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EXPLORING THE CONVERGENCE OF BLOCKCHAIN, AI, AND IOT: INSIGHTS INTO TECHNOLOGICAL INTEGRATION

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Abstract

This study investigates the integration of Blockchain, Artificial Intelligence (AI), and Internet of Things (IoT) technologies through a quantitative research design employing survey data. The research is cross-sectional, focusing on key latent variables such as Perceived Experience (PEXP), Expected Experience (EEXP), System Information (SINF), Functional Condition (FCND), and others. Confirmatory Factor Analysis (CFA) was used to validate these constructs and ensure they accurately measure theoretical dimensions. The sample comprised 200 respondents from Pune, Pimpri-Chinchwad, and Thane, selected through stratified random sampling to ensure balanced representation across demographic categories. Data collection was conducted using a structured questionnaire with a 5-point Likert scale to assess attitudes and experiences. Measurement model testing confirmed the validity and reliability of the constructs, with results showing strong factor loadings and internal consistency, thereby validating the hypothesized model and providing insights into the effectiveness of Blockchain, AI, and IoT integration.

Keywords:*Blockchain, Artificial Intelligence, Internet of Things, Technologies,Factor Analysis.*

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1. INTRODUCTION

Debates about the best framework for businesses hoping to capitalize on the convergence of IoT and blockchain technology have been spurred by recent advancements in these integration frameworks across several industries. The Internet of Things, or IoT, is one of the key ideas driving new possibilities for the industrial revolution and has reached enormous strides. IoT growth was estimated to be over $170 billion globally in 2017 and is predicted to reach roughly $560 billion by the end of the fiscal year 2022. IoT performance has been negatively impacted by several challenges, despite the assertions of numerous experts that it is the next industrial revolution. These challenges date back to the prehistoric era and include scalability issues that impact the system as a whole as well as the absence of a protected ecosystem that would have covered all of the building blocks of IoT design. One of the main factors influencing IoT performance since its inception is the quantity of devices in any given system.

The way the Internet of Things (IoT) has improved the common operating picture (COP) to handle various applications and facets of contemporary living is praiseworthy. Because blockchain has expanded the operations of wireless networks and sensor equipment that could not otherwise connect via the regular IoT network, it has, in this regard, increased the effectiveness of COP. The three main technologies that have propelled the subsequent stage of digital transformation are blockchain, artificial intelligence (AI), and the Internet of Things. It is anticipated that these technologies will facilitate the development of new business models, such as digital IoT, autonomous agents, blockchain-enabled money transfers, and autonomous decision-making as independent economic agents.

With the help of sensing, communication devices, and processing, the Internet of Things (IoT) has made it possible for complex connections of things or items to exchange data, identify physical occurrences, and interact with their surroundings. Monitoring procedures or making decisions about situations that call for human intervention are the goals of these kinds of interactions. The requirement to support real-time information gathering and provide remote, autonomous control mechanisms, which have supplanted the current traditional control and monitoring systems across industries, are two of the most well-known factors contributing to the

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emergence of IoT systems. A new system architecture that governs and advances the majority of inefficient processes related to human wellbeing will be introduced via the integration of blockchain, artificial intelligence, and the Internet of Things.

2. LITERATURE REVIEW

Alnahari et al., (2022)created the initial Blockchain proposal. A variety of technologies, including digital signatures, hashing, cryptography, and decentralized computing, are combined in distributed ledgers, or blockchains. In its most basic form, a blockchain is a distributed database with only majority-confirmed transaction records that is updated by network participants. The approval of the majority, typically 51% or 67%, is required for the transaction to proceed in a consensus process. The blocks are structured with a top-level cryptographically secure header including the previous block header, the transaction timestamp, and the details of the transactions (e.g., contract between participants or asset transfer). Once a record has been authenticated, it is nearly impossible to alter data on the Blockchain since all copies of the ledger are instantly replicated in all nodes and new transactions are always linked to older transactions.

Kshetri and Voas (2018)validated blockchain-based public administration solutions are being considered by governments worldwide. According to Kundu, there are several potential advantages that blockchain technology may provide for the government, such as increased transparency, confidence, and data authenticity as well as decreased corruption and manipulation prevention. The governments of several nations have responded to these potential advantages by eradicating corruption and boosting openness. To fully investigate the technology's potential applications in governmental operations, a number of countries worldwide have launched Blockchain projects. Given their greater susceptibility to fraud, manipulation, and corruption, developing nations may find some potential benefits—such as decentralized trust and transparency—particularly beneficial in comparison to wealthier and industrialized nations.

Batubara et al. (2018)highlighted a critical element of the deployment of blockchain technology in the domain of electronic government. Blockchain adoption in the public sector is still comparatively low, which indicates that this technology's full potential has not yet been achieved, according to the authors' review of the literature. A significant discovery is the paucity of study on the several popular use cases for blockchain, including transactional data collection regarding the issuance of licenses and certificates, ownership of real estate and automobiles, and other vital government information. This constraint shows that blockchain-based applications have not yet fully absorbed the operational architecture of the public sector. On the other hand, most existing ideas in this discipline are essentially conceptual and lack empirical backing for their applicability or effectiveness. This vacuum in the research raises important questions concerning the practical applicability and viability of blockchain technology in e-governance.

Dinh and Thai (2018)highlighted in their study the significance of establishing a wide range of criteria for administering a blockchain network. Blockchain technology's decentralized and immutable ledger feature has made it attractive in a variety of industries, including finance and supply chain management. Blockchain network administration and optimization may be challenging chores, but AI can help. A major topic raised in the literature is the use of AI in automating and optimizing blockchain networks. Blockchain networks often require the use of smart contracts, exact parameter sets, and consensus mechanisms, among other things. thereby, AI algorithms have the potential to increase the effectiveness and precision of these decisions, thereby improving the governance and performance of the network. By analysing historical data and network conditions, artificial intelligence (AI) can recommend configurations that enhance scalability, security, and overall functionality. Another significant subject addressed in the literature is the role of artificial intelligence (AI) in data and transaction validation. For blockchain networks to ensure transaction integrity and accuracy, a consensus-building procedure is necessary. AI can be used to pre-validate data and transactions before they are added to the blockchain.

3. RESEARCH METHODOLOGY

3.1. Research Design

The integration of Blockchain, AI, and IoT technologies is being investigated through a quantitative framework-based study methodology that makes use of survey data. The purpose of this cross-sectional study is to evaluate the associations between important latent variables, including functional condition (FCND), system information (SINF), expected experience

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(EEXP), and perceived experience (PEXP). These constructs were validated using the Confirmatory Factor Analysis (CFA) technique, which makes sure the constructs measure the underlying theoretical aspects appropriately.

3.2. Population and Sample

The study population comprises persons residing in Pune, Pimpri-Chinchwad, and Thane. This ensures that age, gender, education, and occupation are well-represented. The primary objective of the study is to obtain varied opinions from respondents who possess familiarity with technology. Geographic diversity is ensured by the 200 respondents in the sample, of whom 80 are from Pune (40%) and 40 are from Pimpri-Chinchwad (20%) and Thane (20%). In order to reduce bias and guarantee that the sample accurately represents the overall population of these cities, a stratified random sampling technique was employed to proportionally represent demographic variables such as gender (60 percent female, 40 percent male), age (split into four groups), education level, and profession.

3.3. Data Collection

A systematic questionnaire was used to gather data, and it was distributed both in-person and online to get a variety of answers. There were two sections to the questionnaire. Demographic data including age, gender, occupation, education level, and city of residence were gathered in the first section. Thirty-six items in the second section were used to gauge the latent variables. A 5-point Likert scale was used to assess each topic, allowing respondents to express their opinions and experiences about the combination of blockchain, artificial intelligence, and internet of things.

3.4. Variables and Measurements

This study examines PEXP, EEXP, System Information (SINF), Functional Condition (FCND), Anthropomorphism (ANTH), Management of Operations (MLOP), Perceived Benefits (PBEN), Perceived Security (PSEC), Ethics (ETHC), Trust in Technology (TSTC), and Adoption Intention. Theoretical models of technology adoption assist explain how Blockchain, AI, and IoT are used. PEXP (Perceived Experience) has observable variables PEXP1, PEXP2, and PEXP3

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measured by survey items. The observable variables were trustworthy markers of their latent variables when standardized factor loadings from CFA were employed to analyze their relationships.

4. DATA ANALYSIS

4.1. Demographic Data

Table 4.1: Demographic data

Demographic Category	Frequency	Percentage
City		
Pune	80	40
Pimpri-Chinchwad	40	20
Thane	40	20
Gender		
Male	80	40
Female	120	60
Age		
20-30 years	60	30
31-40 years	60	30
41-50 years	40	20
> 65 years	40	20
Education		
12th Std or below	10	10
Diploma level	40	20
Bachelor level	40	20
Masters level	20	10
Doctoral level	80	40
Profession		
Private organization	40	20

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Public sector	40	20
Not working	80	40
Own business	40	20

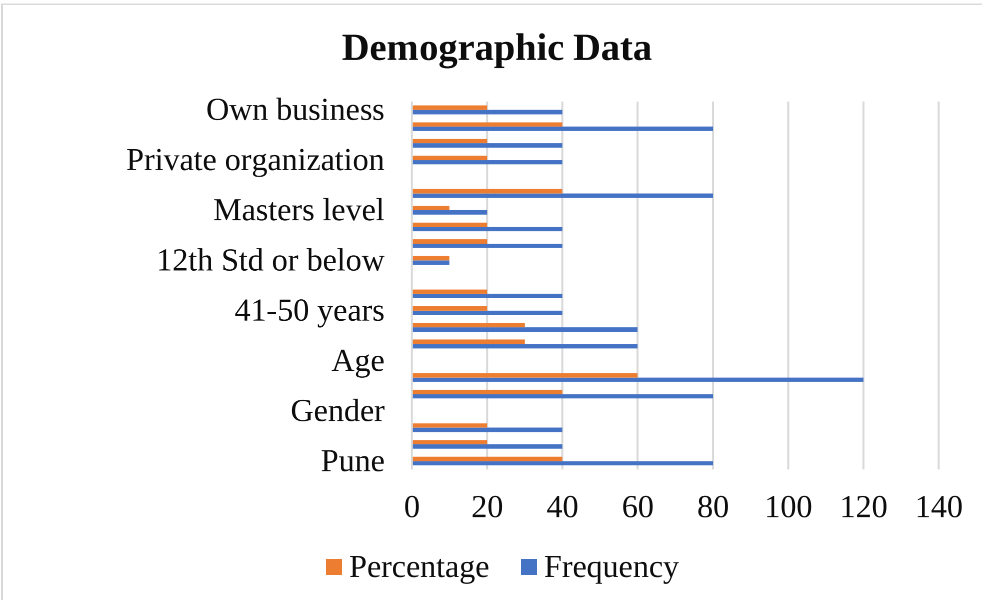

Figure 4.1: Demographic Data

The sample's demographic split reveals a varied representation in a number of categories. Geographically, 20% of responders each are from Thane and Pimpri-Chinchwad, while 40% are from Pune. Participants' gender representation is 60% female and 40% male. With 30% of respondents in each of the 20–30 and 31–40 age groups, and 20% in each of the 41–50 and above 65 age groups, the age distribution is balanced. The distribution of educational attainment is as follows: 10% have completed the 12th grade or less, 20% have diplomas, 20% have bachelor's degrees, 10% have master's degrees, and 40% have doctoral qualifications. In terms of employment, 40% are unemployed, 20% work for private companies, 20% are employed by the government, and 20% own their own companies, giving the study a diverse viewpoint.

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4.2. Measurement model testing

To validate component groupings, all 36 independent variables were introduced. Ten factors explained 70.4% variation. PCA extracted data using Promax oblique rotation. The Kaiser-Meyer-Olkin (KMO) value was 0.897, over the acceptable minimum of 0.5, according to measurement model results. Also significant was Barlett's sphericity test at 0.01 (p 0.000). After assessing factors and variables, all 10 factors loaded properly into factor groups. The measurement model was verified with AMOS V26 and all 36 objects. The hypothesised model requires CFA to validate all key constructs (PEXP, EEXP, SINF, FCND, ANTH, MLOP, PBEN, PSEC, ETHC, TSTC, and ADIN Figure 2 illustrates AMOS V26 measurement model CFA iteration 1.

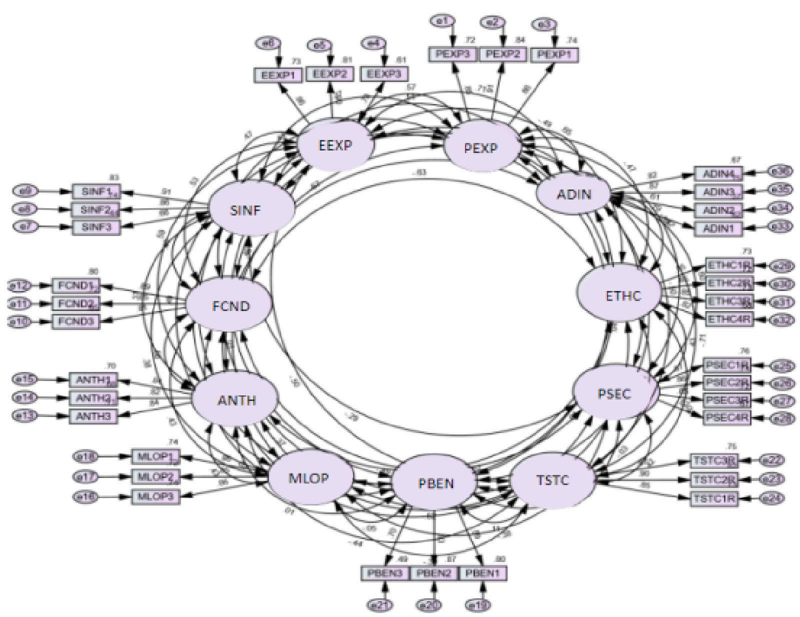

Figure 2: Iteration 1 of the CFA Measurement Model (AMOS V26)

Table 2 presents statistical results indicating that every construct has a satisfactory degree of reliability. The values of the model that were found to exceed the threshold limits. Even though some of the measures are somewhat below acceptable thresholds, the uniqueness of the study components allows for their justified inclusion in the research model. Next, the Harman single factor test was used to determine whether common bias-variance existed in a single dimension.

Using a typical one-factor test, the degree of common variation that may exist in a single dimension is evaluated. This one-factor test only explains 36.53 percent of the total variance, or less than 50%, and there is no evidence of common bias-variance. Cronbach's alpha reliability coefficients are used to evaluate internal consistency.

Table 2: Factor loadings and reliability as a result of confirmatory factor analysis

Latent Variable	Observed Variable	Standardized Factor Loading	AVE	Cronbach's Alpha
PEXP	PEXP1	0.741	0.822	0.936
PEXP	PEXP2	0.859		
PEXP	PEXP3	0.915		
EEXP	EEXP1	0.800	0.822	0.936
EEXP	EEXP2	0.896		
EEXP	EEXP3	0.714		
SINF	SINF1	0.912	0.822	0.936
SINF	SINF2	0.897		
SINF	SINF3	0.782		
FCND	FCND1	0.912	0.874	0.932
FCND	FCND2	0.807		
FCND	FCND3	0.936		
ANTH	ANTH1	0.821	0.714	0.955
ANTH	ANTH2	0.912		
ANTH	ANTH3	0.814		
MLOP	MLOP1	0.896	0.811	0.974
MLOP	MLOP2	0.925		
MLOP	MLOP3	0.936		
PBEN	PBEN1	0.715	0.714	0.958
PBEN	PBEN2	0.936		
PBEN	PBEN3	0.825		
PSEC	PSEC1	0.932	0.962	0.847
PSEC	PSEC2	0.912		
PSEC	PSEC3	0.822		
PSEC	PSEC4	0.933		
ETHC	ETHC1	0.899	0.711	0.874
ETHC	ETHC2	0.924		

ETHC	ETHC3	0.932		
ETHC	ETHC4	0.814		
TSTC	TSTC1	0.941	0.815	0.911
TSTC	TSTC2	0.814		
TSTC	TSTC3	0.961		
ADIN	ADIN1	0.911	0.714	
ADIN	ADIN2	0.715		
ADIN	ADIN3	0.931		
ADIN	ADIN4	0.922		

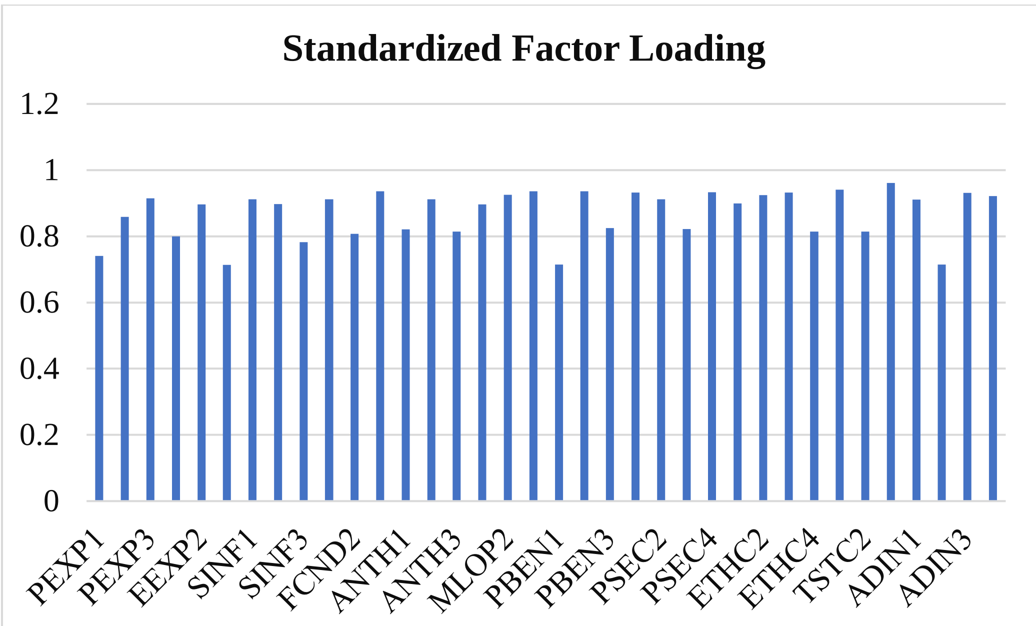

Figure 4.5: Factor loadings and reliability as a result of confirmatory factor analysis

The provided data table displays the relationships between latent variables and the associated observable variables, such as the standardized factor loading, AVE (Average Variance Extracted), and Cronbach's Alpha. The latent variables, which are PEXP, EEXP, SINF, FCND, ANTH, MLOP, PBEN, PSEC, ETHC, TSTC, and ADIN, are created using the observable variables given below them. The degree of positive correlation between each observed variable and its matching latent variable is shown by the standardized factor loading values. In this case, higher factor loading values suggest that the observable variables explain more of the latent

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variable. Greater percentages of the variance in the observable variables are explained by the latent variable, as shown by higher AVE values. The variation represented by the latent variables in relation to the measurement error is estimated by the AVE values. Cronbach's Alpha is another tool used to assess internal consistency reliability; higher values indicate stronger reliability. The latent variables seem to reflect the underlying components they are meant to capture accurately, as seen by their generally good AVE values and factor loadings. There is a shortage of standardized factor loading values for a number of observed variables, including PEXP2, EEXP2, and SINF2. This may call for more study or data collection. Additionally, the latent variables appear to be a reliable measure of the constructs they reflect, as indicated by their good Cronbach's Alpha reliability.

5. CONCLUSION

The study results provide a thorough knowledge of the integration of Blockchain, AI, and IoT technologies via the lens of important latent variables. By confirming that the observed variables are reliable markers of the latent constructs, the Confirmatory Factor Analysis (CFA) verifies the measurement model. The results of the study show that the latent variables, such as perceived experience (PEXP) and expected experience (EEXP), effectively reflect their theoretical components. High factor loadings and good Average Variance Extracted (AVE) values are also revealed. Despite the fact that a few observed variables fell short of ideal levels, Cronbach's Alpha indicates that the model's overall reliability is very high. These findings offer a strong foundation for comprehending the intricate interactions between blockchain, artificial intelligence, and internet of things technologies. The study emphasizes how well these constructs capture the integration of these technologies and emphasizes the need for more research to improve the precision of the model and address small inconsistencies. In order to explore more depth and improve the constructs, future study could build on these findings and contribute to a more sophisticated understanding of technology integration.

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