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Survey System Using Blockchain for Scientific Research

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Abstract

The survey is a list of questions prepared according to a specific plan for the resource people who constitute a universe or sample to understand specific people's feelings, thoughts, and experiences on a subject. However, there are many disadvantages such as lack of transparency, lack of participant privacy, and low level of security due to the centralized structure of existing survey systems. Blockchain is a Digital Trust Protocol that provides agentless, transparent, secure information transfer that protects user privacy with crypto encryption. In this study, we propose a blockchain-based, inter-university survey system to be used in scientific research to solve the problems encountered in existing survey systems. We also do a SWOT analysis of our proposed approach and centralized survey systems, utilize an algorithm in the literature to investigate whether blockchain is suitable for survey applications, compare the central survey systems with the design we propose in terms of transparency using the CNN transparency index. Moreover, we use the technology organization environment (TOE) theory to identify barriers that may arise in technology adoption and use the Fuzzy Decision-Making Trial and Laboratory Evaluation (Fuzzy Dematel) method to evaluate, analyze and prioritize the interactions of these barriers with each other.

Keywords: Blockchain, Survey System, Fuzzy Dematel, TOE

1. Introduction

Surveys are commonly used tools to collect relevant data for scientific research problems. Survey design aims to present an efficient survey system to reach robust conclusions by preserving data validity and reliability throughout the study. The design aims to provide an efficient questionnaire system to reach correct inferences by ensuring data validity and reliability, especially during the data collection phase of the study.

Blockchain is a technology, which emerged with the decentralized digital money transfer system Bitcoin, which was first produced against the central banking system (Mackey, Nayyar and Mackey, 2017a). Manipulation of recorded data is impossible in a blockchain system because the database is distributed over a peer-to-peer network and central authority is distributed to blockchain users without a central server or trusted third-party intermediaries. Therefore, with blockchain technology, organizations that need centralized architectures or trusted third parties can operate decentralized and securely (Casino, Dasaklis and Patsakis, 2019).

Researchers have recently become more interested in blockchain technologies, and prospective applications in a variety of industries are being discussed.

In this study, we present a blockchain-based survey system architecture used in academic studies, where the miners are universities. In this way, we aim to create a shared data repository for academics while providing transparency, user privacy, security, and reliability. In addition, we are investigating whether blockchain technology is suitable for surveys applied in scientific research, and we compare the system we propose with the existing survey systems using SWOT analysis and CNN transparency index.

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Even though there are studies on blockchain in many sectors, and it is promising in terms of being reliable by the public, there has not been any study on the blockchain-based survey system yet. In addition, there are some barriers to identifying technologies that can replace commonly used technologies. In this study, we also identified the obstacles to adopting the blockchain-based survey system using the TOE method. We examined and prioritized the interactions between these obstacles using the Dematel method.

The paper is organized as follows. A blockchain literature review is presented in the second part of the study. Information about the methods to be used is shown in the third part. Section four includes analyzing the suitability of blockchain for survey systems, the system's architectural design, CNN transparency analysis, Swot analysis, and the determination and prioritization of the obstacles encountered in adoption. The fifth chapter is the evaluation, and the sixth chapter is the conclusion.

2. Literature Review

Blockchain first emerged with bitcoin during the 2008 world economic crisis; unlike the existing banking system, it is decentralized, transparent, and provides user privacy with cryptography (Nakamoto, 2008). Since this date, many studies have been carried out on bitcoin and blockchain. We can divide the studies into four categories: blockchain studies concerning bitcoin, studies examining other cryptocurrencies and blockchain networks, studies investigating blockchain technology, presenting development and research proposals, and studies on various application areas of blockchain technology.

Firstly, after introducing the idea of Bitcoin, many studies were carried out that first investigated the pros and cons of blockchain technology and offered development suggestions. The majority of these studies are studies examining blockchain technology over bitcoin (Decker and Wattenhofert, 2013), (Eyal and Emin,2013), (Wang and Liu, 2015), (Heilman et al., 2015), (Baur et al., 2015), (Eyal et al., 2016), (Croman et al., 2016), (Li and Wang, 2017), (B et al., 2015), (Tschorsch and Scheuermann, 2016), (Kraft, 2016). These studies, in general, focused on new protocol proposals for scalability, reliability, and forking issues, bitcoin miner review, bitcoin financial value review, bitcoin exchanges, bitcoin, and blockchain potential.

Secondly, other cryptocurrencies and blockchain networks have been studied. Such studies have focused on another cryptocurrency, Etherium. Unlike Bitcoin, Ethereum has a smart contract feature (Luu et al., 2016), (Grishchenko, Maffei and B, 2018), .(Bhargavan et al., 2016), (Zhang et al., 2016), (Tuan et al., 2020), (Ulusoy and Çelik, 2019). These studies focus on the comparison of blockchain platforms and security of smart contracts.

On the other hand, many studies have been conducted stating that the blockchain is technology beyond bitcoin and cryptocurrencies, offering various development suggestions for the technology to be more useful and suggesting that it could investigate usability in different areas (Yli-Huumo et al., 2016a), (Trevor, 2015), (Pilkington, 2016), (Zheng et al., 2017), .(Xu et al., 2016), (Lemieux, 2016), (Xu et al., 2017), .(Kshetri, 2017), .(Androulaki e al., 2018), (Zheng, Xie and Dai, 2018a), (Casino, Dasaklis and Patsakis, 2019), (Fernando, Rozuar and Mergeresa, 2021), (Bruens and Moehrle, 2018), (Biswas and Gupta, 2019), (Kosba et al., 2016), (Luu and Gilbert, 2016), (Xiong et al., 2018), (Uygun, 2019).

Finally, when it was understood that blockchain is beyond bitcoin and can be used in different areas, many studies have been carried out on various application areas of this technology. Data management system ((Zyskind and Pentland, 2015), (Liang et al., 2017), .(Ma et al., 2018), .(De, Pandey and Pal, 2020)),(Öncü, 2019) internet of things and blockchain integration (Sharma, Chen and Park, 2018), (Christidis and Devetsikiotis, 2016a), (Huh, Cho and Kim, 2017), .(Ahmad and Salah, 2018), (Novo, 2018), .(Tahar, Hammi and Bellot, 2020), (E-textiles, 2018), (Sharma et al., 2017)), health service ((Azaria et al., 2016), (Yue et al., 2016), (Esposito et al., 2018), (Kuo, Kim and Ohno-machado, 2017), (Q. I. Xia et al., 2017), (Q. Xia et al., 2017)), cyber security ((Wang and Han, 2018), (Hassan, Rehmani and Chen, 2019)), E-commerce ((Zhang and Wen, 2015)), energy trading ((Munsing, Mather and Moura, 2017), (Mengelkamp et al., 2018), .(Aitzhan and Svetinovic, 2018), (Guan et al., 2018), (Andoni et al., 2019), (Kang et al., 2017), (Sikorski, Haughton and Kraft, 2017)), smart transportation ((Yuan and Wang, 2016), (Li et al., 2018), (Dorri et al., 2017), (Lei et al., 2017)), smart city (.(Sun and Yan, 2016), (Biswas and Technology, 2016)), sharing economy ((Huckle et al., 2016)), banking ((Guo and Liang, 2016)), process management ((Weber, Xu and Governatori, 2016), (Viriyasitavat et al., 2020)), education ((Sharples and Domingue, 2016), (Information, 2018)), public administration ((Janssen, 2017)), supply chain ((Toyoda, Mathiopoulos and Member, 2017), (Mackey, Nayyar and Mackey, 2017b), (“Kshetri, 2018), (Kim and Laskowski, 2018), (Galvez, Mejuto and Simal-gandara, 2018), (Kamble, Gunasekaran and Sharma, 2020), (Surendra et al., 2020)), e-vote ((Cryptography et al., 2017)), environmental impact assessment(.(Farooque et al., 2020)), artificial intelligence.(Salah, Member and Rehman, 2019) are examples of this category's topics.

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As a result of the literature review, we did not encounter a blockchain-based survey system, so we aim to fill the gap in the literature in this study. The mind map of the literature review is given in figure.2.1.

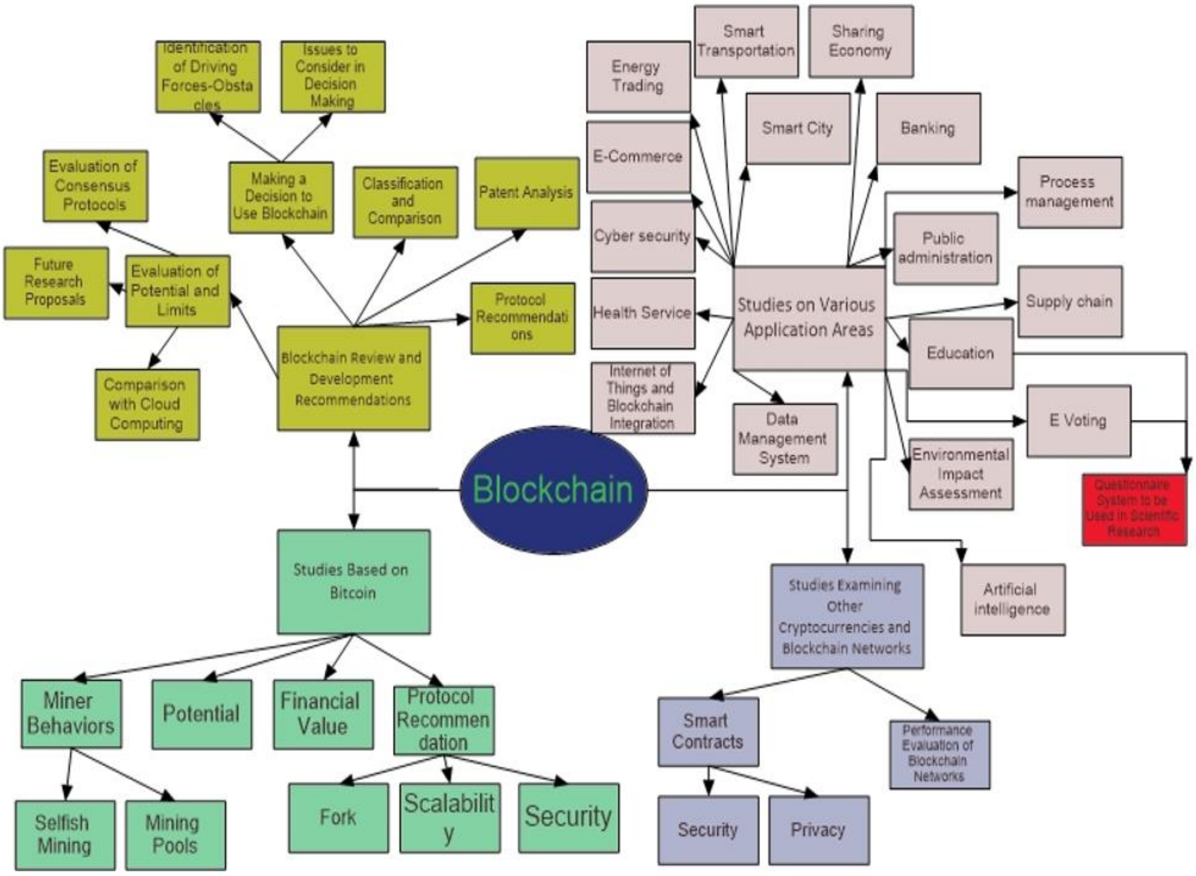

Figure 2.1 Mind Map of Examined Articles Related to Blockchain

3. Method

The methodology of this study which proves that the blockchain is suitable for the survey system, shows that it will be better than the central systems, identifies the obstacles to the implementation of the system, prioritizes these obstacles, is shown in figure 3.1.

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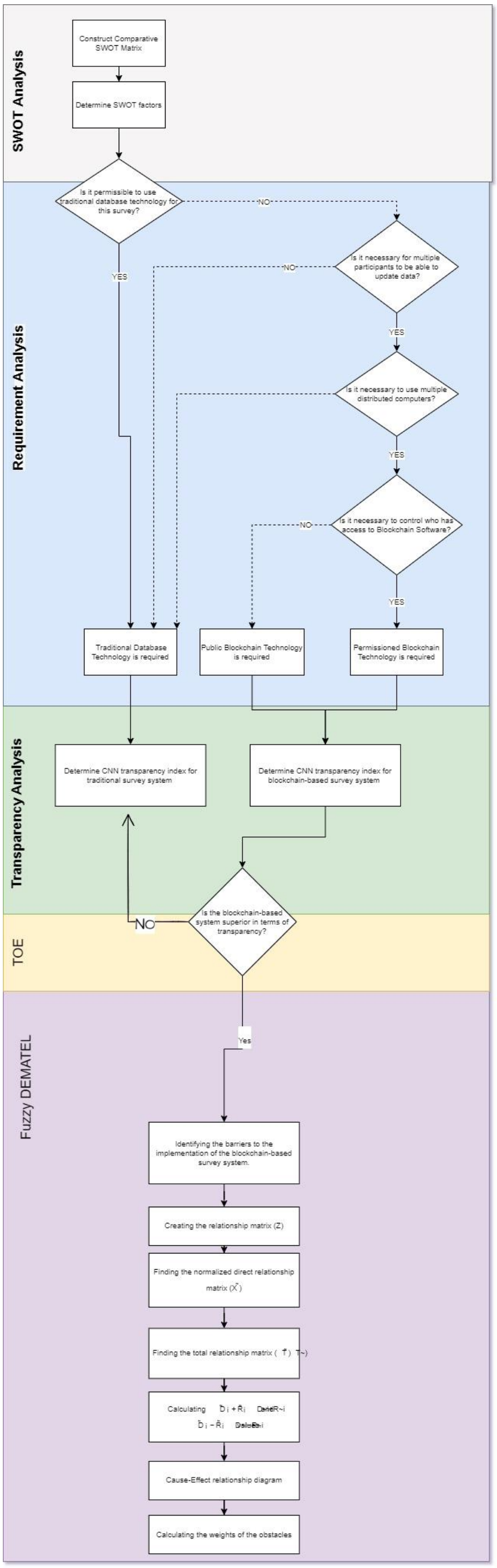

Figure 3.1 Methodology

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3.1. Blockchain

3.1.1. What is Blockchain?

Blocks are data lists with transaction records. Blockchain is a list of records created by blocks, linked to each other by cryptographic methods, and thus secured.

A blockchain can be thought of as a log whose records are grouped into time-stamped blocks. Each block is identified by its hash code. Each block references the hash code of the block before it. This establishes a link between blocks, thus creating a blockchain structure (Christidis and Devetsikiotis, 2016b). The first block without the main block is called a genesis block. The blockchain structure is represented as in Figure 3.2.

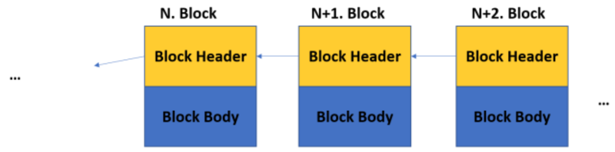

Figure 3.2 Representative Blockchain Structure

A block consists of a block header and a block body. The block header contains the following information; block version, which indicates which block validation rules to follow; parent block hash which shows the previous block's hash code, timestamp which shows current timestamp in seconds since 1970-01-01T00:00 UTC, nBits which shows current hashing target, nonce which indicates the value used to select the node to create the block, merkle tree root hash which shows hash value of all transactions in the block. The block body consists of a transaction counter and transactions. The block structure is shown in figure 3.3 (Zheng, Xie and Dai, 2018b).

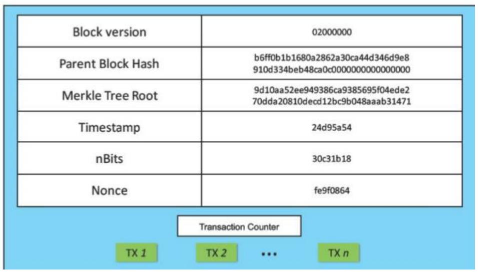

Figure 3.3 Block Structure

As seen in Figure 3.4, the hash codes of the transactions in the block are grouped in pairs for merkle tree roof hash. The obtained hash codes continue to be grouped until a single hash code is obtained.

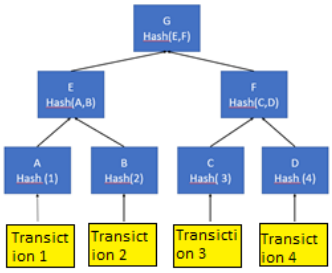

Figure 3.4 Merkle Tree Roof Hash

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3.1.2. Concensus Algorithm

Nodes perform the tasks of verifying online transaction requests and storing transaction records, as the center in central systems does , to create a distributed environment in blockchain technology. However, the problem is how to reach consensus among nodes in the distributed environment of blockchain technology. Also, there is no central node that ensures that the ledgers in distributed nodes are all the same. Some protocols are needed to ensure that the ledgers on different nodes are consistent (Zheng et al., 2017).

There are many different types of consensus protocols designed according to the blockchain type and objectives. According to the Proof of Work (PoW) algorithm used in Bitcoin, nodes find a byte string called nonce. Using nonce, it is aimed that the Hash code will consist of a certain number of leading zeros and ones. Since cryptographic hashes are one-way functions, finding such a nonce can only be done by calculating the hash of the block for all possible nonces until a valid solution is found. Therefore, finding an entry that produces a solution is difficult, but it is simple to verify (Decker and Wattenhofert, 2013). Thus, the nodes prove that they make an effort to create blocks for the system and spread them to other nodes. The nodes that solve the problem first get the right to create a block and share it with other nodes. In Bitcoin, it is aimed to create a block every 10 minutes. Therefore, the difficulty level of the question is increased or decreased by increasing or decreasing the nonce length to achieve the target of 10 minutes.

Although the PoW algorithm successfully chooses the node to create and share blocks, it has been criticized for its high energy requirement. Bitcoin daily energy consumption is determined as 1.5 million dollars/day (Yli-Huumo et al., 2016b). Therefore, various consensus algorithms are used for various blockchain networks such as Proof of Stake (PoS), Proof of Trust (PoT), Proof of Authority (PoA), Proof of Burn (PoB), etc.

3.1.3. Cryptology

Cryptography is the science of encryption. Cryptography provides user privacy and control of whether the data has been changed in the blockchain.

Hash is the method that converts a text to a fixed-length password. There are many algorithms to perform this operation. The SHA 256 algorithm is used in bitcoin, which came into our lives as the first application of the blockchain. According to the SHA 256 algorithm, extracting a summary text from a text is quite simple for computers, while reaching the text from the password is close to impossible with current technology. In addition, it is close to impossible to obtain a similar output from two different inputs.

In the blockchain, according to user information, each user has a unique hash code. Everybody can see transactions, but nobody knows who did this. In this way, user privacy and transparency are provided at the same time. When a block is created, all data in that block is passed through the SHA 256 algorithm. Each block created contains the hash code of the previous block. Thus, the chain structure is formed. If a cyber attack is made on one of the nodes and the information of a block in that node is changed, the hash code of the block whose data has changed will change. Since the hash codes in the parent block and the following block do not match, users will understand that the data in the following block has been changed and will not respect the data in this node. If an attacker wants to change the block's data in a blockchain, he must also change the data in the parent blocks of that block and perform this operation on at least 51% of the available nodes (Kroll, Davey and Felten, 2013). While even decoding a hash code is close to impossible with current technology, this provides data security in the blockchain.

3.1.4. Blockchain Classification

Because the majority of blockchain structures are cryptocurrencies, most researchers classify blockchain networks as financial and non-financial. Some classify it as blockchain 1.0, blockchain2.0, and blockchain3.0 based on the blockchain version. Applications that handle cryptocurrency transactions are Blockchain 1.0, applications extending beyond smart contracts, and cryptocurrency transactions blockchain 2.0. Applications that include applications in areas apart from the previous two versions such as government, health, science, and IoT are defined as Blockchain 3.0 (Casino, Dasaklis and Patsakis, 2019).

It can also be classified as public and private blockchains according to whether or not using the blockchain network is public.

A more detailed classification can be made according to the usage purposes of the blockchain network, such as e-commerce, health, management, education, supply chain applications etc.

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3.2. SWOT Analysis

Swot is one of the most effective evaluation methods to evaluate projects' strengths and weaknesses, opportunities, and threats. Thanks to this technique, we can determine the positive or negative internal and external factors to achieve the goal. Furthermore, our strengths and weaknesses enable us to evaluate internal factors, opportunities, threats allow us to evaluate external factors.

3.3. Technology-Organization-Environment (TOE) Framework

The TOE framework was created in 1990 by Tornatzky, Fleischer, and Chakrabarti. According to this framework, the technological, organizational, and environmental factors that affect the adoption of an innovation are discussed. It has been used in various studies investigating the adoption of blockchain technology (Wong et al., 2020).

The technological context describes the technology variables that influence adoption decisions, such as technical competence and compliance, the organizational context describes the variables of an organization such as firm size and top management support, and the environmental context describes the factors surrounding an organization such as competitive pressure (Fernando, Rozuar and Mergeresa, 2021).

3.4. Fuzzy Dematel

Examining the obstacles to forming a situation is a difficult problem to overcome; as the number of obstacles increases, there are complex relationships between them. For this reason, many multi-criteria decision-making methods have been developed. The analytical hierarchy process (AHP) and the interpretative structural model (ISM) are used by scientists in various applications. Often, researchers consider Ism and Dematel superior to Ahp when examining interdependent factors for both success and failure. In addition, the Dematel technique is considered superior to Ism since it can determine the total effect degree for each factor. Researchers prefer Dematel technique because it can classify factors as causal and receptive groups, establish dependency relationships between factors, and allow working with a limited number of experts (Biswas and Gupta, 2019).

Gabus, A., and Fontela first used the Dematel method at the Geneva Research Center in 1973 to solve global problems such as famine, environmental protection, and race. Since its first use, the field of research has expanded considerably (Yang, Lee and Chang, 2019).

The fuzzy Dematel approach has been developed by using fuzzy set theory to prevent human errors such as bias and uncertainty in decision making (Wu and Lee, 2007). The Fuzzy Dematel method has been used in many kinds of research, such as examining problems in supply chain management, choosing green suppliers, remanufacturing automotive parts, examining barriers to the development of coastal transport as a sustainable and efficient alternative to road transport in India (Farooque et al., 2020).

The following steps should be followed to apply the Fuzzy Dematel method;

Step 1: It is necessary to determine the criteria to create a pairwise comparison matrix.

Step 2: Creating the relationship matrix (Z). After the factors are determined, the relationship between the criteria should be evaluated by experts on a fuzzy scale. The scale is expressed in five linguistic terms: Very high influence, high influence, low influence, very low influence, and no influence. Triangular fuzzy numbers are used in linguistic terms. Linguistic expressions and the equivalent of these expressions as fuzzy triangular numbers are given in Table 3.1. Pairwise comparison matrix is created as much as the number of experts. $\tilde{Z}_{ij}^{k} = l_{ij}^{k}, n_{ij}^{k}, u_{ij}^{k}$ is a triangular fuzzy number and represents that kth researcher's answer for the level of effect of factor i on factor j.

$$\tilde{Z}^{(k)} = \begin{bmatrix} 0 & \cdots & \tilde{z}_{1n}^{(k)} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{n1}^{(k)} & \cdots & 0 \end{bmatrix}; k = 1,2, \dots p \quad (1)$$

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Table 3.1 Linguistic Expression

Impact Score	Linguistic Expression	Triangular Fuzzy Equivalent of Linguistic Expression
0	No Influence	(0,0,0.25)
1	Very Low Influence	(0,0.25,0.5)
2	Low Influence	(0.25,0.5,0.75)
3	High Influence	(0.5,0.75,1.0)
4	Very High Influence	(0.75,1.0,1.0)

Step 3: Finding the normalized direct relationship matrix ($\tilde{X}$). The p pairwise comparison matrices in the fuzzy scale we have obtained are obtained using the following equations.

$$\tilde{X}^{(k)} = \begin{bmatrix} 0 & \cdots & \tilde{x}_{1n}^{(k)} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{n1}^{(k)} & \cdots & 0 \end{bmatrix}; \mathrm{k} = 1,2, \dots \mathrm{p} \tag{2}$$

$$\tilde{x}_{ij}^{(k)} = \frac{\tilde{z}_{ij}^{(k)}}{r^{(k)}} = \left(\frac{l_{ij}^{(k)}}{r^{(k)}}, \frac{n_{ij}^{(k)}}{r^{(k)}}, \frac{u_{ij}^{(k)}}{r^{(k)}}\right), r^{(k)} = \max_{1\le i\le n}\left(\sum_{j=1}^{n} u_{ij}^{(k)}\right) \tag{3}$$

Here the assumption $\sum_{j=1}^{n} u_{ij}^{(k)} < r^{(k)}$ is valid.

A matrix is obtained by averaging the p units normalized direct relationship matrices obtained.

$$\tilde{X} = \frac{(\tilde{X}^{(1)} + \tilde{X}^{(2)} + \cdots \tilde{X}^{(p)})}{p} \tag{4}$$

By using equation number 4, equation r 5 is obtained as $\tilde{x}_{ij} = \frac{\sum_{k=1}^{p} \tilde{x}_{ij}^{(k)}}{p}$

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \cdots & \tilde{x}_{nn} \end{bmatrix} \tag{5}$$

Step 4: Finding the total relationship matrix ($\tilde{T}$). The convergence in equation 6 must be provided to carry out this operation.

$$\tilde{T} = \lim_{k\to\infty}\left(\tilde{X} + \tilde{X}^2 + \cdots \tilde{X}^k\right) = \tilde{X}(I - \tilde{X})^{-1} \tag{6}$$

In this case, the matrix in equation 7 can be created.

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \cdots & \tilde{t}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \cdots & \tilde{t}_{nn} \end{bmatrix} \tag{7}$$

The $\tilde{t}_{ij} = \left(l_{ij}'', n_{ij}'', u_{ij}''\right)$ in equation 7 is the indicator of the evaluation by all experts of the effect level of criterion i on criterion j. Depending on this, the following equations can be written.

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$$[l''_{ij}] = X_l x(I - X_l)^{-1}$$
$$[m'_{ij}] = X_m x(I - X_m)^{-1} \quad (8)$$
$$[u''_{ij}] = X_u x(I - X_u)^{-1}$$

Step 5: Calculating $\widetilde{D}_i + \tilde{R}_i$ and $\widetilde{D}_i - \tilde{R}_i$ values. $\widetilde{D}_i$ is the sum of the row elements the matrix $\tilde{T}$., $\tilde{R}_i$ is the sum of the column elements of the matrix $\tilde{T}$. By using equation 9, $\widetilde{D}_i + \tilde{R}_i$ and $\widetilde{D}_i - \tilde{R}_i$ values obtained in fuzzy scale are clarified, and exact numbers are obtained.

$$\widetilde{D}_i^{def} + \tilde{R}_i^{def} = \frac{1}{4}\left(x_{ij,l} + 2x_{ij,m} + x_{ij,u}\right), \widetilde{D}_i^{def} - \tilde{R}_i^{def} = \frac{1}{4}\left(x_{ij,l} + 2x_{ij,n} + x_{ij,u}\right) \quad (9)$$

Criteria with a positive $\widetilde{D}_i - \tilde{R}_i$ value are called senders and have a higher impact on other criteria. Therefore, it has priority. Criteria with a negative $\widetilde{D}_i - \tilde{R}_i$ value are named recipients and are more affected by other criteria. That's why it has low priority. $\widetilde{D}_i + \tilde{R}_i$ is the expression of the relationship of a criterion with other criteria. Being high means having a high degree in the relationship (Dematel, Makİne and Organ, 2013).

Step 6: The diagram with the horizontal axis $\widetilde{D}_i + \tilde{R}_i$ and the vertical axis $\widetilde{D}_i - \tilde{R}_i$ is created to obtain the Cause-Effect relationship diagram.

Step 7: The weights of the obstacles are obtained with the help of equations 10 and 11.

$$w_i = \left\{\left(\widetilde{D}_i^{def} + \tilde{R}_i^{def}\right)^2 + \left(\widetilde{D}_i^{def} - \tilde{R}_i^{def}\right)^2\right\}^{1/2} \quad (10)$$

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (11)$$

4. Implementation

4.1. SWOT Analysis

When we propose a new technology instead of the commonly used methods, we need to analyze the advantages and disadvantages of the existing techniques and the technology we suggest very well, and research whether the technology we propose can eliminate the disadvantages of the current method. The two-dimensional swot analysis of existing survey systems, and the blockchain-based survey systems is shown in table 4.1.

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Table 4.1 The two-dimensional swot analysis of existing survey systems, and the blockchain-based survey systems

		●	▲	✸
STRENGTHS (S)	Widespread usage at present		✓	
	Low Cost		✓	
	Extensible database	✓		
	Transparent			✓
	Trustworthy			✓
	Unable to change data			✓
	Resistance to data fabrication			✓
WEAKNESS (N)	Lack of transparency		✓	
	Vulnerable to security attacks		✓	
	Possibility of data being changed		✓	
	Inability to provide user privacy		✓	
	Scalability			✓
	Cost			✓
OPPORTUNITIES (O)	Easy to access people	✓		
	Data pool for researcher-Labour saver			✓
	High public confidence to research.			✓
	High rate of participation due to cryptology			✓
THREATS (T)	Modification or fabrication of data		✓	
	Decreased public trust in surveys.		✓	
	Data can be used against individuals due to a lack of user privacy.		✓	
	Resistance to new technology			✓
	Requirement of government policy			✓

● COMMON IN BOTH SYSTEMS ▲ TRADITIONAL SYSTEMS

✸ BLOCKCHAİN-BASED SYSTEMS

As seen in the SWOT analysis, blockchain-based survey systems have many advantages over existing centralized applications. The most important of these advantages are the transparent structure of blockchain technology, the collection of data in more than one center, user privacy and security being provided by cryptology.

4.2. Do You Need a Blockchain?

Although blockchain is seen as a revolutionary technology that will eliminate the disadvantages of existing centralized systems, before moving to blockchain technology in any field, we need to research whether we need blockchain for the system we propose, and what kind of blockchain architecture would be appropriate. For this purpose, we used the algorithm in figure 4.1, which is frequently used in the literature, which helps us understand whether the blockchain meets our needs (PECK, 2017) .

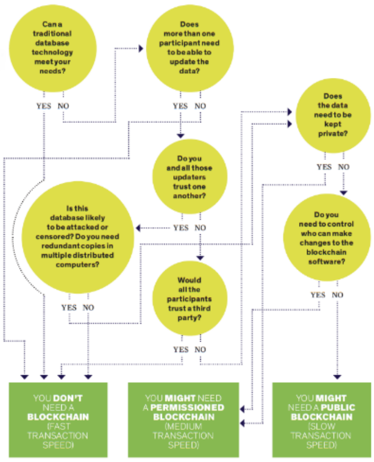

Figure 4.1 Do You Need a Blockchain

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Step 1: Can a traditional database technology meet your needs?: As mentioned in the previous section, it was noted that data abuses occur in some scientific studies, which raises the suspicion that there may be more abuses and that the trust in scientific studies has decreased. In addition there are many studies on scientific ethics on this subject. The Danish Committees on Scientific Dishonesty (DCSD) was established in 1993, the UK Committee on Publication Ethics (COPE) was established in 1997 to deal with violations in research and publication ethics, the United States government established the Office of Scientific Integrity (OSI) and the Scientific Integrity Review Office in 1989. (OSIR) founded (Claxton, 2005). However, the frequency with which scientists generate and falsify data or commit other forms of scientific misconduct is still a matter of debate. Estimates on this subject do not fully reflect reality (Fanelli, 2009).

Step 2: Does more than one participant need to be able to update the data?: We will have two types of users: people who participate in the survey and researchers who upload or solve surveys to the system.

Step 3: Do all participants trust each other?: As mentioned in Step 1, the main reason the traditional system cannot achieve its goals is the problem of trust.

Step 4: Do all participants trust a third party? While editors, communities, publishers, and organizations such as DCSD, COPE, OSI, have tried to protect science through the publication and enforcement of guidelines and rules, there are examples of data abuse, change. How much of this is true, is it just the tip of the iceberg is a matter of debate. Therefore, there is a need for a system where distrustful parties can create a reliable platform.

Step 5: Does data need to be kept private?: Researchers conducting surveys should be able to upload new surveys to the system, participate in existing surveys and see the results of other surveys. However, other users can only view and answer existing surveys.

Step 6: Do you need to control who can make changes to the blockchain software?: To not lose trust in the system, possible changes in the blockchain software should be made by the cooperation of universities.

When all the algorithm steps are followed, a private blockchain system design will be appropriate for the survey system, in which some users can access all the data, and some users can only view and respond to surveys.

4.3. System Architecture

4.3.1. System Users

As a result of the algorithm we followed in section 4.1 of the study, it was concluded that a private blockchain system design would be appropriate. Some users could access all data. On the other hand, some users could only view and respond to surveys. We defined two types of users in this direction: researchers administering surveys and participants solving survey questions. Researchers can upload new surveys to the system, see the results of other surveys, answer the questions of active surveys, or share the results of their analysis using the completed survey data. Participants who solve the survey questions can view the active surveys and answer the questions or see the analysis results.

4.3.2. Participating Organizations

University's responsibilities are approving, publishing, and storing data. Researchers register to the system with their institutional e-mail addresses. In this way, non-academic people cannot open an account as a researcher.

The survey participants' properties must be known, such as age, education level, etc., to properly evaluate the surveys' results. Therefore, integrating the system with E-Government is essential for the evaluation of the questionnaires. This integration will also prevent certain groups from opening different user accounts and sabotaging the survey by participating more than once. Users and institutions included in the system are shown in Figure 4.2.

4.3.3. Consensus

Since it is a public blockchain, we do not need algorithms such as PoW, which requires high energy consumption, or PoS, which can lead to injustice. Since we have a limited number of nodes, we can send transaction requests to all nodes. We use the Practical Byzantine Fault Tolerance principle so that all nodes can reach a consensus. The PBFT algorithm states that for normal execution of a consensus process, there must be at least (2N+1)/3 normal nodes for each consensus calculation among all nodes in the system (Zhu et al., 2021). When this number is reached, the transaction is confirmed, and the block is created.

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4.3.4. Workflow Design

A user who logs into the system as an academic can create a survey or fill other surveys. On the other hand, other participants can log in and fill created questionaries. The online transaction requests are sent to all nodes, according to a consensus algorithm we adopted to approve this transaction, and if at least (2N+1)/3 nodes approve the transaction, the transaction will take place. After the request is approved, a block is created and sent to all nodes. Thus, anyone who enters the system can see this survey, ensuring data security since there is no central server. The proposed system architecture is presented in Figure 4.3.

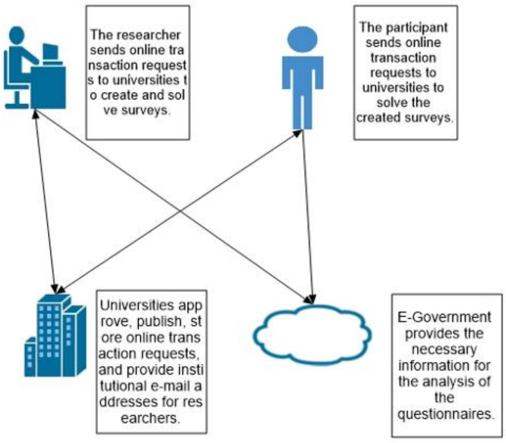

Figure 4.2 System Users and Institutions

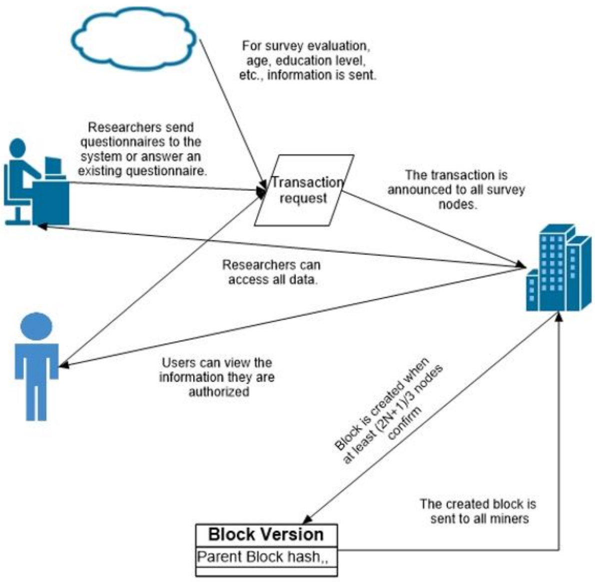

Figure 4.3 Structure of the Proposed System and Workflow Design

4.4. CNN Transparency Index

CNN has released a transparency index that includes a series of questions that need to be answered before releasing the opinion poll to the public. In this study, we compare the system we proposed with the existing systems according to transparency by using the data of a study that was published as a master's thesis in 2020, that used the adaptation of the

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CNN Transparency Index for Turkey to investigate the transparency of the pre-election surveys in Turkey (AYDAŞ, 2020). CNN transparency index categories and scores list is shown in attachment A.

Based on the data shared in the study (AYDAŞ, 2020), we calculated each criterion's average score for election questionnaires between 2011-2019. Table 4.2 shows the information. Unfortunately, no data could be obtained to calculate the average value of criteria 1,2, and 7. Since criteria 1 and 2 are not related to the blockchain, they will not affect the calculation result. However, since the survey time is clearly determined in the system we propose, we will receive 3 points. Therefore, we will use intervals when comparing.

Table 4.2 Evaluation of Pre-Election Polls in Turkey

CRITERION\ELECTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Ortalama
2011 GENERAL	x	1,5	1,9	x	1	1,9	x	0,2	1,1	0	0	1	1	0,2	0,2	1	13,46
2014 ANKARA	x	1,4	1,7	x	1	1,5	x	0	0,9	0,1	0	1	1	0,1	0,1	1	12,16
2014 ISTANBUL	x	1,4	1,4	x	1	1,6	x	0	1	0,1	0	1	1	0,1	0	1	12,3
2014 PRESIDENTIAL	x	1,5	1,7	x	1	1,9	x	0,2	1,1	0,2	0	1	1	0,4	0,1	1	15
2015 GENERAL (JUNE)	x	1,5	1,8	x	1	2,2	x	0,1	1	0,1	0	1	1	0,5	0,1	1	15,28
2015 GENERAL (NOVEMBER)	x	1,3	1,8	x	1	1,8	x	0,1	1	0,2	0	1	1	0,6	0,1	1	15,61
2018 GENERAL	x	1,1	1,4	x	1	1,9	x	0,1	1	0,3	0	1	1	0,8	0,2	1	14,07
2018 PRESIDENTIAL	x	1,2	1,4	x	1	1,9	x	0,1	1	0,3	0	1	1	0,9	0,2	1	14,76
2019 ANKARA	x	1,1	1,2	x	1	1,6	x	0	1	0,3	0	1	1	0,2	0,1	1	11,24
2019 ISTANBUL	x	1,1	1,4	x	1	1,6	x	0	1	0,2	0	1	1	0,2	0,2	1	11,88
2019 ISTANBUL REPEATED	x	1,3	1,7	x	1	1,8	x	0,1	1	0,2	0	1	1	0,4	0,1	1	14,04

The system we propose will receive 2 or 3 points from criterion 6, 3 points from criterion 7, 1 or 3 points from criterion 8, 2 or 3 points from criterion 9, and 1,2 or 3 points from criterion 10, 14, and 15.

Considering this situation, if the pre-election surveys in Turkey were conducted with the blockchain-based survey system, the transparency scores would be as in table 4.3.

Table 4.3 Possible Minimum and Maximum Changes of Election Polls in Turkey if Blockchain Based Survey System were Used

ELECTION	Average Scores of Surveys	Min. Average of Blockchain	Min. % Change	Max.Average of Blockchain	Max. % Change
2011 GENERAL	13,46	18,42	36,87	27,84	106,87
2014 ANKARA	12,16	18,11	48,89	27,58	126,82
2014 İSTANBUL	12,3	17,78	44,57	27,52	123,72
2014 PRESİDENTIAL	15	19,06	27,08	29,06	93,75
2015 GENERAL(JUNE)	15,28	19,36	26,72	29,16	90,85
2015 GENERAL(NOVEMBER)	15,61	19,73	26,41	29,73	90,47
2018 GENERAL	14,07	17,81	26,57	27,81	97,65
2018 PRESİDENTIAL	14,76	18,36	24,36	28,36	92,11
2019 ANKARA	11,24	17,36	54,45	26,12	132,38
2019 İSTANBUL	11,88	17,52	47,47	26,72	124,92
2019 İSTANBUL REPEATED	14,04	18,34	30,60	28,34	101,83

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4.5. TOE and DEMATEL

The list of barriers to the realization of our proposal, created within the framework of the Technology-Organization-Environment theory, is shown in table 4.4.

Table 4.4 Barriers to Implementation of the Proposed System

Barrier Group		Barriers
TECHNOLOGY	T1	Speed and scalability
	T2	Anonymity issue
	T3	Irrevocability of Transaction
	T4	High initial cost
	T5	Inefficient in terms of energy
ORGANIZATION	O1	Difficulties in integrating all universities into the system
	O2	Difficulties in accessing the participant to be surveyed
	O3	Researchers may not want to use the system
	O4	Integration Issues
ENVIRONMENT	Ç1	Negative public perception
	Ç2	The need for government policy support
	Ç3	Hesitation to use new systems

The Dematel method was used to identify and prioritize the relationship between barriers. We sent the matrix we wanted to be filled to 36 experts who had researched blockchain before, and we received feedback from 4 experts. The answers sent to us by the experts are shown in Attachment B.

The D+R and D-R values obtained by following the steps of the Dematel method are shown in table 4.5, and the weights of the factors are shown in table 4.6. The relationships between the elements are shown in figure 4.4.

Table 4.5 D+R and D-R Values

	D+R	D-R
T1	3,400243	-0,07079
T2	4,256155	-0,00023
T3	3,938849	-0,00092
T4	3,855695	0,065331
T5	3,192577	0,002136
O1	5,304758	0,000162
O2	4,632394	-0,00077
O3	5,010914	-0,00048
O4	4,841088	-4,6E-05
Ç1	5,06584	0,001617
Ç2	4,451729	0,001218
Ç3	5,660461	0,002766

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Table 4.6 Weightness of Factors

	w_i	W_i
T1	3,400979	0,063437
T2	4,256155	0,079388
T3	3,938849	0,07347
T4	3,856249	0,071929
T5	3,192578	0,05955
O1	5,304758	0,098947
O2	4,632394	0,086406
O3	5,010914	0,093466
O4	4,841088	0,090299
Ç1	5,06584	0,094491
Ç2	4,451729	0,083036
Ç3	5,660462	0,105582

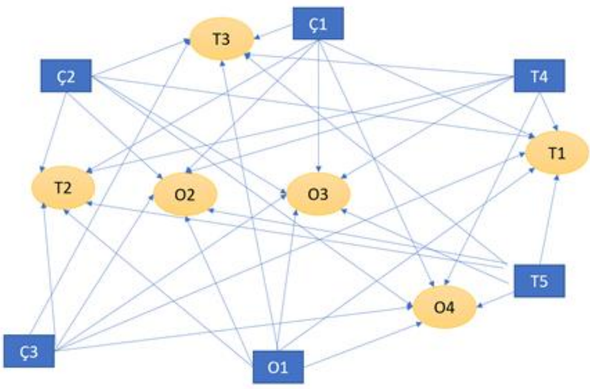

Figure 4.4 Relationships Between Factors

5. Evaluation

Since the user information is encrypted with cryptography in the proposed system, all users can see that a person has answered a survey, but they cannot know who this person is. Furthermore, since all these data are located on the servers of all universities, they cannot be changed, thus increasing the trust in research and a more secure structure against cyber-attacks compared to central systems. In addition, since there will be a shared database between universities, academicians who conduct similar research can use an existing questionnaire in the system; each of them can transform the data into information by using their methods.

According to the results of the CNN transparency index, if the blockchain-based survey system was used in the election surveys in Turkey between the years 2011-2019, the transparency scores of the surveys would increase between 24.36% and 132.38%.

According to the TOE framework, 12 obstacles to the implementation of the system were determined and then these obstacles were evaluated with the Dematel method. According to calculation results, the high initial cost and energy inefficiency of blockchain technology, the necessity of including all universities in the system, the negative public perception about the technology, the need for government support, and the hesitation problems people experience in transitioning to the new system are the factors affecting others. If we can solve these problems, this will impact the

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technology's speed, scalability, anonymity, non-recovery of transactions, reach to the survey person, encouraging researchers to use the system, and integration issues. The order of the weightiness of the factors is as Ç3>O1>Ç1>O3>O4>O2>Ç2>T2>T3>T4>T1>T5.

6. Conclusion

Survey applications are methods that are frequently used in scientific research. Today, there are many options for performing survey applications, such as internet, telephone, face to face, etc. However, no matter the survey's technique, the data obtained are collected in a center; the researcher or research groups in that center transform the data into information and share the result with the public. Due to this centralized structure, data is open to security threats and data abuse. Because of that, the confidence reduces in the research done.

In this study, we investigated blockchain technology, which has been researched in various application areas since the day it emerged, for survey systems. Firstly, we compared blockchain-based survey systems and central survey systems by using swot analysis. Then we researched what kind of blockchain system would be suitable for surveys. After that, we presented a blockchain-based survey architecture, and we compared the questionnaires made with the traditional methods in terms of transparency with the questionnaire system we proposed in the case study. Finally, we investigated and prioritized the obstacles to the implementation of this system.

As a result of the swot analysis, it was understood that blockchain-based survey systems are advantageous over central designs in terms of user privacy, transparency, and security. Following, we used an algorithm frequently used in the literature to investigate whether blockchain technology is suitable for survey systems and what kind of blockchain system would be suitable. We concluded that a private blockchain architecture would be ideal for survey systems, in which some users have access to all data, and some have access to limited data.

After concluding that blockchain technology would suit survey systems, we proposed a blockchain-based system architecture to be used in scientific research, in which universities assume the role of miners. In this system, we suggest, besides providing user privacy, transparency, security, and reliability, a shared database is also created for academics.

We used the CNN transparency index to prove the effectiveness of the proposed architecture in terms of transparency. Based on the study evaluating the pre-election surveys conducted in Turkey between 2011-2019, we sought an answer to how the transparency of the research would change if these surveys were conducted with a blockchain-based system. As a result, we showed that the transparency scores of the surveys increased between 24.36% and 132.38% if they were conducted via a blockchain-based survey system.

We identified the obstacles to realizing this proposed system through a literature review within the framework of the technology-organization-environment theorem. We identified twelve barriers, five technological, four organizational, and three environmental.

Then, using the Fuzzy Dematel method, we showed the relationship between these barriers and their weightiness. As a result of the evaluation of the relationship matrices, which were formed according to the evaluation of four experts in the field, it was determined that the biggest problem to be overcome was the hesitation in transitioning to new systems. In addition, it was understood that six obstacles were influencing factors, and their resolution would affect the other six factors.

We aim to carry out studies to implement this system we propose in the future and then expand the scope of the study to create a national blockchain-based e-voting system.

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8. Attachments

8.1 CNN Transparency Index Categories and Scoring

Category	Score	Criterion
1. The company that made the survey	0	10 years or less experience
	1	More than 10 years of experience
	0	Not a member of a transparency initiative
	1	Member of a transparency initiative
	0	Previous performance is not within top 20
	1	Previous performance is within top 20
2. Survey Mode	0	CATI, mixed, web survey
	1	Unreported
	2	Face-to-face
	3	Face-to-face in households
3. Sponsor	0	Political party, candidate
	1	Unreported
	2	Other sources (newspapers etc.)
	3	Pollster’s own financial sources
4. Sample Size	0	1000 or less
	1	1000-1500, or unreported
	2	1500-2400
	3	2400 or more
5. Language	1	Unreported
6. Survey Questions	0	Unusual wording (e.g., will you vote for party X?)
	1	Unreported
	2	Intended vote
	3	Multiple questions
7.Survey Date	0	Unreported
	1	Without sufficient detail (e.g., in June)
	2	Without sufficient detail (e.g., end of June)
	3	Sufficiently detailed (e.g., between June 3, 2019 and June 6, 2019)
8. Sampling Method & Frame	0	Non-probabilistic or unreported
	1	Defined sampling frame, no sampling method
	2	Probabilistic, no information on the sampling frame
	3	Probabilistic, defined sampling frame
9. Quota Variables	0	0Quota sampling
	1	Unreported
	2	s used in within household selection of respondents, addresses selected ranc
	3	Probabilistic sample
10. Target Population and Representation	0	Unreported
	1	TP missing, defined source (missing mode) or TP is defined (non-F2F)
	2	TP missing, defined source (F2F) or both defined (missing mode)
	3	Defined TP and sampling source (F2F)
11. Cellphone Rate	0	Unreported
	1	Only rates or numbers of mobile and landline phones
	2	Rates or numbers from multiple operators and landline phones
	3	Rates or numbers from all operators and landline phones
12. Callbacks	1	Unreported
13. Verification	1	Unreported
14. Survey Error	0	Misused
	1	Reported, missing sampling method
	2	Probabilistic, margin of error is more than 2 points
	3	Probabilistic, margin of error is less than or equal to 2 points
15. Weighting	0	Unreported
	1	Weighted without explanation
	2	Weighted with insufficient detail (e.g., demographic variables are used)
	3	Weighted with sufficient detail
16. Minimum Subset Size	1	Unreported

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8.2 Pairwise comparison matrix sent by experts

	T1	T2	T3	T4	T5	O1	O2	O3	O4	Ç1	Ç2	Ç3
T1	0	1	3	0	0	2	2	4	4	4	4	4
T2	1	0	4	0	0	4	4	4	3	4	0	4
T3	3	4	0	0	0	3	4	4	3	3	2	3
T4	0	0	0	0	4	2	0	2	2	4	4	4
T5	0	0	0	4	0	4	0	2	3	4	4	4
O1	2	4	3	2	4	0	4	4	4	3	4	4
O2	2	4	4	0	0	4	0	4	2	4	2	4
O3	4	4	4	2	2	4	4	0	4	2	3	4
O4	4	3	3	2	3	4	2	4	0	0	3	3
Ç1	4	4	3	4	4	3	4	2	0	0	4	4
Ç2	4	0	2	4	4	4	2	3	3	4	0	4
Ç3	4	4	3	4	4	4	4	4	3	4	4	0

	T1	T2	T3	T4	T5	O1	O2	O3	O4	Ç1	Ç2	Ç3
T1	0	0	0	1	0	3	1	0	1	1	1	0
T2	0	0	4	0	0	3	3	3	2	3	2	3
T3	0	4	0	0	0	2	3	3	2	2	0	3
T4	1	0	0	0	1	1	0	0	0	0	0	2
T5	0	0	0	1	0	2	0	1	0	4	2	2
O1	3	3	2	1	2	0	4	3	3	1	1	2
O2	1	3	3	0	0	4	0	3	3	3	1	3
O3	0	3	3	0	1	3	3	0	3	3	1	4
O4	1	2	2	0	0	3	3	3	0	1	3	4
Ç1	1	3	2	0	4	1	3	3	1	0	2	4
Ç2	1	2	0	0	2	1	1	1	3	2	0	3
Ç3	0	3	3	2	2	2	3	4	4	4	3	0

	T1	T2	T3	T4	T5	O1	O2	O3	O4	Ç1	Ç2	Ç3
T1	0	2	0	0	3	2	0	0	1	0	0	0
T2	2	0	4	0	0	0	1	1	3	0	0	1
T3	0	4	0	0	0	0	0	1	1	1	0	2
T4	4	0	0	0	1	4	3	2	3	2	2	3
T5	3	0	0	1	0	0	0	0	1	1	0	1
O1	2	0	0	4	0	0	1	3	3	4	2	3
O2	0	1	0	3	0	1	0	3	3	4	2	4
O3	0	1	1	2	0	3	3	0	1	4	2	4
O4	1	3	1	3	1	3	3	1	0	0	1	0
Ç1	0	0	1	2	1	4	4	4	0	0	1	4
Ç2	0	0	0	2	0	2	2	2	1	1	0	3
Ç3	0	1	2	3	1	3	4	4	0	4	3	0

	T1	T2	T3	T4	T5	O1	O2	O3	O4	Ç1	Ç2	Ç3
T1	0	1	1	4	0	3	4	4	4	1	2	2
T2	1	0	1	4	0	4	1	4	4	4	4	4
T3	1	1	0	1	0	4	0	4	4	4	4	4
T4	4	4	1	0	4	4	0	1	4	4	4	4
T5	0	0	0	4	0	4	0	0	3	4	2	4
O1	3	4	4	4	4	0	4	3	4	4	4	4
O2	4	1	0	0	0	4	0	1	4	4	4	4
O3	4	4	4	1	0	3	1	0	4	4	4	4
O4	4	4	4	4	3	4	4	4	0	4	4	4
Ç1	1	4	4	4	4	4	4	4	4	0	4	4
Ç2	2	4	4	4	2	4	4	4	4	4	0	3
Ç3	2	4	4	4	4	4	4	4	4	4	3	0