Article

Evaluation of Sustainable Digital Currency Exchange Platforms Using Analytic Models

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Abstract: This study presents an analytic model to support the general public in evaluating digital currency exchange platforms. Advances in technologies have offered profitable opportunities, but the general public has difficulty accessing appropriate information on digital currency exchange platforms to facilitate their investments and trading. This study aims to provide a decision support system using analytic models that will guide the public in deciding the appropriate digital currency exchange platform for trading and investment. The overarching objective is to support the public in embracing the new era of a dependable, trustworthy, and sustainable digital society. Particularly, this study offers an analytics model that compares numerous well-known digital currency exchange platforms based on the opinions of 34 human expert members on six main criteria to identify the most suitable platform. In this study, the analytic hierarchy process approach, which is a multiple-criteria decision-making method, and Expert Choice software were used for decision support. Using pairwise comparisons of exchanges with respect to the criteria in the software, the weight of each exchange was determined, and these weights became the basis for prioritizing the exchange platform. This study provides valuable insight into how an analytics-driven expert system can support the public in selecting their digital currency exchange platform. This work is an integral part of an effort to help disruptive digital technology become widely accepted by the general public.

1. Introduction

Digital innovations are paving new ways to live in Industry 4.0. Rapid advances in technology have allowed great innovations, such as ubiquitous computing and other smart services [1]. Cryptocurrency, which allows the decentralized control of financial transactions, is one of the most exciting new inventions. Innovation in cryptocurrency has allowed financial transactions with reduced dependability on centralized financial organizations [1,2]. Despite their great innovations and prosperous future opportunities, cryptocurrencies are still restricted by their lack of wide acceptance and use. The main difficulty is the technical complexity for the general community to understand its working mechanism and trust its operations.

Digital currencies use complex codes and encryption protocols to transfer all the information that supports secure transactions. These protocols have been developed

based on the complex principles of mathematics and computer engineering to improve security [1,3]. These protocols can also mask the identity of digital currency users and prevent probing by other organizations; therefore, the rules of engagement in the finance industry have been disrupted.

Such innovations have a fundamental impact on society, and it takes time for the public to understand and trust new instruments. Many investors are interested in investing in cryptocurrencies; thereby, a gap was identified in the literature relating to a lack of sustainable, trustworthy, and dependable sources of information that support naïve customers [2,4]. The general public can use digital exchanges to trade cryptocurrencies, but they are often lost as to which exchanges will provide the best usability or security. Therefore, much of the previous research in the sustainability context has been carried out in isolation from each other and, thus, is weak in terms of explanation and theoretical development [5]. This research is particularly useful in a field such as digital currency exchange, in which the theoretical and conceptual frameworks for this study problem are under-researched and, therefore, possibly inadequate. The main objective is to support the public in embracing the new era of a dependable, trustworthy, and sustainable digital society.

We therefore seek to explore an analytic model to support the general public in evaluating digital currency exchange platforms. We conduct an exploratory study to introduce an analytic methodology for identifying the appropriate digital currency ex-change using industry-benchmarked indices. The question guiding this research is: Which criteria choices exist for selecting the most appropriate digital currency exchange? Expert Choice software was used to conduct pairwise comparisons of the criteria and exchanges. This study invited 34 expert members in digital currency exchange, and their opinions were analyzed to allocate weights to the selected performance indices for digital currency exchange platforms. The refined model is a recommender system for digital currency traders to select an appropriate exchange platform. The experimental outcome demonstrates that a recommender system learns from expert members' opinions, allowing expert members' knowledge to be represented in the model for a broader community to access.

This model helps make sense of occurrences, ensures the important issues are not overlooked, provides a set of digital currency trading platforms to be investigated, and guides the researcher's interpretation and focus in the field. The experimental analysis compared six major digital currency exchange platforms using six performance indices based on the opinions of 34 expert members. As time passes, and the performance indices change, the model may recommend an alternative platform. This represents a knowledge management system that can support future digital currency traders in selecting digital currency exchange platforms. The scientific contribution of this article is significant in setting up an evaluation framework for recommending an appropriate digital currency exchange system given industry-benchmarking variables/indices.

The remainder of this paper is structured as follows: The next section presents the research background of research on digital currency, cryptocurrency, and blockchain. The research method and details of our approach to data collection and analysis are then presented. Next, we present the research findings, and the paper concludes with discussion of future research directions.

2. Literature Review

2.1. Digital Currency

Digital currency has disrupted the financial industry since 2008 with its ability to offer peer-to-peer, faster, cheaper, more secure, more convenient, and efficient payment systems that can outpace traditional banking systems. Today, digital currencies are recognized as alternative methods of currency exchange and are used in many financial transactions, with people using digital currencies for profitable investment [6,7].

Digital currencies such as Bitcoin, Ethereum, and Ripple are emerging as new forms of money and currencies in general. Both digital and traditional currencies can be used to

mediate exchanges, preserve asset value, and act as account control units [8,9]. Bitcoin was the first digital currency introduced in 2009. On 22 May 2010, two pizzas were purchased for 10,000 bitcoins for the first time. At that time, each Bitcoin was worth USD 0.0025. That day is known as "Bitcoin Pizza", in which a real person paid 10,000 bitcoins to buy two pizzas worth approximately $25 [10]. In the second week of May 2021, the same 10,000 Bitcoins were worth more than 500 million dollars. The rise of digital currency has expanded into the business of digital wallets and currency exchange platforms and has introduced platforms that enable investors to trade digital currency [11].

Unlike Fiat currencies, digital currencies have no centralized reference. All transactions are validated by a network of volunteering nodes (miners) and are subsequently registered in the blockchain distribution office after a collective agreement [12]. The ultimate goal of digital currency is to become an alternative payment system that complements or competes with conventional payment systems. Regardless of whether such a goal is achievable, some digital currency performances have prompted competent authorities of some EU countries to grant licenses to digital currency exchange institutions.

Digital currency is an advanced innovation in the field of FinTech and is a universal connection point for many different services and technologies. This evolution has led to a series of public events worldwide [13]. The fundamental cryptocurrency markets are similar to stock markets. However, analysis shows that the digital currency market is more fragile than the stock market, and it is now considered a high-risk financial market [13,14].

2.2. Digital Currency Exchanges

Digital currency exchanges are often targeted and compromised by cyber-attacks, leading to significant losses for depositors and closure of affected exchanges. These threats pose major risks to the lives of public blockchain ecosystems [15].

Digital currency exchanges allow users to buy and sell digital currency. Exchanges play a vital role in the digital currency ecosystem by providing a marketplace for trading, liquidity, and price discovery [16,17]. Many exchanges only offer digital currency trading services, while others support Fiats for digital currency transactions [18,19].

Similar to the stock market, people invest in digital currency exchanges to take advantage of digital currency price changes (if favorable). There are three types of digital currency exchange platforms: centralized exchanges (CEX) managed by a company or organization, decentralized exchanges (DEX) that provide an automated process for peer-to-peer transactions, or a combination of both CEX and DEX [4,20]. Hundreds of digital currency exchange platforms are emerging to facilitate the trading of digital assets as an essential ecosystem in trading platforms. In addition, the market attracts attackers. Many scam attacks on digital currency exchange platforms have resulted in significant financial losses [21].

Digital currency markets have remained attractive. Exchanges are primarily used for commercial profit. However, these trades face certain treatment from traders during their fluctuations and liquidity [14]. Digital currency trading on current digital exchange platforms is a trust-based process in which the parties involved in the exchange must have complete trust in the service provider. It has been proven several times that this trust can lead to fraud, theft of funds, or, for some reason, service providers simply disappear; other times, there may be hacks on platforms that voided digital assets [22,23].

2.3. Cryptocurrency

Cryptocurrencies have a history of poor security, and it is claimed that more than one-third of the exchanges were in jeopardy [24,25]. After being compromised, attackers can copy the exchange wallet (a set of private encryption keys) and steal all of its coins [26,27]. Unlike the regular banking system, all theft transactions through the Bitcoin network are irreversible [28]. Bitcoin market capitalization surpassed all other digital currencies in the market. However, its high monetary value makes it an attractive target for cyber-criminals. Hacking campaigns typically target the weakest points in the digital currency ecosystem.

The weakest point in the Bitcoin ecosystem is the exchange operation system. As every exchange law violation potentially reduces the market value of Bitcoin by billions of dollars, this is a threat not only to exchanges, but also to the majority of Bitcoin owners [12]. Therefore, the effects of transaction volume and exchange size on the level of security breaches have also been examined.

The general public has no way of accessing sensitive information about the past security history of a digital exchange or its operational mechanism. A computer system that learns from the opinions of other professionals in the discipline (of digital currency trading) can help the public make informed decisions. This research focuses on providing such information through analytic modeling of human experts' opinions. This analytical model is discussed in the following section. A summary of the literature review in related fields is provided in Table 1.

Table 1. A Summary of Studies Conducted to Improve the Field of Digital Currencies and Exchanges.

Authors	Descriptions
Alzaatreh and Sulieman [27]	Providing a new location-scale distribution family to understand the distributional characteristics of digital currency return rates
Xia, et al. [21]	Reviewing existing payment protocols and introducing new payment protocols to enhance the exchange of basic payment information
Xia, et al. [21]	Identifying and describing scams in digital currency exchanges
Alonso-Monsalve, et al. [28]	Using convolutional neural network to classify digital exchange rates
Suga, et al. [29]	Checking the security status of digital currency exchanges and determining general management and security instructions
Jang and Lee [30]	Discovering the problems of IDEX and Bithumb exchanges and setting instructions for improving capabilities
Torres, et al. [22]	Determining the basic features of using mathematical modeling systems to predict digital currency rates
Shah, et al. [12]	Identifying pattern of an attack used to exploit Bitcoin currency platforms using an industrial standard to report information on cyber security breaches
Takahashi and Lakhani [31]	Investigating how to achieve the highest security and multi-layer security analysis for digital currency exchange service providers
Aras [32]	Providing analytical insights to help understand digital currency as a financial asset
Czapliński and Nazmutdinova [11]	Examining the efficiency of digital currency markets and examining Kraken, Bitfinex and Bitstamp exchanges
Shih, et al. [33]	Providing a decentralized transaction solution based on smart contracts on the Ethereum network to support users' trust in digital currency providers
Shah, et al. [12]	Examining the problems of digital currency platforms, problems of custody of customer assets and not abusing them
Kim and Lee [34]	Conducting vulnerability analysis of potential digital currency exchanges and users' walletsInvestigating market risk management methods despite the existence of Blockchain
Sohaib, et al. [35]	Investigating the inflexibility of price changes for 20 digital currency exchanges from 2013 to 2017
Johnson, et al. [36]	Providing an economic model to attract short-term motivations for digital currency exchanges with respect to security investments and transaction costs

Table 1. *Cont.*

Authors	Descriptions
McCorry, et al. [37]	Providing a secure theft mechanism to detect theft from exchanges and block withdrawals
Park, et al. [38]	Providing a method of price forecasting and studying the hidden behaviors of investors
Jay, et al. [39]	Identifying the drivers of competition in digital currency transactions
Li and Wang [40]	Determining the exchange rate of Bitcoin against the US dollar with the help of a combination of time series

One of the advantages of digital currency is its decentralized operation. All activities and values in this market are controlled and evaluated by independent complex programming, and banks or government officials have no authority or control over them. This aspect of digital currency has evaded government intervention and market manipulation [3,4].

Digital currencies can also be traded as real currencies [5]. Traders can use digital currency exchange facilities to convert digital currencies into tangible and physical money, such as dollars, pounds, or euros [10,32]. The major risk at this stage is that hackers can block or tamper with money flow during conversions [41].

In the past, many people invested in stock markets to earn profits. The emergence of cryptocurrencies has allowed many investors to invest in digital currencies for profit [15,42].

2.4. Digital Currencies and Blockchain

Digital currencies based on blockchain technologies have difficulties dealing with alternative currencies [16,30]. Digital exchanges have emerged to make buying, selling, and trading digital currencies convenient. The exchange used an online platform that allowed the exchange of digital currencies from one to another based on their current market values. Similar to trading in traditional financial commodities, profit from digital currencies has become more convenient [43,44].

The essential nature of exchange is its ability to trade various digital currencies effectively and conveniently. The exchanges need to offer buying, selling, loss limit, and other typical trading services; therefore, buying and selling the user's digital currency can be convenient and automatic. With the continued expansion of digital currencies, some large exchanges attempted to provide more facilities, including security for users, margin trading capabilities, over-the-counter (OTC) trading, and futures trading.

Margin transactions are transactions in which the user can borrow money up to a certain multifold of her/his current capital, trade with more capital, and return the exchange money once the transaction is complete—either profit or loss. In the case of loss, the exchange may take his/her assets to compensate for the loss [14,42].

However, the OTC market does not have a central physical location. In this market, transactions are made directly between traders without exchange supervision [42]. OTC offices are popular for people who want to sell large quantities of coins without resorting to exchanges. Currently, many digital currency exchanges offer OTC services.

In digital currency futures trading, the user buys an asset at its future price and deposits his/her money at a time of their choosing. Futures trading allows traders to predict the future asset prices. At the conclusion of a futures trade, both parties involved in the transaction will buy and sell goods and assets at an agreed price [11,13]. The total income of the exchanges is provided by the fees they receive for the services provided. Before registering on the cryptocurrency trade platform of any exchange, the user should research the security confidence of that exchange, previous security breach history (if any), costs and pricing, types of coins available in the exchange, and other factors.

3. Research Methods

The (AHP), developed by Wind and Saaty in 1980 [45], is a set of multiple-criteria decision-making models that analyze post-classification outcomes. The AHP is a structured technique for organizing, analyzing, and making complex decisions based on mathematics and psychology because a decision-maker makes his or her judgments based on knowledge and experience. The AHP has a tree-like hierarchy in which the scales are compared in pairs at the level of this tree, and this action considers the essential aspects of a complex problem. As a result, the AHP's approach is consistent with the decision maker's behavior. This theory is known as the leading theory in multiple-criteria decision-making [45].

The AHP uses several levels of objectives, criteria, sub-criteria, and options. These were then compared using a set of pairwise comparisons. These comparisons are used to calculate the weight of the importance of the decision criteria and the relative performance criteria of the options from each decision criteria perspective [46,47].

To decide and prioritize, we must break down the decision into four steps:

- Defining the problem and determining the knowledge structure of the problem.
- Creating a hierarchical structure of the problem from top to bottom by setting decision goals, intermediate levels, and options.
- Creating a set of pairwise comparison matrices. Each criterion at each level is immediately defined as a comparison factor for its lower level.
- The priorities obtained from the comparisons were used to measure the priorities at the lower level of the matrix. This is done for each element; then, the weighted values are added, and the overall prioritization for each element is obtained at the lower level—this process of weighting and adding continues until the least priority options are determined [46].

This study selected a Delphi panel consisting of 34 people familiar with digital currency exchange platforms and experts with academic credentials in this field. The AHP also utilized Expert Choice software.

Expert Choice software can perform pairwise comparisons and prioritize options more easily. This study employed Expert Choice software to analyze and prioritize the options.

This paper provides an overview of well-known exchanges followed by the selection of performance indices. The subsequent sections address the experimental results and provide further discussion.

3.1. An Overview of the Most Well-Known Exchanges

Several exchanges and trading platforms are available in the digital currency market. Therefore, it is difficult to select one option. The number of digital currency exchange platforms is growing daily, and, according to Deloitte [48], there are more than 34,000 current exchanges with active markets. Of all these exchanges, only a few are well known to the public. They continue to build their reputations and credibility through new updates. This study selected 60 digital currency exchange platforms. Six exchange platforms were further identified based on the criteria of security, user interface, support services, trading volume, and the number of tradable digital currencies [16,48]. The selection also considered the opinions of the expert panel.

This study compares and analyzes the six selected major exchange platforms to make appropriate recommendations.

3.2. Prioritization of Digital Currency Exchange Platforms

Choosing a good and safe exchange is the most important step in using digital currencies. The main goal of this study is to select the best exchange based on a number of known and accepted criteria.

In this case, the selection of the best exchange was analyzed using a multiple-criteria method. This study examined and compared six selected exchange platforms: Coinbase, Binance, Kraken, Bittrex, Cex.io, and Bitstamp.

To select an appropriate exchange for digital trading, some factors and criteria can influence the selection based on expectations and needs. The factors in this research include security, user interface, support services, trading volume, number of tradable digital currencies, and trading fees based on a literature review [16,48], as shown in Figure 1.
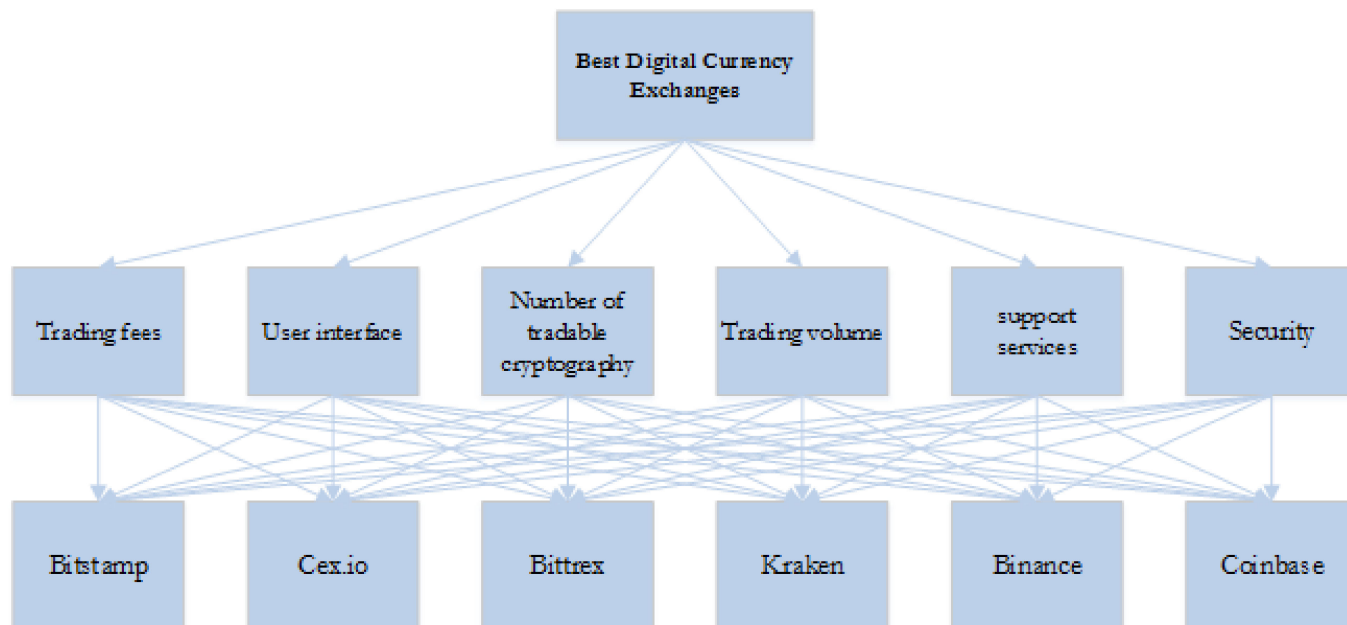

Figure 1. The hierarchical structure of the best exchanges [11–27].

Table 2 lists the literature supporting the selection criteria. The Delphi method was used to learn from the opinions of experts. The Delphi method is a useful research instrument that collects experts' opinions on a specific issue when there is incomplete information or when there are differing opinions. The Delphi method can reach a specific outcome through successive stages of the questionnaire with the anonymity of the experts maintained at every stage [49,50].

Table 2. Results of Delphi research and study on the selection of criteria for prioritizing digital currency exchanges.

Criteria	Research
Security	Rahouti, et al. [9]; Pi, et al. [51]; Roca, et al. [52]
Being user-friendly	Cary [53]; Krishnan, et al. [54]; Wang and Gao [10]
Support services	Cary [53]; Krishnan, et al. [54]; Wang and Gao [10]
Trading volume	Vidal, et al. [55]
Digital currencies	Vidal, et al. [55]
Trading fee	Vidal, et al. [55]

In this study, a Delphi panel asked 34 people who were familiar with digital currency exchange platforms or expert academic members. The Delphi survey was conducted through email to experts for convenience during the COVID lockdowns.
Cary [53]; Krishnan, et al. [54]; Wang and Gao [10]

3.3. Calculation Based on the Proposed Model

After deriving the factors and options, the problem is divided into criteria and options. Our hierarchical model was formed using six criteria and options. The hierarchical structure below shows the goals, options, and criteria for the problem.

Expert Choice software was used to determine the weight of each criterion. We first evaluated each criterion; the more important the criteria are, the more weight they should be assigned. We then evaluated each criterion for each option to calculate the weight of the option (see Table 3). Similarly, the specified weight of each criterion is presented in the table below. Comparisons were stable if the inconsistency rate (CR) was less than 0.1.

Table 3. Criteria's weights.

Criterion	Weight
Security	0.465
User-friendliness	0.046
Support services	0.167
Trading volume	0.139
Number of tradable digital currencies	0.069
Trading fee	0.114

In the next step, information related to each of the criteria for the selected six exchanges was collected, and the evaluation of the criteria was based on their performance history and other information. A decision-making matrix was developed based on the Saaty scale [47] to address this issue. Finally, Table 4 below presents the total score for each exchange, using different criteria.

Table 4. Total score of exchanges.

Criteria	Exchanges					
	Bitstamp	**Cex.io**	**Bittrex**	**Kraken**	**Binance**	**Coinbase**
Security	0.082	0.082	0.270	0.148	0.148	0.270
User-friendliness	0.080	0.366	0.136	0.052	0.136	0.231
Support services	0.415	0.183	0.031	0.77	0.110	0.183
Trading volume	0.075	0.028	0.045	0.099	0.605	0.149
Digital currencies	0.027	0.054	0.349	0.073	0.437	0.061
Trading fee	0.164	0.164	0.164	0.139	0.335	0.033
Overall score	0.133	0.111	0.207	0.126	0.215	0.209

According to Table 2, the best exchange was the Binance Exchange with the highest score of 0.215. The Coinbase Exchange was in second place with a score of 0.209, and Bittrex was in third place with a score of 0.207. Figure 2 shows the sensitivity of exchange performance and the relative importance given to each of the criteria by the decision maker. They can interactively change the length of these bars to understand how the priorities of the software products change. As the length of a bar increases, the weight of the corresponding criterion is increased.
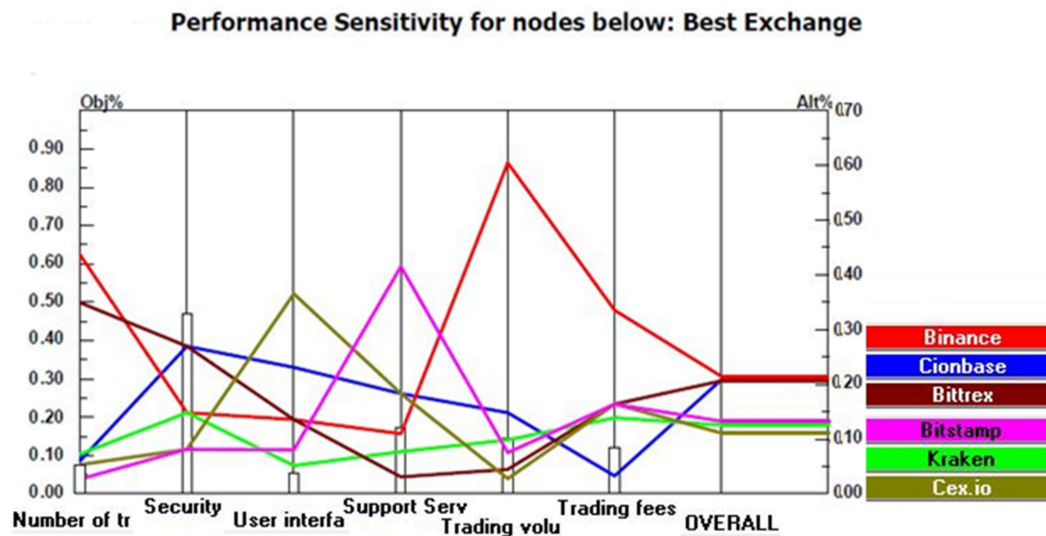
Performance Sensitivity for nodes below: Best Exchange

Figure 2. Performance sensitivities of the exchanges.

4. Discussion

The most important concerns when buying and selling digital currencies are safety and security, and the most critical factor for choosing the right exchange is the security of the exchange. However, other criteria can also affect exchange platform selection. Based on an overview of the literature and expert opinion, security, user-friendliness, support services, volume of exchange trades, number and variety of digital currencies, and trading fees are effective keys in selecting the exchange platform. This study analyzed six major exchange platforms based on these six criteria. As you can see in Figure 2 of the Exchange Performance Analysis, Bitrex Exchange and Coinbase Exchange have higher security scores of 0.270. Third, regarding security, Binance Exchange received a score of 0.148. In terms of user-friendliness, Cex.io Exchange had the highest score of 0.366. Second, Coinbase had a score of 0.231.

According to the evaluation, Bitstamp Exchange offers the best support services, and the score of this exchange in terms of support services is 0.415. According to the trading volume criterion, Binance Exchange had the highest score of 0.605. Binance Exchange was the overall best exchange with a score of 0.215 (see Table 1). With the advancement of technology and the movement of the world towards blockchain, users' interest in buying and selling digital currencies is increasing day by day [56,57]. Following the increase in the selling and buying of digital currencies, users are looking for suitable exchanges with important security factors [58]. In this study, the criteria for security, user-friendliness, support services, trading volume, digital currency, and trading fees were defined according to the research study and experts' opinions in the field of blockchain and digital currencies. Then, six major exchange platforms were reviewed and ranked using the AHP method in Expert Choice software. Some of these indicators are not available to the general public, making this expert system invaluable to the wider public when making informed decisions.

5. Conclusions

This study aimed to develop and deliver an analytic-based system to recommend appropriate digital exchange platform(s) based on expert recommendations. The experts' recommendations were analyzed through a structured analytic hierarchy process. The proposed recommender system should inform and aid the general naïve public to understand and select digital exchanges, so that interruption to digital society is minimized. This research should support human users (who are often left behind in technological advances) to benefit from innovations and disruptions. The overarching contribution of this study is to provide a sustainable solution based on analytics to inform and guide human users for more sustainable future digital communities.

However, in this study, the merits of the six most well-known digital exchange platforms were analyzed based on expert opinions. Human expert opinions were collated and analyzed to build a decision support model that helped identify the most suitable digital exchange platforms using AHP. Such a model can assist the general public in accessing expert opinions through a decision support system. The proposed system can dynamically change its weight values based on external circumstantial changes or changes in expert opinions over time. Such a system is a useful resource for supporting the general public to delve into new emerging technologies in the new era of intelligent systems and digital services.

There are some limitations attributed to this study that should be noted. These limitations stemmed from the research paradigm, approach, and methodology, which is part of the nature of research. First, this quantitative study is based on field data; thus, the generalizability of the research findings to other fields and other contexts is limited. According to Dennis and Valacich [59] applying qualitative and case study methods implies that the research focuses on a non-randomly selected situations and has power in the generalizability of the findings. Nonetheless, this research does not seek to provide generalizable findings from a sample to a population, but rather, it seeks to generalize a particular set of results to a broader theory.

Finally, taking a step further, future research can include more dynamic indicators, such as exchange web network traffic, the daily number of views, wallet type analysis, opinions of a large community of users of each exchange, and user reviews. Therefore, future researchers may opt to interview managers and individuals in several organizations to evaluation of digital currency exchange platforms.

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References

1. Van der Horst, L.; Choo, K.-K.R.; Le-Khac, N.-A. Process Memory Investigation of the Bitcoin Clients Electrum and Bitcoin Core. *IEEE Access* **2017**, *5*, 22385–22398. [CrossRef]
2. Yan, G.; Wang, S.; Yang, Z.; Zhou, Y. Dynamic Game Model for Ranking Bitcoin Transactions Under GSP Mechanism. *IEEE Access* **2020**, *8*, 109198–109206. [CrossRef]
3. Akba, F.; Medeni, I.T.; Guzel, M.S.; Askerzade, I. Manipulator Detection in Cryptocurrency Markets Based on Forecasting Anomalies. *IEEE Access* **2021**, *9*, 108819–108831. [CrossRef]
4. Jagannath, N.; Barbulescu, T.; Sallam, K.M.; Elgendi, I.; Okon, A.A.; Mcgrath, B.; Jamalipour, A.; Munasinghe, K. A Self-Adaptive Deep Learning-Based Algorithm for Predictive Analysis of Bitcoin Price. *IEEE Access* **2021**, *9*, 34054–34066. [CrossRef]
5. Sigaki, H.Y.; Perc, M.; Ribeiro, H.V. Clustering patterns in efficiency and the coming-of-age of the cryptocurrency market. *Sci. Rep.* **2019**, *9*, 1440. [CrossRef]
6. Livieris, I.E.; Kiriakidou, N.; Stavroyiannis, S.; Pintelas, P. An advanced CNN-LSTM model for cryptocurrency forecasting. *Electronics* **2021**, *10*, 287. [CrossRef]
7. Liu, X.F.; Jiang, X.-J.; Liu, S.-H.; Tse, C.K. Knowledge Discovery in Cryptocurrency Transactions: A Survey. *IEEE Access* **2021**, *9*, 37229–37254. [CrossRef]
8. Nghiem, H.; Muric, G.; Morstatter, F.; Ferrara, E. Detecting cryptocurrency pump-and-dump frauds using market and social signals. *Expert Syst. Appl.* **2021**, *182*, 115284. [CrossRef]
9. Rahouti, M.; Xiong, K.; Ghani, N. Bitcoin concepts, threats, and machine-learning security solutions. *IEEE Access* **2018**, *6*, 67189–67205. [CrossRef]

10. Wang, Y.; Gao, J. A regulation scheme based on the ciphertext-policy hierarchical attribute-based encryption in bitcoin system. *IEEE Access* **2018**, *6*, 16267–16278. [CrossRef]

11. Czapliński, T.; Nazmutdinova, E. Using FIAT currencies to arbitrage on cryptocurrency exchanges. *J. Int. Stud.* **2019**, *12*, 184–192. [CrossRef]

12. Shah, A.; Chauhan, Y.; Chaudhury, B. Principal component analysis based construction and evaluation of cryptocurrency index. *Expert Syst. Appl.* **2020**, *163*, 113796. [CrossRef]

13. Corbet, S.; Lucey, B.; Peat, M.; Vigne, S. Bitcoin Futures—What use are they? *Econ. Lett.* **2018**, *172*, 23–27. [CrossRef]

14. Alharbi, A.; Sohaib, O. Technology readiness and cryptocurrency adoption: PLS-SEM and deep learning neural network analysis. *IEEE Access* **2021**, *9*, 21388–21394. [CrossRef]

15. Azizi, N.; Malekzadeh, H.; Akhavan, P.; Haass, O.; Saremi, S.; Mirjalili, S. IoT–Blockchain: Harnessing the Power of Internet of Thing and Blockchain for Smart Supply Chain. *Sensors* **2021**, *21*, 6048. [CrossRef]

16. Akhavan, P. *Digital Currencies: Bitcoin, Blockchain, Base Currencies*; Aati Negar Publication: Tehran, Iran, 2017.

17. Tanwar, S.; Patel, N.P.; Patel, S.N.; Patel, J.R.; Sharma, G.; Davidson, I.E. Deep Learning-Based Cryptocurrency Price Prediction Scheme With Inter-Dependent Relations. *IEEE Access* **2021**, *9*, 138633–138646. [CrossRef]

18. Haass, O.; Azizi, N. Knowledge sharing practice in project-oriented organisations: A practical framework based on project life cycle and project management body of knowledge. *Int. J. Proj. Organ. Manag.* **2019**, *11*, 171–197.

19. Fil, M.; Kristoufek, L. Pairs Trading in Cryptocurrency Markets. *IEEE Access* **2020**, *8*, 172644–172651. [CrossRef]

20. Siddique, S.; Ahsan, A.; Azizi, N.; Haass, O. Students' Workplace Readiness: Assessment and Skill-Building for Graduate Employability. *Sustainability* **2022**, *14*, 1749. [CrossRef]

21. Xia, P.; Wang, H.; Zhang, B.; Ji, R.; Gao, B.; Wu, L.; Luo, X.; Xu, G. Characterizing cryptocurrency exchange scams. *Comput. Secur.* **2020**, *98*, 101993. [CrossRef]

22. Torres, R.; Solis, M.A.; Salas, R.; Bariviera, A.F. A dynamic linguistic decision making approach for a cryptocurrency investment scenario. *IEEE Access* **2020**, *8*, 228514–228524. [CrossRef]

23. Haass, O.; Azizi, N. Challenges and solutions across project life cycles: A knowledge sharing perspective. *Int. J. Proj. Organ. Manag.* **2019**, *12*, 346–379. [CrossRef]

24. Ramos, S.; Pianese, F.; Leach, T.; Oliveras, E. A great disturbance in the crypto: Understanding cryptocurrency returns under attacks. *Blockchain Res. Appl.* **2021**, *2*, 100021. [CrossRef]

25. Azizi, N.; Akhavan, P.; Philsoophian, M.; Davison, C.; Haass, O.; Saremi, S. Exploring the Factors Affecting Sustainable Human Resource Productivity in Railway Lines. *Sustainability* **2021**, *14*, 225. [CrossRef]

26. Moore, T.; Christin, N.; Szurdi, J. Revisiting the risks of bitcoin currency exchange closure. *ACM Trans. Internet Technol.* **2018**, *18*, 1–18. [CrossRef]

27. Alzaatreh, A.; Sulieman, H. On fitting cryptocurrency log-return exchange rates. *Empir. Econ.* **2019**, *60*, 1157–1174. [CrossRef]

28. Alonso-Monsalve, S.; Suárez-Cetrulo, A.L.; Cervantes, A.; Quintana, D. Convolution on neural networks for high-frequency trend prediction of cryptocurrency exchange rates using technical indicators. *Expert Syst. Appl.* **2020**, *149*, 113250. [CrossRef]

29. Suga, Y.; Shimaoka, M.; Sato, M.; Nakajima, H. Securing Cryptocurrency Exchange: Building up Standard from Huge Failures. In *International Conference on Financial Cryptography and Data Security*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 254–270.

30. Jang, H.; Lee, J. An empirical study on modeling and prediction of bitcoin prices with bayesian neural networks based on blockchain information. *IEEE Access* **2017**, *6*, 5427–5437. [CrossRef]

31. Takahashi, H.; Lakhani, U. Multiple Layered Security Analyses Method for Cryptocurrency Exchange Servicers. In Proceedings of the 2019 IEEE 8th Global Conference on Consumer Electronics (GCCE), Kobe, Japan, 15–18 October 2019; IEEE: New York, NY, USA, 2019.

32. Aras, S. Stacking hybrid GARCH models for forecasting Bitcoin volatility. *Expert Syst. Appl.* **2021**, *174*, 114747. [CrossRef]

33. Shih, D.-H.; Wu, T.-W.; Hsu, T.-H.; Shih, P.-Y.; Yen, D.C. Verification of Cryptocurrency Mining Using Ethereum. *IEEE Access* **2020**, *8*, 120351–120360. [CrossRef]

34. Kim, C.Y.; Lee, K. Risk management to cryptocurrency exchange and investors guidelines to prevent potential threats. In Proceedings of the 2018 International Conference on Platform Technology and Service (PlatCon), Jeju, Korea, 29–31 January 2018; IEEE: New York, NY, USA, 2018.

35. Sohaib, O.; Hussain, W.; Asif, M.; Ahmad, M.; Mazzara, M. A PLS-SEM neural network approach for understanding cryptocurrency adoption. *IEEE Access* **2019**, *8*, 13138–13150. [CrossRef]

36. Johnson, B.; Laszka, A.; Grossklags, J.; Moore, T. Economic analyses of security investments on cryptocurrency exchanges. In Proceedings of the 2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), Halifax, NS, Canada, 30 July–3 August 2018; IEEE: New York, NY, USA, 2018.

37. McCorry, P.; Möser, M.; Ali, S.T. Why preventing a cryptocurrency exchange heist isn't good enough. In *Cambridge International Workshop on Security Protocols*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 225–233.

38. Park, S.; Im, S.; Seol, Y.; Paek, J. Nodes in the Bitcoin Network: Comparative Measurement Study and Survey. *IEEE Access* **2019**, *7*, 57009–57022. [CrossRef]

39. Jay, P.; Kalariya, V.; Parmar, P.; Tanwar, S.; Kumar, N.; Alazab, M. Stochastic Neural Networks for Cryptocurrency Price Prediction. *IEEE Access* **2020**, *8*, 82804–82818. [CrossRef]

40. Li, X.; Wang, C.A. The technology and economic determinants of cryptocurrency exchange rates: The case of Bitcoin. *Decis. Support. Syst.* **2017**, *95*, 49–60. [CrossRef]
41. Venter, H. Digital currency—A case for standard setting activity. In *A Perspective by the Australian Accounting Standards Board*; AASB: Melbourne, Australia, 2016.
42. Williamson, S.D. Central bank digital currency: Welfare and policy implications. *J. Political Econ.* **2019**. [CrossRef]
43. Vo, A.; Yost-Bremm, C. A High-Frequency Algorithmic Trading Strategy for Cryptocurrency. *J. Comput. Inf. Syst.* **2018**, *60*, 555–568. [CrossRef]
44. Gao, Y.L.; Chen, X.B.; Chen, Y.L.; Sun, Y.; Niu, X.X.; Yang, Y.X. A secure cryptocurrency scheme based on post-quantum blockchain. *IEEE Access* **2018**, *6*, 27205–27213. [CrossRef]
45. Wind, Y.; Saaty, T.L. Marketing applications of the analytic hierarchy process. *Manag. Sci.* **1980**, *26*, 641–658. [CrossRef]
46. Nerurkar, P.; Patel, D.; Busnel, Y.; Ludinard, R.; Kumari, S.; Khan, M.K. Dissecting bitcoin blockchain: Empirical analysis of bitcoin network (2009–2020). *J. Netw. Comput. Appl.* **2021**, *177*, 102940. [CrossRef]
47. Saaty, T.L. Decision making with the analytic hierarchy process. *Int. J. Serv. Sci.* **2008**, *1*, 83–98. [CrossRef]
48. Akhavan, P.; Dehghani, M. *Blockchain: From Bitcoin to the World of Industry*; Aati Negar Publications: Tehran, Iran, 2019.
49. Zhang, Z.; Dai, H.N.; Zhou, J.; Mondal, S.K.; García, M.M.; Wang, H. Forecasting cryptocurrency price using convolutional neural networks with weighted and attentive memory channels. *Expert Syst. Appl.* **2021**, *183*, 115378. [CrossRef]
50. Lu, Y. Blockchain and the related issues: A review of current research topics. *J. Manag. Anal.* **2018**, *5*, 231–255. [CrossRef]
51. Pi, S.M.; Liao, H.L.; Chen, H.M. Factors that affect consumers' trust and continuous adoption of online financial services. *Int. J. Bus. Manag.* **2012**, *7*, 108. [CrossRef]
52. Roca, J.C.; García, J.J.; De La Vega, J.J. The importance of perceived trust, security and privacy in online trading systems. *Inf. Manag. Comput. Secur.* **2009**, *17*, 96–113. [CrossRef]
53. Cary, M. Down with the #Dogefather: Evidence of a Cryptocurrency Responding in Real Time to a Crypto-Tastemaker. *J. Theor. Appl. Electron. Commer. Res.* **2021**, *16*, 2230–2240. [CrossRef]
54. Krishnan, M.S.; Ramaswamy, V.; Meyer, M.C.; Damien, P. Customer satisfaction for financial services: the role of products, services, and information technology. *Manag. Sci.* **1999**, *45*, 1194–1209. [CrossRef]
55. Vidal, L.-A.; Marle, F.; Bocquet, J.-C. Using a Delphi process and the Analytic Hierarchy Process (AHP) to evaluate the complexity of projects. *Expert Syst. Appl.* **2010**, *38*, 5388–5405. [CrossRef]
56. Wątorek, M.; Drożdż, S.; Kwapień, J.; Minati, L.; Oświęcimka, P.; Stanuszek, M. Multiscale characteristics of the emerging global cryptocurrency market. *Phys. Rep.* **2020**, *901*, 1–82. [CrossRef]
57. Hands, J.; Bessonov, M.; Patel, A.; Smith, R. An inclusive and extensible architecture for electronic brokerage. *Decis. Support. Syst.* **2000**, *29*, 305–321. [CrossRef]
58. Özkan, E.; Azizi, N.; Haass, O. Leveraging Smart Contract in Project Procurement through DLT to Gain Sustainable Competitive Advantages. *Sustainability* **2021**, *13*, 13380. [CrossRef]
59. Dennis, A.R.; Valacich, J.S. Conducting experimental research in information systems. *Commun. Assoc. Inf. Syst.* **2001**, *7*, 5. [CrossRef]