	0.12300	0.14900	0.13900	0.15800	0.14100	0.16300
T63	0.16400	0.16900	0.16900	0.16300	0.15300	0.16900	0.16300	0.17000	0.15300	0.21300

To get an unweighted super matrix, the priorities obtained from the various pair-wise comparisons are utilized. Following the initial estimation of the weighted super matrix as shown in Table 5, the super matrix limit is also estimated. By using local weights, weighted super matrix as well as limits super matrix, global weights and ranks of

TABLE 6. Global Weights through the Hierarchy.

Second Level Attributes	Global Weights	Percentage	Ranks
T11	0.09820	9.82 %	1
T12	0.06480	6.48 %	10
T21	0.04510	4.51 %	14
T22	0.05320	5.32 %	12
T23	0.05540	5.54 %	11
T31	0.06540	6.54 %	9
T32	0.07210	7.21 %	8
T41	0.04520	4.52 %	13
T42	0.08740	8.74 %	3
T51	0.07540	7.54 %	7
T52	0.09250	9.25 %	2
T61	0.07850	7.85 %	6
T62	0.08530	8.53 %	4
T63	0.08150	8.15 %	5

TABLE 7. Subjective Cognition Results of Evaluators in Linguistic Terms.

	A_1	A_2	A_3	A_4	A_5	A_6
T11	4.27000, 6.27000, 8.27000	2.36000, 4.27000, 6.18000	1.45000, 3.00000, 4.91000	1.18000, 2.82000, 4.82000	4.27000, 6.27000, 8.27000	2.45000, 4.45000, 6.45000
T12	2.45000, 4.45000, 6.45000	3.18000, 5.18000, 7.18000	1.64000, 3.55000, 5.55000	0.82000, 2.27000, 4.27000	2.45000, 4.45000, 6.45000	3.55000, 5.55000, 7.45000
T21	2.64000, 4.64000, 6.64000	2.82000, 4.82000, 6.82000	2.55000, 4.45000, 6.45000	2.45000, 4.27000, 6.27000	2.64000, 4.64000, 6.64000	2.90000, 4.80000, 6.70000
T22	2.45000, 4.45000, 6.45000	3.55000, 5.55000, 7.36000	1.36000, 3.36000, 5.36000	1.91000, 3.73000, 5.73000	2.45000, 4.45000, 6.45000	2.36000, 4.27000, 6.27000
T23	3.18000, 5.18000, 7.18000	5.73000, 7.73000, 9.27000	1.64000, 3.55000, 5.55000	1.64000, 3.55000, 5.55000	3.18000, 5.18000, 7.18000	3.55000, 5.55000, 7.27000
T31	2.82000, 4.82000, 6.82000	4.09000, 6.09000, 8.09000	1.18000, 3.00000, 5.00000	1.45000, 3.36000, 5.30006	2.82000, 4.82000, 6.82000	2.09000, 4.09000, 6.09000
T32	3.55000, 5.55000, 7.36000	3.73000, 5.55000, 7.27000	2.82000, 4.82000, 6.73000	1.64000, 3.55000, 5.55000	3.55000, 5.55000, 7.36000	3.09000, 5.00000, 6.82000
T41	4.45000, 6.45000, 8.18000	2.36000, 4.27000, 6.27000	1.20000, 3.00000, 5.00000	1.36000, 3.36000, 5.36000	4.45000, 6.45000, 8.18000	2.45000, 4.45000, 6.45000
T42	4.45000, 6.45000, 8.27000	4.82000, 6.82000, 8.55000	1.09000, 2.82000, 4.82000	0.82000, 2.64000, 4.64000	4.45000, 6.45000, 8.27000	2.36000, 4.27000, 6.18000
T51	5.73000, 7.73000, 9.27000	5.55000, 7.50005, 9.27000	1.82000, 3.73000, 5.73000	1.64000, 3.55000, 5.55000	5.73000, 7.73000, 9.27000	3.18000, 5.18000, 7.18000
T52	5.18000, 7.18000, 8.82000	4.27000, 6.27000, 8.18000	1.73000, 3.55000, 5.55000	1.18000, 3.00000, 5.00000	5.18000, 7.18000, 8.82000	2.82000, 4.82000, 6.82000
T61	4.45000, 6.45000, 8.18000	4.27000, 6.27000, 8.09000	2.91000, 4.82000, 6.73000	2.82000, 4.82000, 6.73000	4.45000, 6.45000, 8.18000	3.55000, 5.55000, 7.36000
T62	6.27000, 8.27000, 9.45000	5.73000, 7.73000, 9.00000	1.64000, 3.36000, 5.36000	1.45000, 3.36000, 5.36000	6.27000, 8.27000, 9.45000	3.91000, 5.91000, 7.55000
T63	4.18000, 6.09000, 7.64000	5.73000, 7.73000, 9.00000	0.82000, 2.45000, 4.45000	1.64000, 3.55000, 5.55000	4.18000, 6.09000, 7.64000	2.82000, 4.82000, 6.64000

attributes are calculated by hierarchy, which can be seen in Table 6.

The researchers applied the inputs given by 56 domain experts onto the technical specifications data of six alternatives. These alternatives included: *Private Blockchain, Public Blockchain, Hybrid blockchain, Permissioned blockchain, Consortium blockchain and Decentralized application*, represented as *A1, A2, A3, A4, A5* and *A6,* respectively [54]. The Fuzzy-TOPSIS approach is assigned global weights of different specified factors generated through fuzzy-ANP as inputs towards generating priority rank for every alternative. The performance result with the help of fuzzy-ANP-TOPSIS has been checked by implementing these equations (15)–(20) as follows: with the help of equations (1)-(9) and equation (15). The Equation (16) has been used for that purpose, and a hierarchical decision-matrix was constructed. Then each standardized decision-matrix cell score (also called the normalized performance value) becomes multiplied by weights of every criterion as well as a fuzzy weighted normalized decision-matrix has been generated by the equation 16 and can be seen in Table 7.

Further, the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative-Ideal Solution (FNIS) were calculated through implementing Equation (17). After that the distance for each choice value from both the FPIS as well as FNIS is calculated applying through Equations (18) and (19) and can be seen in Table 8-9 under the column called D+I and D-I. Subsequently, the output value of each criterion has been determined through implementing Equation (20). Alternatives rating are achieved on the account of the measured success score that has also been showed in Table 10.

Six blockchain technology alternatives defined output as the *A1, A4, A2, A5, A3* and *A6*. In the findings of the research study, *A1* (*Private Blockchain model*) received much more spread exposure in higher weighted alternatives than the other blockchain models, demonstrating its first rank amongst public blockchain, hybrid blockchain, permissioned blockchain, consortium blockchain, and decentralized application to be implemented to deliver more secure and efficient EHR services in the healthcare organizations.

A. SENSITIVITY ANALYSIS

Assessment of sensitivity is conducted by adjusting the variables to determine the validity of the obtained findings [51]. The sensitivity evaluation on resulting weights (variables) was carried out during this data analysis. Throughout this study, at last (2nd) stage 15 variables are taken so that the sensitivities are tested with the help of 14 experiments. The level of satisfaction (CC-i) is determined in every experiment by making adjustments in weights of each factor, whereas the weight of the other factor remains unchanged through both the Fuzzy-ANP-TOPSIS method. Table 11 and Figure 4 indicate estimated effects.

Alternative one (A1) has a strong degree of satisfaction (CC-i), based on the actual performance. Fifteen experiments are performed. The obtained findings show that in 15 experiments the alternative-1 (A1) still maintains a high degree of satisfaction (CC-i). In thirteen other experiments the

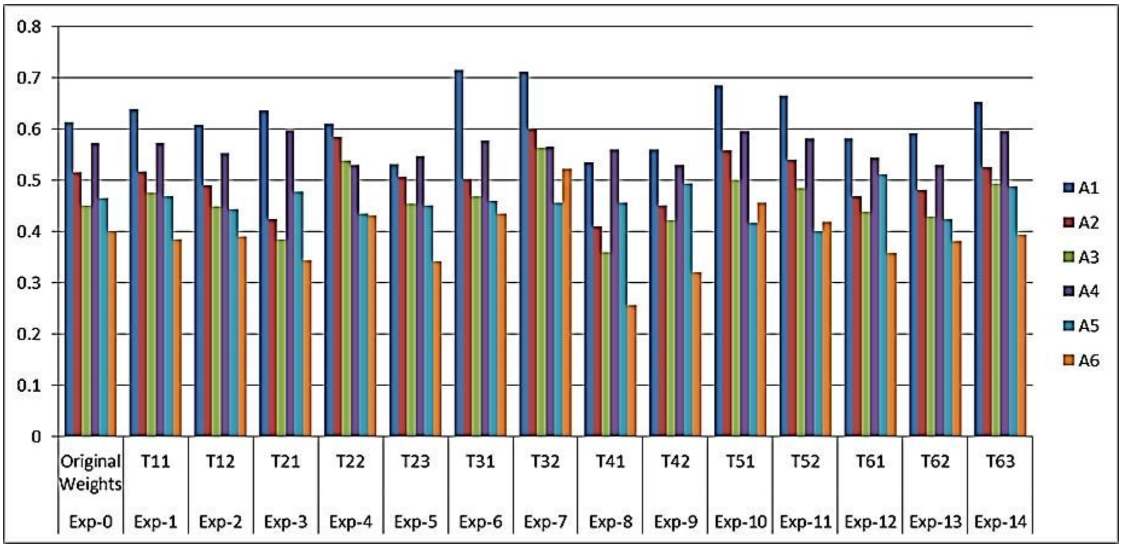

FIGURE 4. Bar graph of the sensitivity analysis.

TABLE 8. The Normalized Fuzzy-Decision Matrix.

	A_1	A_2	A_3	A_4	A_5	A_6
T11	0.46000, 0.67000, 0.86000	0.42000, 0.69000, 0.99000	0.54000, 0.75000, 0.94000	0.35000, 0.61000, 0.88000	0.57000, 0.78000, 0.96000	0.35000, 0.58000, 0.81000
T12	0.54000, 0.75000, 0.92000	0.38000, 0.60000, 0.80000	0.50000, 0.72000, 0.92000	0.31000, 0.57000, 0.82000	0.47000, 0.68000, 0.88000	0.46000, 0.67000, 0.86000
T21	0.39000, 0.59000, 0.79000	0.52000, 0.74000, 0.94000	0.46000, 0.68000, 0.88000	0.33000, 0.59000, 0.86000	0.32000, 0.53000, 0.74000	0.50000, 0.71000, 0.89000
T22	0.46000, 0.67000, 0.86000	0.38000, 0.60000, 0.80000	0.38000, 0.60000, 0.80000	0.57000, 0.78000, 0.96000	0.54000, 0.75000, 0.94000	0.46000, 0.67000, 0.86000
T23	0.50000, 0.71000, 0.89000	0.52000, 0.74000, 0.94000	0.52000, 0.74000, 0.94000	0.51000, 0.72000, 0.90000	0.46000, 0.68000, 0.87000	0.50000, 0.71000, 0.89000
T31	0.46000, 0.67000, 0.86000	0.52000, 0.74000, 0.93000	0.42000, 0.69000, 0.99000	0.47000, 0.68000, 0.87000	0.38000, 0.66000, 0.96000	0.54000, 0.75000, 0.92000
T32	0.50000, 0.71000, 0.89000	0.52000, 0.74000, 0.92000	0.20000, 0.47000, 0.77000	0.47000, 0.68000, 0.88000	0.20000, 0.50000, 0.80000	0.54000, 0.75000, 0.92000
T41	0.54000, 0.75000, 0.92000	0.60000, 0.81000, 1.00000	0.42000, 0.69000, 0.99000	0.61000, 0.82000, 0.98000	0.38000, 0.66000, 0.96000	0.59000, 0.80000, 0.97000
T42	0.54000, 0.75000, 0.92000	0.46000, 0.68000, 0.88000	0.20000, 0.47000, 0.77000	0.55000, 0.76000, 0.93000	0.20000, 0.50000, 0.80000	0.59000, 0.80000, 0.96000
T51	0.59000, 0.80000, 0.97000	0.46000, 0.68000, 0.87000	0.18000, 0.45000, 0.74000	0.47000, 0.68000, 0.87000	0.20000, 0.50000, 0.80000	0.54000, 0.75000, 0.93000
T52	0.59000, 0.80000, 0.96000	0.26000, 0.53000, 0.82000	0.16000, 0.42000, 0.72000	0.43000, 0.64000, 0.86000	0.12000, 0.39000, 0.69000	0.30000, 0.57000, 0.83000
T61	0.54000, 0.75000, 0.93000	0.43000, 0.72000, 1.00000	0.27000, 0.55000, 0.85000	0.39000, 0.61000, 0.81000	0.24000, 0.53000, 0.82000	0.33000, 0.59000, 0.86000
T62	0.46000, 0.67000, 0.86000	0.38000, 0.60000, 0.80000	0.38000, 0.60000, 0.80000	0.57000, 0.78000, 0.96000	0.54000, 0.75000, 0.94000	0.46000, 0.67000, 0.86000
T63	0.50000, 0.71000, 0.89000	0.52000, 0.74000, 0.94000	0.52000, 0.74000, 0.94000	0.51000, 0.72000, 0.90000	0.46000, 0.68000, 0.87000	0.50000, 0.71000, 0.89000

TABLE 9. The Weighted Normalized Fuzzy-Decision Matrix.

	A_1	A_2	A_3	A_4	A_5	A_6
T11	0.00010, 0.00060, 0.00190	0.00200, 0.00600, 0.02000	0.00200, 0.00600, 0.02000	0.00200, 0.00600, 0.02000	0.00100, 0.00400, 0.01700	0.00100, 0.00500, 0.01800
T12	0.00020, 0.00080, 0.00270	0.00200, 0.00800, 0.02500	0.00200, 0.00800, 0.02500	0.00200, 0.00800, 0.02500	0.00000, 0.00400, 0.01700	0.00200, 0.00700, 0.02500
T21	0.00010, 0.00050, 0.00180	0.00200, 0.00700, 0.02200	0.00200, 0.00700, 0.02200	0.00200, 0.00700, 0.02200	0.00000, 0.00200, 0.00900	0.00100, 0.00500, 0.01800
T22	0.00010, 0.00060, 0.00190	0.00200, 0.00600, 0.02000	0.00200, 0.00600, 0.02000	0.00200, 0.00600, 0.02000	0.00100, 0.00400, 0.01700	0.00100, 0.00500, 0.01800
T23	0.00020, 0.00080, 0.00270	0.00200, 0.00800, 0.02500	0.00200, 0.00800, 0.02500	0.00200, 0.00800, 0.02500	0.00000, 0.00400, 0.01700	0.00200, 0.00700, 0.02500
T31	0.00010, 0.00050, 0.00180	0.00200, 0.00700, 0.02200	0.00200, 0.00700, 0.02200	0.00200, 0.00700, 0.02200	0.00000, 0.00200, 0.00900	0.00100, 0.00500, 0.01800
T32	0.00030, 0.00110, 0.00360	0.00200, 0.00900, 0.03000	0.00200, 0.00900, 0.03000	0.00200, 0.00900, 0.03000	0.00200, 0.00900, 0.03400	0.00300, 0.01100, 0.03600
T41	0.00010, 0.00060, 0.00190	0.00200, 0.00600, 0.02000	0.00200, 0.00600, 0.02000	0.00200, 0.00600, 0.02000	0.00100, 0.00400, 0.01700	0.00100, 0.00500, 0.01800
T42	0.00020, 0.00080, 0.00270	0.00200, 0.00800, 0.02500	0.00200, 0.00800, 0.02500	0.00200, 0.00800, 0.02500	0.00000, 0.00400, 0.01700	0.00200, 0.00700, 0.02500
T51	0.00010, 0.00050, 0.00180	0.00200, 0.00700, 0.02200	0.00200, 0.00700, 0.02200	0.00200, 0.00700, 0.02200	0.00000, 0.00200, 0.00900	0.00100, 0.00500, 0.01800
T52	0.00010, 0.00060, 0.00190	0.00200, 0.00600, 0.02000	0.00200, 0.00600, 0.02000	0.00200, 0.00600, 0.02000	0.00100, 0.00400, 0.01700	0.00100, 0.00500, 0.01800
T61	0.00020, 0.00080, 0.02070	0.00200, 0.00800, 0.02500	0.00200, 0.00800, 0.02500	0.00200, 0.00800, 0.02500	0.00000, 0.00400, 0.01700	0.00200, 0.00700, 0.02500
T62	0.00010, 0.00050, 0.00180	0.00200, 0.00700, 0.02200	0.00200, 0.00700, 0.02200	0.00200, 0.00700, 0.02200	0.00000, 0.00200, 0.00900	0.00100, 0.00500, 0.01800
T63	0.00030, 0.00110, 0.00360	0.00020, 0.00090, 0.00300	0.00020, 0.00090, 0.03000	0.00200, 0.00090, 0.03000	0.00200, 0.00900, 0.03400	0.00300, 0.01100, 0.03600

lowest weight of alternative is A3 and A6 in two different experiments. Performance outcome comparisons with each other indicate that the alternatives' scores are weight prone.

TABLE 10. Closeness Coefficients to the Aspired Level among the Different Alternatives.

Alternatives		d^{+i}	d^{-i}	Gap Degree of CC^{+i}	Satisfaction Degree of CC^{-i}
Alternative 1	A1	0.04400	0.02700	0.37900	0.61200
Alternative 2	A2	0.03700	0.03600	0.49700	0.51400
Alternative 3	A3	0.03500	0.04100	0.53900	0.45100
Alternative 4	A4	0.03500	0.02700	0.43900	0.57200
Alternative 5	A5	0.03800	0.04600	0.54500	0.46500
Alternative 6	A6	0.03200	0.04800	0.62500	0.39800

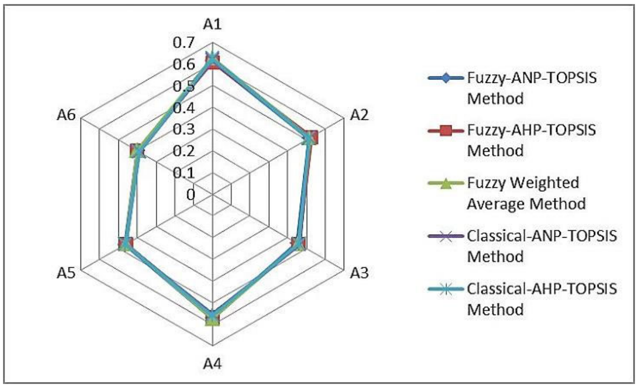

FIGURE 5. Radar chart representation of comparing the results from different methods.

B. COMPARISON OF THE RESULTS

In this research we used various different symmetrical approaches to test the accuracy of the outcome of this study. The researchers used a Fuzzy ANP-TOPSIS method in this analysis to analyze the accuracy of the results of this study. In fuzzy ANP-TOPSIS, the data collection and evaluation process for that dataset is much like the classical ANP-TOPSIS method. Fuzzification and defuzzification are therefore necessary for the Fuzzy-ANP-TOPSIS. Therefore, data is collected in its original numerical form for fuzzy ANP-TOPSIS, and then translated into fuzzy numbers. The differences in the Fuzzy and classical ANP-TOPSIS findings can be seen in Figure 5.

The findings obtained from this study are special and yet essentially the very same. This empirical research took the Pearson Correlation technique for evaluating the association among results. The coefficient correlation demonstrates the effect of the two-value association. The scale ranges from -1 to $+1$ [52]. The value close to -1 indicates the lower connection among values, and the value close to $+1$ indicates the higher connection among values. The Pearson correlation between both the Fuzzy-ANP findings and the classical-ANP findings is 0.89176, indicating the clear similarity between the outcomes obtained. As can be seen in Table 15, the findings with different criteria of Blockchain Technology of the same dataset have already been produced, and all these findings indicate that the correlation among the results of fuzzy-ANP as well as classical-ANP is strongly correlated. The findings of our analysis also demonstrate that the identified variables and their relation to efficient security mechanisms in security tactics perspective are remarkable. Khan *et al.* [53] exclusively incorporated Fuzzy ANP-TOPSIS approach in their study. The reason behind this is that ANP methodology is different than the AHP methodology because of the network structure rather than tree structure. Hence the researchers have adopted design strategies as a participant in the network's first stage in the current study, which essentially improvises the outcomes. There is no symmetric approach for evaluating software security in the context of design strategies with the aid of the fuzzy-ANP-TOPSIS process.

V. DISCUSSION

The main objective of this research paper is to evaluate the impact of blockchain technology models for maintaining the security of EHRs. The results drawn from this investigation would help the engineers to identify and pick the most effective blockchain model, thus making significant technological advancement in the healthcare sector. The researchers utilized MCDM's hybrid fuzzy-ANP TOPSIS system to evaluate the impact of blockchain technology models. Blockchain technology specific features including *Decentralization, Immutability*, as well as *Security* have been incorporated in this analysis so as to base the research on important issues that are currently being faced by the healthcare sector. According to the final tabulations of our study, the Private Blockchain model was acknowledged as the highest weighted alternative, thus securing the first rank amongst the selected Blockchain models to be implemented to deliver secure EHR services in the healthcare organizations. Another author, Castaldo and Cinque [55] developed a monitoring network to promote as well as enhance the sharing of electronic health data over several European countries with the help of private blockchain model and found it to be the safest possible way. Electronic health records are the foundation of the modern health-care. Therefore, supplying consumers with optimal secure healthcare frameworks with the help of private blockchain model is a much needed endeavour in healthcare sectors. The pros and limitations of the overall results in our research work are as follows:

A. PROS

Healthcare professionals as well as blockchain engineers may take support from this research study to prioritize and pick specified attributes of blockchain technology criteria to create secure and trustworthy systems for the healthcare blockchain system. Security of EHRs is a significant concern for developers as well as stakeholders, yet it is overlooked. This research study would provide practitioners with ample understanding to follow different strategies, rather than informal and conventional methods while developing a security mechanism for EHRs.

B. LIMITATIONS

This evaluation can be appropriate for healthcare professionals but is still not final, since the protection of EHRs is both

TABLE 11. Sensitivity Analysis.

Scenario	Weights/Alternatives		A1	A2	A3	A4	A5	A6
Exp-0	Original Weights	Satisfaction Degree (CC-i)	0.61200	0.51400	0.45100	0.57200	0.46500	0.39800
Exp-1	T11		0.63700	0.51700	0.47500	0.57200	0.46800	0.38500
Exp-2	T12		0.60700	0.49000	0.44800	0.55200	0.44300	0.39000
Exp-3	T21		0.63600	0.42300	0.38500	0.59600	0.47700	0.34400
Exp-4	T22		0.60900	0.58400	0.53700	0.52800	0.43400	0.43100
Exp-5	T23		0.53100	0.50500	0.45400	0.54700	0.45100	0.34100
Exp-6	T31		0.71400	0.50200	0.46800	0.57700	0.46000	0.43400
Exp-7	T32		0.71100	0.59800	0.56200	0.56400	0.45600	0.52100
Exp-8	T41		0.53400	0.40900	0.36000	0.55900	0.45500	0.25500
Exp-9	T42		0.55900	0.4500	0.42200	0.52900	0.49400	0.3200
Exp-10	T51		0.68500	0.55700	0.50000	0.59500	0.41700	0.45500
Exp-11	T52		0.66500	0.53900	0.48500	0.58100	0.40000	0.41800
Exp-12	T61		0.58000	0.46800	0.43800	0.54300	0.51100	0.35800
Exp-13	T62		0.59200	0.48100	0.42800	0.52900	0.42300	0.38100
Exp-14	T63		0.65200	0.52600	0.49400	0.59500	0.48800	0.39400

a diverse and complex activity in the blockchain technology setting. Numerous new challenges were posed each day and confronted by users and developers alike. Integrated fuzzy-ANP-TOSIS is an effective and important method for impact evaluation of the blockchain technology for securing EHRs but there may be other effective MCDM symmetrical technology for multiple-criteria decision-making issues.

VI. CONCLUSION

The proposed research uses an integrated fuzzy-ANP-TOPSIS method to evaluate the impact of blockchain technology models for securing electronic healthcare records. The hybrid fuzzy-ANP-TOPSIS method offers an effective way to analyze any MCDM issue with various variables and alternatives, such as blockchain technology assessment. Different factors for the blockchain models impact evaluation are estimated, their weights are measured, alternative rankings are determined and the overall impact of blockchain models for securing EHR is assessed. It has been concluded that alternative- *Private Blockchain* model is the most acceptable means for offering effective and robust service in healthcare blockchain technology. Private Blockchain technology would offer more secure platforms for sharing health data in the healthcare sector by protecting the data over a distributed peer-to-peer infrastructure, thus transforming the way in which the EHRs of patients are exchanged and maintained. This research study will serve as a model or motivation for future research as well as projects of blockchain technology in healthcare settings. Our discussed methodological approaches and categorization will lead to an infrastructure or model's proposal which solves the issues addressed in healthcare blockchain technology. Therefore, a potential path for future research is to assess the implementation of healthcare blockchain technology-based services prioritized on their impact to achieve positive improvements in the healthcare sector.

REFERENCES

[1] M. Gorodnichev, A. Kukharenko, E. Kukharenko, and T. Salutina, "Methods of developing systems based on blockchain," in *Proc. 24th Conf. Open Innov. Assoc. FRUCT*. Helsinki, Finland: FRUCT Oy, Apr. 2019, p. 86.

[2] T. Nugent, D. Upton, and M. Cimpoesu, "Improving data transparency in clinical trials using blockchain smart contracts," *F1000Research*, vol. 5, p. 2541, Oct. 2016.

[3] M. Crosby, P. Pattanayak, S. Verma, and V. Kalyanaraman, "Blockchain technology: Beyond bitcoin," *Appl. Innov.*, vol. 2, nos. 6–10, p. 71, 2016.

[4] Z. Zheng, S. Xie, H.-N. Dai, X. Chen, and H. Wang, "Blockchain challenges and opportunities: A survey," *Int. J. Web Grid Services*, vol. 14, no. 4, pp. 352–375, 2018.

[5] M. Andoni, V. Robu, D. Flynn, S. Abram, D. Geach, D. Jenkins, P. McCallum, and A. Peacock, "Blockchain technology in the energy sector: A systematic review of challenges and opportunities," *Renew. Sustain. Energy Rev.*, vol. 100, pp. 143–174, Feb. 2019.

[6] B. Teufel, A. Sentic, and M. Barmet, "Blockchain energy: Blockchain in future energy systems," *J. Electron. Sci. Technol.*, vol. 17, no. 4, Dec. 2019, Art. no. 100011.

[7] M. Li, S. Shao, Q. Ye, G. Xu, and G. Q. Huang, "Blockchain-enabled logistics finance execution platform for capital-constrained E-commerce retail," *Robot. Comput.-Integr. Manuf.*, vol. 65, Oct. 2020, Art. no. 101962.

[8] F. Damico, "How technology is reshaping financial services: Blockchain use cases in the banking industry," Ph.D. dissertation, Politecnico di Torino, Turin, Italy, 2020.

[9] S. Ølnes, J. Ubacht, and M. Janssen, "Blockchain in government: Benefits and implications of distributed ledger technology for information sharing," *Government Inf. Quart.*, vol. 34, no. 3, pp. 355–364, Sep. 2017.

[10] P. Zhang and M. N. K. Boulos, "Blockchain solutions for healthcare," in *Precision Medicine for Investigators, Practitioners and Providers*. New York, NY, USA: Academic, 2020, pp. 519–524.

[11] P. P. Ray, D. Dash, K. Salah, and N. Kumar, "Blockchain for IoT-based healthcare: Background, consensus, platforms, and use cases," *IEEE Syst. J.*, early access, Jan. 21, 2020, doi: 10.1109/JSYST.2020.2963840.

[12] A. Alammary, S. Alhazmi, M. Almasri, and S. Gillani, "Blockchain-based applications in education: A systematic review," *Appl. Sci.*, vol. 9, no. 12, p. 2400, Jun. 2019.

[13] H. Xiong, T. Dalhaus, P. Wang, and J. Huang, "Blockchain technology for agriculture: Applications and rationale," *Frontiers Blockchain*, vol. 3, p. 7, Feb. 2020.

[14] R. Kandaswamy and D. Furlonger. (Mar. 27, 2018). *Blockchain-Based Transformation: A Gartner Trend Insight Report*. Accessed: May 1, 2020. [Online]. Available: https://www.gartner.com/en/documents/3869696/blockchain-based-transformation-a-gartner-trend-insight-0

[15] K. D. Mandl, D. Markwell, R. MacDonald, P. Szolovits, and I. S. Kohane, "Public standards and patients' control: How to keep electronic medical records accessible but private medical information: Access and privacy doctrines for developing electronic medical records desirable characteristics of electronic medical records challenges and limitations for electronic medical records conclusions commentary: Open approaches to electronic patient records commentary: A patient's viewpoint," *BMJ*, vol. 322, no. 7281, pp. 283–287, 2001.

[16] C. Sullivan and E. Burger, "E-residency and blockchain," *Comput. Law Secur. Rev.*, vol. 33, no. 4, pp. 470–481, Aug. 2017.

[17] P. Beninger and M. A. Ibara, "Pharmacovigilance and biomedical informatics: A model for future development," *Clin. Therapeutics*, vol. 38, no. 12, pp. 2514–2525, Dec. 2016.

[18] N. Kshetri, "Blockchain's roles in strengthening cybersecurity and protecting privacy," *Telecommun. Policy*, vol. 41, no. 10, pp. 1027–1038, Nov. 2017.

[19] M. H. Au, T. H. Yuen, J. K. Liu, W. Susilo, X. Huang, Y. Xiang, and Z. L. Jiang, "A general framework for secure sharing of personal health records in cloud system," *J. Comput. Syst. Sci.*, vol. 90, pp. 46–62, Dec. 2017.

[20] B. Yüksel, A. Küpçü, and Ö. Özkasap, "Research issues for privacy and security of electronic health services," *Future Gener. Comput. Syst.*, vol. 68, pp. 1–13, Mar. 2017.

[21] C. Arsene. (Jan. 27, 2020). *The Global, Blockchain Healthcare Report: 2020 Ultimate Guide for Every Executive*. Accessed: Apr. 21, 2020. [Online]. Available: https://healthcareweekly.com/blockchain-in-healthcare-guide/

[22] O. S. Kemkarl and D. P. B. Dahikar, "Can electronic medical record systems transform health care? Potential health benefits, savings, and cost using latest advancements in ICT for better interactive healthcare learning," *Int. J. Comput. Sci. Commun. Netw.*, vol. 2, nos. 3–6, pp. 453–455, 2012.

[23] I. Al-Turaiki, M. Alshahrani, and T. Almutairi, "Building predictive models for MERS-CoV infections using data mining techniques," *J. Infection Public Health*, vol. 9, no. 6, pp. 744–748, Nov. 2016.

[24] Y. Zhang, M. Chen, D. Huang, D. Wu, and Y. Li, "iDoctor: Personalized and professionalized medical recommendations based on hybrid matrix factorization," *Future Gener. Comput. Syst.*, vol. 66, pp. 30–35, Jan. 2017.

[25] M. T. J. Ansari and D. Pandey, "Risks, security, and privacy for HIV/AIDS data: Big data perspective," in *Censorship, Surveillance, and Privacy: Concepts, Methodologies, Tools, and Applications*. Hershey, PA, USA: IGI Global, 2019, pp. 58–74.

[26] X. Yue, H. Wang, D. Jin, M. Li, and W. Jiang, "Healthcare data gateways: Found healthcare intelligence on blockchain with novel privacy risk control," *J. Med. Syst.*, vol. 40, no. 10, p. 218, Oct. 2016.

[27] M. T. J. Ansari, D. Pandey, and M. Alenezi, "STORE: Security threat oriented requirements engineering methodology," *J. King Saud Univ.-Comput. Inf. Sci.*, vol. 12, pp. 56–62, Dec. 2018.

[28] D. F. Alsubaei, "Blockchain adoption in the gulf states," Policy, Tech. Rep., 2019. Accessed: Aug. 2, 2020. [Online]. Available: https://www.mei.edu/sites/default/files/2019-12/Blockchain%20in%20the%20Gulf.pdf

[29] W. J. Gordon and C. Catalini, "Blockchain technology for healthcare: Facilitating the transition to patient-driven interoperability," *Comput. Struct. Biotechnol. J.*, vol. 16, pp. 224–230, Jan. 2018.

[30] H. F. Atlam, A. Alenezi, M. O. Alassafi, and G. B. Wills, "Blockchain with Internet of Things: Benefits, challenges, and future directions," *Int. J. Intell. Syst. Appl.*, vol. 10, no. 6, pp. 40–48, Jun. 2018.

[31] E. Triantaphyllou, B. Shu, S. N. Sanchez, and T. Ray, "Multi-criteria decision making: An operations research approach," *Encyclopedia Elect. Electron. Eng.*, vol. 15, no. 1998, pp. 175–186, 1998.

[32] İ. Ertuğrul and N. Karakaşoğlu, "Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection," *Int. J. Adv. Manuf. Technol.*, vol. 39, nos. 7–8, pp. 783–795, Nov. 2008.

[33] T. L. Saaty and L. G. Vargas, "The analytic network process," in *Decision Making With the Analytic Network Process*. Boston, MA, USA: Springer, 2013, pp. 1–40.

[34] T. K. Sharma. (Nov. 13, 2019). *Permissioned and Permissionless-Blockchains: A*. Accessed: May 3, 2020. [Online]. Available: https://www.blockchain-council.org/blockchain/permissioned-and-permissionless-blockchains-a-comprehensive-guide/

[35] V. Buterin. (Aug. 7, 2015). *On Public and Private Blockchains*. Accessed: May 3, 2020. [Online]. Available: https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/

[36] V. J. Morkunas, J. Paschen, and E. Boon, "How blockchain technologies impact your business model," *Bus. Horizons*, vol. 62, no. 3, pp. 295–306, May 2019.

[37] W. Vaughan. (Jul. 31, 2015). *Open vs Closed Blockchains—Let's End this Madness*. Accessed: May 3, 2020. [Online]. Available: https://medium.com/@WayneVaughan/open-vs-closed-blockchains-let-s-end-this-madness-8313e4095ead

[38] N. Singh. (Oct. 6, 2018). *Hybrid Blockchain-the Best of Both Worlds*. Accessed: May 3, 2020. [Online]. Available: https://101blockchains.com/hybrid-blockchain/

[39] D. Freuden. (Jun. 7, 2018). *Hybrid Blockchains: The Best of Both Public and Private*. Accessed: May 3, 2020. [Online]. Available: https://bravenewcoin.com/insights/hybrid-blockchains-the-best-of-both-public-and-private

[40] (Jan. 19, 2020). *Private, Public, and Consortium Blockchains—What's the Difference?* Accessed: May 7, 2020. [Online]. Available: https://www.binance.vision/blockchain/private-public-and-consortium-blockchains-whats-the-difference

[41] J. Frankenfield. (Jan. 29, 2020). *Decentralized Applications—dApps*. Accessed: May 3, 2020. [Online]. Available: https://www.investopedia.com/terms/d/decentralized-applications-dapps.asp

[42] N. Gill. (Mar. 19, 2020). *Decentralized Applications Architecture and Blockchain*. Accessed: May 3, 2020. [Online]. Available: https://www.xenonstack.com/blog/decentralized-applications/

[43] T. L. Saaty and K. Kearns, *Analytical Planning; The Organization of Systems*. Oxford, U.K.: Pergamon Press, 1985.

[44] T. L. Saaty, "The analytic hierarchy process Mcgraw Hill, New York," *Agricult. Econ. Rev.*, vol. 70, no. 7, pp. 857–865, 1980.

[45] S. Boran and K. Goztepe, "Development of a fuzzy decision support system for commodity acquisition using fuzzy analytic network process," *Expert Syst. Appl.*, vol. 37, no. 3, pp. 1939–1945, Mar. 2010.

[46] K. Yoon and C.-L. Hwang, "Manufacturing plant location analysis by multiple attribute decision making: Part I—Single-plant strategy," *Int. J. Prod. Res.*, vol. 23, no. 2, pp. 345–359, Jan. 1985.

[47] M. Zelany, "A concept of compromise solutions and the method of the displaced ideal," *Comput. Oper. Res.*, vol. 1, nos. 3–4, pp. 479–496, Dec. 1974.

[48] R. J. Kuo, C. W. Hsu, and Y. L. Chen, "Integration of fuzzy ANP and fuzzy TOPSIS for evaluating carbon performance of suppliers," *Int. J. Environ. Sci. Technol.*, vol. 12, no. 12, pp. 3863–3876, Dec. 2015.

[49] R. Rekik, I. Kallel, and A. M. Alimi, "Ranking criteria based on fuzzy ANP for assessing E-commerce Web sites," in *Proc. IEEE Int. Conf. Syst., Man, Cybern. (SMC)*, Oct. 2016, pp. 3469–3474.

[50] R. Bijoyeta and S. K. Misra, "An integrated fuzzy ANP and TOPSIS methodology for software selection under MCDM perspective," *Int. J. Innov. Res. Comput. Commun. Eng.*, vol. 6, no. 1, pp. 492–501, 2018.

[51] A. Saltelli, M. Ratto, T. Andres, F. Campolongo, J. Cariboni, D. Gatelli, and S. Tarantola, *Global Sensitivity Analysis: The Primer*. Hoboken, NJ, USA: Wiley, 2008.

[52] M. Alenezi, A. Agrawal, R. Kumar, and R. A. Khan, "Evaluating performance of Web application security through a fuzzy based hybrid multi-criteria decision-making approach: Design tactics perspective," *IEEE Access*, vol. 8, pp. 25543–25556, 2020.

[53] S. A. Khan, M. Alenezi, A. Agrawal, R. Kumar, and R. A. Khan, "Evaluating performance of software durability through an integrated fuzzy-based symmetrical method of ANP and TOPSIS," *Symmetry*, vol. 12, no. 4, p. 493, Mar. 2020.

[54] L. Pawczuk, R. Massey, and J. Holdowsky. (May 6, 2019). *Deloitte's 2019 Global Blockchain Survey*. Accessed: May 3, 2020. [Online]. Available: https://www2.deloitte.com/us/en/insights/topics/understanding-blockchain-potential/global-blockchain-survey.html

[55] L. Castaldo and V. Cinque, "Blockchain-based logging for the cross-border exchange of eHealth data in Europe," in *Proc. Int. ISCIS Secur. Workshop*. Cham, Switzerland: Springer, Feb. 2018, pp. 46–56.

[56] A. Kaur, A. Nayyar, and P. Singh, "Blockchain: A path to the future," in *Cryptocurrencies and Blockchain Technology Applications*. Hoboken, NJ, USA: Wiley, 2020, pp. 25–42. [Online]. Available: https://www.wiley.com/en-us/Cryptocurrencies+and+Blockchain+Technology+Applications-p-9781119621164

[57] A. Kumar, R. Krishnamurthi, A. Nayyar, K. Sharma, V. Grover, and E. Hossain, "A novel smart healthcare design, simulation, and implementation using healthcare 4.0 processes," *IEEE Access*, vol. 8, pp. 118433–118471, 2020.

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