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Abstract: Blockchain technology (BT) has become popular in the firms in the present time, however, implementation of BT includes several risk factors from various points of view. Some of these risks can be serious for the processes of firms. These risks should be cautiously recognized and analyzed to reduce the negative impacts of them. Assessment of the risks can be recognized as a multi-criteria decision making (MCDM) problem. In this work, the risks that will occur when implementing BT are assessed by using MCDM methodology built on Single Valued Neutrosophic Sets (SVNSs), Analytic Hierarchy Process (AHP), and Decision Making and Trial Evaluation Laboratory (DEMATEL) methods. The main and sub-criteria risks are collected via a company in the smart village in Egypt and from previous research, hence, the hierarchical form of the problem is built. AHP is used to show the importance of risk factors and the relationships between risk factors obtained by using the DEMATEL method. The main goal of this study is to aid the firms mainly and the firm in Egypt especially to determine which risks are more serious and to which of them causing effect and are being affected. In this study 8 main criterion and 28 sub-criteria, risks are used. As result, the security risk is important in the main risks but energy costs and data leaks are important in sub risks.

Keywords: Blockchain technology (BT), Risks, SVNSs, AHP, DEMATEL

1. Introduction

Firms, industries, and businesses have a critical choice and decision in implementing new technology. The processes of the organization are affected by modem technology. For this reason, the implementation of new technology should be considered seriously. These days, technology can be found anywhere, 67% of adults use the internet based on a survey from 40 states. smartphones have also become common [1]. Technology has been profiled in several parts from the manufacture to service segment. It grows the well-being and life standard of people [2]. Technology choice depends on the competitiveness and effectiveness of organizations [3]. Applying BT in firms has become more popular in the present time because of its importance. The transactions can be done by using a decentralized mechanism because BT is a distributed database. In BT, some blocks are related to each other and they cover many transactions. The transaction should be confirmed in terms of validness before adding to the system as a new block [4]. The chain of transactions can be represented as the blockchain. In Bitcoin, these transactions are public [5]. BT guarantees the transactions more secure for industries, businesses, organizations, and governments, hence the common use of BT will have a big influence on the firms in the future. The transaction data is reserved in various nodes in blockchain and it is known as a dispersed ledger. In the dispersed ledger, every user can enter the public ledger system. This can generate a stable environment and doesn't depend on third parties. The technology reduces system failure and other connected risks in the chain. BT can be a great area for keeping significant information. BT allows users to monitor prior transactions [6]. Implementing a new BT includes various risk factors from various parts. To apply BT at the maximum level, these risks should be assessed cautiously. In this research, these risks have been assessed in multi-criteria decision making (MCDM) and these are ranked by using Single Valued Neutrosophic Sets (SVNSs), Analytic Hierarchy Process (AHP), and Decision Making and Trial Evaluation Laboratory (DEMATEL). SVNSs are used to deal with uncertainties [7] and likely risk factors are hierarchical based on their importance by AHP [8] and the relationship between them with DEMATEL [9]. To get the best of information, ranking BT risks by using the MCDM technique has not been studied yet. This work will provide a decision to the firms to decide which of these risks are more serious and which of them should be reduced primarily. The remainder of the paper follows as section 2 provides a brief description of blockchain technologies. SVNSs are summarized in section 3. The proposed MCDM methodology based on SVNSs is presented in section 4. Section 5 shows the application for risk assessments of BT by using AHP and DEMATEL. The attained outcomes and future research directions have been discussed in section 6.

2. Blockchain Technologies

BT is considered as one of the most significant creations after the Internet [10]. BT and Internet technology are different in some significant parts. On the Internet, only the information and the copies of things are moved but the original information cannot. In BT, the value of the things is reserved in a time-stamped transaction in a common ledger in a safe way [11]. BT is an information technology [11] and is based on a dispersed ledger technology [6]. With this technology, there is no need to depend on a third party. In BT, when a transaction is done, it should be confirmed. The transaction is only accepted when the agreement is ensured. Then, the information about the transaction is kept on a new block and the new block is added after the other blocks on the chain [6]. Once the information is confirmed and added to the chain, it cannot be removed anymore[6, 10]. BT has become common with Bitcoin implementation [11, 12] and is used in various parts like the Internet of things, economics, and medicine, etc. [13]. Though BT suggests various chances for firms, it can only add value to the products if the processes are appropriate for BT implementation. For example, if there is a need for data transparency or immutability, BT will be beneficial, but if the transaction speed is important, BT will not be suitable [14].

3. The Proposed Model for Risk Evaluation of Blockchain Technologies

In this research, MCDM methodology based on SVNSs, AHP, and DEMATEL methods are suggested for risk assessment of BTs. Three key steps in methodology. The first step, factors of risk is recognized by conducting a literature review and specialist reviews. Then BT risk factors are determined and the hierarchical structure of the problem is built. In the second step, the risk factors are assessed. For the second step to be achieved AHP method is used to attain main and sub-criteria weights and the DEMATEL method is used to show the importance of main and sub-criteria and the relationship between them. Finally, the risks are ranked according to the weights of the AHP method and showing the impact of the relationship between main and sub-criteria. The detailed framework of the proposed methodology is shown in figure 1.

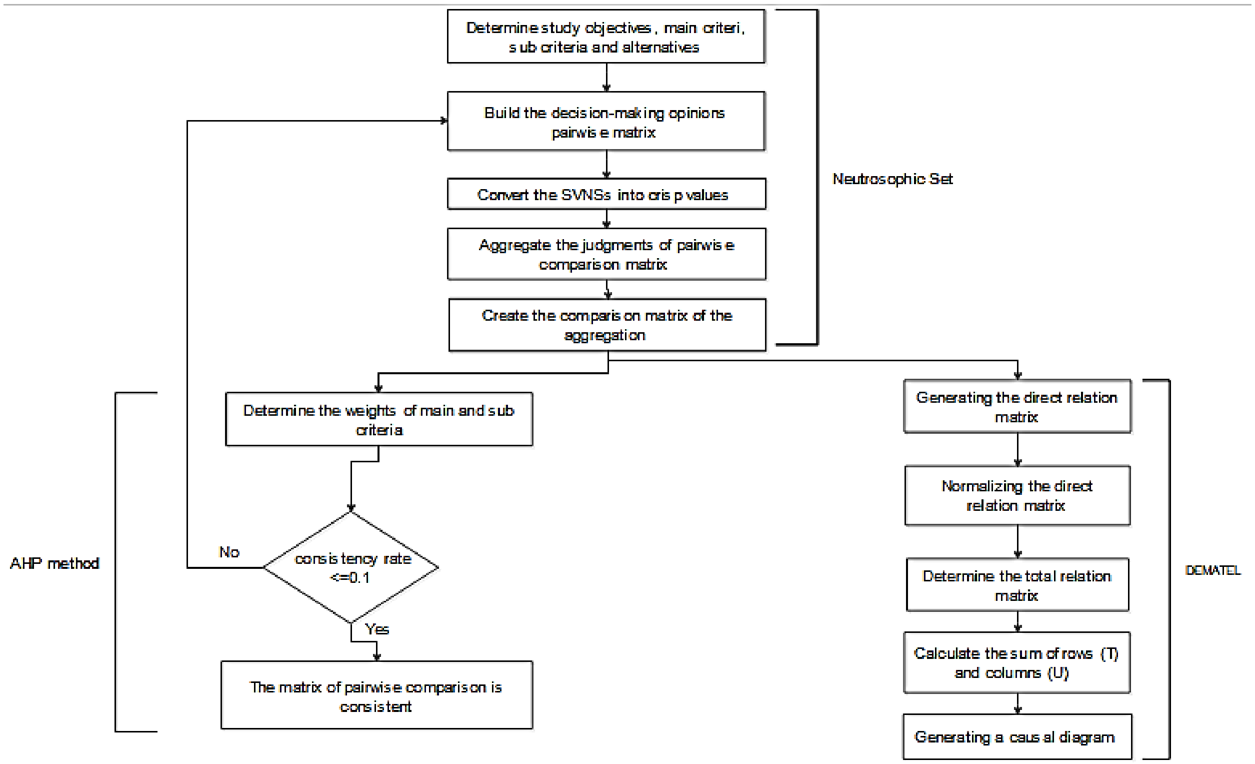

Fig 1. Steps of SVNSs, AHP, and DEMATEL methodology

3.1. Neutrosophic theory

The neutrosophic set can model the decision maker's perspectives in the neutrosophic single value scale [15] and apply aggregation to produce the final vision. Neutrosophic set multiplications and calculations are illustrated in [16]. The steps of the neutrosophic theory are illustrated in [17]:

Step 1. Build the decision-making opinions pairwise matrix according to SVNSs scale in table 1 using the mentioned form:

$$L^E = \begin{bmatrix} l_{11}^E & \cdots & L_{1y}^E \\ \vdots & \ddots & \vdots \\ l_{x1}^E & \cdots & l_{xy}^E \end{bmatrix} \tag{1}$$

Where E pointed to the number of decision-makers.

Table1. Single valued Neutrosophic scale

Linguistic term	SVNSs
Extremely evil	(0.00,1.00,1.00)
Very Highly evil	(0.10,0.90,0.90)
Very evil	(0.20,0.85,0.80)
Evil	(0.30,0.75,0.70)
Medium evil	(0.40,0.65,0.60)
Medium	(0.50,0.50,0.50)
Medium better	(0.60,0.35,0.40)
Better	(0.70,0.25,0.30)
Very better	(0.80,0.15,0.20)
Very Highly better	(0.90,0.10,0.10)
Extremely better	(1.00,0.00,0.00)

Step 2. Convert the SVNSs into crisp values by the use of the score function [18]:

$$V(l_{mn}^{E}) = \frac{2+T_{mn}^{E} - I_{mn}^{E} - F_{mn}^{E}}{3} \tag{2}$$

$T_{mn}^{E}, I_{mn}^{E}, F_{mn}^{E}$ presents truth, indeterminacy, and falsity of the SVNSs.

Step 3. Aggregate the judgments of the pairwise comparison matrix as

$$l_{mn} = \frac{\sum_{E=1}^{E} l_{mn}}{E} \tag{3}$$

Step 4. Create the comparison matrix of the aggregation as following:

$$L = \begin{bmatrix} l_{11} & \cdots & l_{1n} \\ \vdots & \ddots & \vdots \\ l_{m1} & \cdots & l_{mn} \end{bmatrix} \tag{4}$$

3.2. The AHP method

The steps of the AHP method are shown in [17] as :

Step 1: Calculate the weights of the main criteria and sub-criteria.

Step 1.1: Calculate the normalization using the following equation.

$$w_m^x = \frac{w_m}{\sum_{m=1}^{x} w_m}; m = 1,2,3, \ldots \ldots . x \tag{5}$$

Step 1.2: Calculate the row average.

$$w_m = \frac{\sum_{n=1}^{y}(l_{mn})}{y}; m = 1,2,3, \ldots \ldots . x; n = 1,2,3, \ldots \ldots . y; \tag{6}$$

Step 2: Check the consistency of matrix to ensure the consistency the pair-wise comparison matrix [17].

3.3. The DEMATEL method

The steps of the DEMATEL method are illustrated in [19].

Step 1: Generating the direct relation matrix

The matrix of direct relation s x s is obtained through step 4 in neutrosophic theory.

Step 2: Normalizing the direct relation matrix.

The normalized direct relation matrix uses the following equation:

$$\mathrm{B} = \frac{1}{\max\limits_{1 \le x \le s} \sum_{y=1}^{s} l_{mn}} \tag{7}$$

$$\mathrm{V} = \mathrm{B} \times \mathrm{L} \tag{8}$$

Step 3: Determine the total relation matrix.

This step uses the Matlab software to obtain an identity matrix using the following equation:

$$\mathrm{O} = \mathrm{V}(\mathrm{I} - \mathrm{V})^{-1} \tag{9}$$

Step 4: Calculate the sum of rows (T) and columns (U)

Step 5: Generating a causal diagram

The causal diagram is attained by (T + U) and (T − U) is the outcome of the DEMATEL method.

4. Application

The case study for assessing risk factors of BT, in this section. A company in the smart village in Egypt needs to implement BT for its operations. But the managers recognize that some risks can happen during the implementation of operations, so they decided to assess these risks and calculate which of them have more important before the implementation. In the beginning, the factors of risks are collected by using previous work [10, 11, 13, 20-25] and decision-makers. As a consequence of this, 8 main criteria and 28 sub-criteria are calculated for risk assessment of BT as shown in Figure 2. Then three specialists assessed these main and sub-criteria by using AHP and DEMATEL method.

Evaluating Blockchain Technology Risks	C1-Environmental/Cultural	S1: Negative image of BT
		S2: Uncertainty of customers
	C 2- legal and regulatory challenges	S3: Unclear Legal Jurisdictions
		S4: Regulatory barriers
		S5: Antitrust
	C3- Energy	S6: High consumption
		S7: Importing energy efficiency
		S8: Energy intensive cryptocurrency validation process
	C4- Adoption challenges	S9: System speed
		S10: User experience
		S11: Lack of knowledge
		S12: Technology usability
	C5- Organizational and strategic	S13: Need of skilled worker
		S14: Resistance to changing technology
		S15: Lack of equipment and tool
		S16: Lack of management support
	C6- Technical	S17: Lack of customer awareness
		S18: Access to technology
		S19: Limited transaction capacity
		S20: Scaling due to processing requirements
		S21: Untasted code
	C7- Financial	S22: Usage cost
		S23: Training cost
		S24: Energy cost
	C8- Security	S25: Cyberattacks
		S26: Privacy
		S27: Shared data among multiple peer
		S28: Data leaks

Fig 2. Evaluation risk factors (Criteria and sub-criteria)

4.1. Neutrosophic theory results

The neutrosophic set can model the decision maker's perspectives in neutrosophic single value scale as shown in table 1 and apply aggregation to produce the final vision. The steps of the neutrosophic theory are showed as follows:

Step 1: Build the decision-making opinions pairwise matrix according to SVNSs scale using Eqs. (1).

Step 2: Convert the SVNSs into crisp values by the use of the score function using Eqs. (2).

Step 3: Aggregate the judgments of the pairwise comparison matrix using Eqs. (3.)

Step 4: Create the comparison matrix of the aggregation as shown in table 2 using Eqs. (4).

4.2. The AHP results

Step 1: Compute the normalization matrix using Eq. (5) As shown in table 3.

Table 2. Crisp value of aggregated pairwise comparison matrix of criteria.

C_x	C_1	C2	C_3	C_4	C_5	C_6	C_7	C_8
C1	1	0.577333	0.494	0.577333	0.388667	0.316333	0.649333	0.605333
C_2	1.748918	1	0.716	0.394	0.538333	0.538667	0.538667	0.427333
C_3	2.206193	1.415172	1	0.538667	0.460667	0.499667	0.460667	0.394
C_4	1.748918	3.232941	1.874459	1	0.461	0.505	0.394	0.610667
C5	2.714845	1.952573	2.513728	2.203655	1	0.605	0.649333	0.538333
C_6	3.562138	1.874459	2.078114	2.260107	1.819944	1	0.538667	0.460667
C_7	1.5478	2.751943	2.28177	3.464899	1.5478	1.874459	1	0.499667
C8	1.74183	3.157365	3.464899	1.673342	1.952573	2.28177	2.078114	1

Step 1.2: Determine the weights of criteria, local and global sub-criteria using Eq. (6) as shown in table 4. Figure 3 shows the weights of the main criteria.

Table 3. Normalization values of main criteria.

C_{yz}	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**
C_1	0.06146	0.03617	0.034251	0.047666	0.047578	0.041509	0.102925	0.133451
C_2	0.107489	0.06265	0.049643	0.03253	0.0659	0.070683	0.085384	0.094209
C_3	0.135594	0.08866	0.069334	0.044474	0.056392	0.065565	0.07302	0.086861
C_4	0.107489	0.202543	0.129963	0.082563	0.056433	0.066265	0.062453	0.134627
C_5	0.166855	0.122328	0.174286	0.18194	0.122414	0.079387	0.102925	0.11868
C_6	0.21893	0.117434	0.144084	0.186601	0.222787	0.131218	0.085384	0.101558
C_7	0.095128	0.172408	0.158204	0.286072	0.189473	0.245963	0.158509	0.110156
C_8	0.107054	0.197808	0.240235	0.138156	0.239023	0.29941	0.3294	0.220459

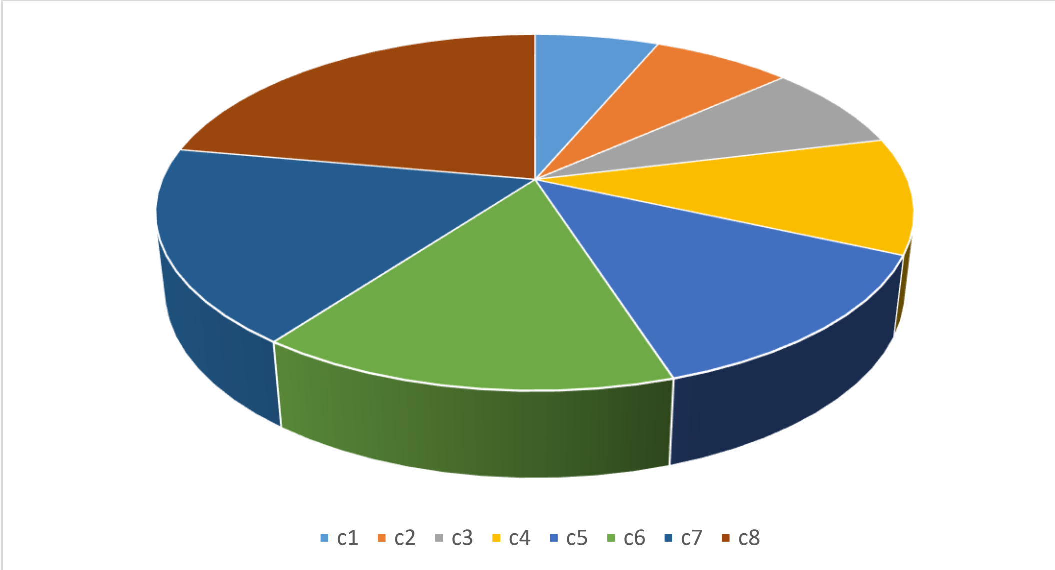

Fig 3. Weights of main criteria.

Step 2: The Consistency Ratio (CR) = 0.10. according to [17] such that CR < =0.1, therefore, the matrix of pairwise comparison is consistent. Table 5 displays the importance of local and global weights of main and sub-criteria based on AHP calculations. Hence C_8 (security) is the most important in the main criteria and C_1 (Environmental/Cultural) is the least important in the main criteria. For sub-criteria S_{24} (Energy cost) is the most important in sub-criteria and S_9 (System speed) is the least important in sub-criteria.

Table 4. Weights of main criteria, local and global sub-criteria.

Main Criteria	Sub criteria	Weights	Local weights	Global
C_1		0.063126		
	S1		0.32903	0.02077
	S2		0.67097	0.042356
C_2		0.071061		
	s3		0.283611	0.020154
	S4		0.315125	0.022393
	S5		0.401263	0.028514
C_3		0.077487		
	S6		0.236806	0.018349
	S7		0.305799	0.023695
	S8		0.457395	0.035442
C_4		0.105292		
	S_9		0.137244	0.014451
	S10		0.204308	0.021512
	S11		0.349301	0.036779
	S12		0.309147	0.032551
C_5		0.133602		

	s_{13}		0.159466	0.021305
	s_{14}		0.292025	0.039015
	S_{15}		0.247912	0.033122
	S_{16}		0.300597	0.04016
C_6		0.150999		
	s_{17}		0.122023	0.018425
	s_{18}		0.200505	0.030276
	S_{19}		0.198784	0.030016
	S_{20}		0.226835	0.034252
	S_{21}		0.251853	0.03803
C_7		0.176989		
	s_{22}		0.211513	0.037435
	s_{23}		0.286858	0.050771
	s_{24}		0.501629	0.088783
C_8		0.221443		
	S_{25}		0.14637	0.032413
	S_{26}		0.25559	0.056599
	S_{27}		0.238016	0.052707
	S_{28}		0.360024	0.079725

4.3. The DEMATEL results

Step 1: Generating the direct relation matrix in table 5 of the main criteria and direct relation matrix for the sub-criteria of security criteria in table 5.

Step 2: Normalizing the direct relation matrix for the main criteria in table 6 using Eqs. (7, 8).

Step 3: Determine the total relation matrix using Eq. (9) In table 7.

Step 4: Calculate the sum of rows (T) and columns (U) in table 8 and rank according to the importance of the main criteria in table 8.

Step 5: Generating a causal diagram as shown in figure 4. It shows the security, financial, technical, and organizational is the most important main criteria. C_5 (Organizational), C_6 (Technical), C_7 (Financial), C_8 (Security) are causing effect while others are being affected

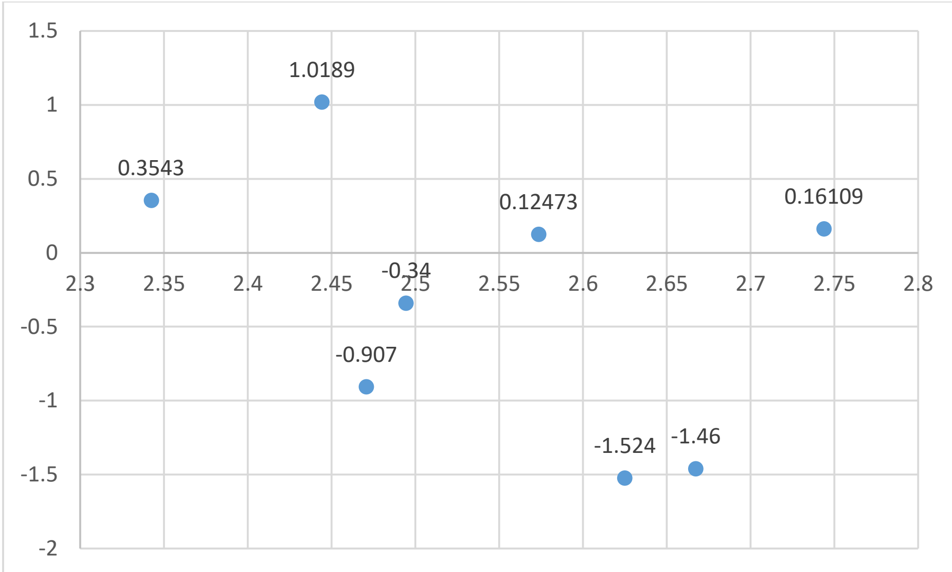

Fig 4. The causal diagram for the main criteria.

Table 5. The direct relation matrix for sub-criteria of security.

S_{yz}	S_{25}	S_{26}	S_{27}	S_{28}
S_{25}	1	0.394	0.671667	0.671667
S_{26}	4.051484	1	0.677333	0.571667
S_{27}	1.687315	1.540713	1	0.671667
S_{28}	1.687315	2.69554	1.687315	1

Table 6. Normalization of direct relation matrix of main criteria.

C_{yz}	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	0.0578	0.03337	0.028553	0.03337	0.022465	0.018284	0.037531	0.034988
C_2	0.101087	0.0578	0.041385	0.022773	0.031116	0.031135	0.031135	0.0247
C_3	0.127518	0.081797	0.0578	0.031135	0.026627	0.028881	0.026627	0.022773
C_4	0.101087	0.186864	0.108344	0.0578	0.026646	0.029189	0.022773	0.035297
C_5	0.156918	0.112859	0.145293	0.127371	0.0578	0.034969	0.037531	0.031116
C_6	0.205892	0.108344	0.120115	0.130634	0.105193	0.0578	0.031135	0.026627
C_7	0.089463	0.159062	0.131886	0.200271	0.089463	0.108344	0.0578	0.028881
C_8	0.100678	0.182496	0.200271	0.096719	0.112859	0.131886	0.120115	0.0578

Table 7. Total relation matrix of main criteria.

C_{yz}	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	0.121175	0.094524	0.081078	0.076915	0.05188	0.046394	0.062404	0.053891
C_2	0.176417	0.124154	0.098908	0.0713	0.064241	0.061554	0.059248	0.04676
C_3	0.211359	0.154533	0.119665	0.082342	0.062187	0.061692	0.057744	0.047614
C_4	0.220165	0.289444	0.193498	0.123948	0.074857	0.074542	0.065226	0.069124
C_5	0.307497	0.250131	0.257612	0.216011	0.11798	0.091106	0.090063	0.074551
C_6	0.376721	0.260514	0.247866	0.233394	0.173768	0.119465	0.089823	0.075681
C_7	0.295829	0.347913	0.287103	0.32493	0.173242	0.183664	0.124348	0.084594

C_8	0.348777	0.401178	0.387831	0.254874	0.219212	0.228671	0.20381	0.123685

Table 7. The sum rows and columns of the main criteria.

C_{yz}	T	U	T+U	T – U	Ranking
C_1	0.588261	2.079	2.6673	-1.46	5
C_2	0.702581	1.9224	2.625	-1.524	1
C_3	0.797136	1.6736	2.4707	-0.907	7
C_4	1.110804	1.3837	2.4945	-0.34	4
C_5	1.40495	0.9374	2.3424	0.3543	8
C_6	1.577232	0.8671	2.4443	1.0189	6
C_7	1.821624	0.7527	2.5737	0.12473	2
C_8	2.168039	0.5759	2.7439	0.16109	3

Figure 5 shows S_2 (Uncertainty of customers) is causing effect while S_1 (Negative image of BT) is being affected in C_1 (Environmental/Cultural). Figure 6 shows S_5 (Antitrust) is causing effect while S_3 (Unclear Legal Jurisdictions) and S_4 (Regulatory barriers) are being affected in C_2 (legal and regulatory challenges). Figure 7 shows S_8 (Energy-intensive cryptocurrency validation process) is causing effect while S_6 (High consumption) and S_7 (Importing energy efficiency) are being affected in C_3 (Energy). Figure 8 shows S_{11} (Lack of knowledge) and S_{12} (Technology usability) are causing effect while S_9 (System speed) and S_{10} (User experience) are being affected in C_4 (Adoption challenges). Figure 9 shows S_{14} (Resistance to changing technology) and S_{16} (Lack of management support) are causing effect while S_{13} (Need of skilled worker) and S_{15} (Lack of equipment and tool) are being affected in C_5 (Organizational and strategic). Figure 10 shows S_{20} (Scaling due to processing requirements) are S_{21} (Untested code) are causing effect while S_{17} (Lack of customer awareness), S_{18} (Access to technology), and S_{19} (Limited transaction capacity) are being affected in C_6 (Technical). Figure 11 shows S_{24} (Energy cost) is causing effect while S_{22} (Usage cost) and S_{23} (Training cost) are being affected in C_7 (Financial). Figure 12 shows S_{27} (Shared data among multiple peers) and S_{28} (Data leaks) are causing effect while S_{25} (Cyberattacks) and S_{26} (Privacy) are being affected in C_8 (Security).

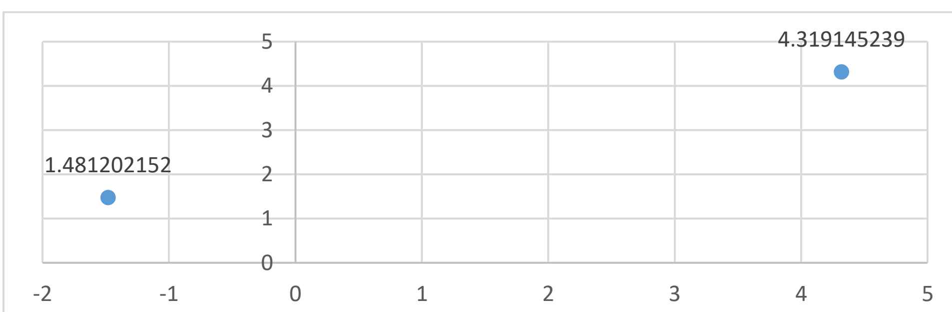

Fig 5. The causal diagram for C_1 (Environmental) sub-criteria.

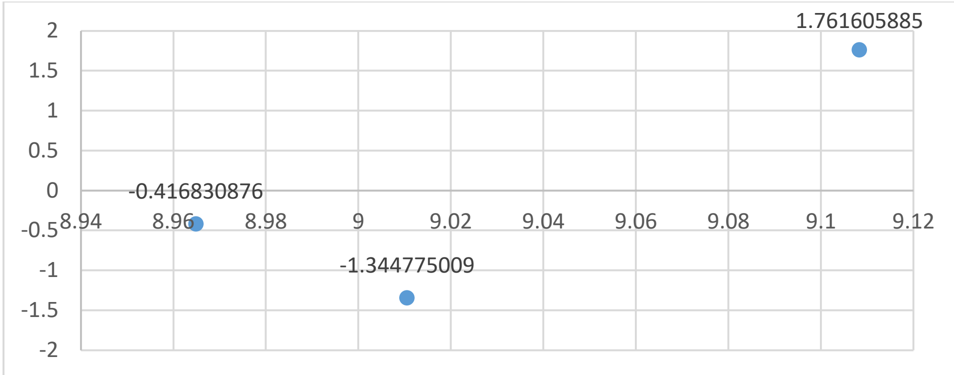

Fig 6. The causal diagram for C_2 (legal and regulatory challenges) sub-criteria.

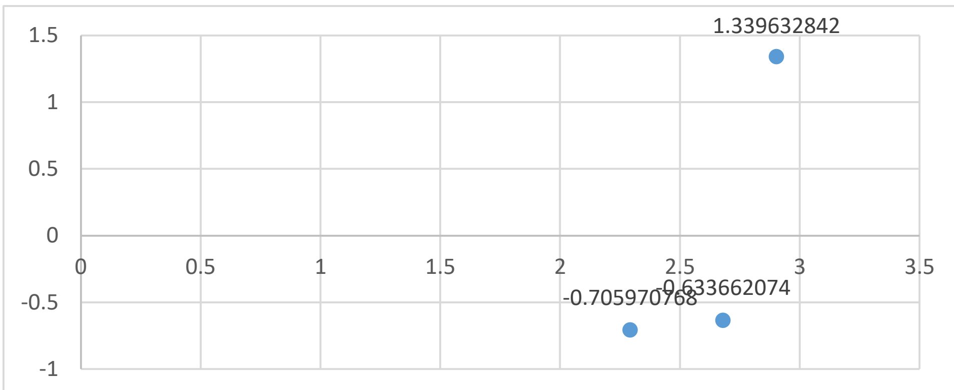

Fig 7. The causal diagram for C_3 (Energy) sub-criteria.

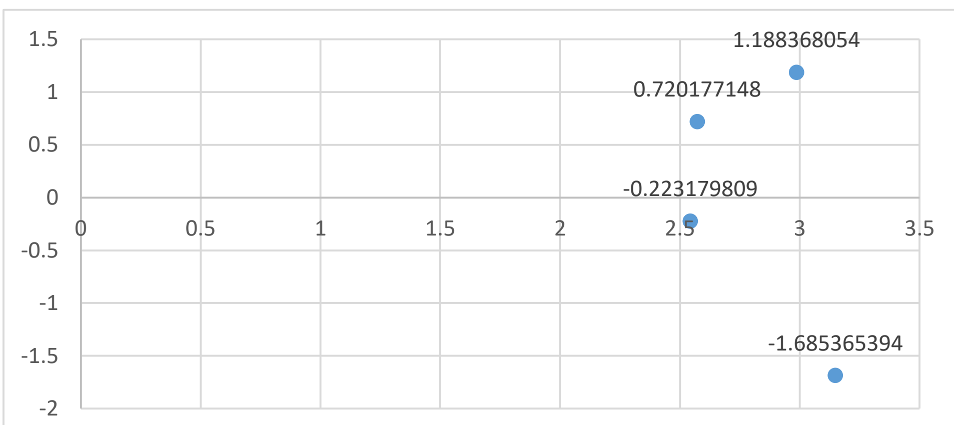

Fig 8. The causal diagram for C_4 (Adoption challenges) sub criteria.

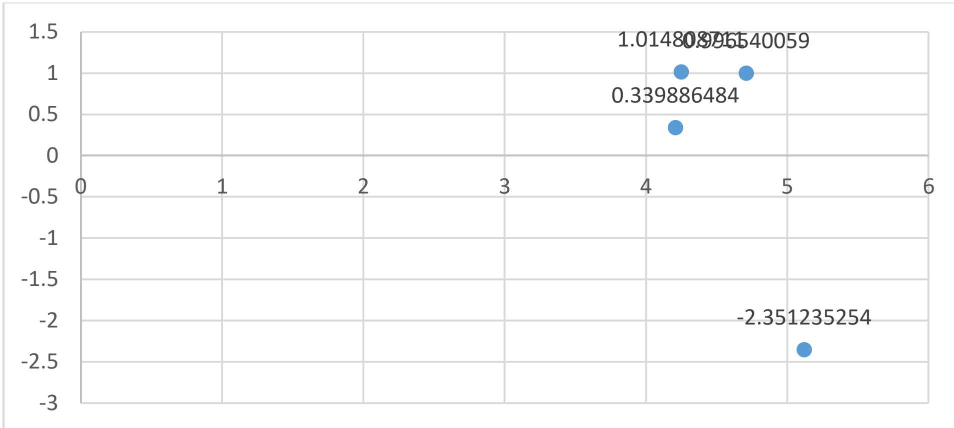

Fig 9. The causal diagram for C_5 (Organizational and strategic) sub-criteria.

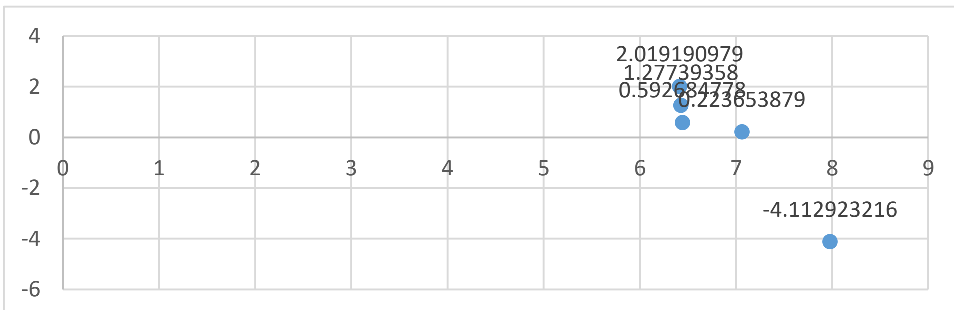

Fig 10. The causal diagram for C_6 (Technical) sub-criteria.

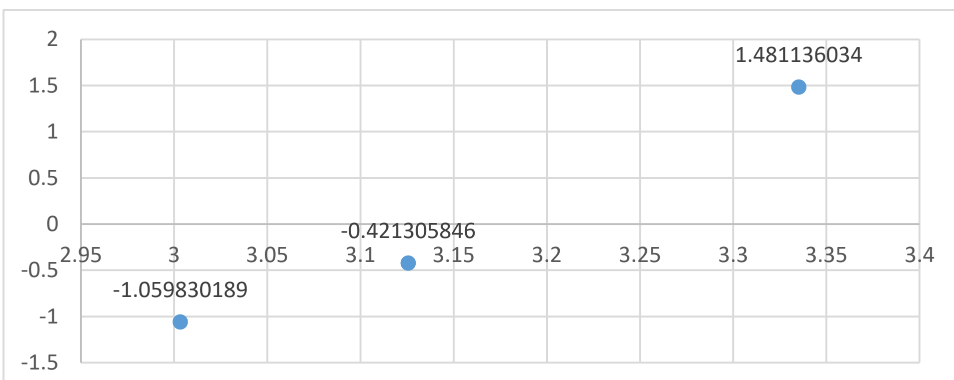

Fig 11. The causal diagram for C_7 (Financial) sub-criteria.

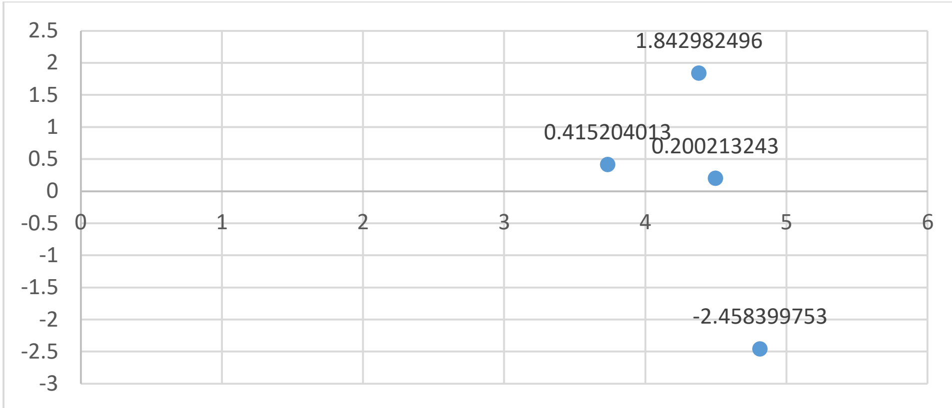

Fig 12. The causal diagram for C_8 (Security) sub-criteria.

5. Conclusion and Future Works

BT is one of the most significant creations of the Internet. The usage of this system has become fairly common for firms. Though, implementing a new BT system in firms includes different risk factors. Consequently, firms need to address and analyze these risks. For this goal, the risks of BT in a firm are measured and ranked by using SVNSs, AHP, and DEMATEL method. In this ranking process, Energy, environmental/cultural, financial, security, organizational, technical, legal, and regulatory challenges and adoption challenges risks are taken into account. 28 sub-risks covered by these risks are assessed under these groups. As a result, security is considered as the most significant risk factor among the eight risks and energy cost, and data leaks are ranked as the first and second important sub-risks correspondingly. DEMATEL results show security, financial cost, technical and organizational are causing effect while others are being affected. So the administrators should give more importance to these types of risks. For future research, the scope of the problem can be extended and the solutions of minimizing the risks for BT can be added as alternatives and the problem can be solved by MCDM techniques.

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