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Factors Affecting Implementation of Integrated AI-Blockchain-IoT in Kenyan Seed Sector

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ABSTRACT

Kenyan seed supply chain has made some positive strides towards digitalization of its operations; however, it is still faced with challenges like counterfeit seeds, lack of transparency, lack of traceability, inefficiencies in operations among others. Integration of Blockchain, IoT and AI in the Kenyan seed supply chain has the potential to digitally transform this sector as well alleviate the challenges that the sector is currently facing. However, practical implementation and full uptake of these technologies in Kenyan seed supply chain are hindered by several factors. This study sought to evaluate the factors that affect the successful implementation of integrated AI-Blockchain-IoT in the Kenyan seed supply chain underpinning the TOE model of technology adoption. The target respondents were KALRO and KSC staff from ICT and Seed units as well as farmers and agro-dealers in Tranzoia County. Data collection instruments were questionnaires and interview schedules, and the collected data were analyzed using both descriptive and referential analysis. The findings of this study revealed that high cost of implementation ($p = 0.034$), limited technical knowledge ($p = 0.021$), lack of awareness of technology benefits ($p = 0.030$), reluctance to transition ($p = 0.048$), and concerns about cost and learning curve ($p = 0.020$) were found to be statistically significant predictors of lower of AI-Blockchain-IoT adoption.This study helps enlighten the practitioners and the stakeholders in this sector on the various adoption factors to consider as well as highlighting the target areas that need more investments on and interventions.

Keywords: Integrated AI-Blockchain-IoT, Seed Sector, factors, Technology Adoption, TOE,

INTRODUCTION

Globally, Seed supply sector like any other sector has made significant digital transformation to automate its processes. However, [1] observe that full uptake of technologies has been limited due to the complex and multi-layered nature of this sector. This is true also for the Kenyan seed sector which has not fully embraced digital technologies especially the AI-Blockchain and IoT [2,3]. This study evaluates these factors affecting the AI-blockchain-IoT in Kenyan seed sector by underpinnig the Technology-Organisation-Environment (TOE) Framework of technology adoption because it gives a holistic approach and is adaptable across industries. TOE was proposed by [4], and it is seen as a triangular structure that has three concepts namely, environmental, organizational, and technical [5,6,7,8,9,10]. Technological factors in this context are factors that are related to technological innovation such as compatibility issues, costs, complexity among others [11]. Organizational factors include the size of the organization, organizations innovativeness, the management support, culture, and human resource capacity [12]. Environmental factors include the factors that exist in the environment where the organization operates. This study sought to evaluate the factors that affect the implementation of AI-Blockchain-IoT technologies in seed supply chain with TOE model of technology adoption in consideration.

METHODS AND MATERIAL

This study used descriptive and linear regression analyses to evaluate the challenges that affect the adoption of AI-Block chain-IoT technologies in the Kenyan seed supply chain with both quantitative and qualitative data. Target respondents for this study were Kenya Agricultural and Livestock Research Organization (KALRO) and Kenya Seed Company (KSC) staff from Information Communications Technology and seed units as well as the farmers and agro-dealers in Tranzoia county. Yamane's formula was used to calculate a representative sample size, resulting in a total of 269 respondents. Data collection instruments involved both structured questionnaires and semi-structured interviews and their reliability was verified using Cronbach's alpha, with their values exceeding recommended 0.70 and validity for both face and content validity scoring more than 0.80.

RESULTS AND DISCUSSION

This study employed both descriptive and regression analysis to evaluate the key challenges that affect the adoption of integrated AI-Block chain-IoT technologies in Kenyan seed supply chain as guided by the TOE framework of technology adoption.

A. Factors Affecting AI-Blockchain-IoT Adoption in Seed Sector

Table 1 presents the responses frequencies and descriptive statistics across the identified factors.

TABLE 1 RESPONDENT VIEWS ON FACTORS AFFECTING AI-BLOCKCHAIN-IOT ADOPTION IN THE SEED SECTOR

#	Challenge	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std Dev
1	High Cost of Implementation	15 (5.7%)	43 (16.0%)	52 (19.5%)	105 (39.1%)	53 (19.7%)	3.52	1.063
2	Limited Technical Knowledge	9 (3.4%)	34 (12.6%)	45 (16.7%)	110 (40.8%)	71 (26.4%)	3.74	0.988
3	Infrastructure Gaps	14 (5.2%)	31 (11.5%)	50 (18.4%)	99 (36.8%)	76 (28.2%)	3.71	1.036
4	Lack of Seed Traceability	17 (6.3%)	28 (10.3%)	46 (17.2%)	94 (35.1%)	83 (31.0%)	3.74	1.102
5	Resistance to Technological Change	22 (8.0%)	48 (17.8%)	63 (23.6%)	94 (35.1%)	42 (15.5%)	3.32	1.107
6	Lack of Awareness of Benefits	26 (9.8%)	40 (14.9%)	60 (22.4%)	90 (33.3%)	52 (19.5%)	3.38	1.139
7	Fear of Complexity	20 (7.5%)	37 (13.8%)	57 (21.3%)	97 (36.2%)	57 (21.3%)	3.50	1.104
8	Reluctance to Transition from Trad. Methods	23 (8.6%)	42 (15.5%)	56 (20.7%)	91 (34.0%)	56 (20.7%)	3.44	1.130
9	Cost & Learning Curve Concerns	15 (5.7%)	35 (13.2%)	62 (23.0%)	96 (35.6%)	60 (22.4%)	3.57	1.075

58.8% of the respondents affirmed that high cost of implementation affects the implementation of these technologies with a mean score of 3.52 and a standard deviation of 1.063. This shows that the costs are still high, suggesting that policy makers need to find ways of making these technologies to be affordable thus encouraging their uptake. Limited technology knowledge, infrastructure gaps and lack of traceability technologies also scored 3.74, 3.71 and 3.74 respectively, indicating that the respondents agreed that they are among the factors that affect the implementation of AI-Blockchain-IoT technologies. Concerns about both cost and the steep learning curve were also identified, with a mean score of 3.57. This shows that that even when stakeholders recognize the benefits of new technologies, they are discouraged by the time, effort, and expense needed to be able to use these technologies effectively. Resistance to technological change was affirmed by 51% of respondents, with a mean score of 3.32 and a standard deviation of 1.107. While were neutral, others noted that many stakeholders such as farmers are cautious to change from familiar traditional methods to digital systems, particularly when they perceive them as complex or unnecessary. Lack of awareness about the benefits of AI and blockchain also affects adoption, as shown by a mean of 3.38 and 53% of respondents. Respondents expressed that unless clear, demonstrable benefits are communicated to stakeholders, they will remain skeptical or indifferent. Awareness campaigns, therefore, are necessary to show the value proposition of such

technologies. Fear of complexity scored a mean of 3.50 with 57% of the respondents agreeing to the statement, indicating that many view AI, blockchain, and IoT as difficult to understand and operate. This perception creates reluctance to engage with the technologies, particularly when users are not confident in their digital skills. Reluctance to transition from traditional methods yielded a mean of 3.44. with 54.7% meaning a significant number of respondents noted that many farmers are deeply rooted in conventional practices, and breaking these routines will require deliberate efforts, such as training and long-term support. The findings of this study revealed that both technological barriers (such as cost, infrastructure, and skills) and organizational barriers (such as resistance, fear, and lack of awareness) and environmental (lack of traceability technologies) need to be addressed. Investments in digital infrastructure, targeted training, stakeholder sensitization, and support systems are essential if AI-blockchain-IoT technologies are to be effectively implemented in the seed supply chain.

B. Effect of Adoption Challenges on AI-Blockchain-IoT Implementation in Seed Sector

To determine whether the challenges identified have a significant influence on the adoption of AI-Blockchain-IoT in the seed sector, a linear regression analysis was conducted using the following null hypothesis

Ho_1: Challenges to AI-Blockchain-IoT adoption have no significant influence on the use of AI-Blockchain-IoT in the seed sector

1. Frequency Distribution of AI –Blockchain-IoT Adoption

Responses on AI, Block chain, and IoT technologies' adoption are shown in table 2

TABLE 2 FREQUENCY DISTRIBUTION OF AI – BLOCKCHAIN-IoT ADOPTION LEVELS

Adoption Level of AIBIoT	Frequency	Percent
1 (Very Low)	38	14.1%
2 (Low)	48	17.8%
3 (Moderate)	81	30.1%
4 (High)	70	26.0%
5 (Very High)	32	11.9%
Total	**269**	**100%**

As shown in Table 2, 14.1% of respondents indicated very low adoption, while 26.0% indicated high adoption of AI-BIoT technologies while other respondents (30.1%) reported moderate levels of adoption.

2. Effects of Challenges on the Adoption AI-Blockchain-IoT *in the Seed Sector*

A linear regression analysis was performed to examine the effect of challenges on the adoption of AI-Blockchain-IoT in the seed sector.

TABLE 3 MODEL SUMMARY OF LINEAR REGRESSION

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1 (Challenges → AIBIoT Adoption)	0.611	0.364	0.280	0.789

As indicated in table 3, The results showed a moderate positive relationship (R = 0.611), with 36.4% of the variance in adoption explained by challenges (R^2 = 0.364). The adjusted R^2 = 0.280 further supports model validity. These findings suggest that challenges to adoption significantly influence the adoption of AI-Blockchain-IoT leading to the rejection of the null hypothesis (H_{o1}).

3. Significance of Regression Model

ANOVA test was conducted to test the overall significance of the regression model.

TABLE 4 ANOVA TEST

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	10.081	67	1.311	3.232	0.005**
Residual	18.223	108	0.496		
Total	29.227	94			

The ANOVA results indicated that the model was statistically significant, F(67, 108) = 3.232, p = 0.005 which is <0.05. This suggests that the set of predictor variables in this case the challenges significantly have effect on AI, Blockchain, and IoT adoption, therefore, the research rejects the null hypothesis (Ho_1).

4. Regression Coefficients

Table 5 shows how each predictor variable contributes to the model with it's respective precision (standard error), test statistics (t-values), and significance levels (p-values)

TABLE 5 REGRESSION COEFFICIENTS

Predictor (Challenges)	Unstandardized B	Std. Error	t	Sig.
(Constant)	1.432	0.511	2.802	0.008**
High Cost of Implementation	-0.201	0.092	-2.185	0.034**
Limited Technical Knowledge	-0.243	0.101	-2.405	0.021**
Infrastructure Gaps	-0.178	0.097	-1.835	0.074
Lack of Seed Traceability	-0.158	0.090	-1.755	0.086
Resistance to Technological Change	-0.134	0.081	-1.654	0.106
Lack of Awareness of Benefits	-0.198	0.088	-2.250	0.030**
Fear of Complexity	-0.160	0.082	-1.951	0.058
Reluctance to Transition from Trad. Methods	-0.189	0.093	-2.032	0.048**
Concerns About Cost and Learning Curve	-0.217	0.090	-2.411	0.020**

Note: **p < 0.05** indicates statistical significance.

Results in Table 5 show that high cost of implementation (p = 0.034), limited technical knowledge (p = 0.021), lack of awareness of benefits (p = 0.030), reluctance to transition (p = 0.048), and concerns about cost and learning curve (p = 0.020) were found to be statistically significant predictors of lower of AI-Blockchain-IoT adoption. These results suggest that as these challenges intensify, the likelihood of adopting these technologies decreases. Other factors, such as infrastructure gaps, seed traceability, and fear of complexity, showed negative coefficients but were not statistically significant at the 0.05 level, though they still suggest a trend of negatively impacting adoption.

The linear regression model confirms that challenges such as high costs, limited technical expertise, lack of awareness, and reluctance to change significantly hinder the adoption of AI-Blockchain-IoT technologies in the seed sector. With R^2 = 36.4%, the model explains a moderate portion of the variation in adoption behaviour. These findings emphasize the need for strategic interventions such as training programs, cost subsidies, and public awareness initiatives to enhance the readiness of stakeholders to adopt AI-Blockchain-IoT technologies in the Kenyan seed sector.

CONCLUSION

This study sought to evaluate the factors that affect the successful implementation of integrated AI-Blockchain-IoT in the Kenyan seed supply chain underpinning the TOE model of adoption. The findings of this study revealed that high cost of implementation, limited technical knowledge, lack of awareness of technology benefits, reluctance to transition and concerns about cost and learning curve were found to be significant predictors of lower of AI-Blockchain-IoT adoption. Investments on digital infrastructure, targeted training, stakeholder sensitization, and support systems are essential if AI-blockchain-IoT technologies are to be effectively implemented in Kenyan Seed Supply Chain.

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