

A Fuzzy SIWEC Methodology for Evaluating the Challenges of Cryptocurrencies in Developing Countries

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ARTICLE INFO

Article history:

Received 12 March 2026

Received in revised form 1 May 2026

Accepted 9 May 2026

Available online 12 May 2026

Keywords:

Cryptocurrencies; fuzzy SIWEC; challenge; developing countries.

ABSTRACT

This study applies a fuzzy simple weight calculation (F-SIWEC) method to systematically assess the challenges of cryptocurrencies in Africa. Data was collected from four domain experts who evaluated six challenges, and the adopted method was then applied to determine the relative importance of each challenge. The findings indicate that market volatility and regulatory uncertainty are the top two critical challenges to cryptocurrencies. Meanwhile, tax considerations and environmental concerns are the least critical challenges. The study makes a meaningful contribution to the decision sciences and management literature by offering practical insights for policymakers and concludes by outlining clear avenues for future research.

1. Introduction

Various countries comprising of Egypt and Algeria, and more recently Thailand, Russia, and Qatar have banned the transactions of cryptocurrencies, yet Bitcoin and other digital currencies have progressively gained considerable international popularity in recent years. For instance, approximately 7% of adults in the United States showed owning and used cryptocurrencies in 2023 [1]. In France, approximately 4.8 million people, held crypto-assets at the start of 2023, and over a quarter showed interest in obtaining them in the future. This tendency is also observed in Africa, which ranks as the second largest area in the world regarding the adoption of cryptocurrency, with nearly 55 million users, behind Asia and North America [2]. Especially, Nigeria stands out, with over 47% of its population evidently using cryptocurrencies, putting it among the countries with the highest degrees of Bitcoin adoption relative to gross domestic product (GDP) [3].

Alongside the quick expansion of these so called “non-regulated digital currencies”, which currently number more than twenty thousand, a rising number of countries are establishing their own state-backed digital currencies, frequently described as sovereign and fundamentally centralized systems. In Africa, this tendency is becoming especially apparent. In Ghana, a pilot project is initiated for its digital currency, the e-Cedi, in September 2021 [4]. Later, in October of the same year, the e-Naira is introduced in Nigeria [5]. In

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<https://doi.org/10.59543/vt0jrv20>

2022, the Central African Republic launched its own digital currency name as the Sango Coin. More recently, Cameroon engaged in discussions by the end of July 2023 to establish a technical and operational abilities required to operate a cryptocurrency platform, partly with the goal of financing some sovereign expenditures in cooperation with neighboring Nigeria. Although various countries are actively pursuing the development of such digital currencies, these initiatives are also accompanied by various emerging risks. Efova *et al.*, [6] presented the opportunities and challenges related to cryptocurrencies in African economies. However, their study failed to prioritize these challenges in order of critical severity. Moreover, their study did not adopt a multi-criteria decision making (MCDM) framework which has been successfully used in various areas [7, 8]. In contrast, the present study goes beyond previous literature by applying an MCDM framework under fuzzy environment tailored to the identification and ranking of the challenges of cryptocurrencies in African economies. Specifically, the study seeks to answer the following research questions: (1) What are the main challenges of cryptocurrencies in this region of the world? (2) How can an MCDM framework enhance decision-making for overcoming these challenges? To support this, a fuzzy simple weight calculation (F-SIWEC) framework is applied in this study to assess these challenges. The objective of the study is to find out the most critical challenges of cryptocurrencies in African economies. The originality of the study lies in the identification and assessment of these challenges under uncertainty. The remaining study is organized in various sections: literature review, problem definition, methodology, application, findings and discussion, and conclusions and future recommendations.

2. Literature review

2.1 Studies related to cryptocurrency

Various studies have been conducted related to cryptocurrency. For instance, Qin *et al.*, [9] established a new wavelet quantile correlation approach to assess the connections of policy uncertainty index of cryptocurrency with those indexes of energy, gold price among distinct time horizons and quantiles. Kim and Fan [10] explored the relations between the usage of social media and attitude related to cryptocurrency behavior. Ke *et al.*, [11] adopted a deep-learning framework to forecast cryptocurrency pin-bar reversal risk events. Lan and Frömmel [12] established and explored an extensive set of risk factors in cryptocurrency pricing. Saeedi and Al-Fattal [13] established a five-dimensional trust framework for cryptocurrency through transparency, regulation, social, technical, and specs aspects. Drăgan *et al.*, [14] assessing the influential parameters to durability cryptocurrency investments, adequately. Baek and Yi [15] investigate the social media content related to marketing of cryptocurrency. Bai *et al.*, [16] determine how the use of credit card is impacted by the cryptocurrency investments in economic downturn times. Rodrigues *et al.*, [17] investigate the enablers and impediments impacting the adoption of cryptocurrency. Ankam and Pattanayak [18] investigating hedging and safe-haven features of cryptocurrencies factors. **Table 1** presents the studies related to cryptocurrencies.

Table 1
 Studies related to cryptocurrencies

Authors	Objective	Methodology
Qin <i>et al.</i> , [9]	Assessing the hedging capacity of gold	New wavelet quantile correlation technique
Kim and Fan [10]	Relationship between crypto investment and social media utilization	Logistic regression
Ke <i>et al.</i> , [11]	Predicting crypto reversal risks	Multi-source deep learning framework
Lan and Frömmel [12]	Assessing the risk factors related to cryptocurrency pricing	Cross-sectional return predictability

Saeedi and Al-Fattal [13]	Exploring trust in cryptocurrency investment	Five-dimensional trust model
Drăgan et al., [14]	Factors influencing sustainable cryptocurrency investment	PLS-SEM; (fsQCA
Baek and Yi [15]	Social media content analysis related to cryptocurrency marketing	Unsupervised latent Dirichlet allocation topic modeling and sentiment analysis
Bai et al., [16]	Investigation of crypto investment during economic downturn	Ordinary least squares regression analysis
Rodrigues et al., [17]	Assessing drivers and barriers to crypto adoption	Mixed method approach
Ankam and Pattanayak [18]	Investigating hedging and safe-haven features of crypto	GARCH and Wavelet quantile correlation

Note: PLS-SEM- Partial least squares structural equation modeling; fsQCA- fuzzy-set qualitative comparative analysis.

2.2 Applications of MCDM to cryptocurrencies related studies

Various scholars have adopted the use of MCDM approaches in crypto related studies. For instance, Ecer *et al.*, [19] assessed the exchanges related to crypto in Türkiye. Shabani *et al.*, [20] applied an empirical approach for assessing and choosing the cryptocurrency funds. Sharma *et al.*, [21] conducted an in-dept analysis to examine the factors that influence the market related to cryptocurrency. Tripathi and Sharma [22] explores how the crypt exchanges show higher liquidity than conventional financial markets. Yang et al., [23] determined the important exchanges and significant aspects related to crypto trading system. Muhiuddin et al., [24] adopted a framework under picture fuzzy rough environment to assess cryptocurrency stock performance. Bulut *et al.*, [25] adopted a hybrid technique for assessing the risk factors related to cryptocurrencies. Pamucar and Biswas [26] used a new integrated approach to compare market performance related to metaverse crypto assets. **Table 2** presents the application of MCDM to the studies of cryptocurrencies.

Table 2
 MCDM applications on cryptocurrencies related studies.

Authors	Objective	Methodology
Ecer <i>et al.</i> , [19]	Assessment of crypto exchanges	FBWM'H-FMARCOS'H
Shabani <i>et al.</i> , [20]	Assessing influential factors to crypto market	DEMATEL, ANP, VIKOR
Sharma <i>et al.</i> , [21]	Assessing influential factors to crypto market	ISM, MICMAC, AHP
Tripathi and Sharma [22]	Assessing the correlation between crypto exchanges and conventional market	MCDM
Yang <i>et al.</i> , [23]	Crypto trading system determination under uncertainty	BWM
Muhiuddin <i>et al.</i> , [24]	Performance of crypto stocks	PFR, MARCOS
Bulut <i>et al.</i> , [25]	Evaluation of risk parameters of crypto	AHP, TOPSIS

Pamucar and Biswas [26]	Comparison of market performance of metaverse crypto assets	LOPCCSA
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Note: **AHP**- Analytic hierarchy process; **ANP**- Analytic Network Process; **BWM**- Best Worst Method; **DEMATEL**- Decision-Making Trial and Evaluation Laboratory; **ISM**- Interpretive Structure Modelling; **MARCOS**- Measurement of Alternatives and Ranking according to Compromise Solution; **MCDA**-Multi-Criteria Decision Analysis; **MICMAC**- Cross-Impact Matrix Multiplication Applied to Classification; **LOPCCSA**- Logarithmic Percentage Change driven Compromise Solution based Appraisal; **VIKOR**- Vlse Kriterijumsk Optimizacija I Kompromisno Resenje.

3. Problem definition

Table 3 outlines the challenges associated with cryptocurrencies in African economies based on the experts’ opinions and previous studies [1, 6, 27].

Table 3
 Challenges associated with cryptocurrencies in Africa

Challenges	References
Security and Fraud Risks (C1)	[1, 6, 27]
Tax Considerations (C2)	
Environmental Concerns (C3)	
Market Volatility (C4)	
Regulatory Uncertainty (C5)	
Lack of Consumer Protection (C6)	

4. Methodology

Puška *et al.*, [28] established a new criteria technique named SIWEC to ease the procedure of finding weight of criteria for decision makers and experts. The evaluation of criteria is done separately in the absence of comparative assessment. Simple steps and procedures are implemented to compute the criteria weights in this technique. Since its adoption, it has been used for African Continental Free Trade Area initiative potential assessment [29], renewable energy adoption [30], green digital technology assessment [31], electric vehicle selection [32], solar energy funding projects [33], transport policy selection [34], tourism in cultural heritages [35], durable logistics and transport systems [36], tourism valorization [37], durable waste disposal technology [38], digital twins technology enhancement [39], and railway infrastructure planning [40]. Fig.1 indicates the flowchart of our methodology.

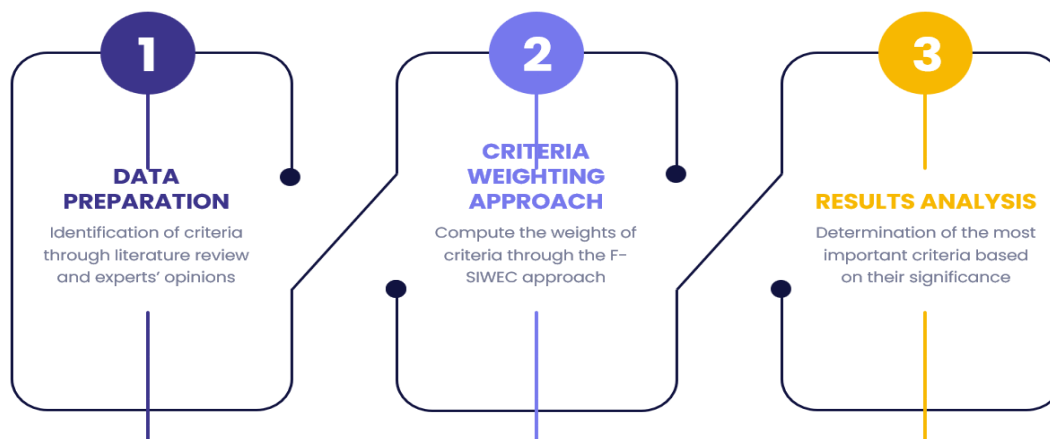


Fig.1. The flowchart of our methodology.
 The steps of fuzzy SIWEC are indicated below.

Step 1. The associated importance of each criterion is evaluated by experts by assigning linguistic variables from **Table 4** to show experts' opinions.

Table 4
 Fuzzy linguistic evaluation scale

Linguistic terms	Membership function
Absolutely bad (AB)	(1,1,1)
Very bad (VB)	(1,2,3)
Bad (B)	(2,3,4)
Medium-bad (MB)	(3,4,5)
Equal (E)	(4,5,6)
Medium-good (MG)	(5,6,7)
Good (G)	(6,7,8)
Extremely good (EG)	(7,8,9)
Absolutely good (AG)	(8,9,10)
Perfect (P)	(9,10,10)

Step 2. Experts presented linguistic assessments which are transformed to triangular fuzzy numbers (TFNs) and defined as lower, middle, and upper bounds, thereby showing the subjectivity in experts' opinions.

$$\tilde{x}_{ij} = (x_{ij}^l, x_{ij}^m, x_{ij}^u) \tag{1}$$

Step 3. The initial fuzzy decision matrix is made based on fuzzy numbers got from the experts' evaluation. Each parameter indicated the observed importance of a defined criterion, comprising the uncertainty through the assessment of linguistics. This matrix shows the basis for criteria weights calculation using the F-SIWEC technique.

$$\begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \dots & \tilde{x}_{2n} \\ \cdot & \cdot & \dots & \cdot \\ \cdot & \cdot & \dots & \cdot \\ \cdot & \cdot & \dots & \cdot \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \dots & \tilde{x}_{mn} \end{bmatrix} \tag{2}$$

Step 4. In this step, fuzzy values are normalized in the decision matrix by dividing them by the higher upper bound ($\max x_{ij}^u$) observed via all criteria and experts.

$$\tilde{n}_{ij} = \frac{x_{ij}^l}{\max x_{ij}^u}, \frac{x_{ij}^m}{\max x_{ij}^u}, \frac{x_{ij}^u}{\max x_{ij}^u} \tag{3}$$

Step 5. The standard deviation (*std.dev_j*) is computed based on fuzzy numbers from experts. This computation indicates consistency or variation in the criteria evaluation, allowing the technique to emphasize criteria where the judgments of experts show greater differentiation, a significant feature of the F-SIWEC technique for showing the related significance under ambiguity.

Step 6. The normalized fuzzy rating is multiplied by the related values of standard deviation to show the normalized fuzzy rating.

$$\tilde{v}_{ij} = \tilde{n}_{ij} \times st.dev_j \tag{4}$$

Step 6. An aggregation of fuzzy weighted values for each parameter is made through the summation of weighted fuzzy assessment offered by all experts. This produced a general representation of each parameter's significance, allowing both independent expert opinions and the ambiguity captured in antecedent steps. The results are an integrated fuzzy weight for each parameter, which becomes a foundation for finding the final significance rankings.

$$\tilde{S}_{ij} = \sum_{j=1}^n \tilde{v}_j \tag{5}$$

Step 8. There is a division of each independent fuzzy value by total sum of all fuzzy values to acquire the normalized fuzzy weight for each parameter. During this procedure, it is important to guarantee that the lower bound is less or equal to the middle value. This is possible only if the logical order of the fuzzy numbers is maintained.

$$\tilde{w}_{ij} = \frac{S_{ij}^l}{\sum_{j=1}^n S_{ij}^u}, \frac{S_{ij}^m}{\sum_{j=1}^n S_{ij}^m}, \frac{S_{ij}^u}{\sum_{j=1}^n S_{ij}^l} \tag{6}$$

Step 9. There is a retention in the final fuzzy weights of each criterion through their fuzzy form or de-fuzzified into crisp values, based on the analytical necessities. In this study, there is a de-fuzzified of fuzzy weights employing a suitable defuzzification approach to transfer each fuzzy number into a unique representative value.

$$w_{jdef} = \frac{w_{ij}^l + 4 \times w_{ij}^m + w_{ij}^u}{6} \tag{7}$$

5. Application

A three-step methodological approach based on the F-SIWEC procedure is adopted to establish data-driven assessment of challenges associated with cryptocurrencies in Africa economies. With the goal to generate a comprehensive guideline for the exploration of this study, six challenges have been found from experts' opinions and literature review. A panel of four experts in the banking sector have been involved. Fuzzy weights are derived from a linguistic decision matrix based on expert evaluations of each challenge, as summarized in **Table 5**, which presents the initial judgments of the four experts.

Table 5

Linguistic decision-making matrix

	C1	C2	C3	C4	C5	C6
E1	AG	MG	E	P	P	G
E2	G	E	MB	AG	AG	MG
E3	G	E	MB	P	AG	G
E4	G	E	B	P	AG	MG

In order to establish an original fuzzy decision matrix based on the opinions of the experts, the data are first normalized to guarantee comparability on a basic scale. Following the F-SIWEC approach, each TFN was divided by the highest upper-bound value across all strategies for each expert, mapping the values into the [0, 1] range. This normalization keeps the proportional relationships among the initial evaluations while removing scale-related bias. The resulting initial and normalized fuzzy decision matrices are presented in **Table 6** and represent the basis for obtaining weights of challenges in the next stage.

Table 6

Normalized fuzzy decision-making matrix

	E1	E2	E3	E4
C1	(0.8, 0.9,1.0)	(0.6, 0.7,0.8)	(0.6, 0.7,0.8)	(0.6, 0.7,0.8)
C2	(0.5, 0.6,0.7)	(0.4, 0.5,0.6)	(0.4, 0.5,0.6)	(0.4, 0.5,0.6)
C3	(0.4, 0.5,0.6)	(0.3, 0.4,0.5)	(0.3, 0.4,0.5)	(0.2, 0.3,0.4)
C4	(0.9, 1.0,1.0)	(0.8, 0.9,1.0)	(0.9, 1.0,1.0)	(0.9, 1.0,1.0)
C5	(0.9, 1.0,1.0)	(0.8, 0.9,1.0)	(0.8, 0.9,1.0)	(0.8, 0.9,1.0)
C6	(0.6, 0.7,0.8)	(0.5, 0.6,0.7)	(0.6, 0.7,0.8)	(0.5, 0.6,0.7)

After normalization, the F-SEWIC method integrates expert consensus by multiplying each normalized fuzzy value by the corresponding standard deviation, thereby embedding opinion variability into the weighting process. This gives greater importance to challenges where expert views diverge, reflecting their contextual

sensitivity. The adjusted values are then summed, as shown in **Table 7**, to produce the first-level fuzzy weights for each challenge while preserving uncertainty. During these calculations, the triangular fuzzy structure was maintained so that each weight satisfies the condition (lower bound \leq mode \leq upper bound).

Table 7
 Obtaining final values of the criteria by using fuzzy SIWEC method

Barriers	\tilde{S}_{ij}	\tilde{W}_{ij}
C1	(0.57,0.66,0.75)	(0.14,0.18,0.23)
C2	(0.37,0.46,0.55)	(0.09,0.12,0.17)
C3	(0.26,0.35,0.44)	(0.06,0.09,0.14)
C4	(0.77,0.86,0.88)	(0.18,0.23,0.27)
C5	(0.73,0.81,0.88)	(0.17,0.22,0.28)
C6	(0.48,0.57,0.66)	(0.11,0.15,0.20)

The results displayed in **Fig. 2** for the defuzzified barriers' weights suggest a clear ranking regarding the perceived influence of the challenges associated with cryptocurrencies.

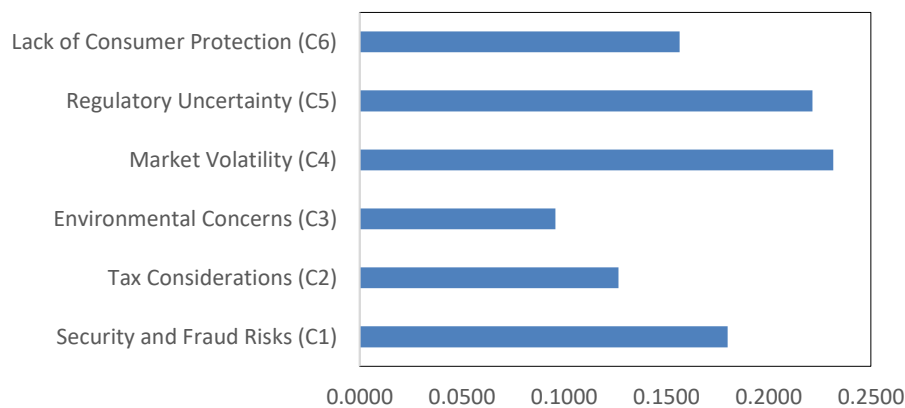


Fig.2. Challenges associated with cryptocurrencies.

6. Findings and discussion

This study provides insights into the adoption of fuzzy simple weight calculation technique for thoroughly identifying and prioritizing the challenges of cryptocurrencies in Africa economies. Through the implemented technique, market volatility (C4) is the most critical challenge to cryptocurrencies in Africa. This is due to the great instability and unpredictability degrees that characterize the digital currencies levels. In Africa, economies of countries frequently struggle with financial instability, currency devaluation, and inflation, which are vulnerable to the critical price variations associated with cryptocurrencies like Ethereum and Bitcoin. This volatility not only makes it complicated to utilize crypto as an adequate store of value or medium of exchange but also undermines the trustworthiness of independent investors and businesses. In regions where there is a restriction in access to conventional banking services and financial literacy, the added complexity of controlling greatly volatile assets can disappoint adoption. Additionally, in the absence of regulatory frameworks, investors in Africa are frequently exposed to the risks of sudden markets shifts in the absence of adequate protection, aggravating the challenges posed by crypto volatility.

The second most critical challenge is the "regulatory uncertainty (C5)". This is due to the absence of clear legal frameworks for their usage, which impede adoption and innovation. Many governments in Africa are still assessing how to regulate digital currencies, with some countries' outright bans or imposing restrictions. This uncertainty produces risks for businesses and investors who are uncertain about the legal implications of

engaging with cryptocurrencies. The absence of adequate regulations also leads to a risen vulnerability to scams and fraud, diminishing public trust and impeding larger financial inclusion.

7. Comparative analysis

To validate the robustness and reliability of the evaluation of the challenges of cryptocurrencies in this area of the globe, a comparative analysis was performed using the fuzzy stepwise weight assessment ratio analysis (F-SWARA) and the fuzzy criteria importance through intercriteria correlation (F-CRITIC) methods. These techniques were selected to provide multi-dimensional validation; while F-SWARA captures the direct subjective expertise of the decision-makers, F-CRITIC extracts weights based on the objective contrast and correlation within the data matrix. As illustrated in the final results presented in **Fig.3**, both techniques yielded a consistent ranking order for all sub-criteria across the four SWOT categories. This mathematical convergence provides compelling evidence for the stability of the established hierarchy. The high degree of rank correlation confirms that the identified priorities are not artifacts of a specific mathematical model.

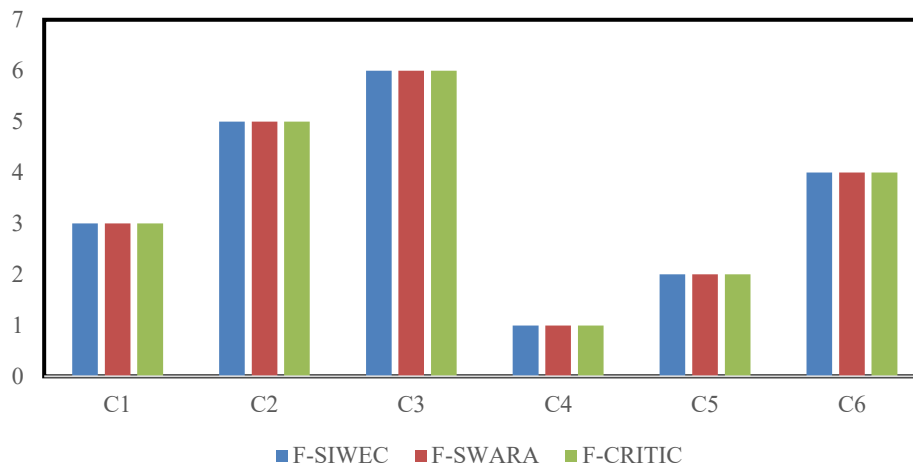


Fig. 3. A comparative analysis of approaches.

8. Conclusions and recommendations

In this study, a fuzzy SIWEC methodology is used to evaluate the challenges of cryptocurrencies in Africa. For that, six challenges are identified based on experts' opinions and literature review. To collect the data, four experts are involved. The results indicated that market volatility is considered as the most critical challenge, followed by regulatory uncertainty. While the study has made some contributions, it has some limitations. First, a small number of experts participated. Second, the study is conducted at continental level. Future studies should consider increasing the number of experts, conducting the study at national or regional levels. In addition, new methodology can be adopted using an integration of data envelopment analysis (DEA) and fuzzy logic [41]. Moreover, the methodology proposed in this paper can be further extended using frameworks such as hyper fuzzy sets [42] and super hyper fuzzy Sets [43].

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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