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An Integrated Fuzzy-BWM-TOPSIS with Chebyshev Distance Approach for Risk Evaluation in E-Business Cooperation

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Abstract: The remarkable expansion of e-business partnership between China and West Africa, especially Ghana, offers significant prospects for mutual economic and technological progress. Still, these collaborations encounter a multifaceted array of institutional, technological, sociological, and legal concerns that may compromise efficiency, trust, and long-term viability. This study assesses these risks utilizing data from 40 experts in Ghana's consumer electronics, telecommunications, digital payments, and online retail industries. A comprehensive methodology integrating Fuzzy logic, the Best-Worst Method (BWM), and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) utilizing Chebyshev distance, was established to rank risks. The findings indicate that institutional obstacles, including insufficient digital transaction legislation and poor data governance, represent the most substantial barriers, closely followed by technology issues encompassing cybersecurity risks and infrastructural deficiencies. Cultural disparities, linguistic obstacles, and divergent customer behaviors hamper international business, while legal ambiguities in intellectual property safeguarding and contract enforcement intensify risk. This research utilizes Transaction Cost Theory, the Technology Acceptance Model, and Commitment-Trust Theory to provide a complete framework for understanding how these risks increase transaction costs and impede the practicality of cross-border e-business. The findings offer practical insights for governments, industry leaders, and investors aiming to reduce risks, enhance trust, and foster a robust digital commerce ecosystem between China and the West.

Keywords: Risk Mitigation, Best-Worst Method (BWM), TOPSIS, Fuzzy Logic, Chebyshev Distance

1. Introduction

The rapid expansion of e-business has fundamentally transformed international trade, creating new opportunities and challenges, particularly in the interactions between developed and emerging economies. As a global leader in digital infrastructure and technology, China has leveraged its vast consumer base, advanced logistics, and innovative platforms to dominate the global digital economy [1]. In parallel, West Africa, led by Ghana's emergence as a digital hub, has become an increasingly attractive market for e-business growth. Ghana's strategic location, youthful population, and proactive digital policies position it as a gateway for international digital commerce in the region [2]. Two major initiatives underscore the relevance of this partnership: the African Continental Free Trade Area (AfCFTA) and China's Belt and Road Initiative (BRI). The AfCFTA, headquartered in Ghana, aims to establish a unified market for goods and services across Africa, promoting economic integration and facilitating cross-border trade, particularly in the digital and e-commerce sectors [3]. The BRI, meanwhile, promotes infrastructural and digital connectivity, offering Chinese businesses a platform to expand their digital services throughout Africa. Together, these initiatives are reshaping the landscape of China-West Africa e-business cooperation, promising mutual economic growth, technological advancement, and increased market access. However, despite these promising prospects, the partnership faces significant and multifaceted risks. Technological vulnerabilities, such as cybersecurity threats and digital infrastructure gaps, expose businesses to data breaches and operational disruptions. Regulatory inadequacies, including inconsistent digital transaction frameworks and weak data governance, create uncertainty for cross-border transactions. Legal uncertainties, particularly around data protection, privacy, and intellectual property, further complicate business operations. Sociocultural differences, such as language barriers, divergent consumer behaviors, and cultural misalignments in digital platforms, add another complexity to cross-border e-business [4]. These risks are not merely theoretical; they have tangible impacts on the efficiency, trust, and sustainability of e-business collaborations. They increase transaction costs, deter investment, and limit the potential for innovation and growth. For Chinese businesses operating in Ghana and the broader West African market, these challenges can result in competitive disadvantages, stalled projects, and missed opportunities for both sides. While previous research has explored various aspects of e-business and digital trade, a critical gap remains: there is no comprehensive, systematic framework for identifying, categorizing, and prioritizing the specific risks associated with China-West Africa e-business cooperation. Existing studies address these risks in isolation or focus on broader economic or technological factors, without integrating them into a cohesive risk management model tailored to this unique context. This absence of a holistic risk assessment limits the ability of policymakers, business leaders, and investors to develop targeted strategies that can effectively mitigate risks and foster sustainable cross-border e-business growth. While this study is grounded primarily in Transaction Cost Theory (TCT), which explains how various risks elevate transaction costs in cross-border e-business, it also draws on the Technology Acceptance Model (TAM) and Commitment-Trust Theory to capture the behavioral and relational dimensions of risk in digital trade. This integrated framework enables a more comprehensive understanding of how institutional, technological, sociocultural, and legal risks interact to shape e-business outcomes between China and West Africa [5]. By applying this integrated framework with TCT as its anchor, this research provides a robust theoretical lens for understanding how institutional, technological, sociocultural, and legal risks translate into increased transaction costs and how these can be managed for more efficient and sustainable cooperation. From a practical perspective, the study responds to the urgent need for actionable insights in risk management. As digital trade between China and Ghana accelerates, public and private sector stakeholders require evidence-based tools to identify, prioritize, and address the most pressing risks. This is essential not only for protecting investments and ensuring compliance but also for building trust, enhancing competitiveness, and supporting the long-term sustainability of e-business partnerships.

The structure of the paper is as follows. Section 2 presents a review of the literature. In Section 3, the methodology of the study is presented. Section 4 presents the results. Section 5 concludes the research.

2. Literature Review

2.1. The Concept of China-West Africa Cooperation

The cooperation between China and West Africa in e-business represents a dynamic and multifaceted partnership that transcends traditional trade, including technological transfer, capacity building, and infrastructural development. This collaboration is deeply embedded within broader strategic frameworks such as China's Belt and Road Initiative (BRI) and the Forum on China-Africa Cooperation (FOCAC), which collectively aim to enhance economic integration and connectivity across Africa [6]. The BRI, in particular, has been instrumental in promoting digital trade by investing heavily in digital infrastructure such as broadband networks, data centers, and smart logistics hubs that are essential for the efficient functioning of e-business platforms [7]. Ghana exemplifies this cooperation's potential as one of West Africa's most digitally advanced countries and a regional hub for e-commerce and digital innovation. Its strategic location, youthful and tech-savvy population, and proactive government policies have positioned Ghana as a gateway for China's digital expansion into West Africa [8]. The African Continental Free Trade Area (AfCFTA), headquartered in Ghana, further amplifies this potential by creating a unified market for goods and services, including digital products, across the continent [9]. This synergy between AfCFTA and BRI initiatives underscores the strategic importance of Ghana in China-West Africa e-business cooperation. Capacity building is another critical dimension of this partnership. Initiatives such as the Beijing Declaration of the Ministerial Forum of China-Africa Health Development emphasize vocational and technical training to enhance human capital in digital skills, vital for sustaining e-business growth [10]. These efforts address the skills gap that often hampers adoption and effective use of digital technologies in emerging economies. Despite these promising developments, significant challenges remain. Regulatory gaps, including inconsistent digital trade policies and weak enforcement mechanisms, create uncertainty for businesses operating across borders. Cybersecurity threats pose risks to data integrity and consumer trust, while the digital divide, especially between urban and rural areas, limits equitable access to e-business opportunities [11]. These challenges highlight the necessity of collaborative governance frameworks that ensure the equitable distribution of benefits, strengthen local capacities, and manage risks effectively. This study is situated within this context, aiming to identify and prioritize the risks faced by Chinese e-business firms in Ghana, thereby contributing to more sustainable and mutually beneficial cooperation.

2.2. E-Business Risks in China-West Africa Cooperation

The rapid expansion of China-West Africa e-business cooperation over the past two decades has brought significant economic opportunities and a complex array of risks that threaten operational success and sustainability. Understanding and managing these risks is crucial for reducing transaction costs, building trust, and fostering long-term growth in digital trade. Institutional Risks are paramount among these challenges. They stem from the quality, stability, and coherence of the institutional environment in which e-businesses operate [12]. In Ghana and the broader West African context, the absence of comprehensive e-business policies, inadequate digital transaction regulations, limited data governance, and weak e-government support create an unpredictable business environment [13]. According to Transaction Cost Theory (TCT), such institutional weaknesses increase uncertainty and information asymmetry, escalating transaction costs related to searching for reliable partners, negotiating contracts, and enforcing agreements [14]. The study's empirical findings confirm institutional risk as the most significant concern, with issues like inadequate digital transaction regulations and insufficient data governance receiving the highest priority. This underscores the urgent need for policy harmonization and institutional strengthening to facilitate smoother digital transactions and reduce operational uncertainties. Technological Risks encompass challenges related to adopting, implementing, and managing technology in e-business operations [15]. These include cybersecurity threats, a lack of skilled IT personnel, and deficiencies in digital infrastructure, such as unreliable internet connectivity and inadequate payment systems. In Ghana, despite notable progress, digital infrastructure gaps and cybersecurity vulnerabilities remain critical barriers to seamless e-business operations. TCT explains that these technological vulnerabilities increase operational uncertainties and the likelihood of disruptions, translating into higher transaction costs due to additional safeguards, monitoring, and recovery mechanisms [16]. Addressing these risks requires investments in hardware and software, human capital development, and robust cybersecurity protocols. Sociocultural Risks arise from interacting with diverse cultural, social, and behavioral norms across China and West Africa. Language barriers, differences in consumer behavior, cultural misalignments in user experience design, resistance to digital payment methods, and perceptions of digital neo-colonialism complicate trust-building and cooperation. These factors increase uncertainty and opportunistic behavior, elevating transaction costs as firms expend more resources on communication, adaptation, and conflict resolution. The study highlights that sociocultural risks significantly affect cross-border e-business operations, emphasizing the need for culturally sensitive strategies and localized digital solutions to mitigate these challenges and enhance cooperation. Legal Risks involve uncertainties related to the legal and regulatory frameworks governing e-business transactions [17]. In West Africa, limited cybercrime legislation, intellectual property rights enforcement challenges, and divergent legal cultures create an unstable legal environment for Chinese firms. These weaknesses increase compliance costs and complicate contract enforcement, consistent with TCT's view that legal uncertainty inflates monitoring and enforcement costs [18]. Strengthening legal frameworks and harmonizing regulations are thus critical for reducing legal risks and fostering a secure environment for e-business cooperation. The study's focus on Ghana leverages its strategic importance as a digital hub in West Africa, making the findings highly applicable for policymakers and business leaders aiming to foster sustainable e-business growth. The research offers actionable insights that enable targeted risk management by employing a hierarchical decision model and the Best-Worst Method (BWM) to prioritize risks. This approach addresses a critical gap in the literature, which often treats e-business risks in isolation without a systematic framework tailored to the unique China-West Africa context.

2.3. Theoretical Framework

This study integrates Transaction Cost Theory (TCT) as the primary economic framework, complemented by the Technology Acceptance Model (TAM) for behavioral insights and Commitment-Trust Theory for relational dynamics. This triad addresses institutional, technological, sociocultural, and legal risks holistically.

2.3.1. Transaction Cost Theory (TCT)

Transaction Cost Theory (TCT), pioneered by Fragomeni et al. [19], asserts that organizations exist to minimize the costs associated with economic exchanges. As the core lens, TCT explains how institutional and legal risks amplify transaction costs through uncertainty and enforcement challenges. For example, Ghana's regulatory gaps force firms to invest in due diligence, raising operational costs [20]. These transaction costs include searching for information, negotiating and enforcing contracts, monitoring compliance, and managing opportunism. In cross-border e-business, these costs are amplified by institutional voids, regulatory inconsistencies, information asymmetry, and cultural distance. In China-West Africa e-business cooperation, TCT is especially salient. This study's empirical findings, based on a sample of 40 e-business managers and practitioners across Ghana's consumer electronics, telecommunications, digital payment, and online retail sectors, reveal that institutional risks are the most significant barrier to efficient cross-border e-business (global weight: 0.363). For example, the absence of coherent e-business policies, inadequate digital transaction regulations, and limited data governance create an unpredictable and uncertain environment. These institutional weaknesses force firms to spend more resources on due diligence, compliance, and dispute resolution, which raises the overall cost of doing business. Moreover, the lack of harmonized regulatory frameworks between China and Ghana means that Chinese firms must navigate a patchwork of local rules, often without clear guidance or legal recourse. This increases compliance costs and exposes businesses to the risk of regulatory arbitrage and sudden policy shifts. From a TCT perspective, these risks make the market less attractive for investment and innovation, as firms must allocate more resources to risk mitigation rather than value creation. TCT also illuminates the importance of reducing information asymmetry and uncertainty. In Ghana, for instance, inconsistent enforcement of digital transaction regulations and data privacy laws can make it difficult for Chinese firms to verify the legitimacy of local partners or ensure the security of cross-border data flows. This increases the risk of opportunistic behavior and fraud, further elevating transaction costs. This study operationalizes TCT by systematically ranking and prioritizing the risks that most significantly elevate transaction costs by employing a hierarchical decision model and the best-worst method (BWM). The insights generated are actionable, enabling managers and policymakers to target institutional reforms and capacity-building initiatives that directly address the most critical sources of inefficiency and uncertainty in the e-business environment. This approach advances theoretical understanding and offers practical risk management tools in rapidly evolving digital markets.

2.3.2. Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), introduced by Unal and Uzun [21], provides a behavioral lens for understanding how individuals and organizations adopt and use new technologies. TAM extends TCT by addressing how technological risks (e.g., cybersecurity gaps) influence perceived usefulness and ease of use. This behavioral layer explains why infrastructural deficits in Ghana elevate transaction costs via low adoption rates. TAM posits that two primary factors, perceived usefulness and perceived ease of use, determine whether a technology will be accepted and integrated into daily operations. This model is especially relevant in digital transformation in emerging markets, where technological readiness and user acceptance are not always guaranteed. Despite significant progress in digital infrastructure in Ghana, technological risks remain a substantial barrier to the widespread adoption of e-business solutions (global weight: 0.286). The study's participants highlighted challenges such as a lack of IT expertise, cybersecurity threats, and persistent deficiencies in digital infrastructure. These issues directly impact perceived ease of use and usefulness, as unreliable internet connectivity, frequent system downtimes, and inadequate technical support can frustrate users and erode confidence in digital platforms. Sociocultural factors further compound these technological challenges. Language barriers, resistance to online payments, and cultural misalignments in user interface design can make digital platforms seem alien or untrustworthy to local consumers. For instance, Ghana's diverse linguistic landscape and varying levels of digital literacy mean that platforms designed for Chinese or Western markets may not resonate with Ghanaian users. As a result, even technologically sound solutions may fail to gain traction if they are not tailored to local preferences and needs. TAM also highlights the importance of user training and capacity-building. The lack of IT expertise among business operators and consumers often leads to under utilizing digital tools, even when infrastructure is available. The study's findings underscore the need for targeted interventions such as digital literacy programs, localized user support, and culturally adapted interface design to enhance perceived ease of use and usefulness among Ghanaian users. By incorporating TAM into the analysis, this study recognizes that risk management in e-business must go beyond technical fixes. It must also address the psychological and social dimensions of technology adoption. This means investing in user education, localizing digital content, and designing intuitive and culturally relevant interfaces. The study's findings underscore the importance of integrating the technical and human factors influencing e-business success.

2.3.3. Commitment-Trust Theory

Commitment-Trust Theory resolves TCT's limitations in sociocultural contexts by emphasizing trust as a cost-reduction mechanism. For instance, legal ambiguities in Ghana are mitigated through relational capital, reducing enforcement costs. Commitment-Trust Theory, articulated by Vtmnescu et al. [22], emphasizes that successful business relationships, especially in cross-border and digital contexts, are built on two foundational pillars: commitment and trust. In environments characterized by legal uncertainty, regulatory inconsistency, and cultural diversity, trust becomes a critical asset that can reduce perceived risks and facilitate long-term cooperation. Legal risks, such as limited cybercrime legislation, weak intellectual property protection, and divergent legal cultures, were identified by study participants as significant obstacles to building trust between Chinese and Ghanaian partners (global weight: 0.174). For example, Ghana's lack of clear legal frameworks for digital transactions and data protection creates ambiguity around liability, dispute resolution, and enforcement. This uncertainty can deter investment and limit the willingness of firms to enter into long-term collaborations. Commitment-trust theory suggests that building and sustaining trust requires more than formal contracts. It involves transparent communication, shared values, and consistently demonstrating reliability and fairness. In the context of China-Ghana e-business cooperation, firms must invest in relationship-building activities, such as joint training programs, regular stakeholder engagement, and the co-creation of culturally sensitive business practices. The theory also highlights the role of social capital in mitigating legal and sociocultural risks. By fostering networks of mutual support and shared understanding, firms can create informal mechanisms for dispute resolution and knowledge sharing that complement formal legal structures. The study's findings reinforce that trust and commitment are desirable outcomes and essential prerequisites for sustainable and mutually beneficial e-business partnerships. Furthermore, Commitment-Trust Theory provides a framework for understanding how reputational capital and long-term orientation can substitute for formal legal protections in environments where the latter are weak or absent. In Ghana, where enforcement of digital contracts and intellectual property rights may be inconsistent, a business partner's reputation and demonstrated reliability can be a decisive factor in establishing and maintaining successful e-business relationships. By synthesizing TCT, TAM, and Commitment-Trust Theory, this study advances the literature on international e-business risk management. This unified framework allows for a nuanced prioritization of risks that considers not only transaction costs but also user acceptance and the critical role of trust and commitment in cross-border digital partnerships. TCT anchors the risk framework economically, while TAM explains technology-adoption behaviors, and Commitment-Trust Theory navigates sociocultural and legal uncertainties. This integration offers a complete transaction-cost analysis for cross-border e-business. Using the Best-Worst Method (BWM) to systematically rank risks, supported by real-world data from Ghana's e-business sector, enables managers and policymakers to allocate resources more effectively and design targeted interventions. For example, the study's results suggest that reforms to digital transaction regulations and investments in IT capacity-building should be prioritized, followed by initiatives to localize digital platforms and strengthen legal protections for e-business.

3. Methodology

This study investigates e-business risks in China-West Africa cooperation, focusing on Ghana as a case study due to its status as one of the most digitally advanced countries in the region. The research targeted e-business managers, practitioners, and stakeholders across four key sectors: consumer electronics, telecommunications, digital payment, and online retail. A total of 40 participants were included in the final analysis. These respondents were selected for their direct involvement in e-business operations and decision-making, ensuring that the data reflected expert perspectives on risk management in the Ghanaian digital economy. Many multi-criteria decision-making (MCDM) methods have been developed and applied in various fields, but there is insufficient research on the application of MCDM in the E-business supply chains, especially in the context of China-West African E-business cooperation. To fill this gap, we utilized a hybrid integration of MCDM techniques to incorporate management decision-making in a multi-criteria framework. We utilized the preliminary ideas in the Analytic Hierarchy Process (AHP) approach proposed by Saaty T. L [23], the Best West Method developed by Rezaei [24] and the Technique for Order Preference by Similarity to Ideal Solution(TOPSIS) approach as proposed by Hwang, C. L. & Yoon, K. [25] in this study. Zhao et al. [31] proposed a hesitant best-worst framework in risk evaluation and prioritization. Liu et al. [26] also applied the AHP-TOPSIS method in Dynamic Supply Chain Decision-Making of Live E-Commerce Considering Netflix Marketing Under Different Power Structures, examining the complexity of decision-making in live e-commerce supply chains, specifically regarding Netflix-inspired marketing strategies, following the model functional assumptions in the work of Gadafi et al. [27]. They modelled the Ethereum price dynamics using a Poisson-Gaussian stochastic model.

3.1. Data Collection Procedure and Sampling

A structured and systematic data collection process was employed to ensure the reliability and validity of the findings on e-business risks in China-West Africa cooperation, with Ghana as a focal case. The study was conducted between January and March 2025, during a period when Ghana's digital sector was experiencing significant growth and transformation. The choice of this timeframe was strategic, as it allowed the research to capture current perspectives from industry practitioners actively engaged in cross-border e-Business operations. The data collection process began with the identification and recruitment of suitable participants. A purposive-sampling strategy was employed to target e-business managers, practitioners, and stakeholders from key sectors, including consumer electronics, telecommunications, digital payments, and online retail, who have direct experience and decision-making authority in digital trade and risk management. This approach aligns with best practices in multi-criteria decision-making research, where expert input is critical for robust risk assessment. A total of 55 invitations were sent to potential participants. Each invitation included a detailed cover letter that described the objectives of the study, the importance of their participation, and assurances about confidentiality and voluntary participation. The cover letter also explained how the data would be used exclusively for academic research and that all responses would be anonymized to protect participants' identities and business interests.

The primary data collection instrument was a structured online questionnaire, designed and administered through the Qualtrics platform. This choice was motivated by several factors: it enabled efficient data management, provided respondents with flexible access, and supported high-quality data collection from busy professionals across different locations in Ghana. The questionnaire was divided into three sections: (1) sociodemographic information, (2) risk evaluation items covering institutional, technological, sociocultural, and legal domains, and (3) Fuzzy logic-BWM-TOPSIS with Chebyshev distance, a preference elicitation section, where participants ranked and rated the relative importance of each risk category. Of the 55 invitations sent, 43 completed questionnaires were received, resulting in a strong response rate of 78.2%. This high participation rate underscores the relevance of the research topic to the targeted professional community. Upon receipt, the responses were subjected to a rigorous quality control process to ensure completeness and consistency. Three responses were excluded due to incomplete responses or inconsistencies in the BWM ranking process, leading to a final sample of 40 valid and reliable responses. This final sample size is consistent with recommendations in the BWM and decision-making literature, which emphasize the importance of expert input over sheer numbers for risk prioritization studies.

Table 1. *Demographic Characteristics of Respondents.*

Characteristic	Category	Frequency(n)	(%)
Gender	Male	28	70
	Female	12	30
Age (years)	20–29	8	20
	30–39	15	37.5
	40–49	11	27.5
	50–59	6	15
Sector	Consumer Electronics	12	30
	Telecommunications	14	35
	Digital Payment	6	15
	Online Retail	8	20

Table 1 shows that the sample included male and female participants, with a slightly higher proportion of males (70%). The age distribution ranged from 20 to 59 years, with the majority (37.5%) falling within the 30-39 age bracket. This age range suggests most respondents are likely experienced professionals in their respective fields. The sector distribution reflects the study's focus on key e-business areas: consumer electronics (30%), telecommunications (35%), digital payment (15%), and online retail (20%). This distribution ensures that the study captures insights from a wide range of e-business activities in Ghana. Figure 1 illustrates the visual representation of the respondents in this study.

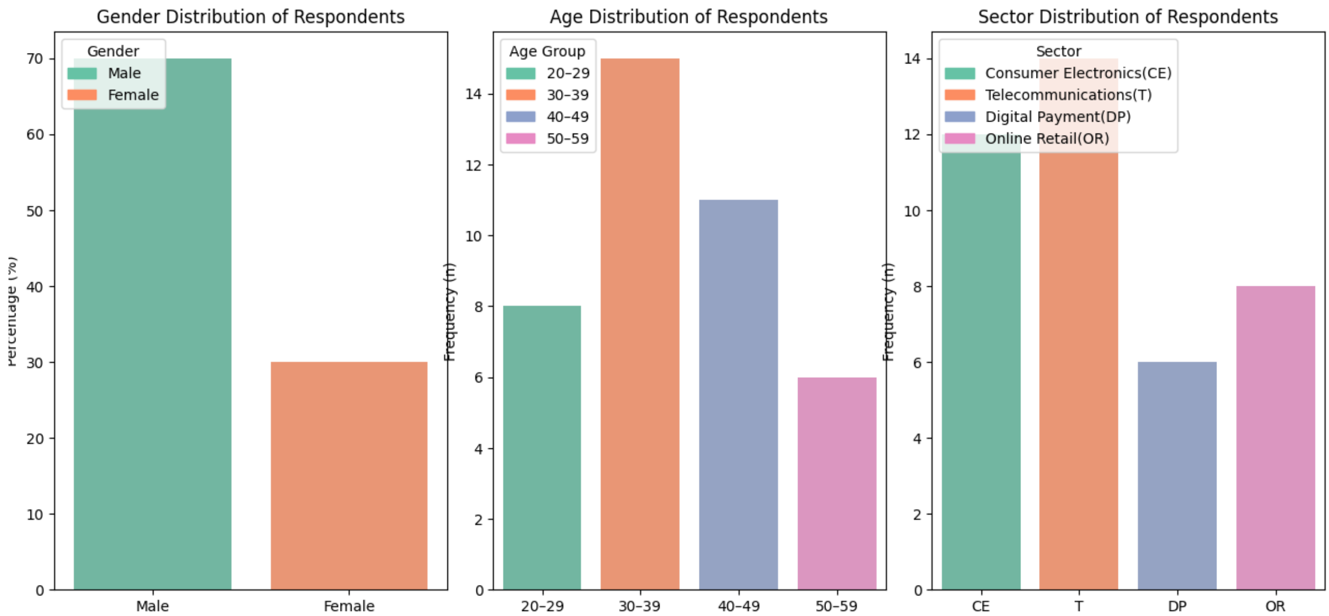

Figure 1. *Demographic Characteristics Visualization.*

3.2. Risk Assessment Items

The core of the questionnaire focused on four main risk domains: institutional, technological, sociocultural, and legal, which were identified as critical to cross-border e-business operations in the literature and through preliminary interviews. Each domain was measured using multiple items adapted from validated scales, with participants rating their level of concern for each risk on a 9-point Likert scale (1 = least concern, 9 = most significant concern). This scale aligns with the requirements of the Best-Worst Method and allows for nuanced differentiation between risk perceptions.

3.3. Institutional Risk Concerns (IRC)

Institutional risks reflect the challenges arising from the regulatory, policy, and governance environment. These risks are particularly salient in emerging markets like Ghana, where regulatory frameworks for e-business are still evolving. The IRC scale comprised four items, each capturing a distinct aspect of institutional vulnerability [28]. Absence of coherent e-business policies, a participant might rate this item highly if their company has struggled to comply with unclear or constantly changing government regulations. Absence of digital transaction regulations assesses the lack of standardized rules for digital payments and online contracts, which can create uncertainty for businesses and consumers. Limited data governance refers to insufficient rules or oversight regarding the collection, storage, and use of digital data, raising concerns about privacy and security. Weak e-government support for digital trade: A respondent may score this item highly if they feel that government agencies do not provide adequate digital infrastructure or support for e-business initiatives. This study found institutional risks to be the most significant, with a global weight of 0.363, highlighting the critical need for regulatory reform and improved governance in Ghana's digital economy.

3.4. Technological Risk Concerns (TRC)

Technological risks encompass the challenges related to digital technology adoption, implementation, and security. The TRC scale included four items [29]. Lack of information technology expertise among staff, for example, a company may face difficulties maintaining or upgrading its e-commerce platform due to a shortage of skilled IT professionals. Cybersecurity risks and vulnerability to data breaches, this item captures concerns about hacking, malware, and unauthorized access to sensitive business or customer data. Digital infrastructure deficiencies (e.g., unreliable internet or payment systems), participants might rate this highly if frequent internet outages or payment failures disrupt business operations. Limited access to advanced e-business tools and platforms refers to challenges in adopting the latest digital solutions due to cost, availability, or compatibility issues. The global weight for technological risks in this study was 0.286, reflecting their substantial impact on the success and sustainability of e-business operations in Ghana.

3.5. Sociocultural Risk Concerns (SRC)

Sociocultural risks pertain to cultural, behavioral, and societal factors influencing e-business activities. This domain was assessed using seven items, reflecting the diversity and complexity of Ghana's social landscape [30]. Language barriers and communication challenges, for example, a Chinese business might struggle to communicate effectively with Ghanaian partners or customers due to differences in language or communication styles. Differences in consumer behavior and digital literacy, this item captures the challenges of adapting marketing strategies and user interfaces to local preferences and levels of digital familiarity. Cultural misalignment in User Experience (UX) design of digital platforms, for instance, a platform designed for Chinese users may not resonate with Ghanaian consumers, leading to low adoption rates. Resistance to online payments due to trust or cultural factors. Some respondents reported that their customers prefer cash transactions, fearing fraud or privacy breaches in digital payments. Perceptions of digital neo-colonialism or foreign dominance, this item assesses concerns that Chinese e-businesses may be viewed with suspicion or resentment, affecting trust and cooperation. Social media-induced cultural conflicts, for example, misunderstandings or negative publicity on social media, can escalate quickly in cross-cultural contexts. Adaptation to local festivals, holidays, and customs, businesses may face operational challenges if they do not align their digital marketing or service delivery with local cultural events. The global weight for sociocultural risks was 0.177, underscoring their importance in shaping user acceptance and business relationships.

Moreover, the linguistic diversity across West Africa presents a significant challenge for scalable e-business operations. While this study focuses on Ghana (an English-speaking nation), Chinese firms aiming to expand regionally must navigate multiple official languages, including French (in Cote d'Ivoire, Senegal, Benin), Portuguese (in Guinea-Bissau), and Spanish (in Equatorial Guinea). This multilingual landscape complicates content delivery, customer support, and marketing communication. However, the solution extends beyond translation. cultural localization adapting digital platforms to local idioms, symbols, date formats, currency displays, and behavioral expectations is critical for building trust and usability. For instance, a platform that displays prices in CFA francs but uses Chinese date formats (YYYY-MM-DD) may confuse users accustomed to DD/MM/YYYY. Similarly, payment options must reflect local preferences for instance, mobile money dominance in Francophone Africa). Without such adaptations, even technically sound platforms may fail to gain traction. This reinforces the importance of investing in local UX design teams and AI-driven localization tools to ensure digital services resonate across linguistic and cultural boundaries.

3.6. Legal Risk Concerns (LRC)

Legal risks address the adequacy and consistency of the legal environment governing e-business [17]. The LRC scale included four items. Weak cybercrime legislation and enforcement, a participant might rate this item highly if their business has experienced cyberattacks with little recourse for legal action. Challenges in protecting intellectual property rights, this item reflects concerns about the risk of imitation, piracy, or unauthorized use of proprietary technology or content. Differences in legal culture and dispute resolution practices, for instance, a Chinese firm may find Ghanaian legal procedures unfamiliar or unpredictable, complicating contract enforcement. Uncertainty regarding cross-border digital contracts, respondents might score this highly if they have faced difficulties drafting or enforcing contracts with international partners. Legal risks received a global weight of 0.174 in this study, indicating their significant but somewhat lower impact than institutional and technological risks. BWM requirements rated all items on a 9-point Likert scale (1 = least concern, 9 = most significant concern).

3.7. Fuzzy-BWM-TOPSIS with Chebyshev Distance Framework

This section provides the step-by-step procedure for the Fuzzy Best-Worst Method (F-BWM) combined with TOPSIS using Chebyshev distance. The goal is to rank alternatives based on fuzzy pairwise comparisons and a closeness-based ranking methodology.

Figure 2 shows the flow chart of the integrated Fuzzy-BWM-TOPSIS with Chebyshev distance methodology step-by-step process. It starts with defining sub-risk local weights and expert fuzzy judgments, followed by calculating global weights, Chebyshev distances, and ranking the alternatives. The process integrates fuzzy logic at the early stages to handle uncertainties and normalize judgments. This flowchart outlines the key steps involved in the decision-making process and shows the flow of information from defining risks to constructing decision matrices and determining rankings. It serves as a comprehensive guide to understanding how the Fuzzy-BWM-TOPSIS framework is applied to prioritize sub-risks and make informed decisions.

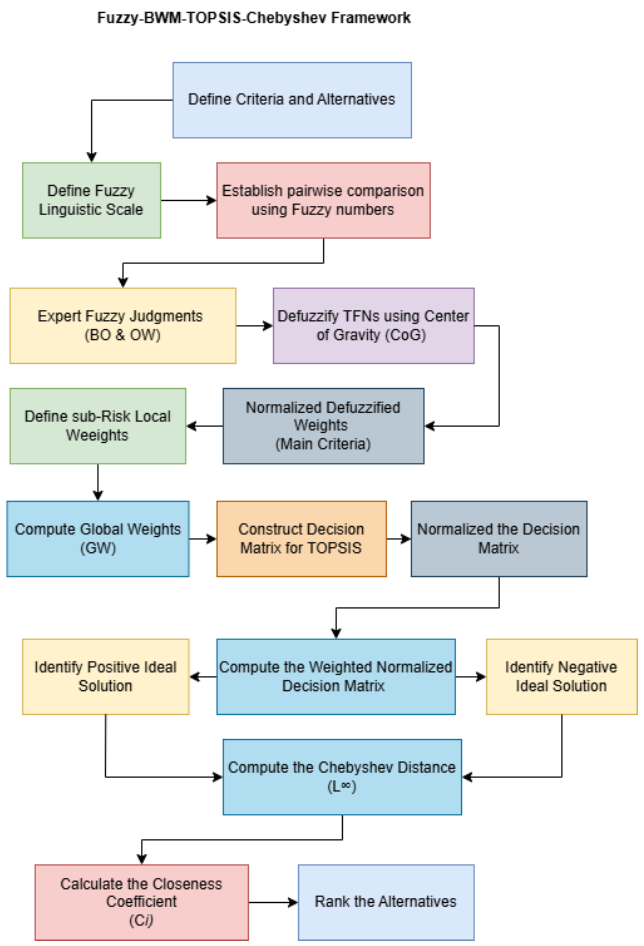

Figure 2. *Integrated Fuzzy-BWM-TOPSIS Framework.*

3.7.1. Define the Criteria and Alternatives

Let there be n criteria $C_1, C_2, \ldots, C_n$ and m alternatives $A_1, A_2, \ldots, A_m$ to be evaluated based on these criteria.

3.7.2. Define Fuzzy Linguistic Scale

The fuzzy linguistic scale is used to compare the importance of criteria. The triangular fuzzy numbers (TFNs) are defined as follows:

$$\text{Fuzzy Scale} = \begin{pmatrix} \text{Equally Important} & (1,1,1) \\ \text{Slightly More Important} & (1,2,3) \\ \text{Moderately More Important} & (2,3,4) \\ \text{Strongly More Important} & (4,5,6) \\ \text{Very Strongly Important} & (6,7,8) \\ \text{Extremely Important} & (8,9,9) \end{pmatrix}$$

Where each linguistic term is represented by a triangular fuzzy number (l, m, u), where l is the lower bound, m is the most likely value, and u is the upper bound.

3.7.3. Establish Pairwise Comparisons Using Fuzzy Numbers

Fuzzy pairwise comparisons are used to compare the best criterion with each other criterion, and the worst criterion with each other criterion. Let the fuzzy number for pairwise comparison be $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$, where: l_{ij} is the lower bound, m_{ij} is the most likely value (the mode), u_{ij} is the upper bound .

3.7.4. Expert Fuzzy Judgments (BO and OW)

The Best-to-Others (BO) and Others-to-Worst (OW) fuzzy judgments are obtained through expert input. These judgments compare the importance of criteria.

$$\text{BO}_{\text{fuzzy}} = \begin{pmatrix} \text{Institutional} & (1,1,1) \\ \text{Technological} & (6,7,8) \\ \text{Sociocultural} & (8,9,9) \\ \text{Legal} & (8,9,9) \end{pmatrix}$$

$$\text{OW}_{\text{fuzzy}} = \begin{pmatrix} \text{Institutional} & (8,9,9) \\ \text{Technological} & (6,7,8) \\ \text{Sociocultural} & (4,5,6) \\ \text{Legal} & (1,1,1) \end{pmatrix}$$

3.7.5. Defuzzify Triangular Fuzzy Numbers (TFNs) Using Center of Gravity (CoG)

To obtain crisp values from the fuzzy numbers, we use the Center of Gravity (CoG) method for defuzzification. The CoG formula is:

$$\text{CoG}(TFN) = \frac{l+m+u}{3} \tag{1}$$

$$\tilde{x}_{ij} = \frac{l_{ij} + m_{ij} + u_{ij}}{3} \tag{2}$$

This is applied to each fuzzy judgment in the BO fuzzy vector:

$$\text{Defuzzified BO}_{\text{fuzzy}} = \begin{pmatrix} \text{Institutional} & \frac{1+1+1}{3} = 1 \\ \text{Technological} & \frac{6+7+8}{3} = 7 \\ \text{Sociocultural} & \frac{8+9+9}{3} = 8.67 \\ \text{Legal} & \frac{8+9+9}{3} = 8.67 \end{pmatrix}$$

Similarly, apply the CoG method to the other criteria.

3.7.6. Normalize Defuzzified Weights

Once we have the defuzzified weights (from the BO judgments), we normalize them by dividing each defuzzified value by the sum of all defuzzified values. The normalization formula is:

$$\text{Total} = \sum_{i=1}^{n} \text{Defuzzified Weights}$$

The normalized weight for each criterion is:

$$w_i = \frac{\text{Defuzzified Weight of } i}{\sum_{i=1}^{n} \text{Defuzzified Weights}} \tag{3}$$

For example, if the defuzzified weights are:

$$\text{Defuzzified Weights} = \{1, 7, 8.67, 8.67\}$$

The total is:

$$\text{Total} = 1 + 7 + 8.67 + 8.67 = 25.34$$

The normalized weights are:

$$w_{\text{Institutional}} = \frac{1}{25.34} = 0.0395$$
$$w_{\text{Technological}} = \frac{7}{25.34} = 0.2767$$
$$w_{\text{Sociocultural}} = \frac{8.67}{25.34} = 0.3424$$
$$w_{\text{Legal}} = \frac{8.67}{25.34} = 0.3424$$

3.7.7. Define Sub-Risk Local Weights

Sub-risk local weights are defined for each main criterion (For instance, Institutional, Technological). These local weights are typically obtained from expert judgments.

Institutional Sub-Risks =

$$\begin{pmatrix} \text{Digital Transaction Regulation} : 0.284 \\ \text{Data Governance} : 0.241 \\ \text{Policy Absence} : 0.238 \\ \text{E-Gov Support} : 0.237 \end{pmatrix}$$

Similar sub-risks and local weights are provided for other domains such as *Technological*, *Sociocultural*, and *Legal*.

3.7.8. Compute Global Weights

The global weight(GW) for each sub-risk is computed by multiplying the normalized weight of the criterion by the local weight of the sub-risk. The formula is:

$$\text{GW}_{i,j} = \text{Normalized Main Weight}_i \times \text{Local Weight}_{i,j} \quad (4)$$

Where i is the main criterion (Institutional, Technological), and j is the sub-risk under each criterion.

For instance, if the normalized weight of the *Institutional* main risk is $w_{\text{Institutional}} = 0.0395$, and the local weight for Digital Transaction Regulation(DTR) is 0.284, the GW for this sub-risk is:

$$\text{GW of DTR} = 0.0395 \times 0.284 = 0.0112$$

This calculation is repeated for all sub-risks under each main risk domain.

3.7.9. Construct a Decision Matrix for TOPSIS

The decision matrix D consists of sub-risks as alternatives and criteria as columns. The matrix is as follows:

$$D = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \dots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \dots & x_{mn} \end{bmatrix} \quad (5)$$

Where x_{ij} is the global weight of sub-risk j under criterion i.

3.7.10. Normalize the Decision Matrix

The decision matrix D is normalized to make all the criteria comparable. The normalization process ensures that the criteria are placed on the same scale, particularly when they have different units or ranges.

For each element x_{ij} in the decision matrix, the normalization formula is:

$$y_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (6)$$

Where:

1. x_{ij} is the global weight of sub-risk j under criterion i,
2. y_{ij} is the normalized value of x_{ij},
3. The denominator $\sqrt{\sum_{i=1}^{m} x_{ij}^2}$ is the Euclidean norm (or L2 norm) for column j of the decision matrix, which ensures that each column is normalized independently.

This process ensures that each criterion is scaled in a way that allows us to make a fair comparison between them. After normalization, all values will be between 0 and 1, enabling us to apply weights consistently in subsequent steps.

Example: If $x_{11} = 4$, $x_{21} = 6$, and the other elements in the column are $x_{ij} = 1, 2, 3, \ldots$, the normalization for x_{11} would be:

$$y_{11} = \frac{x_{11}}{\sqrt{x_{11}^2 + x_{21}^2 + \cdots}} = \frac{4}{\sqrt{4^2 + 6^2 + \cdots}} \quad (7)$$

This ensures that all values for the sub-risks are on the same scale.

3.7.11. Calculate Weighted Normalized Decision Matrix

Once the decision matrix is normalized, each column is multiplied by the corresponding weight from 3.7.4 to obtain the weighted normalized decision matrix Y':

$$Y' = W \times Y \quad (8)$$

Where W is the vector of normalized weights for each criterion.

3.7.12. Identify the Positive-Ideal and Negative-Ideal Solutions

The ideal solution A^+ consists of the maximum value for each criterion, and the negative-ideal solution A^- consists of the minimum value for each criterion.

Positive-Ideal Solution A^+: The maximum value for benefit criteria.

Negative-Ideal Solution A^-: The minimum value for benefit criteria.

3.7.13. Calculate the Chebyshev (L_∞) Distance

The Chebyshev distance (L_∞) is used to calculate the distance between each alternative and the positive-ideal and negative-ideal solutions. For each alternative A_i, the Chebyshev distance to the ideal solution A^+ is:

$$S_i^+ = \max_j |y_{ij} - a_j^+| \tag{9}$$

Where y_{ij} is the value of alternative A_i for criterion j, and a_j^+ is the positive-ideal solution for criterion j.

The Chebyshev distance to the negative-ideal solution A^- is:

$$S_i^- = \max_j |y_{ij} - a_j^-| \tag{10}$$

Preliminary Definitions and Foundation

The Chebyshev Distance, also known as the L_∞-norm or maximum metric, is a measure of distance in n-dimensional space. It is defined as the maximum absolute difference between the coordinates of two points.

Definition 1: Chebyshev Distance

Let $A = (a_1, a_2, \ldots, a_n)$ and $B = (b_1, b_2, \ldots, b_n)$ be two points in $\mathbb{R}^n$. The Chebyshev Distance $d_\infty(A, B)$ between points A and B is defined as:

$$d_\infty(A, B) = \max_{1 \le i \le n} |a_i - b_i| \tag{11}$$

Where: a_i and b_i are the coordinates of points A and B respectively, $|a_i - b_i|$ is the absolute difference between the corresponding coordinates.

This distance measure is particularly useful in decision-making and optimization problems where the maximum deviation across dimensions is the most significant factor.

Propositions

The Chebyshev Distance is a valid distance metric because it satisfies the four required properties of a metric. These properties are:

1. *Non-negativity*: $d_\infty(A, B) \ge 0$, and $d_\infty(A, B) = 0$ if and only if $A = B$.
2. *Symmetry*: $d_\infty(A, B) = d_\infty(B, A)$.
3. *Triangle inequality*: $d_\infty(A, C) \le d_\infty(A, B) + d_\infty(B, C)$.
4. *Identity of indiscernibles*: $d_\infty(A, B) = 0$ if and only if $A = B$.

Proposition 1: Non-negativity

The Chebyshev Distance is non-negative, that is, $d_\infty(A, B) \ge 0$. Also, it equals zero if and only if the two points are identical:

$$d_\infty(A, B) = 0 \quad \text{if and only if} \quad A = B \tag{12}$$

Proof: By definition, $d_\infty(A, B) = \max_{1 \le i \le n} |a_i - b_i|$, and since the absolute value of any real number is always non-negative, we have $|a_i - b_i| \ge 0$ for all i. The maximum of non-negative values is also non-negative. Hence, $d_\infty(A, B) \ge 0$.

For $d_\infty(A, B) = 0$, we require $|a_i - b_i| = 0$ for all i, which means $a_i = b_i$ for all i, i.e., $A = B$. Thus, $d_\infty(A, B) = 0$ if and only if $A = B$.

Proposition 2: Symmetry

The Chebyshev Distance is symmetric, meaning:

$$d_\infty(A, B) = d_\infty(B, A) \tag{13}$$

Proof: From the definition of Chebyshev Distance in equation(11):

$$d_\infty(A, B) = \max_{1 \le i \le n} |a_i - b_i|$$

Since the absolute difference is symmetric:

$$|a_i - b_i| = |b_i - a_i| \tag{14}$$

Thus:

$$d_\infty(A, B) = \max_{1 \le i \le n} |a_i - b_i| = \max_{1 \le i \le n} |b_i - a_i| = d_\infty(B, A) \tag{15}$$

This proves the symmetry property.

Proposition 3: Triangle Inequality

The Chebyshev Distance satisfies the triangle inequality:

$$d_\infty(A, C) \le d_\infty(A, B) + d_\infty(B, C) \tag{16}$$

Proof: Using the definition of Chebyshev Distance, we want to show:

$$\max_{1 \le i \le n} |a_i - c_i| \le \max_{1 \le i \le n} |a_i - b_i| + \max_{1 \le i \le n} |b_i - c_i| \tag{17}$$

For any i, by the triangle inequality for real numbers:

$$|a_i - c_i| \le |a_i - b_i| + |b_i - c_i| \tag{18}$$

Taking the maximum over all i:

$$\max_{1 \le i \le n} |a_i - c_i| \le \max_{1 \le i \le n} (|a_i - b_i| + |b_i - c_i|) \tag{19}$$

Since the maximum of a sum is less than or equal to the sum of the maximums:

$$\max_{1 \le i \le n} (|a_i - b_i| + |b_i - c_i|) \le \max_{1 \le i \le n} |a_i - b_i| + \max_{1 \le i \le n} |b_i - c_i| \tag{20}$$

Thus, we have equation (16) below:

$$d_\infty(A, C) \le d_\infty(A, B) + d_\infty(B, C)$$

This proves the triangle inequality.

Proposition 4: Identity of Indiscernibles

The Chebyshev Distance is zero if and only if the points are identical:

$$d_\infty(A, B) = 0 \quad \text{if and only if} \quad A = B \tag{21}$$

Proof: From the definition of Chebyshev Distance in equation(11):

$$d_\infty(A, B) = \max_{1\le i\le n} |a_i - b_i|$$

If $d_\infty(A, B) = 0$, then $|a_i - b_i| = 0$ for all i, which implies $a_i = b_i$ for all i, thus $A = B$.

Conversely, if $A = B$, then $a_i = b_i$ for all i, and hence $d_\infty(A, B) = 0$.

Thus, $d_\infty(A, B) = 0$ if and only if $A = B$.

Lemma

Lemma 1: Relationship with Other Distance Metrics

The Chebyshev Distance is less than or equal to both the Manhattan Distance and the Euclidean Distance:

$$d_\infty(A, B) \le d_1(A, B) \le d_2(A, B) \tag{22}$$

Where:

Manhattan Distance is presented below as:

$$d_1(A, B) = \sum_{i=1}^{n} |a_i - b_i| \tag{23}$$

and

Euclidean Distance is expressed as:

$$d_2(A, B) = \sqrt{\sum_{i=1}^{n} (a_i - b_i)^2} \tag{24}$$

Proof: By definition:

The Chebyshev Distance considers the maximum difference between corresponding coordinates. The Manhattan Distance sums the absolute differences. The Euclidean Distance takes the square root of the sum of squared differences.

Since the Chebyshev Distance focuses on the maximum deviation, it is always less than or equal to the Manhattan and Euclidean distances, as the Manhattan and Euclidean distances aggregate all differences. Thus equation(22):

$$d_\infty(A, B) \le d_1(A, B) \le d_2(A, B)$$

This completes the proof of lemma 1.

The Chebyshev Distance is chosen in this framework for several reasons. First, it is particularly sensitive to the maximum deviation between alternatives across the criteria. By calculating the maximum difference between the values, it focuses on the worst-case scenario, which ensures that the largest disparity in any given criterion is emphasized. This approach is beneficial in situations where one criterion may dominate the others, and failing significantly on just one criterion could be a dealbreaker.

Moreover, the Chebyshev Distance ensures consistency in ranking by giving higher ranks to alternatives that are closer to the ideal solution. This is achieved even if an alternative performs poorly on some criteria but excels in others. The Chebyshev method helps avoid the situation where smaller differences across criteria could inadvertently elevate an alternative that is poor in one significant aspect, but good in others. In other words, the distance calculation is robust against such inconsistencies, which makes it a reliable choice for decision-making.

The simplicity and robustness of the Chebyshev Distance are key advantages. The computation is straightforward and provides a robust measure of similarity, as it focuses on the maximum deviation between the ideal and alternative solutions. Unlike other distance metrics, such as Euclidean distance, which averages out differences across criteria, Chebyshev gives a clearer indication of how well an alternative performs in comparison to the ideal solution, considering only the most significant deviations.

3.7.14. Calculate the Closeness Coefficients

The closeness coefficient C_i for each alternative is calculated as:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{25}$$

Where S_i^+ is the distance to the ideal solution, and S_i^- is the distance to the negative-ideal solution.

3.7.15. Rank the Alternatives

The alternatives are ranked based on their closeness coefficient C_i. The higher the value of C_i, the better the alternative.

4. Results

In this section, we illustrate the results obtained from the proposed Fuzzy-BWM-TOPSIS with the Chebyshev Distance Framework. Except for 3.7.8 and 3.7.9, the rest of the results are presented in this paper. From 3.7.8 is the decision matrix obtained from the expert judgment, and 3.7.9 is the normalized decision matrix. Some of the results are presented as figures.

From 3.7.8, we obtained the Global Weights of Sub-Risks in Table 2 below:

Table 2. *Global Weights of Sub-Risks.*

Sub-Risk	Domain	Local Weight	GW
DTR	Institutional	0.284	0.0112
Data Governance	Institutional	0.241	0.0095
Policy Absence	Institutional	0.238	0.0093
E-Gov Support	Institutional	0.237	0.0092

Sub-Risk	Domain	Local Weight	GW
Cybersecurity	Technological	0.311	0.0868
IT Expertise	Technological	0.278	0.0770
Infrastructure	Technological	0.231	0.0630
Platform Access	Technological	0.180	0.0493
Language Barrier	Sociocultural	0.192	0.0659
Digital Literacy	Sociocultural	0.181	0.0620
Payment Resistance	Sociocultural	0.172	0.0589
UX Misalignment	Sociocultural	0.119	0.0407
Neo-colonialism Perception	Sociocultural	0.112	0.0383
Social Media Conflict	Sociocultural	0.112	0.0383
Cultural Adaptation	Sociocultural	0.112	0.0383
Cybercrime Law	Legal	0.246	0.0830
IP Rights	Legal	0.217	0.0744
Legal Culture Gap	Legal	0.200	0.0680
Contract Uncertainty	Legal	0.337	0.1151

From 3.7.12, we illustrated the positive-ideal and negative-ideal solutions in Table 3 as:

Table 3. *Positive-Ideal and Negative-Ideal Solutions.*

Criteria	Max(+ ideal Solution)	Min(-Ideal Solution)
Institutional	0.0044	0
Technological	0.0845	0
Sociocultural	0.0587	0

From 3.7.13, we obtained the Chebyshev Distance to positive-ideal and negative-ideal solutions illustrated in Table 4.

Table 4. *Chebyshev Distance to Positive-Ideal and Negative-Ideal Solutions.*

Sub-Risk	(S^+)	(S^-)
Digital Transaction Regulation(DTR)	0.0044	0
Data Governance	0.0036	0
Policy Absence	0.0037	0
E-Gov Support	0.0036	0
Cybersecurity	0	0.0845
IT Expertise	0	0.0773
Infrastructure	0	0.0628
Platform Access	0	0.0500
Language Barrier	0	0.0587
Digital Literacy	0	0.0536
Payment Resistance	0	0.0517
UX Misalignment	0	0.0349
Neo-colonialism Perception	0	0.0320
Social Media Conflict	0	0.0320
Cultural Adaptation	0	0.0320
Cybercrime Law	0	0.0270
IP Rights	0	0.0234
Legal Culture Gap	0	0.0222
Contract Uncertainty	0	0.0328

Figure 3 represents the weighted normalized decision matrix, showing how sub-risks are evaluated across each domain. The color intensity reflects the weighted normalized score, with darker shades signifying higher values. From the heatmap, it's clear that sub-risks like Contract Uncertainty and Cybercrime Law have substantial scores in the Legal domain, which reflects their critical role in the decision-making process. Similarly, Sociocultural factors such as Language Barrier and Payment Resistance also exhibit high scores, demonstrating their importance in that domain. This helps assess how each sub-risk is prioritized within its corresponding domain, facilitating a more focused decision-making approach.

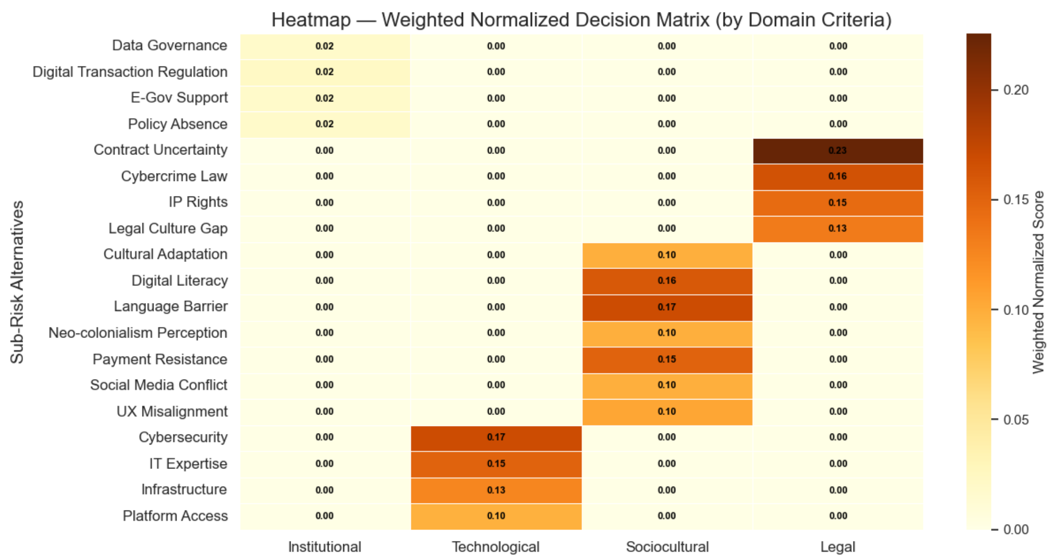

Figure 3. *Heatmap Weighted Normalized Decision Matrix (by Domain Columns).*

The network graph illustrated in Figure 4 shows the relationships between different domains (Legal, Sociocultural, Technological, and Institutional) and the associated sub-risks. Each node represents a sub-risk, while the edges show their connections to the various domains. This helps visualize the classification of each sub-risk within the decision-making framework.

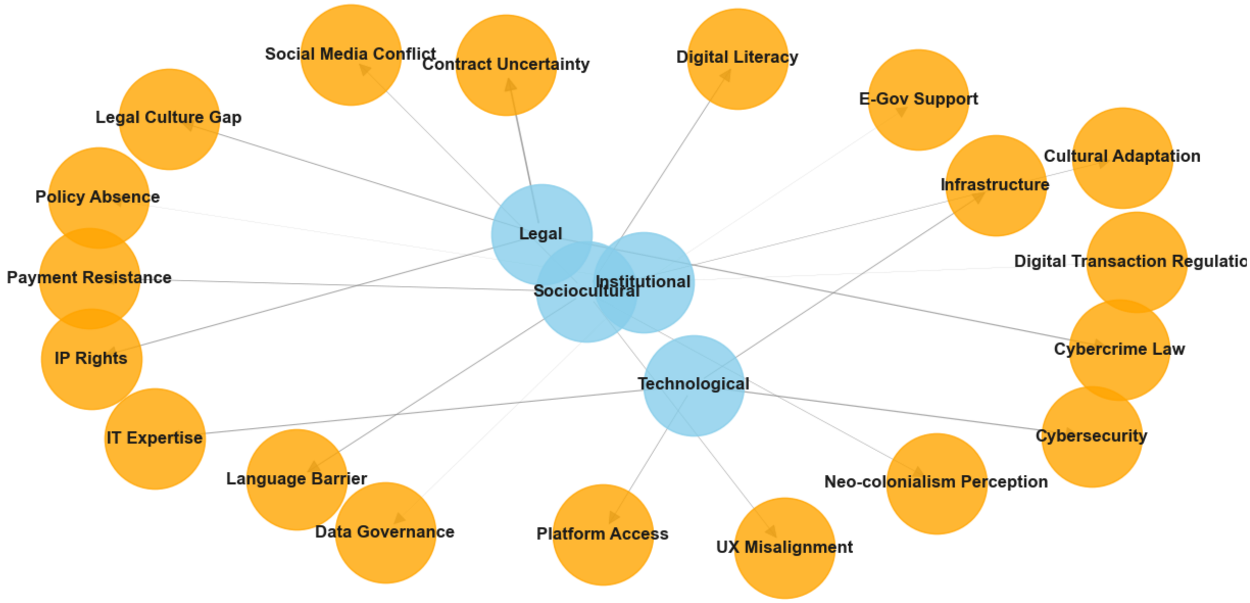

Figure 4. *Network Graph - Domain to Sub-Risk Relationships.*

The Figure 4 highlights that the Legal and Institutional domains are most strongly associated with subrisks like contract uncertainty, cybersecurity, and IP rights, while the Sociocultural and Technological domains deal with risks such as Digital Literacy, Platform Access, and Cultural Adaptation. This provides an understanding of which domains influence specific sub-risks more significantly.

Figure 5 provides insights into the distribution of BWM global weights across different sub-risks. Contract Uncertainty emerges as the most significant sub-risk, with high global weights, followed by Cybersecurity and Cybercrime Law. Notably, the Legal domain (shown in blue) dominates the weight distribution, indicating that legal concerns are particularly impactful in this analysis.

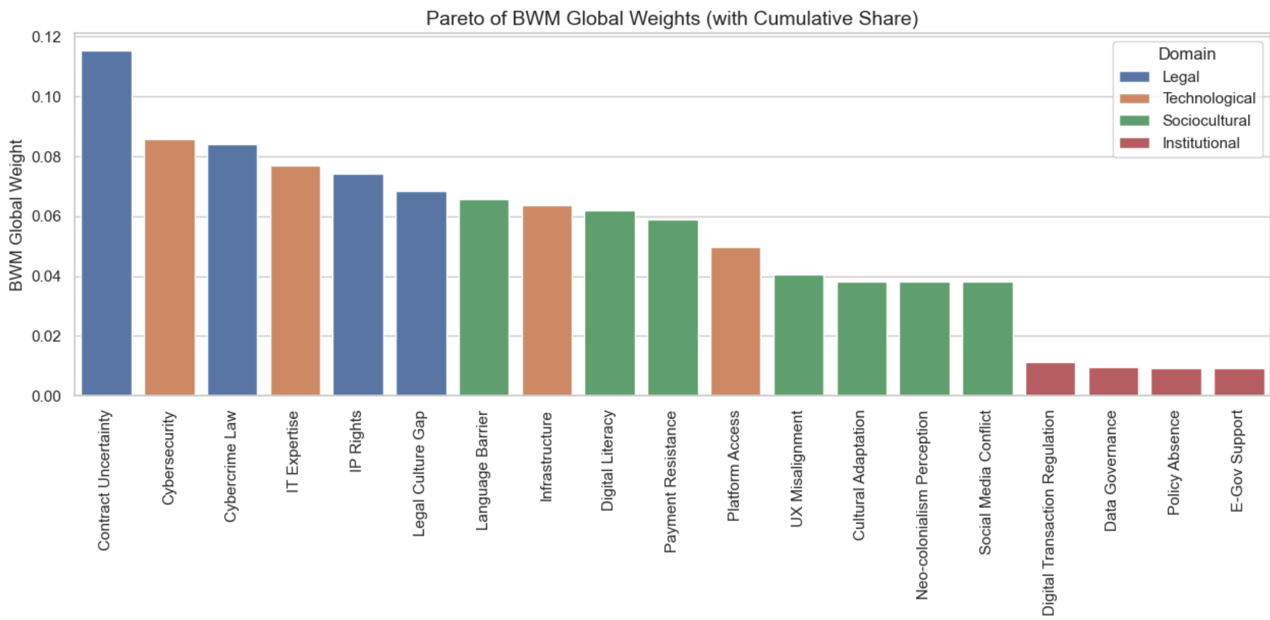

Figure 5. *BWM Global Weights.*

This reveals that addressing legal uncertainties is paramount in mitigating risks across the identified domains, suggesting that resolving legal issues may lead to a more robust risk management strategy.

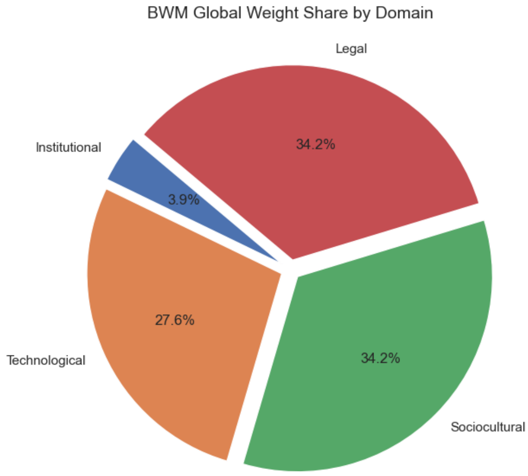

Figure 6. *BWM Global Weight Share by Domain.*

Figure 6 divides the BWM global weight share among the four domains: Legal, Sociocultural, Technological, and Institutional. Legal and Sociocultural domains each contribute 34.2% to the global weight, while the Technological domain accounts for 27.6%. The Institutional domain contributes a significantly smaller share of only 3.9%. This distribution emphasizes the relative importance of legal and sociocultural factors in the decision-making process, suggesting that interventions in these domains are likely to have the most substantial impact. Institutional risks, though important, appear to play a secondary role.

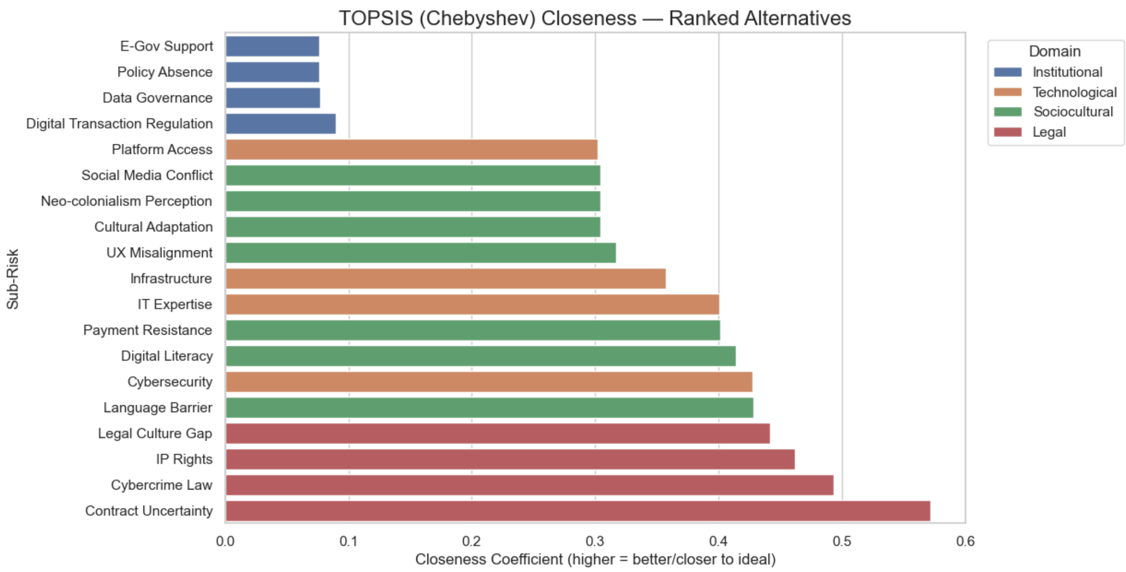

Figure 7. *TOPSIS (Chebyshev) Closeness Ranked Alternatives.*

Figure 7 ranks the sub-risks based on their closeness to the ideal solution using the Chebyshev distance method in TOPSIS. Sub-risks like E-Gov Support, Policy Absence, and Data Governance rank higher in the Institutional and Technological domains, indicating that they are closer to the ideal solution. On the other hand, sub-risks such as Cybercrime Law, IP Rights, and Contract Uncertainty are ranked lower, suggesting they are further from the ideal solution. This ranking helps identify which sub-risks should be prioritized for improvement, with the Institutional and Technological risks being perceived as more easily addressed than the legal ones.

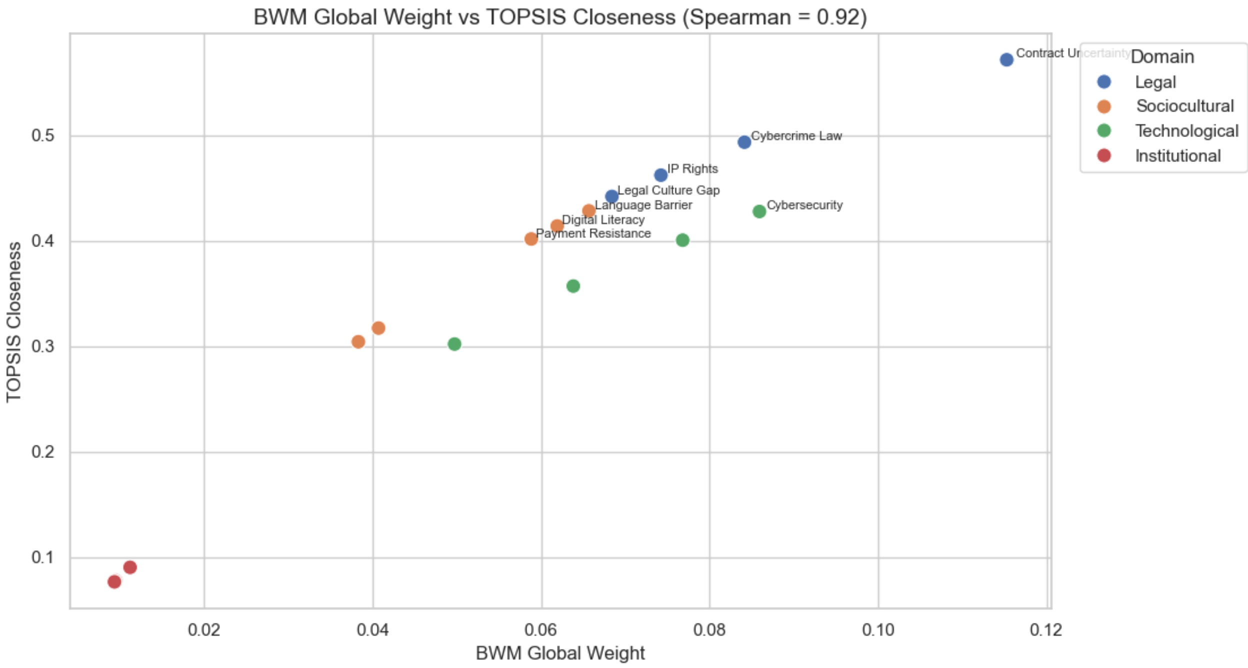

Figure 8. *BWM Global Weight vs TOPSIS Closeness.*

Figure 8 compares BWM global weights with TOPSIS closeness for each sub-risk, with a Spearman correlation of 0.92, indicating a strong positive relationship. It shows that sub-risks with higher BWM global weights, such as Contract Uncertainty, Cybersecurity, and Cybercrime Law, also tend to have higher TOPSIS closeness scores. This suggests that these sub-risks are critical both in terms of their weighted importance and their proximity to the ideal solution in the decision-making process. In contrast, sub-risks like IP Rights and Legal Culture Gap are less impactful, with lower scores in both dimensions, indicating they are not as urgent in the current context.

The Fuzzy-BWM-TOPSIS framework emphasizes the critical importance of legal and sociocultural risks in the decision-making process. Legal risks, especially Contract Uncertainty and Cybercrime Law, hold significant global weight and also show up as being further from the ideal solution, requiring urgent attention. Sociocultural risks like Language Barriers and Cultural Adaptation also play crucial roles and show a high degree of closeness to the ideal solution. Meanwhile, the Institutional domain, despite having a small share in the global weights, addresses issues such as E-Gov Support and Data Governance that are considered relatively closer to the ideal solution.

This analysis illustrates that by focusing on legal and sociocultural risks while addressing institutional and technological aspects, a more effective strategy can be developed for mitigating risks and improving decision-making. The framework provides a structured approach to handling uncertainty through fuzzy logic while ranking and prioritizing alternatives using the TOPSIS method and Chebyshev distance.

4.1. Comparative Analysis and Theoretical Integration

Our finding that institutional risks-particularly inadequate digital transaction regulations and weak data governance are the most critical aligns with the work of Adam and Alhassan [13], who emphasize that regulatory instability in West Africa significantly hampers e-business readiness. Similarly, Fragomeni et al. [19] argue that institutional voids elevate transaction costs, a claim strongly supported by our empirical data from Ghanaian e-business managers. The high prioritization of legal risks, especially contract uncertainty and cybercrime legislation, resonates with Taherdoost [17], whose framework identifies legal ambiguity as a core barrier to cross-border digital trust. Moreover, our identification of sociocultural risks such as language barriers and cultural misalignment in UX design echoes findings by Huo et al. [4], who observed that cultural insensitivity in platform design leads to low user adoption in African markets. The prominence of technological risks, especially cybersecurity and infrastructure gaps, is consistent with Mkansi [15] and Chowdhury et al. [16], who highlight infrastructure deficits as a persistent challenge in emerging digital economies. By triangulating our results with these studies, we reinforce the validity of our risk hierarchy and demonstrate its alignment with broader patterns in digital trade risk literature.

The applicability of transaction cost theory in explaining institutional and legal risks in digital trade is further validated by McManus [18], who demonstrates how legal uncertainty increases monitoring and enforcement costs. Likewise, the Technology Acceptance Model's role in explaining low adoption due to poor perceived usefulness is supported by Unal and Uzun [21] in educational technology contexts, our study extends this logic to cross-border e-commerce platforms. While some studies for instance Shi & Wei [1] place greater emphasis on technological over institutional factors in digital economies, our results reflect the unique context of Ghana, where institutional development lags behind technological diffusion-a phenomenon also observed in other African digital markets [2]. This suggests that risk priorities may shift depending on the maturity of the digital ecosystem.

4.2. Study Implication

This study presents substantial theoretical, practical, and policy implications for enhancing cross-border e-business between China and West Africa. This theoretically enhances the literature on international e-business risk management by amalgamating Transaction Cost Theory, the Technology Acceptance Model, and Commitment-Trust Theory into a cohesive framework, providing a comprehensive perspective on the interplay of institutional, technological, sociocultural, and legal risks in shaping transaction costs, technology adoption, and trust. The utilization of the Fuzzy-BWM-TOPSIS method, employing Chebyshev distance, offers a consistent and methodical framework for assessing and ranking intricate hazards in evolving market environments.

The findings instruct corporate executives to strategically invest in cybersecurity, infrastructure, and IT capacity, while customizing digital platforms to align with local languages, cultural norms, and payment preferences to enhance adoption and confidence. Investors may utilize the rated risk profile to discern prospects with controllable risk exposure, while foreign partners are urged to foster trust-based, enduring partnerships to mitigate inadequate legal enforcement. The study highlights the necessity of aligning digital commerce regulations, enhancing data governance, establishing stringent cybersecurity legislation, and executing capacity-building activities to address skills deficiencies and foster digital inclusion.

From a managerial perspective, the findings underscore that linguistic inclusivity and cultural localization are not optional but strategic imperatives in West African e-business. Chinese companies should move beyond basic translation and adopt deep localization strategies that integrate language, culture, and user behavior. This includes offering multilingual interfaces, employing local content moderators, customizing payment gateways, and designing culturally appropriate user experiences.

For example, platforms targeting Francophone markets should not only offer French language support but also adapt to local expressions, imagery, and trust signals (displaying local customer testimonials). Such efforts enhance perceived ease of use and usefulness (TAM) and foster relational trust (Commitment-Trust Theory), reducing perceived risk and increasing adoption. Policymakers and industry associations could support this by establishing regional digital localization standards or funding cross-border UX innovation labs to promote interoperability and inclusivity in the AfCFTA digital economy.

5. Conclusions

This study offers a significant advancement in the understanding of e-business risks in China-West Africa cooperation by introducing an integrated theoretical and methodological framework. Theoretically, it bridges economic, behavioral, and relational perspectives through the synthesis of Transaction Cost Theory, the Technology Acceptance Model (TAM), and Commitment-Trust Theory. Methodologically, the integration of Fuzzy-BWM-TOPSIS with Chebyshev distance provides a novel, robust approach to risk prioritization under uncertainty, particularly suited for environments where worst-case deviations must be minimized. Practically, the findings guide policymakers in regulatory reform, businesses in localization strategies, and investors in risk assessment. By focusing on Ghana, a strategic digital hub in West Africa and host of the AfCFTA Secretariat, this research not only addresses a critical gap in the literature but also contributes to the broader goal of building sustainable, trust-based digital partnerships between China and Africa.

The results indicate that institutional and technological risks are the most critical barriers, with inadequate digital transaction legislation, cybersecurity vulnerabilities, and infrastructure deficiencies dominating expert concerns. Legal uncertainties, especially contract enforcement and cybercrime legislation and sociocultural challenges such as language barriers and cultural misalignment in UX design further complicate cross-border operations. These findings validate and extend existing theoretical models, showing how institutional voids increase transaction costs (TCT), how poor technological readiness reduces user acceptance (TAM), and how relational trust can substitute for weak legal enforcement (Commitment-Trust Theory).

Despite its contributions, the study acknowledges limitations, including its focus on Ghana, reliance on cross-sectional expert data, and modest sample size. Future research could expand geographically to other West African countries, adopt longitudinal designs, and incorporate macro-level variables such as geopolitical risk or environmental sustainability.

However, this research provides a strategic framework for stakeholders aiming to build secure, inclusive, and resilient digital trade ecosystems. By prioritizing high-impact risks and aligning interventions across policy, technology, and culture, China and West Africa can unlock the full potential of their digital partnership.

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Abbreviations

BWM	Best-Worst Method

TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
HF-BWM	Hesitant Fuzzy Best-Worst Method
TCT	Transaction Cost Theory
TAM	Technology Acceptance Model
BO	Best-to-Others
OW	Others-to-Worst
TFNs	Triangular Fuzzy Numbers
CoG	Center of Gravity
DM	Decision Matrix
WDM	Weighted Decision Matrix
PIS	Positive-Ideal Solution
NIS	Negative-Ideal Solution
S^+	Distance to Positive-Ideal Solution
S^-	Distance to Negative-Ideal Solution
CCi	Closeness Coefficient
d_∞	Chebyshev Distance
L2	Euclidean Norm
GW	Global Weight
DTR	Digital Transaction Regulation
IPR	Intellectual Property Rights
UX	User Experience
e-Gov	Electronic Government
IT	Information Technology
ICT	Information and Communication Technology
AI	Artificial Intelligence
BRI	Belt and Road Initiative

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Conflicts of Interest

The authors declare no conflict of interest in this paper.

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