

# Evaluating AI-Blockchain-IoT Capabilities and Effects on Transparency in Kenyan Seed Supply Chain

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## ABSTRACT

Agricultural sector plays a very crucial role in Kenyan national economy and within it, is the seed sector which is its driver and sustainer. Despite the strides that have been made towards digitalization of the seed sector, still, there are challenges facing it, one of them being lack of transparency. This has resulted in farmers purchasing counterfeit seeds which have adverse effects on the overall crop yields and great financial losses to farmers. This study sought to evaluate the capabilities and the effects of integrating AI-Blockchain-IoT technologies to improve transparency within the seed supply chain. Data was collected from KALRO and KSC staff, farmers and agro-dealers through questionnaires and interviews and data analyses carried out were both descriptive and inferential. Findings revealed varying perceptions on the capabilities of these technologies which show that more awareness needs to be done to enlighten the stakeholders on the benefits of these technologies as well as benefits of their integration. In addition, the findings on the effects revealed that integration of AI-Blockchain-IoT technologies has a statistically significant positive effect on transparency in the seed supply chain. This study contributes to practice by providing insights into technologies that can enhance transparency so that all stakeholders can have clear visibility and access to information on the entire seed supply chain operations.

**Keywords:** Blockchain, IoT, AI, Transparency, Seed Supply Chain, Technology Integration

## INTRODUCTION

In Kenya, agriculture sector plays a very important role in economic development given that it contributes to almost 30% of the total Gross Domestic Product (GDP) and employs over 40% of the Kenyan population [1]. Seed sector is an equally important part within the agricultural sector because it determines its success and sustainability. Kenyan seed sector is made up of both formal system where certified seeds are used and the informal sector where farmers source, save, and share seeds locally [2]. There are strides that have been made towards digitalization of certain processes in the seed sector, however it is still highly fragmented with digital tools operating in isolated silos like apps and USSD codes [3,4,5,6]. Studies on the capabilities of these stand-alone systems have shown that there is a lot of fragmentation which bring inefficiencies, data redundancies, limited visibility, lack of transparency and mistrust [7,8].

In their study, [9,10] agreed that there is need for transparency in seed supply chain and it has been cited as the biggest challenge facing this sector. Without transparency, stakeholders like farmers are not privy of the information flow in the supply chain which in turn affects their decisions. This lack of transparency has brought issues like purchase of counterfeit seeds which is currently crippling the seed sector and affecting the overall crop yields [11,12]. In spite of the the studies on the capabilities of these stand-alone systems in the seed supply chain, studies on the capabilities of integrated AI, IoT, and blockchain technologies specifically to improve transparency in seed supply chain in Kenyan seed supply chain is lacking.

This study sought to evaluate the capabilities and the effects of AI-Blockchain-IoT technologies within the seed supply chain. Specifically, it sought to evaluate the effects of integrating these technologies to enhance transparency in seed Kenyan seed supply chain. This will benefit the stakeholders in

understanding the technologies that can help improve transparency in seed supply chain.

## METHODS AND MATERIAL

This study employed descriptive and regression analyses to evaluate capabilities of integrated AI, blockchain and IoT in seed supply chain and it utilized both quantitative and qualitative data. The research philosophy was pragmatism approach that allowed the study to have deep exploration of experiences which enabled the study to gain deep insight into the integrated technologies and into the seed supply chain. The target population for this study were farmers and agro dealers from Tranzoi county as well as seed breeders and multipliers. Purposive sampling was used sample Kenya Agricultural and Livestock Research Organization (KALRO) for the seed breeders because it is the main seed breeder in Kenya and Kenya Seed Company (KSC) for the multipliers because it is state owned and its one of the main seed multipliers in Kenya. Staff from Information Communications Technology section as well as seed units/sections were purposely sampled from these organizations because it is believed they are informed enough about seed supply chain and associated technologies. Yamane's formula was used to calculate a representative sample size, resulting in 269 respondents. Data collection involved both structured questionnaires and semi-structured interviews. Data collection instruments' reliability was verified using Cronbach's alpha, with values exceeding the 0.70 recommended value and validity was as well established through expert evaluations where the instruments scored more than 0.80 (80%) for both face and content validity.

## RESULTS AND DISCUSSION

By using both descriptive and regression analysis, this study sought to evaluate the capabilities and effects of integrated AI-Blockchain-IoT in enhancing the seed

supply chain operations, specifically in the context of improving transparency.

**A. Capabilities Of AI- Blockchain–Iot Integration In Kenyan Seed Supply Chain**

To assess the capabilities of these technologies, this study collected responses from the respondents to

evaluate various aspects of AI, Blockchain, and IoT using a five-point Likert scale with a range from Strongly Agree to Strongly Disagree. Table 1 provides a summary of the respondents' views.

**TABLE 1** RESPONSES ON AI-BLOCKCHAIN-IOT CAPABILITIES IN SEED SUPPLY CHAIN

S/NO	Item (Summary)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	STD
E1	Integration improves operations	54 (20.3%)	128 (47.7%)	32 (12%)	28 (10.5%)	26 (9.5%)	3.6	1.1
E2	AI dashboards suggest improvement in SSC	47 (17.5%)	86 (31.8%)	53 (19.6%)	55 (20.6%)	28 (10.5%)	3.3	1.2
E3	AI forecasts demand & planting times	55 (20.6%)	111 (41.3%)	28 (10.5%)	55 (20.6%)	19 (7%)	3.5	1.1
E4	AI optimized route/delivery	28 (10.5%)	167 (62.2%)	22 (8.3%)	23 (8.5%)	28 (10.5%)	3.5	1.3
E5	AI classifies seed quality	86 (32.1%)	110 (41%)	23 (8.5%)	28 (10.3%)	22 (8.1%)	3.8	1.2
E6	AI detects fraud/tampering	54 (20%)	134 (50%)	27 (10%)	26 (9.5%)	28 (10.5%)	3.5	1.1
E7	AI enables automates decision making	55 (20.6%)	84 (31.1%)	50 (18.6%)	52 (19.2%)	28 (10.5%)	3.3	1.1
E8	Blockchain tracks seed origin/movement	84 (31.1%)	111 (41.3%)	27 (10%)	23 (8.5%)	24 (9.1%)	3.7	1.2
E9	Blockchain secures & shares data	111 (41.3%)	90 (33.6%)	22 (8%)	20 (7.5%)	26 (9.6%)	3.8	1.2
E10	Blockchain authenticates certifications	34 (12.5%)	88 (32.8%)	55 (20.6%)	58 (21.6%)	34 (12.5%)	3.1	1.0
E11	Blockchain reduces disputes	55 (20.6%)	135 (50.2%)	26 (9.7%)	24 (9%)	28 (10.5%)	3.6	1.1
E12	Smart contracts automate transactions	44 (16.5%)	86 (31.8%)	55 (20.6%)	55 (20.6%)	28 (10.5%)	3.2	1.2
E13	Blockchain records location and handovers	31 (11.5%)	84 (31.4%)	32 (11.8%)	88 (32.8%)	34 (12.5%)	2.9	1.1
E14	IoT monitors conditions	84 (31.1%)	114 (42.3%)	25 (9.3%)	25 (9.2%)	21 (8.1%)	3.7	1.2
E15	IoT tracks shipments	55 (20.6%)	156 (57.9%)	15 (5.5%)	17 (6.5%)	26 (9.5%)	3.7	1.2

S/NO	Item (Summary)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	STD
E16	IoT alerts abnormal conditions	36 (13.5%)	86 (32.1%)	58 (21.6%)	60 (22.3%)	28 (10.5%)	3.1	1.1
E17	IoT supports predictive maintenance	55 (20.6%)	111 (41.3%)	28 (10.5%)	51 (19.1%)	23 (8.5%)	3.4	1.2
E18	IoT logs full supply chain	59 (21.8%)	139 (51.7%)	31 (11.5%)	23 (8.5%)	17 (6.5%)	3.7	1.1
E19	IoT prevents spoilage	42 (15.5%)	84 (31.1%)	60 (22.3%)	55 (20.6%)	28 (10.5%)	3.2	1.2
E20	IoT collects field data	49 (18.3%)	159 (59.2%)	23 (8.5%)	20 (7.5%)	18 (6.5%)	3.7	1.1
Composite Mean and Composite SDT							<b>3.4</b>	<b>1.1</b>

Table 1 shows that a noteworthy number of respondents agree that integrating AI, Blockchain, and IoT technologies enhances processes effectiveness in seed supply chain having 68% of the respondents agreeing to it and a mean score of 3.6 with a standard deviation of 1.1.

Data visualization and decision-making automation had moderate response with a mean of 3.3 with a standard deviation of 1.1 and 1.2 respectively, suggesting that respondents remained neutral, indicating some uncertainty regarding these AI capabilities. On the other hand, forecast demands, optimized routing/delivery, classification, and fraud detection, had positive responses with a mean ranging from 3.5 and 3.8 and a standard deviation between 1.1 and 1.3 suggesting strong agreement by the respondents.

There was a strong agreement to blockchain's ability on traceability, data security, data sharing and dispute reduction evident by the mean scores of between 3.6 and 3.8 and a standard deviation between 1.1 and 1.2 suggesting strong agreement by the respondents. However, respondents remained neutral on the ability of blockchain to authenticate certifications, smart contracts automation of transactions and recording of location and handovers as shown by a

mean score of between 2.9 and 3.2 and a standard deviation between 1.1 and 1.2 suggesting that respondents were not sure of these capabilities.

There was a strong agreement on IoT's capabilities on conditions monitoring, shipment tracking, supply chain logging and field data collection which was indicated by a mean of between 3.7 each and standard deviation between 1.1 and 1.2 suggesting strong agreement by the respondents. On the other hand, respondents remained neutral on the ability of IoT to give alerts on abnormal conditions, predictive maintenance and to prevent spoilage as shown by a mean score of between 3.1 and 3.4 and a standard deviation between 1.1 and 1.2 suggesting that respondents were not sure of these capabilities.

This variability aligns with the notion that the full capabilities of these technologies are not yet uniformly perceived or implemented. These findings suggest that there is a need for better training, awareness programs, and further integration of these technologies within the seed supply chain to bridge the gaps between perception and practical implementation. This also reflects the mixed reception of new technological innovations, where a proportion of stakeholders might not fully grasp their potential, as suggested by previous studies by [13] on

technology adoption in agricultural systems. A composite means of 3.4 with a standard deviation of 1.1 suggests that, on average, participants were undecided or neutral, but their individual responses were quite widespread, indicating mixed opinions or uncertainty across the group.

**B. Effect of AI-Blockchain-Iot Integration on Transparency in Seed Supply Chain**

To establish the effect of AI Blockchain-IoT integration on transparency in the seed supply chain, an Ordered Logistic Regression test was carried out. The analysis aimed to test the following null hypothesis at a 0.05 level of significance:

$H_{01}$ : The integration of AI- Blockchain-IoT technologies has no effect on transparency in the seed supply chain.

**1. Perceived Impact on Seed Supply Chain Transparency**

The respondents' views on how AI- Blockchain-IoT contribute to transparency were categorized and summarized in Table 2.

**TABLE 2 FREQUENCY DISTRIBUTION OF EFFECT OF AI-BLOCKCHAIN-IOT ON TRANSPARENCY**

Effect	N	%
[EFFECT= 1 Strongly Disagree (1)	48	17.8%
[EFFECT= 2 Disagree (2)	71	26.4%
[EFFECT= 3 Neutral (3)	62	23.1%
[EFFECT= 4 Agree (4)	53	19.7%
[EFFECT= 5 Strongly Agree (5)	35	13%

In Table 2, most of the respondents, (26.4%) expressed disagreement with the negative impact of AI, Blockchain, and IoT technologies on transparency in the seed supply chain, while 17.8% strongly disagreed. However, 23.1% of respondents were neutral, while 32.7% generally agreed. This reflected a generally divided opinion on the overall effectiveness of technology in enhancing

transparency nonetheless rejecting the null hypothesis ( $H_{01}$ ) and conclude that digital technology integration significantly enhances transparency in the seed sector hypothesis.

**2. Model Fit**

From Table 3, the statistically significant chi-square statistic ( $p < 0.05$ ) indicates that the final model provides a significant improvement over the baseline intercept-only model.

**TABLE 3 MODEL FIT**

Model	-2 Likelihood	Log Chi-Square	df	Sig.
Intercept Only	348.213			
Final Model	320.045	28.168	13	<b>0.018</b>

The likelihood ratio Chi-Square test ( $\chi^2 = 28.168$ ,  $df = 13$ ,  $p = 0.018$ ) indicates that ordered Logistic Regression model with AI, Blockchain, and IoT predictors fits the data significantly better than the intercept-only model. This suggests that the inclusion of AI- Blockchain-IoT technologies in the analysis helps in predicting transparency in the seed supply chain Therefore, the study rejects the null hypothesis ( $H_{02}$ ) and conclude that digital technology integration significantly enhances transparency in the seed sector.

**3. Goodness -of-Fit**

The logistic regression model's fit was examined using Pearson ( $\chi^2 = 309.101$ ,  $df = 269$ ,  $p = 0.172$ ) and deviance ( $\chi^2 = 312.434$ ,  $df = 269$ ,  $p = 0.203$ ) goodness-of-fit tests.

**TABLE 4 GOODNESS-OF-FIT**

Test	Chi-Square	Df	Sig.
Pearson	309.101	269	<b>0.172</b>
Deviance	312.434	269	<b>0.203</b>

As shown in Table 4, the p-values for both the Pearson ( $p = 0.172$ ) and Deviance ( $p = 0.203$ ) goodness-of-fit tests p-values exceed 0.05, the study fail to reject the null hypothesis, suggesting that the model's predictions do not significantly deviate from the observed data and thus indicate an acceptable fit. This implies that the logistic regression model's predictions align well with the observed data, and the model is a good fit for the data.

**4. Pseudo R-Square**

As shown in Table 5, the Pseudo R-Square values were Cox and Snell = 0.137, Nagelkerke = 0.154, and McFadden = 0.089, indicating that the model explains approximately 13.7% to 15.4% of the variation in seed supply chain transparency.

**TABLE 5 PSEUDO R-SQUARE ( $R^2$ )**

Cox and Snell	Nagelkerke	McFadden
0.137	0.154	0.089

While this is relatively modest value, it indicates that these technologies do have a meaningful but limited impact on transparency which is acceptable in studies involving complex human and technological factors.

**5. Multicollinearity Tests**

Diagnostic tests were performed to evaluate whether the AI-Blockchain-IoT data met the basic assumptions necessary for statistical analysis. To assess multicollinearity, both the tolerance value and Variance Inflation Factor (VIF) were computed.

**TABLE 6 MULTICOLLINEARITY TESTS FOR AI-BLOCKCHAIN-IOT DATA**

Model	Collinearity Statistics	
	Tolerance	Variance Inflation Factor
AI Integration	0.766	1.16
Blockchain	0.722	1.25

Model	Collinearity Statistics	
IoT Integration	0.714	1.23
Transparency	0.728	1.34

The results from Table 6 show that all tolerance values exceed 0.7, and the VIF values are below 2, indicating no significant multicollinearity among the independent variables, and the regression coefficients can be interpreted reliably. This suggests that the predictor variables (AI, Blockchain, IoT) are not highly correlated and do not pose issues for the regression model.

The Ordered Logistic Regression model with AI-Blockchain-IoT predictors fits the data significantly better than a model without them  $p = 0.018$ . This showed that the inclusion of AI-Blockchain- IoT technologies in the analysis helps in predicting transparency in the seed supply chain, significantly better than simply guessing based on marginal probabilities. The inferential analysis further validates the influence of these technologies on transparency within the seed supply chain. Strong positive correlations between AI- Blockchain-IoT and transparency affirm that these technologies collectively contribute to improving visibility and accountability in seed supply chains. This corroborates the work of [14], who advocate for integrated digital solutions to enhance traceability and food safety.

**CONCLUSION**

This study sought to evaluate the capabilities and the effects of integrating AI-Blockchain-IoT technologies to improve transparency within the seed supply chain. Findings on the capabilities of these technologies revealed diverse responses. This variability aligns with the notion that the full capabilities of these technologies are not yet

uniformly perceived which requires training, awareness programs and further integration of these technologies within the seed supply chain to bridge the gaps between perception and practical implementation. On the effects of these technologies on transparency, the findings revealed that indeed the integration of AI-Blockchain-IoT technologies has a statistically significant positive effect on transparency in the seed supply chain, therefore there is need for adoption of these integrated technologies to improve transparency and visibility in Kenyan seed supply chain.

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