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An Enhanced Integrated Knowledge Management System and Industrial Revolution 4.0 Technology Framework for Enhancing Business Value.

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Abstract— *This study explores the integration of Knowledge Management Systems (KMS) with Industrial Revolution 4.0 (IR4.0) technologies by incorporating an Explainable Artificial Intelligence (XAI) model to address the critical challenges of transparency and trust in AI-driven decision-making. The research aims to enhance the interpretability of AI models within organizational knowledge management frameworks, facilitating better decision-making processes and improved business value. A structured research methodology involving literature review, survey data collection, framework enhancement, and statistical evaluation was employed. A field survey was conducted among IT professionals, managers, and users working with KMS and IR4.0 technologies to assess the applicability of XAI integration. The data was analyzed using descriptive statistics, Cronbach's Alpha reliability test, and regression analysis to evaluate the impact of XAI on the integrated framework. The findings indicate that integrating XAI into the KMS and IR 4.0 framework has significantly improved the transparency of the framework, enhances user trust, and fosters efficient knowledge-sharing. Regression analysis results demonstrate a strong positive correlation between the two models. Additionally, the work expressed readiness for organizations integrate XAI into their KMS by highlighting its practical applicability.*

Keywords— Explainable Artificial Intelligence (XAI), Knowledge Management System (KMS), Industrial Revolution 4.0 (IR4.0), Organizational Challenges (OC), Technology Integration (TI).

1. INTRODUCTION

The integration of Industrial Revolution 4.0 (IR4.0) technologies has also revolutionized the business landscape, presenting organizations with unprecedented opportunities to drive innovation, efficiency, and value creation (Omotayo, 2022). Key technologies such as artificial intelligence (AI), Internet of Things (IoT), Machine Learning (ML), 5G Networks, big data analytics, Cloud Computing and Robotic Process Automation (RPA) have emerged as crucial enablers of digital transformation. By harnessing the power of these technologies, organizations can optimize operations, make data-driven decisions, and gain a competitive edge in the dynamic and fast-paced market (Adesina and Ngo, 2020). But integration of KMS with IR4.0 technologies remains a challenge due to the complexity and heterogeneity of data sources, as well as the need for effective decision-making and collaboration among different stakeholders (Tien et al., 2020). However, many businesses have invested in projects involving knowledge management, assuming it will significantly contribute to improving their business values, but not all are obtaining the expected bottom-line results (Sharma, 2021). This is because effective management of knowledge has been a critical ingredient for organisations seeking to ensure sustainable strategies for enhancing business values (Omotayo, 2022). In the knowledge economy and information society, knowledge management has emerged as a trend that cannot be ignored (Tien et al., 2021). Business experts regard an organization's knowledge as one of its most significant assets. This has made knowledge management to become one of the important concepts of modern management (Wojcak and Lukáš, 2022).

A study by (Botega and Silva, 2020) stated that integration of new techniques and new technologies into organizations' knowledge will help to bring effective knowledge management and transform individual knowledge into organizational knowledge. There is also need for businesses to pay attention to the development of new appropriate methods that will foster knowledge management implementation (Hermann, 2023). Since the business value of KM reveals that most of the work on evaluating the effectiveness of KM efforts is concentrated on studying the association between KM and firm performance, there is a need for the integration of new revolutionary techniques into organizations' knowledge systems to improve the business value of the organization in term of performance, innovations, new skill and new ideas to be relevant in this era of advancing technology (Tien et al., 2021).

Korycinski et al., (2020) have creatively proposed the ideas and frameworks for Integrating Knowledge Management Systems with Industrial Revolution 4.0 technologies, however their study did not explain how integrating explainable AI (XAI) into this framework can provide interpretability challenges in the existing frameworks.

The study of (Mustapha, 2023) conducted a comprehensive review to explore the integration of explainable AI (XAI) techniques in knowledge management systems during the Industrial Revolution 4.0 (IR4.0). Their study focuses on identifying the challenges in

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implementing XAI within the context of IR4.0 technologies and suggested the need to provide a framework that emphasizes the need for interpretable AI models to promote trust, transparency, and effective knowledge sharing in organizations during the IR 4.0 era.

A survey by (Lista and Tortorella, 2022) stated that one major problem associated with the Integrated KMS and IR4.0 technology framework by (Tien et al., 2023 and Korycinski et al., 2023) is that their framework lacks interpretability and explainability in its model. Therefore, businesses face a significant challenge to trust the decisions made by this framework due to the perceived disadvantages associated with it. Another study by (Berman, 2022) highlighted that integrating XAI into organizational KMS during IR4.0 can allow organizations to effectively harness the combined power of KMS and IR4.0 technologies for enhancing business value.

The overwhelming majority of the researchers were fundamentalists about the importance of providing interpretable explanations for AI-driven decision systems, but no framework was proposed. While some studies provide solutions by highlighting the relevance of XAI in the context of IR4.0. Like the studies by (Manesh et al., 2020 and Gavrilova et al., 2019) mainly focused on identifying the challenges and Opportunities in implementing Explainable AI within the context of IR4.0 technologies. Moreover, in the framework for Integrating Knowledge Management Systems with Industrial Revolution 4.0 technologies by (Tien et al., 2022), the study only highlighted the significance of integrating explainable AI in various domains including emerging technologies. But did not provide any model that can be used to achieved the integration.

Therefore, there's a need to enhance these frameworks so as to improve organizational decision-making process by providing interpretability to decision made by machines. To achieve this, the study enhanced the Integrating Knowledge Management Systems with Industrial Revolution 4.0 technologies framework by (Tien et al., 2019) by adding an XAI model into it. So that the framework can provide interpretability into A.I decision making models.

Building upon this foundation, a novel explainable AI framework is developed and validated through various case studies, evaluating its efficacy in enhancing business value within organizations. This study enhanced the existing Integrated KMS and IR4.0 Technology framework by incorporating an explainable AI (XAI) model into it. The enhanced framework has provided interpretation to decisions made by machines in context of enhancing business values. Then evaluate the enhanced framework through various case studies.

2. MATERIALS AND METHODS

2.1 Research design

The survey design was used in designing and developing the framework. The process will begin by reviewing extant kinds of literature to obtain all the relevant framework that facilitates the integration XAI into Knowledge Management Systems (KMS) and Industrial Revolution 4.0 (IR4.0) technologies. For developing the research, a questionnaire was structured into sections.

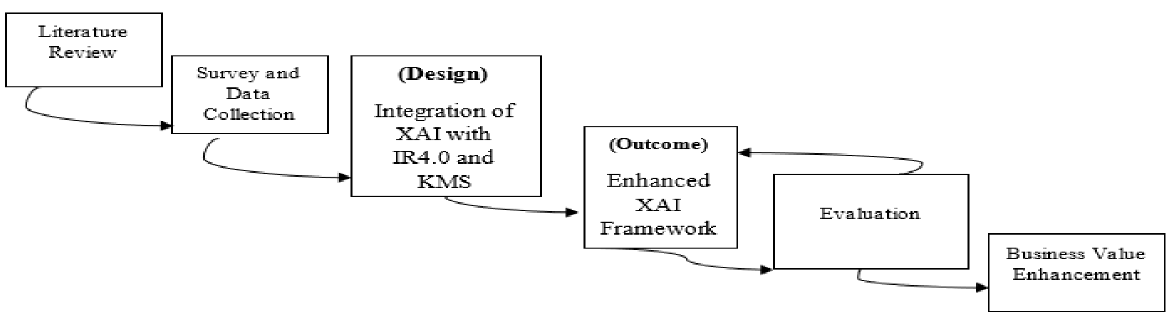

Figure 1: Research Methodological Stages. Adapted from (Korycinski et al., 2020)

The first section will be aimed at collecting the demographic profile of the sample. While subsequent section, will contain questions on IR4.0 technologies and KMS measured by (Liu et al., 2020) model which has been consistently reported and used in the literature on XAI and IR4.0. The methodological stages are six (6), as shown in figure 1 below, thus stage one literature review, stage two survey and data collection and stage three is the integration of XAI with IR4.0 and KMS model four is the designing the enhanced framework, stage five is the evaluation.

2.2 Model Enhancement

Figure 2 shows the XAI model, it provides a valuable insight into the complex landscape of integrating XAI into the KMS and IR4.0 framework, guiding the development of the new XAI framework. The method of data analysis to be used in this research is that the data will be collected from the instrument, and the scores obtained will be analyzed and help in making decisions using mean and standard deviation to analyze the collected research questions data from the questionnaire distributed. Appropriate statistical tools will also be applied for interpretations. The data was collected and analyzed with Statistical Package for the Social Sciences (SPSS) based on the research questions for data presentation. The data are presented and interpreted using a table, histogram and pie chart. At this stage, the model is enhanced by Integrating the KMS and IR4.0 Technology frameworks with explainable AI model which will be evaluated. In order to achieve the objective of this research, the below images represent the XAI model which will be integrated into a the integrated KMS and IR4.0 technology framework.

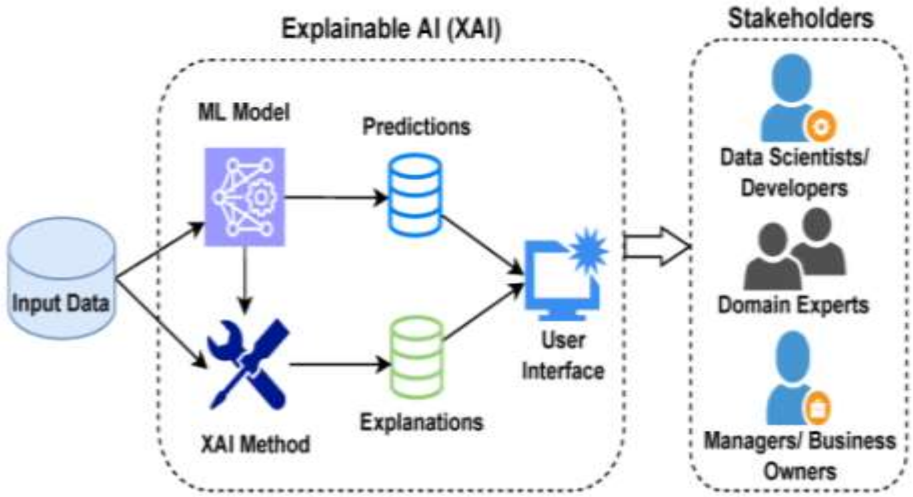

Figure 2: XAI Model.

2.3 AN ENHANCED INTEGRATED KMS AND IR4.0 FRAMEWORK

Figure 3 shows a comprehensive XAI framework that seamlessly integrates KMS and IR4.0 technologies while emphasizing transparency and interpretability in AI-driven decisions, addressing concerns associated with the opacity of AI models.

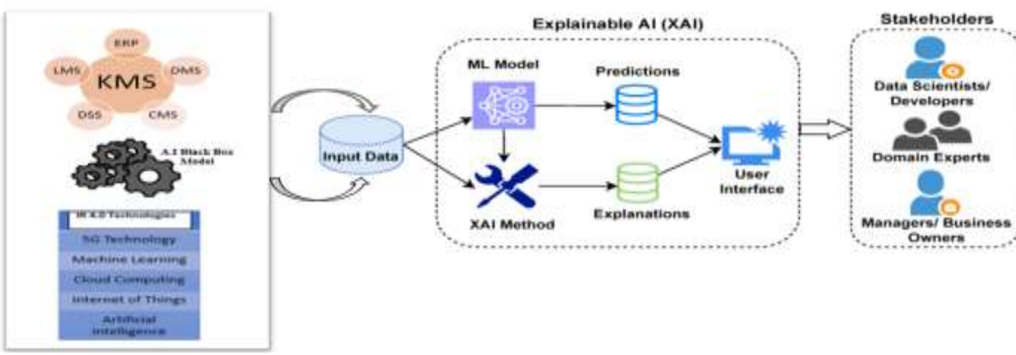

Figure 3: Enhanced Integrated KMS and IR4.0 Framework.

3 RESULT AND DISCUSSION

3.1 Data Testing and Analysis

The questionnaires were administered to 189 participants, out of which 187 responses were received and 179 of the responses were recorded and analyze as valid data as attached as appendix A. Then Cronbach's Alpha analysis is used to test for internal consistency, and determine if the variable items of the questionnaire are reliable (Lukáš et al., 2022). The correlation between variables and their moderating effects are examined using multi-level regression analysis. Both the Correlation Test and the Cronbach's Alpha analysis is done in this work using SPSS software. The reasons for the use of this method is that, the computational procedure is fairly simple as compared with other techniques. Also, this method has been used by different researchers with fairly satisfactory results been gotten (Ibrahim et al., 2019), (Shodiya, 2021) & (Lukáš et al., 2022). Due to the nature of the data used, SPSS makes it easy to establish a valid relationship between the dependent variable and the independent variables (Ananthi et al., 2019)

3.2 Determining how well the XAI model fits into the Integrated KMS and IR4.0 technology framework

Table 1 shows the descriptive statistics of the estimate values. It shows the mean, standard deviation, and sample size (N) for three variables: XAI, IR4.0, and KMS. On average, the value of the XAI variable is 4.38. This suggests that the central tendency of the data points is relatively high on the scale being used. The standard deviation is less than 1 (0.978), indicating that the values of XAI are clustered closely around the mean. There is relatively low variability in responses. The average value for the IR4.0 variable is 3.70.

Table 1: Descriptive Statistics

	Mean	Std. Deviation	N
XAI	4.38	.978	179
IR4.0	3.70	1.372	179
KMS	3.75	1.394	179

This suggests a moderate central tendency, likely on a similar scale as XAI. The standard deviation is higher than that of XAI, indicating more variability in the responses. The data points are more spread out from the mean. The average value for the KMS variable is 3.75, which is close to the mean value for IR4.0. This suggests a moderate central tendency. The standard deviation is similar to that of IR4.0 and higher than XAI, indicating a similar level of variability to IR4.0 and more spread out than XAI. We can conclude that XAI has the highest mean, suggesting that on average, it scores higher than IR4.0 and KMS. This indicate more positive responses or higher values on the scale for XAI. XAI has the lowest standard deviation, indicating that responses are more consistent and closer to the mean compared to IR4.0 and KMS. IR4.0 and KMS have higher variability, suggesting a wider range of responses.

Table 2: Reliability Statistics

Reliability Statistics		
Cronbach's Alpha	Variable N of Items	Variable
.854	7	XAI
.913	13	IR4.0
.923	14	KMS

In table 4.2, the Cronbach's Alpha analysis test for internal consistency on questions asked on XAI was measured to be 0.854, this means that the internal consistency among the item used to measure the variable is a “Good scale”. IR4.0 was 0.913, this means that the internal consistency among the variable items used to measured questions on IR4.0 is an “Excellent Scale”. For KMS, the Cronbach's Alpha value is 0.923, indicating that the internal consistency among the variable items used to measured questions on KMS is an “Excellent Scale”. The means that the questionnaire is reliable, and can be used for data analysis.

The Cronbach's Alpha analysis take the form of

$$\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N} \sigma_i^2}{\sigma_T^2}\right)$$

where:

- N is the number of items.
- σ_i^2 is the variance of item i.
- σ_T^2 is the variance of the total scores (sum of all items for each respondent).

Table 3 provides the R, R², adjusted R², and the standard error of the estimate and Durbin-Watson, which can be used to determine how well a regression model fits the data.

Table 3: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.722[a]	.578	.569	1.991	2.593
a. Predictors: (Constant), KMS, IR4.0					
b. Dependent Variable: XAI					

The correlation coefficient *R*, measures the strength and direction of the linear relationship between two or more variables. From the above model summary, the value of R = 0.722 represents the Pearson correlation. This value is positive and indicates "positive linear relationship" between the dependent variable (XAI model) and the independent variables (KMS and IR4.0 framework). A positive R also indicates that as one variable increases, the other variable also tends to increase (Gupta et al., 2018). The value of Durbin Watson was 2.593 which is greater than 1 and less than 3. This shows that there is an independence of observation, meaning there is no auto correlation. Therefore, integrating XAI model into KMS and IR4.0 framework is statistically significant. And the independent variables (KMS & IR4.0) used are truly independent. R^2 is the square of the correlation coefficient. It represents the proportion of the variance in the dependent variable that is predictable from the independent variable(s). The R^2 value was 0.578 which showed that 57.8%, variations in the XAI model is explained by KMS and IR4.0 framework, and the remaining 42.2% of the variation is accounted for by other factors not captured in this model. Thus, the value of R square can differ, because it deals with human behavior, which is very difficult to predict. High value of R-squared is almost impossible. However, this does not mean that any predicted model to such a case is always useless; a good model can have a low R^2 value (Adhikari, 2022).

The multiple regression equation is used to predict the value of a dependent variable based on the values of multiple independent variables (Adhikari, 2022). The general form of the multiple regression equation is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k + \epsilon$$

Where:

- Y is the dependent variable.
- β_0 is the intercept.
- $\beta_1, \beta_2, \beta_3, \ldots, \beta_k$ are the coefficients for the independent variables $X_1, X_2, X_3, \ldots, X_k$.
- $X_1, X_2, X_3, \ldots, X_k$ are the independent variables.
- ϵ is the error term.

3.3 Statistical significance of the enhanced framework

The F-test is used to find out whether integrating the XAI model actually have any significant influence on the KMS and IR4.0 framework. The F-test is often referred to in the context of ANOVA (Analysis of Variance), which is a statistical test used to determine whether there are significant differences between the means of three or more groups (Wu et al., 2020). The test will also helps in assessing the overall significance of the regression model. Both the ANOVA and regression analysis have their objective, the determination of the various factors which cause variation of the dependent variable, and this resemblance has led to the combination of the two methods in most scientific fields (Adhikari, 2022).

Table 4: ANOVA Test

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	30.350	5	15.175	19.102	.000[b]
	Residual	139.817	176	.794		
	Total	170.168	178			
a. Dependent Variable: XAI						
b. Predictors: (Constant), KMS, IR4.0						

Table 4 shows that the KMS and IR4.0 framework statistically significantly predict the XAI model. Because the F- ratio in the ANOVA table where F (2,176) = 19.102, p(0.000)<0.05. This means, the regression model is "a good fit of the data". In other words, there is a significant relationship between XIA model and the integrated KMS and IR4.0 technology framework. This show that, there is an improvement in the prediction of the variables. This is because the F ratio is greater than 1.

Table 5: Coefficients Test

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.012	.234		12.855	.000
	KMS	.229	.051	.321	4.507	.000
	IR4.0	.139	.050	.198	2.776	.006
a. Dependent Variable: XAI						

Table 5 shows a constant of 3.012, is the predicted value for the dependent variable when all of the independent variables are held constant or assumed to be 0. This means that we will expect an average increase of 3.012 in KMS and IR4.0 framework when integrated into the XAI. The unstandardized coefficient indicated how much the XAI model varies with the KMS & IR4.0 framework when all variables are held constant. The regression coefficient provides the expected change in the XAI for a unit increase in the framework. Referring to the coefficients above, the unstandardized coefficients for KMS is 0.229. This means that for every unit increase in KMS there is 0.229 increase in XAI. Which is statistically significant as p (0.001) < (0.02) which proves that there is substantial contributions from XAI model to the framework. Multicollinearity problem does not exist in the model as the Variance Inflation Factor (VIF) for all variables < 5 and Tolerance is > 0.1)

Adaptation of the enhanced framework

From the survey responses gathered, a total of 179 respondents responded to the survey. This implies that the number of responses received with respect to the research which was conducted on the subject matter as it relates to the enhancement of the KMS and IR4.0 framework is valid, because 93% of the total responses is applicable. The questionnaire was filled by IT professionals, Users and Managers who are familiar with the integrated KMS and IR4.0 framework. These experts are from various sectors like Education, Finance and Technology.

Table 6: Percentage of XAI survey participants base on Role/Position

		Frequency	Percent	Valid Percent
Valid	IT Professional	73	40.8	40.8
	Manager	47	26.3	26.3
	User	59	33.0	33.0
	Total	179	100.0	100.0

Figure 5 and Table 6 shows the distributions of the respondents by their roles. From the survey, it is observed that 73(40.8%) of the respondents are IT Professionals, while 47 (26.3%) are manager of various in sectors, and 59 (33%) are users who operates the KMS.

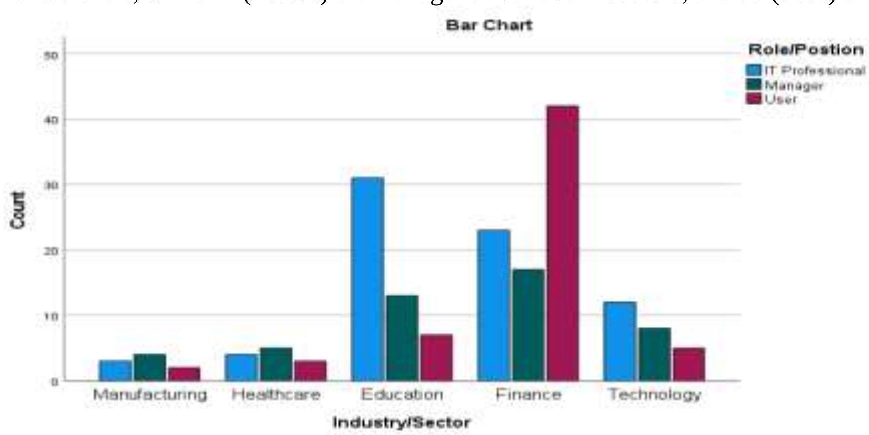

Figure 5: Bar chart showing respondents base on role/position

4 CONCLUSION

This research effectively integrates an Explainable Artificial Intelligence (XAI) model into the Industrial Revolution 4.0 (IR4.0) technology framework and Integrated Knowledge Management System (KMS). Addressing the issues of interpretability, transparency, and confidence in AI-driven decision-making in corporate knowledge management systems was the main goal. The results of the study show that incorporating XAI greatly increases the effectiveness of decision-making, boosts corporate value, and promotes improved knowledge-sharing by offering understandable, interpretable AI-generated insights. The efficiency of the improved framework was further supported by statistical analysis, which showed that it could account for 57.8% of the variances in AI decision-making. This study included regression modelling and Cronbach's Alpha reliability testing.

One of the greatest obstacles to adoption in many businesses is still the opaqueness of AI models. In order to address this, the paper suggests a hybrid strategy that combines natural language generation methods, rule-based explanations, and model visualization to improve the interpretability and reliability of AI-driven judgments. The findings also show that 64.8% of firms are open to incorporating XAI into their KMS, indicating the usefulness of the suggested framework. It is advised that enterprises adopt standardized XAI models, put strong security measures in place, and give AI users ongoing training in order to optimize the advantages of this improved framework. To guarantee the smooth integration and optimization of AI-driven knowledge management procedures, companies should also encourage cooperation between AI developers, business analysts, and decision-makers.

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