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Exploring Factors Influencing Cryptocurrency Adoption: A Comprehensive Modeling Based on Fuzzy Cognitive Maps Approach

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ABSTRACT

Cryptocurrencies, with their decentralized nature, are gaining rapid international adoption as a means of payment or a valuable digital asset, independent of the economic policies of governments and without the need for a supervisory institutions such as banks. However, limited research has been conducted on the adoption of cryptocurrencies, most of which employ a general technology acceptance/ adoption model with a positivist approach. The main problem with previous studies is that they have been limited to the structure of general adoption models and only examined a few constructs due to the increasing complexity of the model. On the other hand, due to cryptocurrencies' unique nature and rapid developments, it is necessary to create new comprehensive models that include different dimensions. This paper aims to identify influential factors in the adoption of cryptocurrency technology, understand their interrelationships, and ultimately develop a comprehensive model. With a constructivist approach, this study uses the most important research of the past decade in the field of cryptocurrency adoption and creates a cognitive model of their constructs through a systematic approach. The focal point of our approach is constructivism, accompanied by considering the impact of constructs on each other using fuzzy cognitive maps, which has not been previously done in cryptocurrency adoption. The results of the proposed model indicate that perceived usefulness, attitude, financial value, and perceived ease of use are the most significant constructs that influence the creation of positive intention toward the use and adoption of cryptocurrencies.

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1. INTRODUCTION

According to many researchers, blockchain technology and cryptocurrencies are radical or disruptive innovations in the sense that they have the potential to destroy previous technologies and replace them [1-3]. Although some consider them complementary to existing technologies, not as a replacement for them [4]. In any case, due to the increasing trend of using cryptocurrencies worldwide and their acceptance by some countries, it seems that cryptocurrencies' popularity is increasing, and this technology is very close to achieving widespread adoption [5]. However, prohibitions in certain countries and inadequate regulation can temporarily hinder their acceptance in some regions of the world. Nevertheless, with the cryptocurrency market exceeding one trillion dollars in value, it demonstrates global interest in this technology and its potential for investment and income generation in the future. Although research on the reasons for their popularity and understanding the reasons for user adoption can significantly impact the future of this technology [2], limited studied have been conducted in this area [6]. Therefore, the need for qualitative and conceptual research for technologies at the beginning of adoption is essential [4], and it even seems that this is a higher priority for cryptocurrency technology compared to other emerging technologies. Understanding the reasons for the adoption of cryptocurrencies can be highly valuable for policymakers, legislators, and many governmental and private organizations due to creating a proper understanding of citizens' behavior and even

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predicting their future acceptance. Properly understanding this phenomenon can pave the way for adopting correct cryptocurrency strategies and policies [7, 8].

The speed of cryptocurrency adoption in recent years has increased, and in the same way, the factors influencing their adoption have also increased; Therefore, understanding and modeling the effective constructs in cryptocurrency adoption has become more complex in this new space. This research aims to extract these constructs based on the most important studies of cryptocurrency adoption to identify the most important adoption factors through cognitive modeling. It is worth mentioning that most of the research conducted on the acceptance/ adoption of cryptocurrencies has adopted a positivist approach, where the authors conducted surveys to collect data from respondents and then analyzed them to prove their hypothesis. However, with a constructivist approach, this research independently examined and analyzed existing studies and their frameworks, independent of acceptance/adoption model structures and personal opinions. The approach in this stage is construct-oriented rather than model-centric, as all the constructs of the models and technology acceptance/adoption theories in the literature on cryptocurrencies were encoded and transformed into a fuzzy cognitive model.

The rest of this paper is organized as follows: In the second section (literature review), relevant research has been reviewed and analyzed, and a categorization of studies in this field has been presented. In the third section (explanation of the gap and the proposed method), the deficiencies of existing research have been explained, and the reasons for the need for the proposed method have been outlined. The fourth section (fuzzy cognitive map) provides a brief overview of the history and functioning of fuzzy cognitive mapping. Then in the fifth section (methodology), the research steps are described. The sixth section (model design) explains the proposed method and the model construction process from the influential adoption factors. The seventh section (model implementation) explains the model's implementation method and extracting the most important constructs. Finally, in the eighth section (discussion and interpretation of results), the most important constructs of the model's output will be described and interpreted.

2. LITERATURE REVIEW

Blockchain technology has gained fame primarily due to cryptocurrencies [9]; also, our focus in this study is only on the adoption of cryptocurrencies and does not include other applications of blockchain technology. In general, academic research in the field of cryptocurrencies can be divided into four categories: technical, economic, regulatory, and social sciences, with the social sciences category having the least amount of research devoted to it [10, 11] and the technical category is the most popular research area in the field of cryptocurrencies [12]. Most research in cryptocurrencies considers Bitcoin as the representative of this technology and has focused its research on it. This point is also true in the acceptance/adoption field, where the adoption of Bitcoin is considered the adoption of all cryptocurrencies. Research conducted on the adoption of cryptocurrency technology can be categorized into five groups, as presented in Table 1. Qualitative research studies have not been included in future reviews due to their lack of relevance to this article.

Most research on the adoption of cryptocurrency technology has used a general technology adoption/acceptance model (Category 1). However, it appears that well-known models such as "Technology Acceptance Model (TAM)", models adapted from TAM (TAM2, TAM3), or “Unified Theory of Acceptance And Use Of Technology” (UTAUT) may not be sufficiently

TABLE 1. Classification of cryptocurrency technology adoption studies

Category	Description	Sample
1. Use a basic model	Studies that have used the structure of the models or general theories of acceptance/ adoption.	[4] - TBP [1]
2. Combination of basic models	Studies that combined the constructs of two or more acceptance/ adoption models or theories.	[13] - UTAUT 2 and DOI [2]
3. Combination of basic models and external constructs	Studies that used one or more basic models but developed them with new constructs according to cryptocurrency technology.	[14] -Adding “security” and “awareness” constructs to UTAUT
4. Other systematic methods	Studies that used systematic methods with a constructivist approach to modeling the acceptance/ adoption of cryptocurrencies. In some cases, the structure of these researches originates from basic models.	[15] - Neural network, PLS-SEM [3] and TAM
5. Purely qualitative	Studies that did not use acceptance/ adoption models and were often based on open or semi-structured interviews.	[16]

[1] Theory of Planned Behavior

[2] Diffusion of Innovation Theory

[3] Partial Least Squares Structural Equation Modeling

qualified to study emerging technologies [17]. This can be exacerbated for emerging technologies such as cryptocurrencies due to the unique nature of the adoption process compared to other technologies [18, 19]. For example, the complexity of this technology can significantly affect the design of hypotheses regarding usage intention and actual usage [20]. In other words, many theories and models have been criticized for their poor fit with innovation and the absence of some of their specific features [2]. To the extent that some researchers believed that a particular model does not apply to a wide range of technologies, which is a fundamental and limiting factor for researchers who only use a specific model for studying the adoption of technology [3].

Furthermore, many researchers have concluded that combining multiple theories (Category 2) creates more research power to investigate the adoption of innovation and a better understanding of that innovation [3, 21-24]. However, merely combining models and theories with past structures sometimes lacks the necessary innovation to provide new insights [25]. Adding new constructs to previous models (Category 3) is another way to overcome previous models' complexity and lack of comprehensiveness in accepting/adopting cryptocurrencies. However, this can also carry the risk of bias.

3. EXPLANATION OF THE GAP AND THE PROPOSED METHOD

Limiting oneself to the structure of technology acceptance/adoption models will result in the loss of information. Given that understanding all the main reasons for technology adoption is often complicated [25]. Generally, acceptance/adoption model structures are usually limited and focus on the most critical factors. On the other hand, considering more constructs due to the structure of acceptance/adoption models causes the model to become more complex [26]. In Fact, researchers are reluctant to increase the minimum constructs in the base model. Some researchers have even removed some constructs from the base models to reduce complexity. For instance, Sun et al. [27] eliminated the moderating constructs from the UTAUT model [28] to cope with complexity. However, acceptance/ adoption modeling requires considering various constructs related to individual characteristics [25] and technology characteristics [23]. From a structural point of view, there are criticisms of models and theories of technology adoption in cryptocurrencies. For example, none of the studies on cryptocurrency adoption consider the internal causal relationships between different adoption constructs and the measurement of the influence or impact of constructs on each other. Additionally, the uncertainty of relationships has been overlooked, while the need for a map of causal relationships and dependencies between constructs in adoption models has been considered necessary [26] as uncertainty-based techniques are essential for understanding emerging technologies [29, 30].

Also, a technology adoption model should simultaneously consider both human and technological variables and characteristics that may affect the use of technology. On the other hand, the constructs of existing technology adoption models rarely focuses on a specific technology's features [25]. This is more important for cryptocurrencies, which have unique features compared to other technologies [18, 19, 31], and the structure of the designed model should be able to consider different dimensions as well. Besides that, the characteristics of cryptocurrency technology adoption are large-scale and highly complex [32]. Therefore, the proposed method to overcome the mentioned shortcomings is to innovatively use a fuzzy cognitive map (FCM) based on the structure of cryptocurrency research. FCM can describe different dimensions of adoption by showing causal relationships and the influence of constructs on each other. Also, considering that the current research area is in the category of social science research, the determination of adoption structures is generally done qualitatively, and modeling these structures, even with mathematical relationships, is complicated. When mathematical models cannot be used due to the system's complexity, cognitive maps by modeling this complex system are considered a very suitable tool to show a qualitative perspective [33].

4. FUZZY COGNITIVE MAP (FCM)

The fuzzy cognitive map was first introduced in 1986 by Kosko based on Lotfizadeh's fuzzy logic and Axelrod's cognitive models. FCMs evolved from cognitive maps developed by social scientists to record and analyze the cognitions of decision-makers and experts. A cognitive map is a mental model that shows the causal knowledge of experts and is obtained experimentally through social learning [34, 35]. Fuzzy cognitive maps are one of the most widely used graphic models for modeling dynamic systems and seek to model the system as it is understood [36].

In the fuzzy cognitive mapping method, a system is shown and modeled with several nodes and directional lines. Nodes represent the system's states, characteristics, inputs, outputs, and effective parameters. In the basic structure of FCM, each node has a number in the range [0 1]. Each edge between nodes indicates the influence of one node on another node. The weight of each edge means the degree of connection between nodes. In the structure of fuzzy cognitive maps, the weight of each is a number between [-1 1], where the weight of 1 indicates a complete direct connection and the weight of -1 indicates a full reverse connection. The numbers between these two numbers show the relative degree of relationship [36]. A simple example of FCM is shown in Figure 1.

5. METHODOLOGY

This article's method is adapted from the process introduced by Jetter and Kok [37]. Based on this process, a standard and general methodology for modeling fuzzy cognitive maps is presented in 6 steps.

We need a set of basic information to create a fuzzy cognitive map. In general, the following methods can be used to create a cognitive map [36-38]:

(1) Experts: The relationships between nodes are determined based on experts' opinions, and their views can also be used to determine the nodes themselves.

(2) Extracting nodes and relationships from previous research

(3) Existence of previous FCMs and their consolidation with new rules

(4) Network training: In this method, there is no need for an expert or a commenter to determine the influence of one node on another node, and relationships are extracted by network training.

We will use a combination of the first three methods to consider each of the past studies as an expert, and based on the results of that research, we will consider each of the factors affecting adoption as a node of the fuzzy cognitive map. Then, based on the structure of each study, we will draw causal relationships to reach an FCM of each study (first and second methods). Then we will combine each of the obtained mappings considering a specific weight (third method).

Extracting the important points of the text and adapting them to some of the desired functions is always one of the crucial concerns [39]. Since the previous studies are considered experts, we will use the method developed by Alizadeh and Jetter [40] to extract nodes and relationships from secondary data. In fact, in phases 4 and 5 of Figure 2, the following steps will be followed:

- Drawing raw FCM from the results of each research
- Consolidating identical concepts
- Adopting consistent terms for similar concepts
- Determining details for concepts and sub-concepts
- Identification and managing island FCMs

6. MODEL DESIGN

According to section 5, to create a comprehensive cryptocurrency adoption model, it is necessary to get help from past researchers as experts to form each FCM. For this purpose, the most important studies in the field of cryptocurrency adoption were carefully examined in two phases, and their structures and relationships were extracted.

In the first phase, a structural approach developed by Webster and Watson [41] was used to find related works in four general steps. Keywords such as acceptance, adoption, attitude to use, and cryptocurrency were used in Google Scholar and Scopus databases to find studies (step 1). After reviewing valid studies (step 2); Fast scanning of full text (step 3); and preliminary analysis (step 4), 30 studies were selected for more detailed review, which is shown in Table 2.

In the second phase, the "citation average per year" index based on the Google Scholar database was used to identify the most important studies. This index shows its relative importance by adjusting the publication time of the research [42, 43]. Using this index is to ensure the benefit of valid experts. Because as past research in different fields has shown, experts play a very important role in developing new models and should be carefully selected [44, 45].

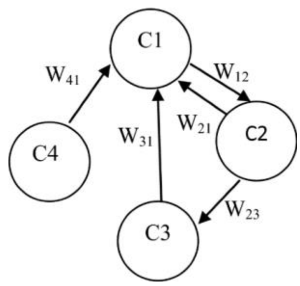

Figure 1. A simple example of a fuzzy cognitive map

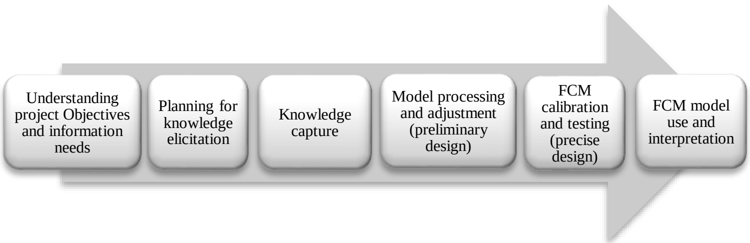

Figure 2. Standard steps of modeling with fuzzy cognitive mapping derived from [37]

Table 2 shows potential experts in order of importance (based on citation average per year). Should note that the data of each study has been examined in a country/region. Therefore, if a study conducted in a country is considered as one of the experts of the final model, related studies in that country will not be included at a lower rank in the proposed model to ensure an appropriate distribution of input data.

TABLE 2. Researches in the field of cryptocurrency adoption (as FCM experts)

Rank	Authors	Citation average per year	Total cites	Theory/Model/ Method used	Country/ Region	Sample size	Included in the proposed model?
1	Arias-Olive et al. [46]	45.5	182	UTAUT, PLS- SEM	Spain	402	Yes
2	Abbasi et al. [47]	37.5	75	UTAUT2, PLS-SEM, ANN [1]	Malaysia	314	Yes
3	Shahzad et al. [2]	33.8	169	TAM	China	376	Yes
4	Folkinshteyn and Lennon [4]	32.29	226	TAM	USA	–	Yes
5	Mazambani and Mutambara [48]	31.6	95	TPB	South Africa	269	Yes
6	Sas and Kheyrodin [16]	25.33	152	-	England	20	No/ Purely qualitative and small sample size
7	Sohaib et al. [15]	23.25	93	TAM, PLS-SEM, ANN	Australia	140	Yes
8	Miraz et al. [49]	21	21	UTAUT 2	Malaysia	263	No/ Existence of Malaysia
9	Bhimani et al. [50]	21	21	Correlation and regression analysis	137 Countries	–	No/ Review national development issues
10	Alharbi and Sohaib [51]	20	40	PLS-SEM, ANN	Australia	160	No/ Existence of Australia
11	Yeong, et al. [24]	18	18	UTAUT2, PLS-SEM	Malaysia	176	No/ Existence of Malaysia
12	Jonker [32]	17.25	69	Binomial probit	Netherlands	768	No/ Review at the retailer level
13	Schaupp and Festa [52]	16.8	84	TPB	USA	117	No/ Existence of USA
14	Chen et al. [53]	15	15	PLS-SEM	Malaysia	295	No/ Existence of Malaysia
15	Walton and Johnston [54]	14	70	TAM, TPB	South Africa	237	No/ Existence of South Africa
16	Schaupp et al. [55]	11	11	TPB	USA	492	No/ Existence of USA
17	Jalan at al. [8]	10	10	GLM on WVS [2] wave 7	48 Countries	70867	No/ Results based on tweets and Google trends
18	Alaklabi and kang [56]	9.5	19	TRA [3]	Saudi Arabia	368	Yes
19	Lee et al. [57]	9	36	UTAUT	USA	127	No/ Existence of USA
20	Gunawan and Novendra [58]	8.33	50	UTAUT	Indonesia	49	Yes
21	Mahomed Nadim [20]	6.17	37	UTAUT 2	South Africa	300	No/ Existence of South Africa

[1] Artificial Neural Network
[2] Generalized Linear Models Analysis in the World Values Survey
[3] Theory of Reasoned Action

22	Esmaeilzadeh et al. [59]	4.75	19	UTAUT	USA	165	Existence of USA
23	Nseke [13]	4.4	22	UTAUT 2 DOI	African Countries	–	No/ Disconfirmation of hypotheses
24	Kumpajaya and Dhewanto [60]	4	32	TAM DOI	Indonesia	108	No/ Existence of Indonesia
25	Silinskyte [18]	3.78	34	UTAUT	–	111	Yes
26	García-Monleón et al. [6]	2	2	UTAUT PLS-SEM	-	175	Yes
27	Bommer et al. [31]	2	2	Meta-analysis	-	42	No/ Meta-analysis
28	Andraschko and Britzelmaier [61]	2	6	TAM2	Germany	31	No/ Organizational level
29	Liew et al. [62]	1	1	Questionnaire	27 Countries	42223	No/ Purely qualitative
30	Wesley [3]	0.8	4	DOI	USA	20	No/ Existence of USA

According to Table 2, 10 studies were selected as experts, and we will create an FCM from each of them. The raw FCMs formed from each study will be based on the results of the confirmed hypotheses of that study and do not include all the mentioned constructs. Also, if the weight of the relations was clear in the research, the same weight is used as the FCM edge weight; otherwise, the weight of all edges will be the same and equal to the fixed value of 0.5.

6. 1. FCM Creation from Each of the Selected Studies

Based on UTAUT, Arias-Olive et al. [46] propose six hypotheses for the constructs affecting the adoption of cryptocurrencies, and three hypotheses are rejected after analyzing the model. The confirmed constructs are shown in Table 3.

Due to failing to confirm all hypotheses, the Social Influence, Perceived Risk, and Financial Literacy constructs were not used in the final FCM construction shown in Figure 3. In this study, the final node is the intention to use cryptocurrencies.

The above method can be applied to other selected studies similarly. The constructs and FCM adapted from Abbasi et al. [47] study are as follows (Table 4 and Figure 4).

The constructs and FCM adapted from Shahzad et al. [2] study are as follows (Table 5 and Figure 5):

TABLE 3. Effective adoption constructs derived from [46]

Symbol	Node	Output edge weight
A1	Intention to use	-
C1-1	Performance expectancy	0.68
C1-2	Effort expectancy	0.05
C1-3	Facilitating conditions	0.15

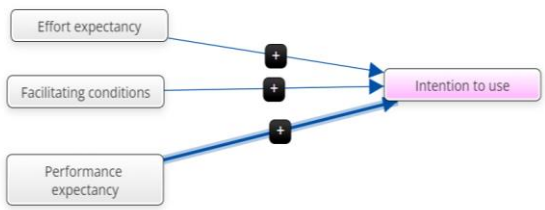

Figure 3. Raw FCM designed from [46]

TABLE 4. Effective adoption constructs derived from [47]

Symbol	Node	Output edge weight
A2	intention to adopt	-
C2-1	Performance expectancy	0.09 to A2-1; 0.21 to C2-5
C2-2	Effort expectancy	A2-1 to 0.17 ; 0.24 to C2-1
C2-3	Trust	0.3
C2-4	Hedonic Motivation	0.26 to C2-5; 0.42 to C2-1
C2-5	Price Value	0.15
C2-6	Personal Innovativeness	0.23

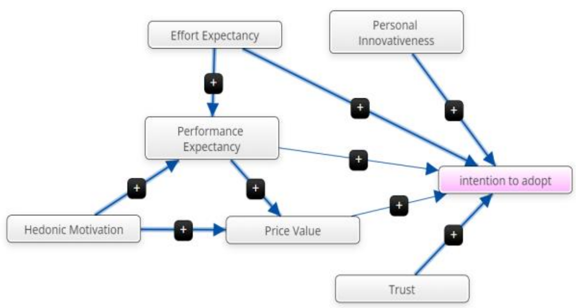

Figure 4. Raw FCM designed from [47]

TABLE 5. Effective adoption constructs derived from [2]

Symbol	Node	Output edge weight
A3	Intention to use	-
C3-1	Perceived ease of use	0.125 to A3; 0.353 to C3-2
C3-2	Perceived usefulness	0.236
C3-3	Perceived Trustworthiness	0.33
C3-4	Awareness	0.229

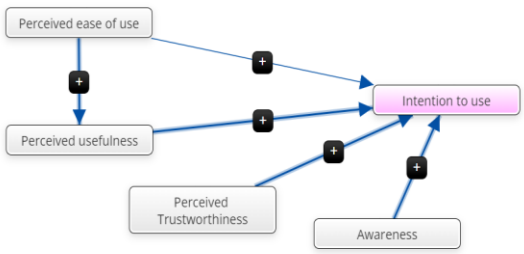

Figure 5. Raw FCM designed from [2]

The constructs and FCM adapted from Folkinshteyn and Lennon [4] study are as follows (Table 6 and Figure 6):

The constructs and FCM adapted from Mazambani and Mutambara [48] study are as follows (Table 7 and Figure 7):

The constructs and FCM adapted from Sohaib et al. [15] study are as follows (Table 8 and Figure 8):

The constructs and FCM adapted from Alaklabi and kang [56] study are as follows (Table 9 and Figure 9): The constructs and FCM adapted from Gunawan and Novendra [58] study are as follows (Table 10 and Figure 10):

TABLE 6. Effective adoption constructs derived from [4]

Symbol	Node	Output edge weight
A4	Intention to transact	-
C4-1	Perceived ease of use	0.5 to A4; 0.5 toC4-2
C4-2	Perceived usefulness	0.5
C4-3	Perceived Risk	- 0.5

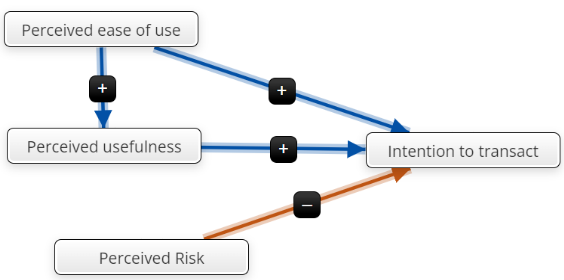

Figure 6. Raw FCM designed from [4]

TABLE 1. Effective adoption constructs derived from [48]

Symbol	Node	Output edge weight
A5	Intention	-
C5-1	Attitude	0.74
C5-2	Perceived Behavioural	

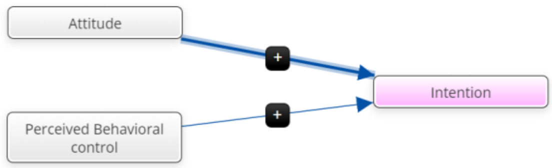

Figure 7. Raw FCM designed from [48]

TABLE 2. Effective adoption constructs derived from [15]

Symbol	Node	Output edge weight
A6	Cryptocurrency use intention	-
C6-1	perceived ease of use	0.486 to A6, 0.321 to C6-2
C6-2	perceived usefulness	0.514
C6-3	Discomfort	-0.08 to C6-2; -0.1 to C6-1
C6-4	Insecurity	-0.16 to C6-2; -0.21 to C6-1
C6-5	Optimism	0.242 to C6-2; 0.4 to C6-1
C6-6	Innovativeness	0.191 to C6-2; 0.285 to C6-1

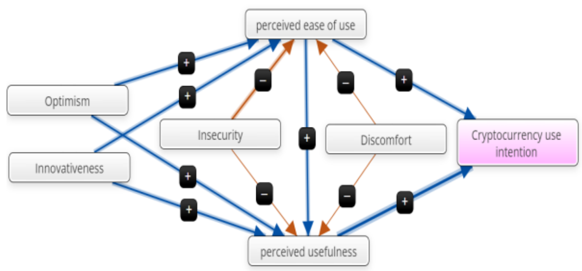

Figure 8. Raw FCM designed from [15]

TABLE 9. Effective adoption constructs derived from [56]

Symbol	Node	Output edge weight
A7	Intention to adopt cryptocurrency	-
C7-1	Attitude	0.5
C7-2	Subjective norm	0.5
C7-3	Security Risk (Perceived Risk)	- 0.5
C7-4	perceived usefulness	0.5 to A7 and C7-1
C7-5	Perceived Enjoyment	0.5 to A7 and C7-1

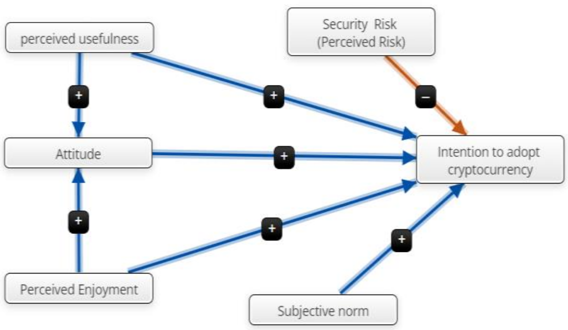

Figure 9. Raw FCM designed from [56]

TABLE 10. Effective adoption constructs derived from [58]

Symbol	Node	Output edge weight
A8-1	use behavior	-
A8-2	behavioral intention	0.5
C8-1	Performance expectancy	0.5
C8-2	Social influence	0.5
C8-3	Facilitating condition	0.5

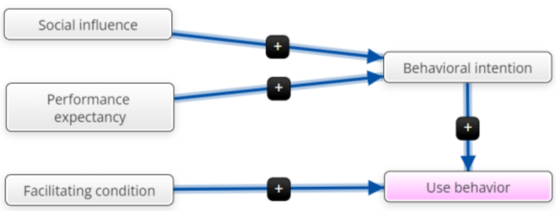

Figure 10. Raw FCM designed from [58]

The constructs and FCM adapted from Silinskyte [18] study are as follows (Table 11 and Figure 11):

The constructs and FCM adapted from García-Monleón et al. [6] study are as follows (Table 12 and Figure 12):

6. 2. Unification of Similar Concepts and Integration of FCMs

In the previous stages, the cognitive network structure of each research was

TABLE 3. Effective adoption constructs derived from [18]

Symbol	Node	Output edge weight
A9-1	Use Behavior	
A9-2	Behavioural intentions	0.487
C9-1	Effort expectancy	0.473
C9-2	Facilitating conditions	0.448
C9-3	Performance expectancy	0.707

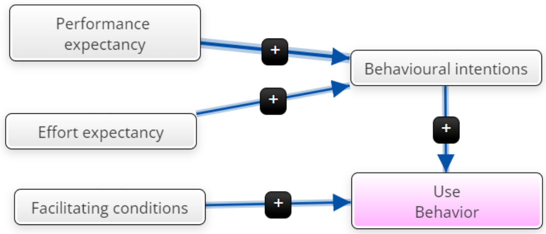

Figure 11. Raw FCM designed from [18]

TABLE 12. Effective adoption constructs derived from [6]

Symbol	Node	Output edge weight
A10-1	Intention to use cryptocurrency	-
C10-1	Emotional perceived value	0.533
C10-2	Financial perceived value	0.545
C10-3	knowledge path	0.677
C10-4	Hedonic motivation	0.027
C10-5	Social influence	0.004
C10-6	Trust	0.243
C10-7	Effort expectancy	0.093
C10-8	Performance expectancy	0.26
C10-9	Facilitating conditions	0.149
C10-10	Environmental sustainability	0.238
C10-11	Social sustainability	0.169

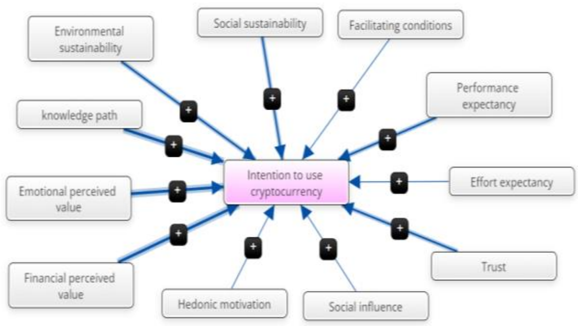

Figure 12. Raw FCM designed from [6]

prepared; now, all constructs in similar concepts used in the above FCMs should be unified and coded. Table 13 shows the final constructs for creating a comprehensive FCM.

In Table13 , some constructs (second column) have been integrated into one code (first column) based on Yadegari ey al. [43]. For example, Effort expectancy and Perceived ease of use have the same concept and are mapped to the PEU code, or perceived usefulness is similar to performance expectancy [63] and receives the same code (PU).

TABLE 4. Coding model concepts

Final code	Symbol	Node	References
ITU (Intention to use)	A1 A3 A9-1	Intention to use	[2, 6, 46]
	A2 A7	Intention to adopt	[47, 56]
	A4	Intention to transact	[4]
	A5	Intention	[48]
	A6	Cryptocurrency use intention	[15]
	A8-2 A10-2	Behavioral intention	[18, 58]
USE	A8-1 A10-1	Use behavior	[18, 58]
(PU) Performance usefulness	C1-1 C2-1 C8-1 C9-8 C10-3	Performance expectancy	[6, 18, 46, 47, 58]
	C3-2 C4-2 C6-2 C7-4	Perceived usefulness	[2, 4, 15, 56]
PEU (Perceived ease of use)	C1-2 C2-2 C9-7 C10-1	Effort expectancy	[6, 18, 46, 47, 58]
	C3-1 C4-1 C6-1	Perceived ease of use	[2, 4, 15]
FC (Facilitating conditions)	C1-3 C8-3 C9-9 C10-2	Facilitating conditions	[6, 18, 46, 58]
PT (Perceived Trust)	C2-3 C9-6	Trust	[6, 47]
	C3-3	Perceived trustworthiness	[2]
HM (Hedonic Motivation)	C2-4 C9-4	Hedonic motivation	[6, 47]
	C7-5	Perceived enjoyment	[56]
FV (Financial value)	C2-5	Price value	[47]
	C9-2	Financial perceived value	[6]
INV (Innovativeness)	C6-6	Innovativeness	[15]
	C2-6	Personal innovativeness	[47]
AW (Awareness)	C3-4	Awareness	[2]
	C9-3	Knowledge path	[6]
PR (Perceived Risk)	C4-3	Perceived risk	[4]
	C7-3	Security risk (perceived risk)	[56]
	C6-4	Insecurity	[15]
AT (Attitude)	C5-1 C7-1	Attitude	[48, 56]
PBC	C5-2	Perceived behavioural Control	[48]
DC	C6-3	Discomfort	[15]
OP	C6-5	Optimism	[15]
SN	C7-2	Subjective norm	[56]
SI	C8-2 C9-5	Social influence	[6, 58]
EPV	C9-1	Emotional perceived value	[6]
ES	C9-10	Environmental sustainability	[6]
SS	C9-11	Social sustainability	[6]

One of the great features of fuzzy cognitive maps is the possibility of combining several maps; in such a way that the nodes are added to each other, and a weighted average is taken from the common edges. Figure 14 shows the graphical representation of the aggregated fuzzy cognitive map. This figure shows the causal relationship of all the constructs mentioned in the first column of Table 13 based on the structure of the previous models.

7. MODEL IMPLEMENTATION

In fuzzy cognitive maps, an initial value should be considered for each node. In this research, this value is assumed to be 0 for all nodes so that the conditions of all

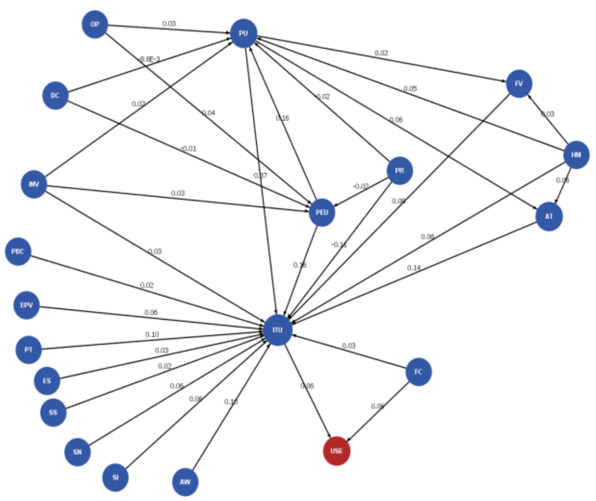

Figure 14. Aggregated fuzzy cognitive map

nodes are the same for the final selection. In each iteration, the effect value of the nodes on each other is added to or subtracted from this initial value. It can be said that choosing any initial value does not affect the final result as long as it is the same for all nodes.

Equation (1) to calculate the value of each node recursively. According to this Equation, the value of a node is the sum of the effects of all nodes that influence it, as well as the node's previous value [36].

$$\mathrm{A}_{\mathrm{i}}^{\mathrm{t}} = f\left(\sum_{\substack{j=1 \\ j \neq i}}^{n} A_j^{t-1} W_{ji} + A_i^{t-1}\right) \quad (1)$$

t = iteration
A_i^t = the value of concept i in the t^{th} iteration
W_{ji} = the impact value of concept i on concept j

To ensure that the values of concepts remain within the range of [0 1], a compression function f is employed, which is typically represented by Equation (2). This equation is commonly referred to as a logistic compression function.

$$f(X) = \frac{1}{1+e^{-\lambda x}} \quad (2)$$

In Equation (2), λ determines the slope of the logistic function, and it must be a number greater than zero, which is considered 1 in this research. Also, e is the number of Neper (=2.71).

To calculate the final value of each node, the iteration is done until either the node's value reaches a stable state or its value changes in a finite state cycle. A stable state means that the values of all concepts have reached the final stable values without changing in future iterations. Only in this case can the model outputs be interpreted and used for decision-making [59, 64].

As it is clear in Figure 15, in the first iteration, the value of all the nodes goes from 0 to 0.5. After the first iteration, according to the strength of each edge, the nodes affect each other, and finally, after seven repetitions, the value of all nodes will be stable without change. Table 14 shows the final value of the most important constructs. In this table, a higher value means a greater impact on the adoption of cryptocurrencies.

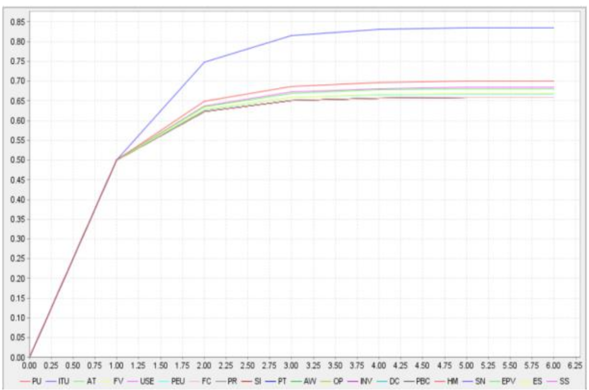

Figure 15. Stability of the cryptocurrency adoption constructs in the proposed model

8. DISCUSSION AND INTERPRETATION OF RESULTS

As many studies have pointed out, the intention to use cryptocurrencies (ITU) is the main factor in cryptocurrency adoption. In fact, the stage before adoption and then using cryptocurrencies is the intention of the user to this technology, which is positive means adoption, and being negative means not adopting it. Although we must distinguish between acceptance, adoption, and use ("technology acceptance can be considered to precede technology adoption, and these two precede technology use" [43, 65]). What is clear is that any constructs that significantly affect this factor will ultimately directly influence the adoption of cryptocurrencies. According to the results of the proposed model, perceived usefulness (PU), attitude (AT), financial value (PV), and perceived ease of use (PEU) of this technology are the most important factors that positively influence the adoption of cryptocurrencies.

Perceived usefulness refers to the degree to which a person believes using cryptocurrency can improve their performance [66]. If a person evaluates that a cryptocurrency helps him/her to do his work and is useful, the probability of using it increases. Presenting real applications and successful examples where cryptocurrencies have been used can be one of the ways to familiarize a person with the applicability of this technology and lead to the intention of using it. Due to the high importance of this construct, paying attention to the current and future needs of users and expressing the benefits of a specific cryptocurrency that can cover that need more efficiently than before can lead to the user's intention to use it.

Another factor affecting the adoption of cryptocurrencies is attitude, which means A person's feeling of the positive or negative effect of a certain behavior [67]. In other words, attitude refers to how a

TABLE 5. The final value of the most important constructs

Code	Node	Final value
ITU	Intention to use	0.8359
PU	Perceived usefulness	0.7001
AT	Attitude	0.6801
FV	Financial value	0.669
PEU	Perceived ease of use	0.6668
Other	-	Less than 0.659

person feels and believes about technology, including its advantages and disadvantages, its actual value, and how it relates to his/her environment. Perceived usefulness directly makes a person's attitude towards use positive. Therefore, clearly stating the benefits of this technology and how to deal with the risks can significantly improve a person's attitude toward cryptocurrencies.

The financial value that the user perceives from cryptocurrencies is another important factor that leads to user adoption. Historical data also shows that whenever the financial value of cryptocurrencies has increased, the number of users of this technology has also grown significantly; As the predictions show, the value of cryptocurrencies will grow significantly due to the decentralized future of financial systems, which will lead to greater adoption in the future.

Also, perceived ease of use is the degree to which a person can effortlessly use cryptocurrencies [66]. Considering the existence of this construct in the selected factors, it seems that the complexity of using cryptocurrency technology for end users is still high, and it can hurt the users' attitude. Therefore, cryptocurrency service providers should focus on simplifying the user interface, training users, and adapting the processes as much as possible to the systems that the user used before.

9. CONCLUSION

Cryptocurrency adoption models can provide comprehensive insight to policymakers, legislators, and organizations interested in cryptocurrency. Legislators and policymakers can use the adoption model to create regulations that support cryptocurrency adoption factors while reducing cryptocurrency risks. Organizations interested in cryptocurrency can also use adoption models to inform product designs, promotions, and services. Organizations can increase their chances of success in the cryptocurrency market by aligning their strategies with the affecting adoption factors.

For the first time, this research has developed a comprehensive modeling of the factors influencing the adoption of cryptocurrencies using the fuzzy cognitive mapping approach based on the results of credible research in this field. This approach considered each selected study on the acceptance/ adoption of cryptocurrencies as an expert and used the research outputs as input for the model to take advantage of global data prevalence systematically to create a comprehensive model. This method enabled the integration of all the previous models into one scalable fuzzy cognitive map. The results of the final FCM indicant the most important constructs and their greater effect on the final node.

The findings of the presented model show that the perceived usefulness, attitude, financial value, and Perceived ease of use of cryptocurrency technology are the most important factors that cause a positive attitude toward adopting this technology. Considering the conditions of each society, finding tools and methods that can satisfy these factors can significantly impact the adoption of cryptocurrencies on a large scale.

This study was also faced with some limitations and challenges, the most important of which was the dependence on past studies and the selection of the most important ones. The constructs of the past models form the initial structure of the fuzzy cognitive map, and if they are not carefully selected, they may affect the final results. In this study, we used one selected study from each country. Using more studies with different selection criteria can produce different results than this research. Another limitation was due to the nature of fuzzy cognitive maps. In some technology acceptance models, moderator variables such as age and gender are used. Since these moderator variables affect the relationship between two constructs, they cannot be directly modeled on the fuzzy cognitive map and were not considered in this model.

For future studies, it is suggested to define a criterion to define the importance of fuzzy cognitive maps adapted from each study so that when combining the maps, studies with higher importance have a greater contribution to the final results. For example, this criterion can be adapted from conventional criteria for evaluating and measuring the credibility of articles and then normalizing it for use in FCM. Also, converting the moderator variables into intermediate nodes in FCM and considering their impact on the constructs of adopting cryptocurrencies can result in a more accurate model and is of interest to researchers. Finally, collecting all the studies related to digital currencies in a country and modeling them comprehensively in the manner described in this study can provide an applicable model specific to that country.

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Persian Abstract

چکیده

رمزارزها با ماهیت غیرمتمرکز خود، مستقل از سیاست‌های اقتصادی دولت‌ها و بدون نیاز به نهادهای نظارتی مانند بانک‌ها، به‌سرعت به‌عنوان وسیله‌ای پرداخت یا دارایی دیجیتال ارزشمند، در حال پذیرش بین‌المللی هستند. با این حال، تحقیقات محدودی در مورد پذیرش رمزارزها انجام شده است، که اکثر آن‌ها از یک مدل پذیرش فناوری عمومی با رویکرد اثبات‌گرایانه استفاده می‌کنند. مشکل اصلی مطالعات قبلی این است که آن‌ها به ساختار مدل‌های عمومی پذیرش فناوری محدود شده‌اند و تنها چند سازه محدود را به دلیل افزایش پیچیدگی مدل، بررسی می‌کنند. از سوی دیگر، با توجه به ماهیت منحصربه‌فرد و پیشرفت‌های سریع رمزارزها ، ایجاد مدل‌های جامع جدید که ابعاد مختلف را در بر می‌گیرد، ضروری به نظر می‌رسد. هدف این مقاله شناسایی عوامل تأثیرگذار در پذیرش فناوری رمزارزها، درک روابط متقابل آن‌ها و در نهایت توسعه یک مدل جامع است. این پژوهش با رویکرد سازه‌انگاری، از مهم‌ترین تحقیقات دهه گذشته در زمینه پذیرش رمزارزها استفاده کرده و با رویکردی نظام‌مند، مدلی شناختی از سازه‌های آنها ایجاد می‌کند. نقطه کانونی رویکرد ما ساخت‌گرایی، همراه با در نظر گرفتن تأثیر سازه‌ها بر یکدیگر با استفاده از نقشه‌های شناختی فازی، که قبلاً در پذیرش ارزهای دیجیتال انجام نشده است می‌باشد نتایج مدل پیشنهادی نشان می‌دهد که سودمندی درک شده، نگرش، ارزش مالی و سهولت استفاده درک‌شده مهم‌ترین سازه‌هایی هستند که بر ایجاد قصد مثبت نسبت به استفاده و پذیرش ارزهای دیجیتال تأثیر می‌گذارند.