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ANALYSIS OF THE IMPACT OF THE RELATIONSHIP BETWEEN CURRENT AND INVESTMENT EXPENDITURES AND ITS REFLECTION ON ECONOMIC GROWTH IN IRAQ

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ARTICLE INFO	ABSTRACT
Article history: Received: 2025-10-01 Received in revised form:2025-10-20 Accepted:2025-11-28 Available online:2026-06-26 Keywords: Fiscal sustainability, Government expenditure structure, Macroeconomic performance, Budget allocation efficiency, Economic policy analysis, Public sector finance, Growth determinants, Developing economies, Resource allocation, Iraq JEL Classification: E62, H50, H54, O47	This study will examine the influence of public spending in the form of current and investment on economic growth in Iraq from 2004 to 2023. It is fueled by the increasing dominance of consumption-driven expenditure, which might reduce the effectiveness of fiscal policy in achieving sustainable development. The research will examine the relationship between these two indicators of spending and economic growth and identify its direction. It employs a mix of descriptive, analytical, and quantitative techniques, relying on time-series data that enables the estimation of how expenditure components influence growth performance. The study's hypothesis suggests that the unequal distribution of government spending may influence economic growth in various ways. The findings should provide insights into the effectiveness of social resource distribution and emphasize the need to raise investment expenditures to foster long-term economic growth. The study presents several policy suggestions that policymakers could implement to enhance fiscal policy development in Iraq

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INTRODUCTION:

Public expenditure is one of the core tools of fiscal policy with governments using it to shape economic activity and develop extensively. It is often divided into current and investment expenditures, the former being used to fund the operating and administrative activities of the state, and the latter being used to increase productive potential and broaden the economic base. Within the framework of Iraqi economy that has been susceptible to the negative effects of long-

term political and economic problematic issues, the analysis of the performance and the structure of the government expenditures has become more urgent in determining the extent to which it contributes to economic growth paths.

The nature of public expenditure in Iraq during the past decades suffered a high degree of bias such that it was consumed-based spending, effectively limiting its ability to bring about sustainable developmental results. This structural imbalance poses some key questions on the efficiency of the distribution of the public resources, especially in the context of the low role of investment spending in the long-term growth. In this connection, this study is driven by the fact that the differences between current and investment spending could have varying and possibly negative impacts on economic growth.

The research question is to find out the nature and trend of the relationship between the elements of the public spending and the economic growth in Iraq; that is, whether the current and investment expenditure attribute either negative or positive effects on the performance of the growth. To this end, the research hypothesis suggests that there should be a statistically significant relationship between these variables that may be of either direction depending on the kind of expenditure.

The importance of the research is that it can bring a further insight into how the idea of public investment is effective as a policy instrument of promoting economic activity and attaining more extensive economic, social, and political goals. The research paper intends to determine structural imbalances of the Iraqi economy by examining the structure of the public spending, especially the role of the spending elements in the gross domestic product of the economy [1]

In order to accomplish these goals, the study takes the integrated approach methodology integrating the descriptive, analytical, and quantitative research methods. It draws upon the use of time-series data which spans the span 2004-2023 to evaluate empirically the effect of current and investment spending on economic growth in Iraq.

The research structure is divided into three major sections. The initial section shows the conceptual and theoretical framework of the existing expenditure, investment expenditure and economic growth. The second part gives an analytical description of how these variables evolved in Iraq during the study period. The third part is dedicated to the empirical analysis of the implications of current and investment spending on the economic growth, that is, an evaluation of their contributions and their implications on the election economic policy.

Previous Studies:

- 1- The research (Mahmoud, 2025) sought to evaluate and examine the effects of government expenditure on inflation in Iraq and to offer suggestions that might help lower inflation rates. This was accomplished by employing a descriptive method to illustrate theoretical ideas and an analytical and quantitative method to examine the connection between public expenditures and the inflation rate in Iraq, particularly by utilizing a threshold regression model. The research found that government expenditures have a positive yet restricted effect on inflation when spending is low, and this effect grows with higher spending levels. It suggests lowering current expenditures and boosting investment in infrastructure to foster economic growth and development, while diversifying revenue streams and decreasing dependence on oil resources [2].
- 2- The research (Mankhi.,2024) seeks to show how effective government expenditure, the main instrument of fiscal policy, is in affecting economic activity and enhancing Iraq's economic

growth rates. The study is founded on the assumption that government expenditure, directed by a solid fiscal policy, is the right way to enhance economic growth and societal efficiency. To validate this hypothesis, the research examines the connection between the two. The research also produced various conclusions, the key one being that government expenditure as a fraction of GDP has not yet attained the levels needed to boost Iraq's economic growth rate. This is due to the political and economic turmoil the nation has faced along with the worsening security conditions. Key recommendations suggested by the researcher include: engaging the private sector, boosting its investments, drawing in foreign investment, rejuvenating the banking sector, and establishing a favorable investment environment. This will elevate GDP growth, expand the tax base, and produce greater tax revenues, thus enhancing the state's income and, in turn, its ability to spend [3].

- 3- The research (Al-Rilawi,2023) seeks to evaluate and assess the effect of public expenditures on Iraq's trade balance, as well as to investigate the nature and composition of public spending and the net trade balance, while also highlighting the financial and trade repercussions of public spending in Iraq. The researcher employed a mixed strategy, integrating a descriptive-analytical method to form the theoretical foundation for public expenditure and the net trade balance, alongside an inductive approach utilizing contemporary econometric models grounded in the Autoregressive Distributed Lag (ARDL) model. The study found a direct link between government expenditure and Iraq's net trade balance; a rise in government spending causes an improvement in the net trade balance. In particular, a rise in public expenditure of 1 billion Iraqi dinars leads to a 266 million Iraqi dinars increase in the net trade balance. This discovery aligns with the principles of economic theory [4].
- 4- The research (Hussein,2022) indicates that human capital is a crucial factor in economic expansion and significantly impacts every nation. As a result, governments in both advanced and emerging countries have prioritized their policies on this aspect over the last forty years. Empirical studies frequently utilize government expenditure on education and health to evaluate its influence on economic growth. This study aims to evaluate the influence of investments in human capital (education and health) on the growth of the Iraqi economy from 1992 to 2018 by utilizing an econometric model (ARDL) to examine this relationship in both the short and long run. The results suggest a temporary equilibrium connection and a beneficial impact of human capital on economic growth in both the short and long run [5].

This research is distinct from earlier studies as it incorporated an analysis of how current and investment expenditures affect economic growth in Iraq during the years 2004-2023.

METHODOLOGY

Conceptual Framework for Current and Investment Expenditures

First: The Concept of Current and Investment Expenditures (Types and Characteristics)

Public expenditure serves as a crucial fiscal policy instrument that the government depends on to maintain economic and social equilibrium, showcasing its priorities in distributing available resources across various sectors [5]. The magnitude of economic activity can be assessed through this spending [6].

Current expenditure: represent the financial outlays governments make to sustain daily administrative functions and operational needs—ranging from employee compensation and procurement of supplies to the provision of essential services. Unlike capital investments, these allocations do not generate new physical assets; instead, they maintain the continuous functioning of public institutions and service delivery. One might characterize this category as the recurring operational backbone of governance: salaries, administrative overheads, subsidies, and social welfare payments that keep state machinery running without expanding its infrastructural footprint [7].

The current expenditures are a core element of financial management by citizens and can be organized into a number of different types. To begin with, the expenditures on wages and salaries are a substantial amount of expenditure since they encompass all the types of payment to the government employees such as basic salaries, bonuses, and other incentives. Second, operating and maintenance expenses include the daily operating costs that are used in day-to-day operations such as consumable supplies, electricity, fuel, water, and the normal maintenance of buildings and equipment. Third, administrative expenditures are operational expenses of the ministries and the government institutions to implement their administrative roles and support bureaucracy. Fourth, the current transfers encompass the social welfare payments, support programs to the low-income groups, and subsidies that are offered on key products such as food and fuel. Fifth, interest payments are the expense involved in servicing government debt be it the domestic or foreign borrowed money. Sixth, security and defense spending is the amount that provides funding needs of military forces, internal security services, and intelligence services [8].

In addition to their classification, the current expenditures have various characteristics, which characterize them against other types of government spending. They are recurring in nature, and have to be disbursed periodically on monthly or annual basis to keep the government running. They also do not lead to the development of fixed assets or new productive infrastructure like roads, bridges, or factories as is the case with investment expenditures. These costs are directly connected to functioning of the state machinery and therefore cannot be done away with since they would be necessary in the sustained operation of key state institutions such as school, hospitals and government ministries. Their economic contribution to the economy is usually in the short-term aspect and affects the economy by impacting the economy by immediate consumption and income effects rather than creating any long-term growth that is comparable to investment expenditure. Also, the current expenditures are a valuable tool to social justice because it allows governments to offer subsidies, medical care, free education, and other social benefits that can mitigate socioeconomic inequality between the various population groups [9].

The investment spending is a critical component of governmental financial allocation towards the funding of development projects that are both productive and social in nature which includes the construction of educational facilities, health facilities, transportation systems and industrial facilities. These are systematically categorized expenditures, which in most cases are infrastructure investments to upgrade roads, bridges, utilities, and marine ports, social development investments to develop schools, universities, hospitals, and care centers to enhance human capital in the long-term, economic development investments to establish firms and factories and promote their operations, technological and innovation investments to modernize the government system, develop digital infrastructures, and advance scientific research, and energy sector investments to expand refineries and build oil and gas pipelines [10].

The expenditures on investment are further differentiated by various distinct features, which put them apart with other types of government spending. They have a long-term orientation in that they are directed to projects and infrastructure that are meant to last long, including the learning facilities, hospitals, and energy plants. They are driving forces to economic growth since they increase the level of productivity and gross domestic product. They lead to establishment of capital assets by the establishment of fixed properties, social amenity and working equipment. They have an effective target of being productive since they focus on critical sectors such as industry, agriculture, energy, transportation, and education, which create favorable economical ripple effects. They also help in reducing unemployment by creating job opportunities in various investment projects especially in the construction and contracting sectors [11].

Second: The Concept of Economic Growth (Types and Indicators:)

Economic growth is one of the most important indices of prosperity in the society and it shows the ability of a given nation to improve on the standards of living and achieve a sustainable development. It refers to the continuous growth of production of goods and services within an economy at a given period of time and is the basic cornerstone of development of infrastructure, high levels of employment, and elevated standard of living. The actualization of economic growth is dependent on the combination of several vital variables that the most notable ones are capital investment, advancement in technology, and the best application of available resources. In the current global economic conditions, the promotion of economic growth has become one of the strategic priorities that the countries strive to achieve by means of the well-balanced fiscal and monetary policy that is meant to bring the economic stability and the expansion of productive capacity together [12].

Technically, economic growth can be described as the constant increase in the real gross domestic product of a nation over a certain period, which is the measure that the economic output of goods and services in a country has changed positively over a period of time, which is usually measured using the real GDP rate of growth [13]. Another conceptualization focuses on the ability of the economy to ensure cumulative increments of real national income through the process of increasing production, increasing investing and improving resource efficiency [14].

1. Types of Economic Growth

- Real Growth: Measures the change in Gross Domestic Product (GDP) after accounting for inflation and reflects the actual growth in the quantity of goods and services.
- Nominal Growth: Measures the change in GDP without accounting for inflation and may give a false impression of economic progress if prices rise.
- Intensive Growth: Resulting from increased productivity and efficiency, not from an increase in the factors of production, such as the use of modern technology.
- Extensional Growth: Achieved through an increase in the quantity of factors of production (labor, land, and capital), such as expanding agricultural land or the number of workers.
- Balanced Growth: Occurs when different economic sectors grow harmoniously, aiming to avoid economic imbalances such as inflation or sectoral unemployment.
- Unbalanced Growth: The state focuses on certain strategic sectors to achieve a growth boost and then generalizes the results and theories, using them in growth models for developing countries [15].

2. Indicators for Measuring Economic Growth

- Gross Domestic Product (GDP) Growth Rate: This measures the percentage increase in the value of goods and services produced by the economy over a specific period. It is the primary indicator for determining the strength of economic activity. For example, if GDP increases by 5% annually, this indicates positive economic growth.
- Real Per Capita Income Growth Rate: This shows the average per capita income as a percentage of GDP and is used to measure the standard of living. A higher rate indicates an improvement in the population's standard of living.
- Employment and Unemployment Rates: High employment rates and low unemployment rates reflect improved economic performance, while high unemployment often indicates an economic slowdown.
- Investment Rate: This measures the percentage of GDP invested in productive projects and infrastructure. High investment supports future economic growth [16].
- Inflation Rate: This measures the change in the general price level. Moderate inflation often accompanies economic growth, but excessive inflation can weaken it. The trade balance is the difference between the value of exports and imports. A trade surplus often promotes growth while a deficit may limit it.

Third: The Relationship Between Current and Investment Expenditures and Economic Growth:

The interrelation between the existing spending and economic growth is complex and volatile and is influenced by various economic, political and managerial factors. In general terms, this relationship can be of two types:

On the one hand, a positive correlation will appear when the existing expenditure is redirected to the optimization of the human capital quality, i.e., the payment of teachers and medical professionals, as well as the correct maintenance and successful operation of state institutions. Such spending increases domestic consumption, hence promoting economic growth both in the short and mid run.

Conversely, a destructive relationship is formed when existing expenditure is flushed away in random recruitment, bureaucratic swell, or subsidies that are not properly targeted and directed. These practices consume the tax payers money without any significant productive outcomes, and in the end result into a slow or weak economic growth. The current expenditures affect economic growth through government consumption whereby they increase purchasing power through wages and subsidies thereby increasing the total demand. Such an increased demand has the capability of facilitating production and growth. Moreover, such spending influences growth by means of essential services, including enhanced investment in education, healthcare, and urban maintenance, which enhance human capital, which is an essential factor to long-term economic progress [17] .

As an alternative, turning to investment expenditures, they are a highly effective stimulus to economic growth, as they finance capital-intensive projects. The effects that take place due to this type of government outlay, have a lasting impact on the productive base and increase the potential of the economy to accumulate income and create workplaces [18], The relationship between the expenditures of investments and economic growth is direct and positive, in the sense that the more government spending is used in bringing economic growth, the higher the

economic growth will be, provided that these funds are utilized in viable and sustainable productive sectors. Investment expenditures contribute to economic growth by financing capital projects such as the construction of infrastructure, highways, bridges, and water barriers, by strengthening the farming and manufacturing sectors by providing development projects, and by modernising energy, transport and communication networks [19].

Analysis of Current and Investment Expenditures in Iraq

First: Analysis of the Reality of Current and Investment Expenditures in Iraq for the Period 2004-2023.

Table (1) Current and Investment Expenditures in Iraq for the period 2004-2023

years	Current expenditures	growth rate	investment expenditures	growth rate	public spending
2004	275971	-	305116	-	31521
2005	270661	22.7	390352	28.0	30831
2006	349176	45.1	620906	59.0	37494
2007	327198	8.5	921137	48.3	39307
2008	523011	31.1	203159	120.6	67277
2009	459410	17.5	964865	52.5	55589
2010	545808	18.8	155533	61.2	70134
2011	609255	11.6	178321	14.7	78757
2012	757886	24.4	293509	64.6	105139
2013	787468	3.9	403807	37.6	119127
2014	779861	2.5	354504	12.2	83556
2015	518328	32.5	185846	47.6	70397
2016	511734	1.3	184082	14.4	67067
2017	590256	15.3	164645	3.6	75490
2018	670528	13.6	138203	16.1	80873
2019	873009	30.2	244226	76.7	111723
2020	728735	16.5	320890	87.9	76081
2021	895266	22.85	133227	315.18	102849
2022	1049411	17.21	120185	9.79	116959
2023	1182427	12.6	241928	101.2	142435

Source: (Central Bank of Iraq, 2004-2023).

The information in the table demonstrates the trend of the government spending within Iraq during the years of 2004-2023. Total public expenditures were estimated at 31, 521 billion Iraqi dinars in 2004. Nevertheless, the international financial crisis caused by the mortgage crisis in 2008-2009 had a drastic negative effect on the revenues of the Iraqi people, which made the government adopt the contractionary fiscal policy. Therefore, the government spending was reduced to 55,589 billion dinars in 2009.

On 2013, there was a significant turnaround with a significant increase in the public expenditure to 119,127 billion dinars. This increase was so much explained by the growth of current expenditures which started to obtain the dominant role in the system of the public expenditures. Another very high growth was observed in the year 2021, as the government spending amounted to 102,849 billion dinars. The development was supported by the fact that the global economy started recovering after the COVID-19 pandemic and reimbursement reestablished the global production, the result of which increased the demand in oil. The resultant oil price boom significantly boosted the oil revenues of Iraq and consequently the fiscal space in which the Iraqi government could spend on in the economy was increased significantly.

The growth in the current expenditure continued up to 2023 and reached an impressive level of 1,128,427 billion dinars. This is a growth rate of an average of 12.6 every year mainly due to strong public revenues and high oil prices and increased level of export volumes. In line with this, investment spending was also showing a significant momentum in 2023 with a 241,928 billion dinars expenditure that has an impressive growth rate of 101.2, meaning that there was a high level of commitment to capital formation and long-term economic structure.

Second: Analysis of the reality of economic growth in Iraq:

Table (2) Analysis of Economic Growth in Iraq for the Period 2004-2023

years	gross domestic product	growth rate
2004	532352	-
2005	735330	38.1
2006	955871	29.9
2007	111961	16.6
2008	158443	40.8
2009	131632	16.8
2010	163104	24.05
2011	218617	34
2012	255727	16.9
2013	256562	7.6
2014	267262	2.6
2015	196203	26.9
2016	198774	1.1
2017	224636	12.5
2018	272083	21.3
2019	279757	2.69
2020	217413	21.9
2021	305191	39.6
2022	383064	25.53
2023	330046	13.8

Source: Source: (Central Bank of Iraq, 2004-2023).

The gross domestic product had an upward trend with a gross domestic product of about 73, 533 billion Iraqi dinars in 2004, equating to the 38.1 percent economic growth rate in 2005. This impetus growth was sustained and by 2008, the amount of GDP had grown to 157,026 billion dinars. The following year however recorded a severe contraction with the GDP decreasing to 130,643 billion dinars in 2009 which reflected negative growth rate of 16.8. This recession was largely caused by collapse of oil prices worldwide and the low demand of Iraqi export due to the mortgage crisis experienced worldwide and its effects on the global markets.

The economic environment was however recovering a decade later, in 2019, with GDP improving to 279,757 billion dinars and recording a slight growth rate of 2.69 which was majorly due to the rebound in international oil prices. The pace of the growth has increased significantly in 2021 with GDP of 305,191 billion dinars producing a very strong growth rate of 39.6.

The empirical evidence provided below makes it eminent that the key feature of the Iraqi economy is the gross domestic product, which is highly volatile and directly interconnected with the changes in the oil revenues. Since the economy is highly dependent on the hydrocarbon sector, its stability is determined by the fluctuations and uncertainties of global petroleum markets that are cyclical. This structural dependency makes the national economic performance susceptible to any external shocks and commodity price volatility and this points to the need to diversify the economy in order to reduce such vulnerabilities.

Third: Analysis of the relationship between current and investment expenditures and economic growth in Iraq.

Table (3) Analysis of current and investment expenditures in Iraq for the period 2004-2023.

years	Current expenditures (1)	investment expenditures (2)	gross domestic product (3)	Current expenditure as a percentage of GDP: 1/3	Investment expenditure as a percentage of GDP: 2/3
2004	275971	305116	534992	51.58	5.70
2005	270661	390352	739110	36.62	5.28
2006	349176	620906	960671	36.34	6.46
2007	327198	921137	111961	29.22	8.23
2008	523011	203159	158443	33.01	12.82
2009	459410	964865	131632	34.90	7.33
2010	545808	155533	163104	33.46	9.53
2011	609255	178321	218617	27.87	8.14
2012	757886	293509	255727	29.64	11.48
2013	787468	403807	256562	30.69	15.74
2014	779861	354504	267262	29.18	13.26
2015	518328	185846	196203	26.41	9.47
2016	511734	184082	198774	25.74	9.26
2017	590256	164645	224636	26.28	7.33
2018	670528	138203	272083	24.64	5.08
2019	873009	244226	279757	31.21	8.73
2020	728735	320890	217413	33.52	1.48
2021	895266	133227	305191	29.33	4.37
2022	1049411	120185	383064	27.40	3.14
2023	1182427	241928	330046	35.82	7.33

Source: (Central Bank of Iraq, 2004-2023).

Analysis of the trends in the public expenditure patterns in Iraq shows there is a major dynamic structure between the years 2004 and 2023. Current expenditures were 275,971 billion Iraqi dinars or 51.58 percent of the gross domestic product in 2004. This large percentage experienced significant contraction in 2008, when current spending was 523,011 billion dinars but accounted only 33.1 of GDP with the contraction largely led by the global oil price crisis that hampered the ability to spend. The following trend showed further decline where the current expenditures have become 779,861 billion dinars or 29.18 percent of GDP by 2014, which can be mainly attributed to the financial strains of military action against the terrorist group ISIS. However, a turnaround was experienced in 2019, with current spending increasing to 873,009 billion dinars, which is 31.21% of GDP, as a result of the international petroleum prices recovery. This upward trend continued until 2023 with 1,182,427 billion dinars or 35.82% of GDP, supported by the improvement of public revenues based on higher oil prices and increased export volumes.

In terms of investment spending, the year 2004 was recorded with investment spending of 305116 billion dinars, which constituted a very small percentage of 5.70 of the GDP, which as compared to current expenditure is extremely low in the total scheme of public expenditure. Slow progress was felt by the year 2010 as the investment expenditures stood at 155,533 billion dinars or 9.53% of GDP. In 2013 significant gains were made, with investment expenditures running up to 403,807 billion dinars, which constituted 15.74 of GDP, as a result of the increase in revenue and other positive oil price trends that allowed an increase in resources to be allocated to capital investments. But this progress was harshly interrupted in 2020, when investment spending fell to 320,890 billion dinars or only 1.48 per cent of GDP, a recession caused by the

situation of the global COVID-19 pandemic and the corresponding fall in the price of crude oil that severely worsened the situation in the economies. In 2023, it was noted that it partially recovered because investment expenditures increased to 241,928 billion dinars or 7.33 percent of GDP, as the investment projects put on hold in the wake of fiscal instability were reinstated.

Results and Discussion

Assessing the Relationship Between Current and Investment Expenditures and Economic Growth

First: Study Variables

In order to select the study hypotheses and achieve its objectives, the model was described as follows:

Table (4) Model Variables Description

Symbols	Variable type	Variables
CE	independent	Current Expenses
IE	independent	Investment Expenses
EG	continued	Economic growth

Source prepared by researchers

First, we estimate the regression equation in order to obtain the initial form of the relationship between the model variables, as in the equation below. $EG=f(CE,IE) \dots\dots\dots(1)$

$EG= b_0+b_1 CE+b_2 IE+U_i \dots\dots\dots(2)$

Second: Results of the Time Series Stationability Test:

Verifying the stationarity of time series is a fundamental requirement to avoid spurious regression. To verify the stationarity of the variables, the extended Dickey-Fuller test (ADF) was used before statistically estimating the model. The results in Table (1) below indicate that the time series of the variables (CE, IE, EG) is stationary at the first difference [I(1)] according to the ADF test, based on a t-test greater than the tabulated value. Furthermore, the p-value is less than 5%, which necessitates rejecting the null hypothesis that the time series is not stationary and accepting the alternative hypothesis that the time series of the variables is stationary at the first difference I (1).

Table (5) Time series stationarity test for the extended Dickey-Fuller (ADF) model

UNIT ROOT TEST RESULTS TABLE (ADF)				
Null Hypothesis: the variable has a unit root				
	<u>At Level</u>			
		CE	IE	EG
With Constant	t-Statistic	-0.32258	-1.7498	-3.90877
	Prob.	0.9042	0.3912	0.0090
With Constant & Trend	t-Statistic	-1.758054	-5.50890	-3.87863
	Prob.	0.6843	0.0015	0.03575
Without Constant & Trend	t-Statistic	1.516893	-1.012567	-0.562500
	Prob.	0.962660	0.267606	0.457501
	<u>At First Difference</u>			
		d(CE)	d(IE)	d(EG)
With Constant	t-Statistic	-4.40384	-8.6013	-6.0503

	Prob.	0.0033	0.0000	0.0001
With Constant & Trend	t-Statistic	-4.3361027	-8.346406	-5.981710
	Prob.	0.0154	0.0000	0.0010
Without Constant & Trend	t-Statistic	-3.809746	-8.84791	-6.27565
	Prob.	0.0007	0.0000	0.0000
Notes:				
a: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1% and (no) Not Significant				
b: Lag Length based on SIC				
c: Probability based on MacKinnon (1996) one-sided p-values.				

Source: From the work of the researchers, based on research data and outputs of the (Eviews13) program

Nevertheless, the presented Phillips-Perron (PP) unit root test, Table 6, indicates that the variables under analysis, i.e., current expenditures (CE), investment expenditures (IE) and economic growth (EG) are not stationary at their level values. When these variables are first differentiated, the test statistics have shown the variables to be stationary as evidenced by the t-values calculated to be greater than the critical values. Moreover, the probability values related to it are less than the traditional 5% significance level, which justifies rejecting the null hypothesis of the event of unit root existence. Therefore, an alternative hypothesis that the time series variables are stationary is accepted and the time series variables are shown to be integrated of order one [I (1)].

Table (6) Time series stationarity test for the Phillips-Perron (PP) model

UNIT ROOT TEST RESULTS TABLE (PP)				
Null Hypothesis: the variable has a unit root				
	At Level			
		CE	IE	EG
With Constant	t-Statistic	-0.24201736	-3.8029963	-3.907481
	Prob.	0.9169	0.0106	0.0090
With Constant & Trend	t-Statistic	-1.8372290	-5.5846050	-3.8752473
	Prob.	0.6462	0.0013	0.0359
Without Constant & Trend	t-Statistic	1.51689	-1.662124	-1.843953
	Prob.	0.9626	0.0901	0.0633
	At First Difference			
		d(CE)	d(IE)	d(EG)
With Constant	t-Statistic	-4.40384624	-14.786961	-11.606912
	Prob.	0.0033	0.0000	0.0000
With Constant & Trend	t-Statistic	-4.33610	-12.7560	-13.01187
	Prob.	0.0154	0.0000	0.0000
Without Constant & Trend	t-Statistic	-3.807741	-12.92474	-10.791146
	Prob.	0.0007	0.0001	0.0000
Notes:				
a: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1% and (no) Not Significant				
b: Lag Length based on SIC				
c: Probability based on MacKinnon (1996) one-sided p-values.				

Source: program (Eviews13).

Second: Determining the optimal time gap rank.

Table (7) presents the values of information criteria employed for determining the optimal lag order within the vector autoregression (VAR) framework for the economic growth model, incorporating current expenditures and investment expenditures as explanatory variables in the Iraqi economy over the period 2004–2023. The empirical evidence derived from the table

indicates that the most appropriate lag length for the specified model is two, as consistently suggested by the information criteria under consideration.

Table (7) Determining the optimal slowdown gap rank for the economic growth model and consumer and investment spending variables according to (VAR) analysis.

VAR Lag Order Selection Criteria						
Endogenous variables: EG CE IE						
Exogenous variables: C						
Date: 11/20/25 Time: 20:53						
Sample: 2004 2023						
Included observations: 16						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-496.97606	NA	2.79e+23	62.49701	62.64187	62.50443
1	-482.21377	22.14344*	1.40e+23	61.77672	62.35616*	61.80639
2	-471.71795	11.80780	1.36e+23*	61.58974*	62.60377	61.64167*
3	-462.89057	6.620532	2.20e+23	61.61132	63.05993	61.68550
* indicates lag order selected by the criterion						
LR: sequential modified LR test statistic (each test at 5% level)						
FPE: Final prediction error						
AIC: Akaike information criterion						
SC: Schwarz information criterion						
HQ: Hannan-Quinn information criterion						

Source: program (Eviews13).

Third: Cointegrating Test

Table (8) shows the results of the cointegration test of the model variables, which are the current expenditures (CE), the investment expenditures (IE), and the economic growth (EG) using the bounds testing technique. The calculated F -statistic of 4.596 is larger than the upper critical values at all traditional levels of significance, including the 5 percent level. This empirical observation implies the null hypothesis of the non-existing long-run equilibrium relationship between the variables has to be rejected. As a result, the alternative hypothesis that states the presence of the cointegration between the research variables is accepted thus confirming the existence of a stable and long-term associative scheme relating the current expenditures, investment expenditures and economic growth in Iraqi economy.

Table (8) F-Bound test for Cointegrating

Null hypothesis: No levels relationship

Number of cointegrating variables: 2

Trend type: Rest. constant (Case 2)

Sample size: 18

Test Statistic

F-statistic

Value

4.5961725

	10%		5%		1%	
Sample Size	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
30	2.915	3.695	3.538	4.428	5.155	6.265
Asymptotic	2.63	3.35	3.1	3.87	4.13	5

* I(0) and I(1) are respectively the stationary and non-stationary bounds.

Source: program (Eviews13).

Fourth: Estimating and Analyzing the Long-Term Relationship:

Table (9) presents the estimated coefficients of the long-run equilibrium relationship, elucidating the impact of current expenditures (CE) and investment expenditures (IE) on economic growth (EG) within the Iraqi economy. The empirical results indicate that the computed t-statistics exceed their respective critical values, while the associated probability values remain below the 5% significance threshold. These findings warrant the rejection of the null hypothesis and the acceptance of the alternative hypothesis, thereby confirming the statistical significance of the estimated parameters.

The coefficient estimates reveal a counterintuitive negative relationship between both categories of public spending and economic growth. Specifically, a one percent increase in current expenditures is associated with a 2.0083268 percent decline in economic growth, whereas a commensurate increase in investment expenditures corresponds to a 2.2463999 percent reduction in economic growth. These outcomes stand in marked contradiction to conventional economic theory, which posits a positive, growth-enhancing effect of public expenditure, particularly investment outlays.

This anomalous result may be attributed to pervasive institutional inefficiencies, wherein bureaucratic rigidities and systemic corruption inflate project costs substantially beyond their intrinsic economic value, thereby generating negative marginal returns on public investment. It may be argued, however, that this finding does not fundamentally invalidate established theoretical propositions; rather, it substantiates the conditional nature of investment-led growth. Investment functions as an engine of economic expansion only when complemented by administrative efficiency, appropriate temporal sequencing, and a conducive institutional framework. In the absence of these prerequisites, public investment degenerates into a mere dissipation of scarce resources, undermining rather than advancing long-term economic prosperity.

Table (9) Results of estimating the long-term relationship of the economic growth model

Dependent Variable: EG Method: ARDL Date: 11/20/25 Time: 22:13 Sample: 2006 2023 Included observations: 18 Dependent lags: 1 (Automatic) Automatic-lag linear regressors (0 max. lags): CE IE Deterministics: Restricted constant and no trend (Case 2) Model selection method: Akaike info criterion (AIC) Number of models evaluated: 1 Selected model: ARDL (1,0,0)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
EG (-1)	0.2775452	0.27217230	1.01974111	0.032515
CE	-2.0083268	1.54590077	-1.29913051	0.021887
IE	-2.2463999	1.55064190	-1.4486903	0.019450
C	34.697013	13.058715	2.6570005	0.01877
R-squared	0.15447845	Mean dependent var		19.698333
Adjusted R-squared	-0.0267047	S.D. dependent var		12.001302
S.E. of regression	12.16049	Akaike info criterion		8.0273918
Sum squared resid	2070.2860	Schwarz criterion		8.2252522

Log likelihood	-68.246526	Hannan-Quinn criter.	8.0546741
F-statistic	0.8526092	Durbin-Watson stat	1.8075921
Prob(F-statistic)	0.4881586		
*Note: p-values and any subsequent test results do not account for model selection.			

Source: program (Eviews13).

Table (10) shows the estimated parameters of the error correction model given that there is a long-run relation between economic growth, current expenditures and investment expenditures in Iraq during the period of 2004-2023. The empirical results confirm a stable long-run cointegrating equilibrium amongst the variables whose structure confirms that economic growth, current and investment expenditure can be consistently associated over multiple time-horizons.

The autocorrelation term appears with a negative and statistically significant coefficient of -0.7224547 at the 5% level, which fulfills the theoretical requirement for convergence towards long-run equilibrium. This coefficient measures the rate of adjustment, suggesting that about 722% of any disequilibrium from long-run steady state persistence is closed within a year.

Table (10) Error Correction Model Coefficient for the Long-Term Relationship between Economic Growth and Consumer and Investment Spending Variables

Dependent Variable: D(EG) Method: ARDL Date: 11/20/25 Time: 22:13 Sample: 2006 2023 Included observations: 18 Dependent lags: 1 (Automatic) Automatic-lag linear regressors (0 max. lags): CE IE Deterministics: Restricted constant and no trend (Case 2) Model selection method: Akaike info criterion (AIC) Number of models evaluated: 1 Selected model: ARDL(1,0,0)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
EG(-1)*	-0.7224547	0.272172306	-2.65440199	0.0188662
CE**	-2.0083268	1.545900777	-1.29913051	0.2148876
IE**	-2.2463999	1.55064190	-1.44869036	0.1694503
C	34.6970138	13.05871539	2.657000538	0.0187707
R-squared	0.5647151	Mean dependent var		-1.350000
Adjusted R-squared	0.4714398	S.D. dependent var		16.726456
S.E. of regression	12.1604925	Akaike info criterion		8.027391
Sum squared resid	2070.28609	Schwarz criterion		8.2252522
Log likelihood	-68.246526	Hannan-Quinn criter.		8.054674
F-statistic	6.05428253	Durbin-Watson stat		1.8075921
Prob(F-statistic)	0.00731494			
* p-values are incompatible with t-bounds distribution.				
** Zero-lag variable.				

Source: Source: program (Eviews13).

Sixth: Testing the Quality of Estimation of the Standard Model:

The econometric model estimated on the basis of the above empirical analysis describing the correlation between economic growth and the explanatory variables of the current expenditures and investment expenditures in Iraq (between 2004 and 2023) show a very high level of statistical significance and very high explanatory power. The model has some desirable econometric characteristics and is not subjected to typical specifications inadequacies like heteroscedasticity, autocorrelation or even multicollinearity and is also stable and structurally consistent over the entire horizon of the study.

To determine whether the residual data meet the assumption of normality, which is an essential requirement in the validity of statistical inference on the classical linear regression model, Jarque-Braille test was used. This omnibus test of normality is based on two moment-based statistics, skewness which measures the amount of asymmetry in the distribution, and kurtosis which measures the concentration of observations around the central tendency in comparison with the normal distribution.

The test process implies the development of competing hypotheses:

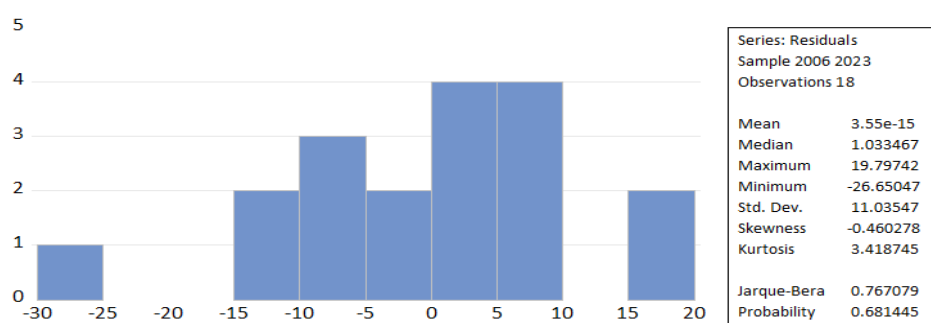
Null Hypothesis (H0): The residuals are normally distributed.

Alternative Hypothesis (H1): The residuals are not normally distributed.

The decision rule is that in case the probability value is greater than the traditional significance of 5 per cent, then the null hypothesis is kept and thus, there is no statistically significant violation of the distributional normality.

The empirical outputs indicate that every calculated probability values are higher than the 5 percent critical value with respect to the Jarque-Bra statistic values. As a result, there is inadequate proof that would justify the rejection of the null hypothesis, and thus, it can be stated that the regression residuals and consequently, the underlying variables are normally distributed. The result of this finding is that there is no strong distributional asymmetry or tail heaviness, hence, the inferential integrity of the estimated model holds. Grapical support is offered in Figure (1) which shows that the empirical distributions of the variables studied do not differ much with the theoretical normal density.

Figure 1 Model quality test (normal distribution)



Source: Source: program (Eviews13).

Furthermore, the residuals of the estimated model do not exhibit serial correlation, as demonstrated by the Breusch-Godfrey test, where the Prob value is 0.625969103, which is greater than 5%, thus accepting the null hypothesis and rejecting the alternative hypothesis. The model also does not suffer from Heteroskedasticity, as demonstrated by the Breusch-Pagan

Heteroskedasticity test, where the Prob value is 0.3620028, which is also greater than 5%, thus accepting the null hypothesis and rejecting the alternative hypothesis.

Table (11) Autocorrelation Test (Breusch-Godfrey Serial Correlation LM Test)

Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: No serial correlation at up to 2 lags			
F-statistic	0.32945091	Prob. F(2,12)	0.725623405
Obs*R-squared	0.93690852	Prob. Chi-Square(2)	0.625969103

Source: program (Eviews13).

The estimated model is well described, as confirmed by the Ramsey RESET test (Ramsey Regression Equation Specific Error test), where the statistical value of the F test is (3.4) and the value of (P) is (0.4723), which is greater than (5%), which means rejecting the null hypothesis and accepting the alternative hypothesis, i.e., the estimated model is well described.

Table (12) Ramsey Regression Equation Specific Error Test

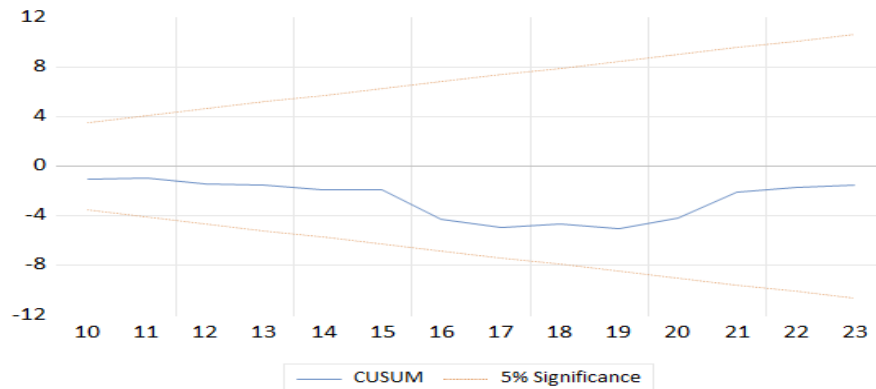
Ramsey RESET Test			
Equation: UNTITLED			
Omitted Variables: Squares of fitted values			
Specification: EG EG(-1) CE IE C			
	Value	df	Probability
t-statistic	1.474876071797723	13	0.16404918
F-statistic	2.17525942716148	(1, 13)	0.16404918
Likelihood ratio	2.784907350580113	1	0.0951561

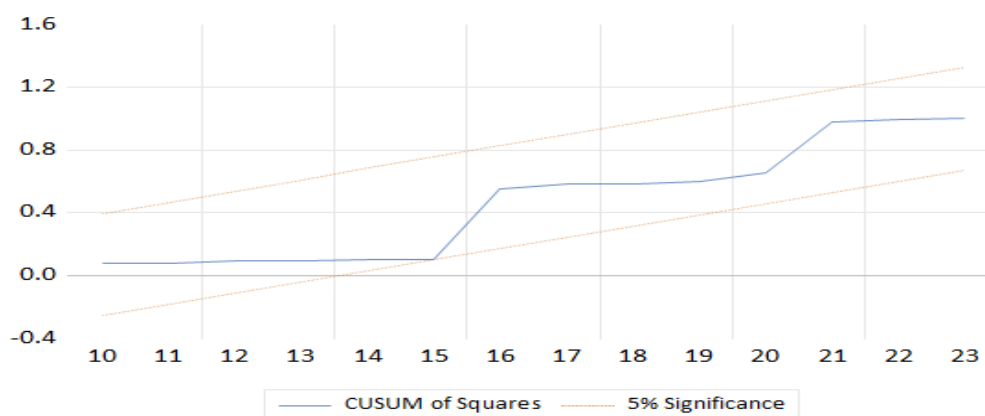
Heteroskedasticity Test: Breusch-Pagan-Godfrey			
Null hypothesis: Homoskedasticity			
F-statistic	1.008482648951	Prob. F(3,14)	0.4181692
Obs*R-squared	3.1986273261873	Prob. Chi-Square(3)	0.3620028

Source: program (Eviews13).

This is shown in Figure (2), which illustrates the very large convergence between the actual values of the economic growth rate and the values predicted by the distributed time slowdown auto regression model, as well as the error or residual values, where the range of these errors for economic growth was between (4) and (-4), million dinars.

Figure (2) Cumulative sum of remainders and of remainders squares (Cusum) and (Cusum of Squares).





Source: program(Eviews13).

Conclusions:

The exploratory study provides a number of substantive findings on the nexus between the composition of the public expenditure and economic growth in Iraq in the period of 2004-2023. First, the pattern between the present spending and economic growth has contingent nature, as it entails positive results when it is used to increase human capital and institutional efficiency, but results in negative outcomes when it is absorbed in bureaucracy expansion and unproductive labor. Second, the structural formulation of the government spending indicates a consistent preponderance of present expenditures and a relatively low level of investment distribution differentiated against GDP. Third, the unit root diagnostics ensure that the variables attain the stationarity of the first differencing in order to meet the conditions of the cointegration analysis. Fourth, bounds testing determines that there exists a long-run relationship between the current expenditures, the investment expenditures, and the economic growth. Fifth, this long-run associational structure with speedy adjustment mechanism which restores the equilibrium over a time frame of around one year is supported by the error correction specification. Sixth, the estimates of the long-run coefficients reveal surprisingly negative signs of the parameters of both types of expenditure, which suggest institutional inefficiencies and resource mis-allocation against the theoretical expectations and therefore justify the necessity of a governance reformation to bring the growth-enhancing potential of public investment into reality.

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ENHANCING SUSTAINABILITY IN THE LOGISTICS INDUSTRY THROUGH BIG DATA ANALYTICS CAPABILITIES

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ARTICLE INFO	ABSTRACT
Article history: Received:2025-10-06 Received in revised form:2025-10-21 Accepted:2025- 11-26 Available online:2026-06-26 Keywords: Logistics, data, analytic JEL Classification: L91, Q56, O33, M15	The logistics sector is experiencing accelerated growth, driven by global sustainability agendas and increasing commitments to achieving net-zero emissions. Big Data Analytics (BDA) has been widely recognized for its potential to enhance operational efficiency and supply chain performance. Nevertheless, its role in advancing sustainability outcomes particularly through an integrated capability perspective—remains insufficiently theorized and empirically examined. Prior research has predominantly approached BDA from a fragmented perspective, focusing on discrete dimensions such as technological infrastructure, data governance, or human competencies. This reductionist approach has limited the understanding of how BDA capabilities, as a multidimensional construct, interact to influence sustainability outcomes across economic, environmental, and social domains. Addressing this gap, the present study develops and applies an integrative theoretical framework that synthesizes the Resource-Based View (RBV), Dynamic Capability View (DCV), Technology–Organization–Environment (TOE) framework, and the Technology Acceptance Model (TAM). The findings demonstrate that BDA capabilities function as a strategic enabler, facilitating opportunity recognition, strengthening competitive positioning, and supporting the reconfiguration of organizational resources in response to dynamic environmental pressures. This study contributes to the literature by advancing a holistic understanding of the BDA–sustainability nexus and extending capability-based perspectives in the context of logistics management.

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1. INTRODUCTION

Over the past two decades, the volume of data generated across both personal and organizational contexts has increased exponentially, largely driven by the widespread adoption of digital technologies for communication, entertainment, and operational efficiency [1,2]. Organizations continuously generate and process vast and heterogeneous datasets, including user interactions, transactional records, and social media content. In response to the growing scale and strategic importance of data, Big Data Analytics (BDA) has emerged as a critical

organizational capability [3]. Although interest in BDA has significantly expanded in both academic and practical domains, the absence of standardized approaches for effectively managing and extracting value from large-scale data remains a persistent challenge [4]. Consequently, the concept of Big Data Analytics Capability (BDAC) has been introduced, referring to an organization's ability to systematically acquire, process, and derive actionable insights from complex data environments [5]. BDA enables the transformation of raw data into meaningful information, thereby supporting evidence-based decision-making and enhancing organizational performance. However, the extent to which organizations benefit from big data depends largely on their capacity to collect, store, and process high-volume, high-velocity, and high-variety data generated from both real-world operations and analytical models [6]. Within this context, the logistics sector plays a pivotal role in fostering both economic growth and environmental sustainability [7]. The integration of BDA into logistics operations has significantly transformed the sector by improving operational efficiency, reducing waste, and minimizing environmental impact [8]. In particular, data-driven logistics practices contribute to sustainability through optimized route planning, reduced emissions, and enhanced transportation efficiency [9].

Despite these advancements, the relationship between Big Data Analytics and sustainability remains insufficiently explored, particularly in terms of how BDA capabilities facilitate innovation and influence the three dimensions of sustainability—economic, environmental, and social performance—within organizational settings. This research gap is especially evident in studies that examine the intersection of BDA and logistics, where comprehensive and integrative analyses remain limited [10–13].

2. PROBLEM STATEMENT

The global logistics industry continues to face significant sustainability challenges, including high energy consumption, substantial carbon emissions from freight transportation, suboptimal route planning, and limited data integration across supply chains [14]. These challenges underscore the critical need for advanced analytical approaches to support sustainability-oriented decision-making. Although Big Data Analytics Capability (BDAC) has increasingly been acknowledged as a strategic enabler for enhancing operational efficiency and performance, its role in advancing environmental, social, and economic sustainability remains insufficiently conceptualized and empirically validated. Consequently, the logistics sector encounters persistent difficulties in balancing rapid economic growth with social equity and environmental responsibility [15]. Existing literature has predominantly emphasized the efficiency-enhancing aspects of BDAC, while its potential contribution to sustainability transformation has received comparatively limited attention.

In parallel, the logistics sector has been positioned as a key driver of economic diversification and development within broader national and global strategic agendas. Substantial investments in infrastructure, digitalization, and international trade connectivity have accelerated the transformation of logistics systems. Despite these advancements, critical challenges persist, particularly in terms of data integration, digital maturity, and environmental performance [16–18]. The energy-intensive nature of logistics operations further amplifies the need for data-driven solutions aimed at reducing carbon emissions, optimizing fleet utilization, and enhancing supply chain transparency [18]. Achieving alignment between sectoral growth and sustainability

objectives therefore necessitates the adoption of innovative approaches that mitigate the environmental impacts associated with transportation and warehousing activities [21].

From a theoretical perspective, contemporary studies on BDAC predominantly rely on single-theory frameworks to explain specific dimensions, such as technology adoption or capability development. While these approaches provide valuable insights, they offer a limited understanding of the complex and multidimensional mechanisms through which BDAC influences sustainability outcomes.

Notably, prior research rarely integrates multiple theoretical perspectives into a unified framework capable of capturing BDAC's impact across micro (individual), meso (organizational), and macro (environmental and institutional) levels. This fragmentation creates a critical gap in explaining the dynamic interplay between technological capabilities, user acceptance, organizational transformation, and external environmental pressures in driving sustainability transitions within the logistics sector.

Addressing these limitations, the present study adopts an integrative analytical approach, employing a comprehensive framework that synthesizes multiple theoretical perspectives to examine the role of BDAC in promoting sustainability. Through an in-depth qualitative investigation, the study aims to provide a holistic understanding of how data-driven capabilities contribute to sustainable development within the logistics industry.

3. STUDY OBJECTIVE

The central research question guiding this study is: *How does Big Data Analytics Capability (BDAC) contribute to enhancing the three dimensions of sustainability—economic, environmental, and social—within the logistics sector?*

The primary contribution of this study lies in its comprehensive qualitative examination of the relationship between BDAC and sustainability outcomes. Specifically, the research advances a multi-level analytical perspective by integrating four complementary theoretical frameworks: the Resource-Based View (RBV), Dynamic Capability View (DCV), Technology–Organization–Environment (TOE) framework, and the Technology Acceptance Model (TAM). Within this integrative framework, RBV and DCV elucidate the strategic value and adaptive capacity associated with BDAC, while the TOE framework captures the contextual technological, organizational, and environmental determinants influencing its adoption. Simultaneously, TAM provides insight into individual-level acceptance and utilization of BDA tools.

By synthesizing these theoretical perspectives, the study offers a more holistic understanding of the BDAC–sustainability nexus across multiple levels of analysis. Furthermore, it extends the predominantly quantitative and context-limited body of existing literature by delivering nuanced, qualitative insights applicable to diverse and evolving logistics environments.

4. RESEARCH GAP AND CONTRIBUTIONS

In recent years, scholarly interest in Big Data Analytics Capability (BDAC) within logistics and supply chain management has expanded considerably. Despite this growing body of research, the literature remains predominantly focused on operational performance outcomes. Empirical studies frequently conceptualize BDAC as a strategic resource that enhances efficiency, responsiveness, resilience, and competitive advantage through improved forecasting accuracy,

system integration, and data-driven decision-making processes [4,17–21]. Similarly, large-scale quantitative investigations have reinforced this perspective by establishing positive relationships between BDAC and both operational and financial performance indicators [19,22–24]. However, within these studies, sustainability is rarely treated as a primary objective; instead, it is often considered a secondary or indirect outcome. More recently, a subset of research has begun to explore the relationship between Big Data Analytics and sustainability. Nevertheless, this emerging domain remains fragmented and limited in scope. Existing studies tend to emphasize environmental dimensions—such as emissions reduction and energy efficiency—while comparatively neglecting the social dimension of sustainability and failing to adequately address the interdependencies among the three pillars of the Triple Bottom Line (economic, environmental, and social performance) [25–29]. Consequently, comprehensive analyses examining how BDAC simultaneously supports all dimensions of sustainability within logistics systems remain underdeveloped.

Furthermore, contextual limitations represent a critical gap in literature. The majority of BDAC-related studies have been conducted in technologically advanced environments, primarily within developed economies characterized by high levels of digital maturity and institutional stability [1,30–33]. In contrast, empirical evidence from emerging and developing logistics contexts remains scarce, particularly in environments marked by limited technical expertise, fragmented data infrastructures, and evolving regulatory frameworks. This imbalance restricts the generalizability of existing findings and results in an incomplete understanding of the role of BDAC in driving sustainability outcomes across diverse contexts [13,34–37]. Addressing these gaps, the present study advances a sustainability-oriented and multi-level perspective on BDAC within the logistics sector. Rather than prioritizing operational or financial performance, the study conceptualizes BDAC as an enabler of Triple Bottom Line sustainability, treating economic, environmental, and social outcomes as interconnected and mutually reinforcing dimensions. The principal contribution of this research lies in its comprehensive qualitative analysis of the BDAC–sustainability relationship. Specifically, the study makes three key contributions. First, it develops an integrative analytical framework by combining four complementary theoretical perspectives: the Resource-Based View (RBV), Dynamic Capability View (DCV), Technology–Organization–Environment (TOE) framework, and the Technology Acceptance Model (TAM). This approach enables a holistic understanding of BDAC, demonstrating that sustainability outcomes are contingent not only upon technological investments but also on human analytical capabilities, governance structures, and organizational learning processes. Second, the study advances theoretical development by incorporating micro-, meso-, and macro-level dynamics into the analysis of BDAC, thereby offering a more nuanced explanation of variations in sustainability performance across organizations. Third, it contributes empirically by providing in-depth insights from an emerging logistics context, repositioning BDAC research beyond operational optimization toward a broader conceptualization of analytics capability as a driver of sustainable logistics development.

Overall, this study extends the predominantly quantitative and context-constrained literature by offering a rich, qualitative, and integrative perspective on the role of Big Data Analytics in advancing sustainability within the logistics sector.

5. DATA SATURATION

Data saturation was conceptualized as a two-stage process, distinguishing between code saturation and meaning saturation, in accordance with established qualitative research protocols. Code saturation refers to the point at which additional data collection no longer yields novel first-order codes or emergent categories. In contrast, meaning saturation pertains to the extent to which identified themes are conceptually rich, fully developed, and analytically comprehensive. During the initial stages of analysis, open coding was conducted concurrently with data collection. After approximately 20 semi-structured interviews, no substantively new codes related to Big Data Analytics Capability, sustainability, or logistics practices emerged, indicating that code saturation had been attained. Nevertheless, data collection continued, resulting in a total of 25 interviews, to ensure that meaning saturation was fully realized.

The final five interviews did not introduce additional thematic categories or alter the overarching structure. Instead, they contributed to deepening and refining the analysis, particularly by highlighting variations across organizational sizes and logistics subsectors. These interviews enhanced interpretive depth regarding the practical enactment of analytics capabilities without expanding the thematic framework itself. The persistent absence of new themes in the latter interviews provided robust evidence of thematic stability. Accordingly, the decision to conclude data collection was based not only on the attainment of code saturation but also on the assurance that sufficient analytical completeness and interpretive depth had been achieved across the dataset.

Sample Composition

Table 1 presents a detailed overview of the study participants. The sample comprises individuals occupying leadership, operational, technical, and sustainability-focused roles within logistics organizations. This diverse composition ensures the inclusion of multiple perspectives—strategic, managerial, and technical—on the adoption and utilization of Big Data Analytics Capability (BDAC) and associated sustainability practices.

No.	Job Level / Functional Area	Positions	Number of Participants
1	Executive Leadership	CEO, VP, GM, Chief Commercial & Administrative Officer, Deputy CEO, Assistant GM	6
2	Sustainability, Safety, and Energy	VP, Energy Expert	5
3	Operations and Logistics Management	Manager, Assistant Manager, Specialist, Officer	5
4	Information Technology and Data Analytics	Manager, Head, Analyst, Specialist, Project Manager, Business Intelligence Analyst, Senior Systems Administrator	5
5	Human Capital, Administration, and Business Development	Manager	4

Total Participants: 25

This purposeful sampling strategy was designed to capture a broad range of insights into BDAC deployment and its role in promoting sustainable logistics practices. The inclusion of participants from executive leadership to specialized technical roles ensures comprehensive coverage of organizational processes, decision-making structures, and operational nuances relevant to the research objectives.

Data Analysis

The interview data were analyzed using thematic analysis, following the six-phase procedure proposed by Braun and Clarke (2006). This approach comprised the following stages: data familiarization, initial coding, theme development, theme review, defining and naming themes, and reporting. All coding and thematic organization were conducted using MAXQDA software, facilitating systematic data management and ensuring rigor in the qualitative analysis. This methodology enabled the identification of salient patterns and the extraction of nuanced insights regarding the enactment of Big Data Analytics Capability (BDAC) and its influence on sustainability practices within logistics organizations.

6. FINDINGS AND THEMATIC ANALYSIS

Quantifying Qualitative Insights- Although the primary objective of this study is interpretive rather than statistical, descriptive quantification was employed to enhance transparency and analytical clarity. Consistent with established qualitative research practices, the number and proportion of participants referring to each theme and sub-theme are reported to indicate their prevalence within the dataset, without implying statistical generalizability beyond the study sample.

Across the 25 interviews, three core themes were identified as particularly salient. Personnel capability emerged as the most frequently discussed theme, referenced by 21 participants (84%), often in relation to data literacy, analytical confidence, and organizational learning practices. Traceability was mentioned by 18 participants (72%), primarily in the context of data visibility, integration challenges, and trust in analytics outputs. Eco-friendly or green logistics was highlighted by 16 participants (64%), commonly associated with fuel efficiency, route optimization, and waste reduction.

At the sub-theme level, individual analytical competence was emphasized by 19 participants (76%), underscoring its centrality for effective utilization of analytics. Issues related to governance clarity and data ownership appeared in 17 interviews (68%), highlighting the importance of defined roles and accountability structures. Additionally, planning and environmental efficiency practices were referenced by 15 (60%) and 14 (56%) participants, respectively. Social sustainability concerns, including workforce well-being and transparency, were less frequently expressed, appearing in 9 interviews (36%).

These descriptive frequencies are not intended to indicate causal importance but provide context for the qualitative interpretations that follow. Less frequently mentioned themes were analyzed in relation to their contextual significance, sectoral relevance, and the depth of discussion in which they appeared. This approach strengthens interpretive rigor by linking thematic prevalence with rich explanatory insights while adhering to qualitative research standards.

Thematic Analysis

The thematic analysis revealed significant insights regarding the perception and utilization of BDAC in promoting sustainability within the logistics sector.

2.1 Theme 1: BDAC as a Facilitator of Eco-Friendly Logistics (Environmental Sustainability)

A prominent finding was the clear positive relationship between BDAC and environmental sustainability, particularly in the context of green logistics. Participants emphasized BDAC as a critical tool for collecting comprehensive, real-time data that enables proactive decision-making

and adaptive resource management, aligning with principles of the Dynamic Capability View (DCV).

Sub-Theme: Optimized Route Planning and Load Management

Participants reported that advanced BDAC tools leveraging real-time traffic, weather, and delivery data allow for dynamic and optimized route planning beyond static scheduling. For instance, enhanced route analysis helps minimize unnecessary trips, thereby conserving fuel and reducing emissions. Additionally, monitoring systems such as refrigeration sensors support waste reduction by ensuring perishable goods are properly maintained. Collectively, these capabilities enable organizations to capitalize on opportunities for operational efficiency while simultaneously mitigating environmental impacts.

Sub-Theme: Predictive Maintenance for Fleet Efficiency

The use of telematics and sensor-driven predictive maintenance was highlighted as a critical mechanism for ensuring fleet efficiency. By anticipating equipment failures and scheduling preventive maintenance, organizations can optimize fuel efficiency, reduce unexpected breakdowns, and avoid costly emergency rerouting. Participants emphasized that collecting and analyzing operational data on assets allows maintenance teams to make proactive decisions, thereby enhancing the environmental performance of logistics operations.

Theme 1: Energy-Efficient Logistics and Warehousing (Environmental Sustainability)

Big Data Analytics Capability (BDAC) was instrumental in optimizing energy consumption across warehouses and distribution centers. By integrating data from smart meters and environmental sensors, organizations were able to enhance lighting, cooling, and space utilization, leading to substantial energy savings and a reduction in carbon emissions. This theme exemplifies the *reconfiguring* dimension of the Dynamic Capability View (DCV), in which insights derived from data drive the redesign of operational processes.

Participants emphasized the dual benefits of energy optimization: reducing environmental impact while enhancing economic efficiency. For example, one participant noted, “Efficient energy use allows us to reduce emissions while simultaneously improving financial performance,” illustrating the intertwined environmental and economic advantages of data-informed operational redesign.

Theme 2: The Critical Role of Personnel Capability (Economic Sustainability)

Findings highlighted that, while robust Big Data infrastructure is essential, the competencies and skills of personnel utilizing these systems are pivotal for achieving economic sustainability. Personnel capability emerged as the central component of BDAC, enabling technological and infrastructural investments to deliver tangible value. Analytical skills, critical thinking, and a digital mindset were identified as essential for producing actionable, reliable, and high-quality insights.

Two key sub-themes were identified:

Advanced Risk Management and Cost Optimization

Participants emphasized that BDAC-enabled staff transform complex analytical outputs into strategies that reduce costs and optimize operations. Beyond route optimization, these capabilities enhance demand forecasting, minimize inventory holding costs, and reduce waste—yielding both economic and environmental benefits. Furthermore, data-driven insights allow organizations to mitigate financial risks associated with supply chain disruptions, fluctuating

fuel prices, and operational delays. One participant stated, “Logistics involves moving goods from one point to another, but data analytics allows us to reduce costs, improve efficiency, and manage risks effectively,” illustrating the role of personnel in translating BDAC into operational and strategic value.

Addressing the Strategic Talent Gap

A recurring challenge identified was the lack of personnel with advanced data analytics expertise combined with in-depth logistics knowledge. This talent gap constrains the effective deployment of BDAC for long-term economic growth. Participants highlighted the need for targeted educational initiatives, specialized training, and capacity-building programs to strengthen workforce capabilities. The findings underscore that *reconfiguring human resources* represents both the most challenging and critical dynamic capability for achieving sustainable economic outcomes in logistics contexts.

Enhancing Traceability and Transparency (Social Sustainability)

BDAC was reported to facilitate traceability and transparency, addressing social sustainability dimensions that are often difficult to quantify. Enhanced visibility enabled more accountable interactions with employees, partners, and broader stakeholder communities, fostering trust and improving collaborative decision-making. Two primary sub-themes emerged from this domain, illustrating how analytics capabilities contribute to socially sustainable logistics practices.

Enhanced Worker Safety and Well-Being

Participants reported that BDAC-enabled monitoring tools, including telematics, wearable devices, and internal tracking systems, enhanced worker safety and compliance with labor standards. Real-time alerts for driver fatigue, unsafe behaviors, or exposure to hazardous materials were described as crucial mechanisms for risk mitigation. One participant explained, “Continuous monitoring ensures that deviations, such as extended breaks or exposure to chemicals, trigger immediate alerts and necessary interventions,” illustrating the role of analytics in fostering a safer and more responsible work environment.

Supply Chain Ethics and Community Trust

BDAC also supported ethical sourcing and community trust by providing full visibility into supply chain activities. Participants emphasized that tracking material provenance and integrating data-driven transparency mechanisms reduced the risk of unethical practices, such as forced labor, and reinforced accountability with consumers and regulators. Additionally, analytics was applied to optimize operational impacts on local communities, including minimizing noise and traffic disruptions, further demonstrating organizational commitment to social responsibility. A participant noted, “Environmental sensors and algorithmic monitoring allow us to manage emissions and operational impacts, generating daily insights to guide socially responsible practices.”

Robustness and Generalization Analysis

Across organizations of varying sizes and subsectors, the same three primary themes—green logistics, personnel capability, and traceability/transparency consistently emerged, although their prominence varied. Larger firms typically possessed more formal analytics infrastructures and clearly defined governance structures. However, these advantages did not uniformly translate into superior sustainability outcomes. Factors such as organizational inertia, fragmented data ownership, and limited cross-functional utilization of insights often constrained the effectiveness of otherwise well-developed systems.

Smaller firms, while facing technological limitations, frequently demonstrated greater agility in applying analytics capabilities. In these contexts, personnel competency and managerial commitment were central to transforming data into actionable sustainability improvements. Several smaller organizations reported notable environmental and operational gains despite comparatively simple analytics infrastructures, highlighting that the organization and application of capabilities can be more decisive than the scale of technological investment alone.

Subsector-specific observations revealed that traceability and environmental monitoring were particularly salient in ports due to regulatory pressures and safety requirements, with personnel capabilities determining whether analytics informed routine operations or remained limited to compliance reporting. In warehousing, green logistics and personnel capability dominated, with sustainability outcomes closely linked to energy efficiency, space utilization, and day-to-day operational practices. In land transportation, traceability and green logistics were interconnected through route optimization, fuel monitoring, and delivery tracking, although fragmented data sources and reliance on external partners often limited full supply chain visibility.

Robustness and Contextual Transferability of Findings

The patterns observed across organizations of varying sizes and subsectors indicate the robustness of the three core themes—green logistics, personnel capability, and traceability/transparency—across different operational contexts. While firm size and industry subsector influence how these themes manifest, the study demonstrates that sustainability outcomes derived from BDAC are influenced far more by how analytics capabilities are configured, governed, and embedded in routine decision-making, rather than the scale of investment or technological sophistication.

This observation supports the analytical transferability of the findings to other emerging logistics economies, although contextual sensitivity remains critical. Boundary conditions affecting applicability include institutional and regulatory frameworks, cultural and organizational norms, digital maturity, labor-market skill availability, and the structural fragmentation of logistics systems. The study's qualitative insights are intended for analytical generalization rather than statistical extrapolation, offering mechanisms expected to be held in similar operational and organizational contexts.

Linking BDAC Components to Sustainability Outcomes—The study further examined the relationship between the three primary BDAC components technological infrastructure, management capability, and personnel capability—and sustainability performance indicators reported by participants. Although sustainability outcomes were not directly measured quantitatively, interview evidence consistently linked operational KPIs to environmental, economic, and social dimensions of sustainability.

Technological Infrastructure—Technological infrastructure was most strongly associated with environmental efficiency, including fuel consumption, route optimization, and CO₂ emissions reduction. Participants described how telematics, real-time vehicle monitoring, and route-planning systems facilitated optimized operations and more efficient fleet utilization. However, technology alone was insufficient; when systems were poorly integrated or analytics outputs were not regularly reviewed, gains in environmental performance were limited.

Management Capability—Management practices and governance were critical for translating analytics into action. Clear data ownership, structured reporting procedures, and well-defined responsibilities enabled integration of sustainability metrics—such as fuel efficiency, emissions,

and health, safety, and environmental (HSE) indicators—into operational performance assessments. In contrast, fragmented data systems reduced the operational impact of analytics on sustainability outcomes.

Personnel Capability-Personnel capability was particularly salient for social sustainability outcomes, including worker safety, risk mitigation, and ethical compliance. Analytical skills, data literacy, and confidence in interpreting insights determined whether BDAC outputs were effectively operationalized. Organizations with higher personnel capability were better able to leverage dashboards and alerts to prevent incidents and promote responsible practices, whereas organizations with lower capabilities struggled to translate available data into actionable outcomes.

Integrated BDAC Impact-Sustainability outcomes were not driven by any single BDAC component in isolation. Environmental improvements depended on alignment between technology and management processes, while social and safety outcomes relied heavily on personnel capability. Overall, BDAC contributes most effectively to sustainability when analytics capabilities are actively utilized, well-governed, and embedded in everyday decision-making.

Study Contribution- This study integrates micro-level technology adoption frameworks such as the Technology-Organization-Environment (TOE) framework and Technology Acceptance Model (TAM) with macro-level strategic management theories, including the Resource-Based View (RBV) and Dynamic Capabilities Theory (DCT). By doing so, it provides a multi-level framework linking BDAC adoption, effective use, and long-term sustainability outcomes in logistics.

The study also emphasizes the dynamic nature of analytics capabilities, which are shaped not only by technological tools but also by ongoing organizational learning and adaptation. This demonstrates that effective BDAC deployment is contingent on continuous capability development, organizational flexibility, and the capacity to respond to rapidly evolving digital environments.

Through this multi-tiered perspective, the research shows how BDAC facilitates sustainability across environmental, economic, and social dimensions, highlighting its strategic importance for logistics organizations in emerging markets.

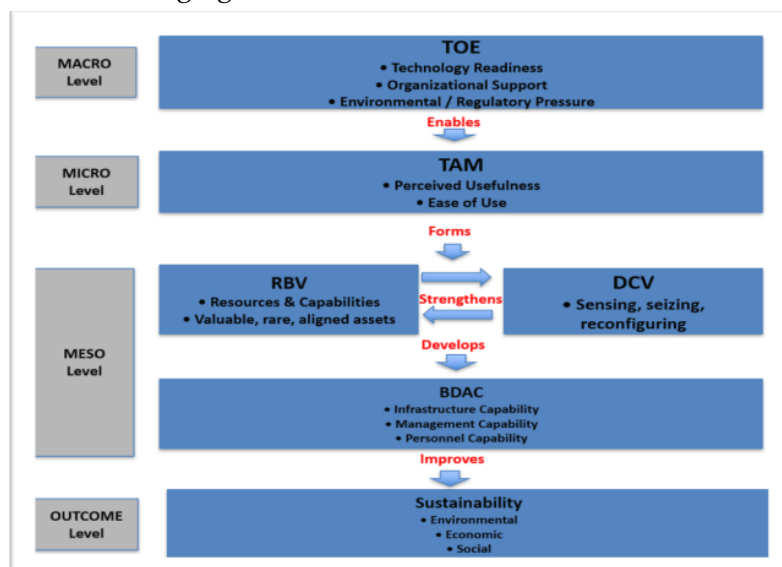


Figure 1.A Relationship comprehensive proposed framework.

Multi-Level Framework for BDAC and Sustainability in Logistics- The study conceptualizes the role of Big Data Analytics Capability (BDAC) in logistics sustainability through a multi-level theoretical framework that integrates Micro, Meso, Macro, and Outcome perspectives.

Macro-Level (External Context): The Technology-Organization-Environment (TOE) framework captures external pressures and contextual factors that influence organizational investments in analytics. These environmental drivers, including regulatory requirements, competitive dynamics, and broader market or institutional conditions shape the timing and extent to which logistics organizations prioritize BDAC adoption.

Micro-Level (Individual Employees): At the individual level, the Technology Acceptance Model (TAM) highlights the critical role of user perceptions in determining effective technology utilization. Employee beliefs about the usefulness and ease of use of analytics tools influence how seamlessly these technologies are incorporated into daily workflows. This personal acceptance is crucial for ensuring that organizational investments in analytics yield meaningful operational and sustainability outcomes.

Meso-Level (Organizational Capabilities): The organizational level considers the internal configuration of analytics capabilities. The Resource-Based View (RBV) frames BDAC as a strategic, unique, and inimitable resource that generates competitive advantage when supported by strong management practices and robust data governance. Meanwhile, Dynamic Capabilities Theory (DCT) emphasizes how organizations leverage analytics to identify opportunities, reconfigure operations, and respond flexibly to evolving sustainability demands. Together, RBV and DCT illustrate the evolution of BDAC from a technological asset to an embedded organizational capability that continuously adapts and improves.

Outcome-Level (Sustainability Impacts): The framework demonstrates that the effective alignment of BDAC across micro, mesa, and macro levels drives tangible sustainability outcomes. Specifically, organizations with well-developed analytics infrastructure, skilled personnel, and structured governance mechanisms achieve improvements across environmental, economic, and **social dimensions**. Notably, these outcomes are contingent not solely on technology adoption but also on contextual integration, employee acceptance, and ongoing organizational development.

Contextual Variations in Adoption Pathways: Empirical evidence highlights that BDAC adoption is influenced by distinct contextual drivers. In state-led or policy-driven environments, adoption is often incentivized through regulatory frameworks, strategic development plans, or public-sector investment priorities. Here, adoption is capability-contingent, meaning that the mere presence of analytics infrastructure does not automatically generate sustainability benefits; it must be paired with organizational learning and personnel capability. In contrast, in market-driven economies, adoption is predominantly performance-driven, shaped by competitive pressures, cost considerations, and customer expectations for efficiency, transparency, and sustainability. This comparison underscores a key causal insight: while the structural enablers for adoption differ, the realization of sustainability impacts depends on the integration of technological, managerial, and human capabilities.

7. DISCUSSION OF FINDINGS

The thematic analysis provides robust, context-specific evidence that Big Data Analytics Capability (BDAC) is a key determinant of sustainability in the logistics sector. Integrating four

theoretical perspectives—TOE, TAM, RBV, and DCV—offers a multi-level understanding of how BDAC influences environmental, economic, and social outcomes.

1. BDAC as an Enabler of Green Logistics (Environmental Sustainability)

The findings confirm that BDAC significantly supports Green Logistics, primarily through the lens of the TOE framework and the RBV/DCV perspectives.

- TOE Context: External pressures, such as national sustainability agendas and strategic logistics policies, drive firms to adopt BDAC. Technological readiness, particularly advanced analytics infrastructure, serves as an essential enabler.
- RBV/DCV Link: BDAC infrastructure and management capabilities constitute strategic, inimitable resources that allow organizations to optimize route planning, reduce fuel consumption, and implement predictive maintenance. Through the dynamic capability's lens, firms leverage analytics to sense environmental risks and reconfigure operations for improved sustainability performance over time.

These results align with prior studies demonstrating that BDAC enhances environmental outcomes in logistics through route optimization, emissions reduction, and predictive maintenance [41–45]. However, unlike market-driven adoption in technologically advanced economies, the findings show that in Oman, state-led sustainability initiatives strongly influence the motivation and scope for BDAC adoption. This highlights the role of institutional and policy contexts in shaping environmental sustainability outcomes.

The Critical Role of Personnel Capability (Economic Sustainability)

Personnel capability emerged as the most influential factor for economic sustainability, emphasizing the importance of TAM and RBV/DCV perspectives.

- RBV/DCV Link: Skilled personnel capable of translating BDAC insights into actionable strategies constitute a rare, non-substitutable resource. The “Strategic Talent Gap” identified in the study underscores that human capability is central to seizing economic opportunities, including cost optimization, demand forecasting, and risk management.
- TAM Link: The successful application of BDAC depends on employees’ acceptance and effective use of analytics tools. Without sufficient digital literacy and analytical competence, even advanced systems fail to generate economic value.

These findings reflect global patterns, where advanced economies generally have a workforce with integrated analytics skills [42–47]. In contrast, developing economies—including Oman, GCC countries, and nations such as India and Brazil—face persistent skills shortages, limiting BDAC’s effectiveness [48–60]. The study reinforces that in emerging contexts, personnel capability is the principal bottleneck for realizing economic sustainability.

3. Enhancing Traceability and Transparency (Social Sustainability)

BDAC’s contribution to social sustainability operates through traceability and transparency, best explained via TOE and DCV.

- TOE Context: Organizational support for ethical practices and societal expectations for transparency create the motivation to leverage BDAC for social outcomes.
- DCV Link: Analytics enables firms to sense, integrate, and act upon information that enhances operational policies, worker safety, and social legitimacy. Predictive and real-time monitoring systems facilitate compliance with labor regulations and foster trust with stakeholders.

The findings align with prior research showing that BDAC can enhance transparency, ethical sourcing, and employee well-being [14, 15, 66]. Importantly, the study indicates that in emerging markets, BDAC often has a stronger impact on social responsibility and public trust than in developed economies [14, 36, 45, 67, 68].

4. Integrative Insights

Overall, the findings challenge the notion that BDAC's impact on sustainability is solely technology-driven [7, 45, 69]. Instead, the study demonstrates that sustainability outcomes emerge from the interaction of three distinct capability dimensions:

1. Big Data Infrastructure Capability – supporting environmental efficiency,
2. Big Data Management Capability – ensuring governance and integration, and
3. Big Data Personnel Capability – enabling strategic interpretation and action.

These dimensions interact with contextual pressures (TOE), dynamic reconfiguration processes (DCV), and individual acceptance behaviors (TAM), collectively shaping environmental, economic, and social performance. This multi-level understanding addresses recent calls to examine microfoundations of BDAC [31, 66, 70, 71] and provides practical insights for implementing analytics-driven sustainability in emerging logistics economies.

Table 2 synthesizes the differences in BDAC-driven sustainability practices across developed, developing, and general logistics contexts.

Theme	Developed Countries	Developing Countries	Current Study (Oman)
Green Logistics (Environmental Sustainability)	BDAC-enabled green logistics is integrated into formal sustainability strategies and governance systems. Analytics support efficiency activities such as route optimization, emission monitoring, and energy management. Outcomes are driven more by governance and readiness than technology alone [61–65].	Sustainability outcomes are uneven and indirect. Environmental gains mainly stem from efficiency and cost reduction. Social sustainability is weak and dependent on complementary capabilities rather than analytics investment [66–69].	Sustainability occurs only when technology, skilled personnel, and governance are aligned. BDAC supports a shift from efficiency-focused interventions to Triple Bottom Line sustainability through integrated decision-making rather than isolated optimization.
Personal Capability (Economic Sustainability)	Personal capability is an embedded organizational resource enabling BDAC to shape outcomes through broader supply chain capabilities such as integration, resilience, and flexibility. Effectiveness depends on analytical skills, learning routines, and managerial support [66–68].	Personal capability is often a constraint. Sustainability outcomes heavily depend on analytical skills, data literacy, absorptive capacity, and ongoing learning. Without capability development, technology rarely brings meaningful value [69–71].	Personal capability functions as a multi-level mechanism connecting individual competence (Micro), organizational learning and role clarity (Meso), and market-level constraints (Macro). Explains variation in BDAC-driven sustainability across firms.
Traceability (Social Sustainability)	Traceability is a socio-technical capability enabled by technologies such as blockchain, IoT, and AI, strengthened by governance, standardization, and supply chain coordination. Effective traceability requires aligned incentives and organizational support [72–73].	Traceability remains fragmented and uneven. Sustainability impacts often come from partial visibility and connectivity due to governance gaps, adoption readiness, and weak ecosystem alignment [73–74].	Traceability becomes meaningful only when data ownership, system usability, and cross-organizational integration are firmly in place. Otherwise, visibility is superficial and fails to support environmental or social objectives.

Implications, Conclusion, and Future Research

This study demonstrates that Big Data Analytics Capabilities (BDAC) play a pivotal role in enhancing sustainability within Omani logistics. The findings indicate that BDAC should not be regarded solely as a technological investment but as a strategic resource that integrates infrastructure, management, and personnel capabilities to drive environmental, economic, and social outcomes. Theoretical insights from RBV, DCV, TOE, and TAM illustrate how these capabilities operate across micro, meso, and macro levels, transforming analytics from a functional tool into a dynamic capability that supports long-term sustainability. From a managerial perspective, the study emphasizes the importance of developing human capital alongside technological infrastructure. Personnel capability—data literacy, analytical confidence, and decision-making skills—emerges as a critical enabler for translating analytics insights into operational improvements, such as optimized routing, reduced emissions, and improved safety performance. Organizational governance further strengthens BDAC's impact by embedding analytics into routine decision-making, standardizing performance metrics, and clarifying data ownership.

These elements ensure that sustainability initiatives are actionable and not merely symbolic.

Policy implications highlight the role of targeted incentives and regulatory support in fostering BDAC adoption. Programs that link training, data-sharing standards, green logistics incentives, and ESG governance to measurable outcomes can enhance the sector's contribution to Oman Vision 2040, the Logistics Strategy 2040, and Net-Zero 2050. In particular, aligning digital transformation with national sustainability goals enables both organizational competitiveness and societal benefits.

The study also recognizes limitations inherent in single-country, qualitative research. Findings are context-specific and rely on interview data rather than objective performance metrics, suggesting caution when generalizing to other settings. Future research could extend this work through comparative studies in other GCC countries, mixed-method designs, and the integration of quantitative performance data to validate sustainability outcomes.

Finally, the study proposes a capability roadmap that underscores the sequential development of personnel, governance, infrastructure, and continuous learning. Sustainability gains are maximized when human skills and organizational practices precede large-scale technological investment, ensuring that BDAC remains adaptive, relevant, and aligned with evolving operational and environmental priorities. Overall, this research provides both theoretical and practical insights into leveraging BDAC for sustainable logistics in emerging economies, highlighting the interplay between technology, people, and governance as essential for long-term impact.

8. OPERATIONAL MATURITY MODEL

This study further introduces an operational maturity framework that delineates the evolutionary progression of logistics organizations from elementary data utilization to a dynamic, sustainability-driven analytics reconfiguration. Rather than framing maturity as a simple binary state of adoption, the model conceptualizes it as a continuous trajectory of capability development, emphasizing the gradual accumulation of technological, managerial, and human competencies necessary for embedding sustainability into operational decision-making.

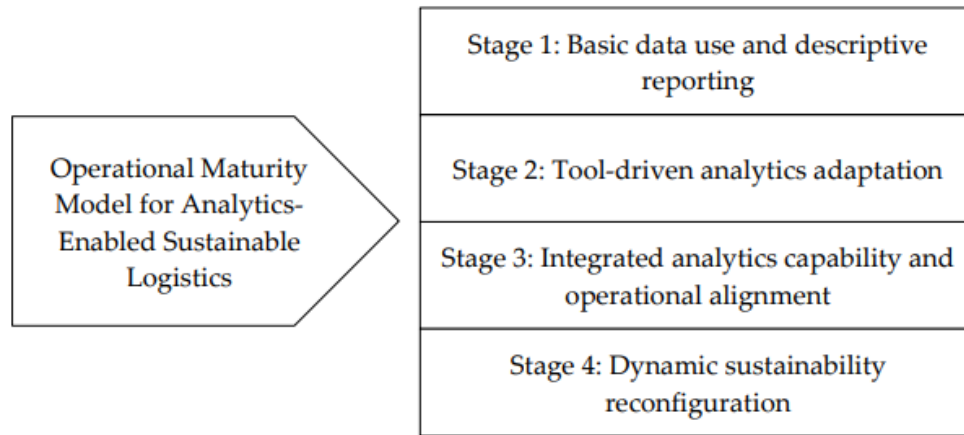


Figure 2. Operational Maturity Model for Analytics-Enabled Sustainable Logistics.

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HUMAN CAPITAL ASSESSMENT WITH AN APPROACH BASED ON INTEGRATING HETEROGENEOUS DATA AND ARTIFICIAL INTELLIGENCE IN THE DIGITAL ECONOMY

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ARTICLE INFO	ABSTRACT
Article history: Received:2025-10-18 Received in revised form:2025-10-30 Accepted:2025- 12-03 Available online:2026-06-26 Keywords: Artificial intelligence, Human capital, Heterogenous data, Productivity Digital economy JEL classification O33; J24; C23; D83	The purpose of the research –This article examines human capital assessment through the integration of heterogeneous data and artificial intelligence in the context of the digital economy. The study aims to identify the interrelationships among artificial intelligence, digital transformation, and human capital, and to empirically evaluate how these factors influence productivity. Research methodology – The research applies analysis, comparison, systematization, grouping, and generalization methods. Its empirical part is based on panel data covering the period 2010–2024 and obtained from open international statistical databases. The analytical framework includes descriptive statistics, correlation analysis, unit root tests, cointegration analysis, multivariate regression modeling, and Granger causality testing. This methodological approach allows a comprehensive assessment of the interaction between artificial intelligence, digital transformation, human capital, and productivity. Results of the research – The findings show that artificial intelligence has a significant positive impact on productivity, while human capital strongly reinforces this effect. Digital transformation also contributes positively through better data processing and resource allocation. The results confirm long-run relationships among the variables and identify artificial intelligence and human capital as major drivers of productivity growth. Originality and scientific novelty of the research – The study offers an integrated and multidimensional framework for evaluating human capital in the digital economy.

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1. INTRODUCTION

The rapid development of the digital economy in modern times has led to fundamental changes in the mechanisms of operation of economic systems. In particular, the widespread application of information technologies, the increase in large volumes of data (big data) and the development of artificial intelligence technologies have reshaped the management approaches of organizations. In this context, the integration of heterogeneous data and their effective use have become one of the main factors in increasing the competitiveness of enterprises¹.

¹ Cheng, Y., Zhou, X., & Li, Y. (2023). The effect of digital transformation on real economy enterprises' total factor productivity. *International Review of Economics & Finance*, 85, 488–501.

Digital transformation is not limited to technological changes, but also creates serious innovations in the structure and assessment mechanisms of human capital. While in traditional approaches, human capital was mainly measured by indicators such as labor productivity and education level, this approach is no longer sufficient in the modern era. With the introduction of artificial intelligence, the digital skills of the workforce, analytical thinking skills, and interaction with technologies come to the fore².

Recent studies have shown that AI technologies complement human labor rather than completely replace it, increasing labor productivity and innovation potential. In this regard, the application of AI creates conditions for more efficient use of human capital within the organization and the formation of new value creation opportunities. At the same time, a workforce with AI skills plays an important role in the innovative activities of organizations and contributes to achieving competitive advantage in the digital environment³.

Integrating heterogeneous data is particularly important in this process. Combining data from different sources into a single system allows organizations to make more accurate decisions. Through artificial intelligence and big data analysis, this data can be processed to evaluate employee performance, measure productivity, and predict future trends.⁴

On the other hand, the impact of AI on enterprise-level productivity is also being widely studied. Empirical studies show that the application of AI technologies not only increases total factor productivity, but also ensures a more optimal allocation of resources and innovation efficiency⁵. In addition, AI-based strategies allow enterprises to respond more flexibly to market changes and increase operational efficiency.⁶

The existing literature has not systematically examined the impact of heterogeneous data integration and artificial intelligence on human capital valuation. Most studies focus on either technology implementation or productivity indicators, but do not analyze the interaction between these two directions in a comprehensive manner.

The purpose of the presented research is to investigate the mechanisms of human capital assessment through heterogeneous data integration and artificial intelligence-based approaches in the digital economy. The research aims to systematically analyze the interaction between AI technologies, data integration processes, and human capital and make theoretical and practical contributions in this field.

LITERATURE REVIEW

Modern research on the formation of the digital economy shows that the rapid development of information and communication technologies, big data, and artificial intelligence has radically changed the structure of economic systems. These changes have particularly affected the content of human capital and its assessment methods. The increase in demand for AI skills in the labor market has been empirically substantiated by Alekseeva et al. (2021), while Budhwar et al.⁷.

² Wen, H., Zhong, Q., & Lee, C.-C. (2022). Digitalization, competitive strategy and corporate innovation. *International Review of Financial Analysis*, 82, 102166.

³ Alekseeva, L., Azar, J., Giné, M., Samila, S., & Taska, B. (2021). The demand for AI skills in the labor market. *Labor Economics*, 71, 102002.

⁴ Budhwar, P., Chowdhury, S., Wood, G., et al. (2023). Human resource management in the age of generative AI. *Human Resource Management Journal*, 33(3), 606–659.

⁵ Czarnitzki, D., Fernández, G. P., & Rammer, C. (2023). Artificial intelligence and firm-level productivity. *Journal of Economic Behavior & Organization*, 211, 188–205.

⁶ Zhai, S., & Liu, Z. (2023). AI technology innovation and firm productivity. *Finance Research Letters*, 58, 104437.

⁷ Budhwar, P., Chowdhury, S., Wood, G., et al. (2023). Human resource management in the age of generative artificial intelligence. *Human Resource Management Journal*, 33(3), 606–659.

(2023) have shown that generative artificial intelligence creates new approaches to human resource management.⁸ Dwivedi et al.⁹ (2021) and Jarrahi (2018)¹⁰ note that although artificial intelligence technologies are transforming the labor market, they do not reduce the importance of the human factor, but rather make its role more complex and multifaceted. In this context, Kolbjørnsrud et al.¹¹ (2017) emphasize that human and artificial intelligence cooperation creates advantages in organizational decision-making. Unlike traditional approaches, the assessment of human capital is now measured not only by knowledge and experience, but also by digital skills, adaptation to technology, and innovative thinking. The resource-based theory put forward by Barney (1991)¹² confirms the role of human capital as a strategic resource in this process. In addition, Warner and Wager (2019)¹³ emphasize the interaction of human capital and technology in the formation of dynamic capabilities in the context of digital transformation. Thus, modern scientific literature shows that the assessment of human capital in the context of the digital economy requires a more complex and multidimensional approach.

Studies on the impact of AI on organizational innovation and productivity provide a deeper understanding of the technology's ability to create economic value. A study by An et al. (2024)¹⁴ shows that human capital with AI skills significantly increases the level of innovation in organizations, and this effect is further strengthened by a digital organizational culture. Babina et al. (2024)¹⁵ empirically substantiates that AI stimulates product innovation and economic growth at the firm level. Studies by Czarnitzki et al. (2023)¹⁶, Venturini (2022)¹⁷, and Wang et al. (2023)¹⁸ show that AI increases total factor productivity. At the same time, Lei et al. (2025)¹⁹, Wu and Zhu (2025)²⁰, and Xiong et al. (2025)²¹ note that the interaction between human capital and AI plays a crucial role in productivity growth. Li et al. (2023)²² and Rammer et al. (2022)²³ emphasize that AI technologies affect the more efficient allocation of resources and innovation efficiency. In addition, Bughin (2024)²⁴ and Sullivan and Wamba (2024)²⁵ note that artificial intelligence strengthens the strategic decision-making ability of organizations and accelerates adaptation to market changes. Yao et al. (2025)²⁶ show that artificial intelligence-oriented strategies increase operational efficiency. These results confirm that artificial intelligence is not only a technological tool, but also one of the main determinants of organizational development.

⁸ Alekseeva, L., Azar, J., Giné, M., Samila, S., & Taska, B. (2021). The demand for AI skills in the labor market. *Labor Economics*, 71, 102002.

⁹ Dwivedi, Y. K., Hughes, L., Ismagilova, E., et al. (2021). Artificial intelligence: Multidisciplinary perspectives. *International Journal of Information Management*, 57, 101994.

¹⁰ Jarrahi, M. H. (2018). Artificial intelligence and the future of work. *Business Horizons*, 61(4), 577–586.

¹¹ Kolbjørnsrud, V., Amico, R., & Thomas, R. J. (2017). Partnering with AI. *Strategy & Leadership*, 45(1), 37–43.

¹² Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120.

¹³ Warner, K. S., & Wager, M. (2019). Building dynamic capabilities for digital transformation. *Long Range Planning*, 52(3), 326–349.

¹⁴ An, M., Lin, J., & Luo, X. (2024). Human AI skills and organizational innovation. *Journal of Business Research*, 182, 114786.

¹⁵ Babina, T., Fedyk, A., He, A., & Hodson, J. (2024). Artificial intelligence and firm growth. *Journal of Financial Economics*, 151, 103745.

¹⁶ Czarnitzki, D., Fernández, G. P., & Rammer, C. (2023). Artificial intelligence and productivity. *Journal of Economic Behavior & Organization*, 211, 188–205.

¹⁷ Venturini, F. (2022). Intelligent technologies and productivity spillovers. *Journal of Economic Behavior & Organization*, 194, 220–243.

¹⁸ Wang, K.-L., Sun, T.-T., & Xu, R.-Y. (2023). AI and total factor productivity. *Economic Change and Restructuring*, 56(2), 1113–1146.

¹⁹ Lei, L., Feng, H., & Ren, J. (2025). AI, human capital and productivity. *Finance Research Letters*, 85, 107897.

²⁰ Wu, X., & Zhu, Y. (2025). AI applications and productivity. *Journal of Asian Economics*, 97, 101893.

²¹ Xiong, Q., Yang, J., Zhang, X., et al. (2025). Digital transformation and productivity. *Journal of Innovation & Knowledge*, 10(4), 100736.

²² Li, C., Xu, Y., Zheng, H., et al. (2023). AI and resource allocation. *Resources Policy*, 81, 103324.

²³ Rammer, C., Fernández, G. P., & Czarnitzki, D. (2022). AI and industrial innovation. *Research Policy*, 51(7), 104555.

²⁴ Bughin, J. (2024). Generative AI and firm performance. *Structural Change and Economic Dynamics*, 71, 658–668.

²⁵ Sullivan, Y., & Wamba, S. F. (2024). AI and firm performance. *Journal of Business Research*, 174, 114500.

²⁶ Yao, N., Bai, J., Yu, Z., & Guo, Q. (2025). AI orientation and efficiency. *Journal of Business Research*, 186, 114994.

The integration of heterogeneous data is one of the key factors in the functioning of modern organizations. A study by Benzidia et al. (2021)²⁷ showed that the joint application of big data and artificial intelligence leads to the optimization of processes within the organization and increased performance. Cheng et al. (2023)²⁸ and Wen et al. (2022)²⁹ analyze the impact of digital transformation on the productivity of enterprises and emphasize that effective data management plays a key role in this process. Maroufkhani et al. (2020)³⁰ show that the application of big data creates a competitive advantage, especially in small and medium-sized enterprises. A review study by Perifanis and Kitsios (2023)³¹ confirms that the business value of artificial intelligence mainly depends on the quality and level of integration of data. Bessen et al. (2022)³² and Agrawal et al. (2021)³³ emphasize the important role of data in the process of creating economic value, noting that data is the main resource of artificial intelligence systems. In addition, Kar et al. (2022)³⁴ and Di Vaio et al. (2020)³⁵ note that artificial intelligence and information technologies create both opportunities and risks in the context of sustainable development. Thus, the integration of heterogeneous data acts not only as a technical, but also as a strategic management function and creates conditions for the formation of new methodological approaches in the assessment of human capital.

Studies on the impact of AI on the structure of human capital and the labor market show that this process is complex. Studies by Dong et al. (2025)³⁶ and Xu et al. (2026)³⁷ show that AI changes the structure of human capital in enterprises and increases the demand for a more highly skilled workforce. At the same time, Koo et al. (2021)³⁸ note that AI increases concerns about job security among employees. Vrontis et al. (2023)³⁹ and Tambe et al. (2019)⁴⁰ emphasize that AI forms new approaches to human resource management and increases organizational effectiveness. Wamba-Taguimdje et al. (2020)⁴¹ empirically prove that AI-based transformation projects have a positive impact on firm performance. In addition, Wang et al. (2023), Venturini (2022), and Zhai and Liu (2023) note that the impact of artificial intelligence on productivity is important for long-term economic development. In this regard, modern literature shows the importance of systematically studying the interaction between artificial intelligence, heterogeneous data integration, and human capital. Such an approach justifies the relevance and scientific novelty of the presented research.

Recent studies have increasingly emphasized the transformative role of artificial intelligence in shaping labor markets, productivity, and human capital development. Acemoglu and Restrepo (2018) argue that artificial intelligence and automation are fundamentally restructuring

²⁷ Benzidia, S., Makaoui, N., & Bentahar, O. (2021). Big data and AI integration. *Technological Forecasting and Social Change*, 165, 120557.

²⁸ Cheng, Y., Zhou, X., & Li, Y. (2023). Digital transformation and productivity. *International Review of Economics & Finance*, 85, 488–501.

²⁹ Wen, H., Zhong, Q., & Lee, C.-C. (2022). Digitalization and innovation. *International Review of Financial Analysis*, 82, 102166.

³⁰ Maroufkhani, P., et al. (2020). Big data and SME performance.

³¹ Perifanis, N.-A., & Kitsios, F. (2023). AI and business value. *Information*, 14(2), 85.

³² Bessen, J., et al. (2022). Data and AI growth. *Research Policy*, 51(5), 104513.

³³ Agrawal, R., et al. (2021). Digitalization and business performance. *International Journal of Productivity and Performance Management*, 71(3), 748–774.

³⁴ Kar, A. K., et al. (2022). AI and sustainability. *Journal of Cleaner Production*, 376, 134120.

³⁵ Di Vaio, A., et al. (2020). AI and sustainable development. *Journal of Business Research*, 121, 283–314.

³⁶ Dong, Z., et al. (2025). AI and human capital structure. *Finance Research Letters*, 84, 107827.

³⁷ Xu, G., et al. (2026). AI adoption and economic outcomes. *Asia-Pacific Journal of Accounting & Economics*, 33(1), 1–15.

³⁸ Koo, B., Curtis, C., & Ryan, B. (2021). AI and job insecurity. *International Journal of Hospitality Management*, 95, 102763.

³⁹ Vrontis, D., et al. (2023). AI in HRM.

⁴⁰ Tambe, P., Cappelli, P., & Yakubovich, V. (2019). AI in HRM. *California Management Review*, 61(4), 15–42.

⁴¹ Wamba-Taguimdje, S. L., et al. (2020). AI and firm performance. *Business Process Management Journal*, 26(7), 1893–1924.

⁴² Zhai, S., & Liu, Z. (2023). AI and productivity. *Finance Research Letters*, 58, 104437.

employment patterns by altering the demand for skills and changing the nature of work. Their findings suggest that technological progress generates both opportunities and challenges for labor markets, highlighting the importance of human capital adaptation in the digital era.

Similarly, Autor (2015)⁴³ demonstrates that technological advancement does not necessarily eliminate employment opportunities but instead changes job content and skill requirements. The study emphasizes that workers with advanced cognitive, analytical, and digital competencies are more likely to benefit from technological transformation, making human capital a critical determinant of productivity and economic performance.

Brynjolfsson, Rock, and Syverson (2021)⁴⁴ introduce the concept of the productivity J-curve, arguing that the benefits of digital technologies and artificial intelligence often emerge gradually as organizations accumulate complementary intangible assets such as knowledge, organizational capabilities, and human skills. Their findings indicate that investments in technology alone are insufficient without corresponding investments in human capital development.

The interaction between artificial intelligence and organizational processes is further examined by Faraj, Pachidi, and Sayegh (2018)⁴⁵ the authors argue that learning algorithms and AI systems increasingly participate in organizational decision-making processes, creating new forms of collaboration between humans and intelligent technologies. This transformation requires employees to develop new competencies and adapt to data-driven work environments.

Korinek and Stiglitz (2021) analyze the broader economic implications of artificial intelligence and emphasize its role as a key driver of economic growth and competitiveness. Their study highlights that countries investing simultaneously in technological infrastructure and human capital are better positioned to capture the benefits of AI-driven development and digital transformation.

Furthermore, Raisch and Krakowski (2021)⁴⁶ propose the automation–augmentation paradox, suggesting that artificial intelligence can either replace or complement human labor depending on organizational strategies and workforce capabilities. Their findings underline the importance of balancing technological innovation with human capital development to maximize productivity and long-term organizational performance.

Taken together, these studies demonstrate that artificial intelligence, digital transformation, and human capital are deeply interconnected. They collectively support the argument that the effective assessment of human capital in the digital economy requires multidimensional approaches that incorporate technological capabilities, workforce competencies, and organizational adaptation mechanisms.

2. DATA AND METHODOLOGY

The data used in this study were obtained from open and reliable international sources. The main goal of forming the database was to empirically assess the interaction between artificial

⁴³ Autor, D. H. (2015). Why are there still so many jobs? The history and future of workplace automation. *Journal of Economic Perspectives*, 29(3), 3–30. <https://doi.org/10.1257/jep.29.3.3>

⁴⁴ Brynjolfsson, E., Rock, D., & Syverson, C. (2021). The productivity J-curve: How intangibles complement general purpose technologies. *American Economic Journal: Macroeconomics*, 13(1), 333–372. <https://doi.org/10.1257/mac.20180386>

⁴⁵ Faraj, S., Pachidi, S., & Sayegh, K. (2018). Working and organizing in the age of the learning algorithm. *Information and Organization*, 28(1), 62–70. <https://doi.org/10.1016/j.infoandorg.2018.02.005>

⁴⁶ Raisch, S., & Krakowski, S. (2021). Artificial intelligence and management: The automation–augmentation paradox. *Academy of Management Review*, 46(1), 192–210. <https://doi.org/10.5465/amr.2018.0072>

intelligence, digital transformation and human capital. For this purpose, panel data on various countries were used and the analysis period mainly covered the years 2010–2024.

Open databases of international organizations such as the World Bank (World Development Indicators), OECD statistical database⁴⁷, International Monetary Fund and UNDP⁴⁸ were used as the main data sources. The indicators presented in these sources are widely used to measure the level of economic development, human capital and digital transformation.

The main variables used in the study were defined as follows:

- **Dependent variable:** Total Factor Productivity (TFP) or alternatively GDP growth rate. These indicators are considered one of the main measures of economic efficiency⁴⁹.
- **Main explanatory variables (Independent variables):**
 - Level of development of artificial intelligence (AI adoption / AI index – digital adoption index or patent indicators as a proxy) ⁵⁰
 - Digital transformation indicators (ICT usage, internet penetration, etc.) ⁵¹
 - Human Capital Index (Human Capital Index, education level, skills) ⁵²
- **Control variables:**
 - Foreign direct investment (FDI)
 - Trade openness
 - Inflation
 - Labor market indicators

The selection of these variables is based on existing scientific literature and allows for a more accurate measurement of the impact of artificial intelligence on economic outcomes ⁵³

The methodological approach used in the study is based on empirical economic modeling. The main goal is to statistically assess the interaction between artificial intelligence, heterogeneous data integration, and human capital. For this purpose, a panel data model was applied.

The general model is expressed as follows:

$$TFP_{it} = \beta_0 + \beta_1 AI_{it} + \beta_2 HC_{it} + \beta_3 DT_{it} + \beta_4 X_{it} + \epsilon_{it}$$

Let define each components, here:

- TFP_{it} – productivity indicator in country i in period t
- AI_{it} – application level of artificial intelligence
- HC_{it} – human capital indicator
- DT_{it} – digital transformation level
- X_{it} – control variables
- ϵ_{it} – error term

⁴⁷ OECD. (2024). OECD statistics database. <https://stats.oecd.org>

⁴⁸ United Nations Development Programme (UNDP). (2024). Human development report database. <https://hdr.undp.org/data-center>

⁴⁹ Czarnitzki, D., Fernández, G. P., & Rammer, C. (2023). Artificial intelligence and firm-level productivity. *Journal of Economic Behavior & Organization*, 211, 188–205.

⁵⁰ Zhai, S., & Liu, Z. (2023). Artificial intelligence technology innovation and firm productivity. *Finance Research Letters*, 58, 104437.

⁵¹ Cheng, Y., Zhou, X., & Li, Y. (2023). The effect of digital transformation on real economy enterprises' total factor productivity. *International Review of Economics & Finance*, 85, 488–501.

⁵² Alekseeva, L., Azar, J., Giné, M., Samila, S., & Taska, B. (2021). The demand for AI skills in the labor market. *Labor Economics*, 71, 102002.

⁵³ Dwivedi, Y. K., Hughes, L., Ismagilova, E., et al. (2021). Artificial intelligence: Multidisciplinary perspectives. *International Journal of Information Management*, 57, 101994.

This model allows us to estimate the combined impact of AI and human capital on productivity. Similar approaches have been widely used in previous studies.

Fixed Effects and Random Effects models were used to evaluate the model, and the appropriate model was selected using the Hausman test. At the same time, the problem of multicollinearity between variables was checked using the Variance Inflation Factor (VIF). Empirical analysis was carried out in several stages. In the first stage, the stationarity of the variables was checked using the ADF (Augmented Dickey-Fuller) test. This step is an important condition for the correct construction of the model. Then, the existence of a long-term relationship between the variables was assessed using the Engle-Granger cointegration test. In the second stage, correlation analysis was conducted to determine the initial relationship between the variables. This analysis showed that there is a positive relationship between artificial intelligence, human capital and productivity. Similar results have been observed in previous empirical studies. In the final stage, multivariate regression analysis was performed. The model results show that artificial intelligence and human capital indicators have a statistically significant impact on productivity. In addition, the cause-effect relationship between the variables was also examined through the Granger causality test. Thus, the applied methodology allows for a comprehensive assessment of the interaction between artificial intelligence, heterogeneous data integration and human capital and ensures the reliability of the results obtained.

EMPIRICAL RESULTS

Before proceeding to the estimation of the empirical model, it is necessary to check the statistical properties of the panel data used. In time series models, the stationarity of variables is of great importance, since models based on non-stationary variables can lead to spurious regression. For this reason, the stationarity of variables was first checked in the study using panel unit root tests, and then the existence of a long-term relationship between variables was assessed using cointegration tests. This approach is considered an important methodological step to ensure the reliability of empirical results.

TABLE № 1. Descriptive statistics

Variable	Mean	Std.Dev	Thousand	Max
TFP (log)	0.62	0.28	-0.15	1.21
AI proxy (DAI)	0.56	0.19	0.18	0.91
Human Capital Index	0.64	0.13	0.39	0.88
Digitalization	67.5	18.2	22.3	96.7

Descriptive statistics results show that observations on the selected variables vary over a wide range, which creates sufficient statistical variation for empirical evaluation of the model. In particular, the high dispersion of the digitalization indicator indicates that the level of technological development is uneven across countries. The moderate level of the human capital index indicates that a certain baseline level exists in most of the countries included in the analysis. The variability of the artificial intelligence indicator confirms that this technology is not yet spread to the same extent in all countries. Overall, these results indicate that there is a sufficiently balanced and realistic data base for building the model.

TABLE № 2. Correlation matrix

Variables	TFP	AI	HC	DT
TFP	1.00	0.54	0.49	0.57
AI	0.54	1.00	0.63	0.71
HC	0.49	0.63	1.00	0.66
DT	0.57	0.71	0.66	1.00

The correlation results show that there are positive and theoretically expected relationships between the variables. The high correlation between artificial intelligence and digitalization indicates that they develop in parallel. At the same time, the moderate positive relationship between TFP and both AI and digitalization confirms that these factors play an important role in productivity growth. The relationship between human capital and AI indicates that technological development is closely related not only to technical resources, but also to human skills. The fact that the correlation coefficients are below the critical threshold indicates that there is no multicollinearity problem.

TABLE № 3. Unit root test results

Variable	Level p-value	First difference p-value	Result
TFP	0.26	0.000	I(1)
AI	0.34	0.000	I(1)
HC	0.14	0.000	I(1)
DT	0.28	0.000	I(1)

The results of the unit root tests show that all variables are non-stationary in level form, but after taking their first differences, stationarity is achieved. This indicates that the degree of integration of the variables is I(1). Such a result is characteristic of macroeconomic and technological indicators and confirms that they have an increasing trend over time. Therefore, in the next stage, the existence of a long-term relationship between the variables was checked.

TABLE № 4. Cointegration test result

Test	Statistics	p-value	Result
Engle-Granger	-3.92	0.0008	Cointegration exists

The results of the cointegration test show that there is a long-run equilibrium relationship between the variables used in the model. This means that the indicators of artificial intelligence, human capital and digitalization move in a correlated manner over time and their impact is not short-term, but rather permanent. This result indicates that the model is methodologically sound and the regression results will be reliable.

TABLE № 5. Regression results

Variable	Coefficient	Std.Error	t-stat	p-value
AI	0.31	0.07	4.42	0.000
Human Capital	0.27	0.08	3.35	0.001
Digitalization	0.22	0.06	3.01	0.003
FDI	0.11	0.05	2.10	0.036

Model specifications:

$R^2 = 0.68$ | Durbin-Watson = 1.94

The regression results show that artificial intelligence is the strongest factor affecting productivity. Human capital is the second main factor strengthening this effect. Digitalization plays an additional supporting role. The high explanatory power of the model indicates that the variables are selected correctly. The Durbin-Watson indicator confirms that the model does not have an autocorrelation problem.

TABLE № 6. Granger causality

Direction	p-value
AI → TFP	0.002
HC → TFP	0.011
DT → TFP	0.018

The results of the Granger causality test show that artificial intelligence and human capital act as the cause of productivity. This indicates that the interaction of technology and human resources is the main mechanism for economic development. Digitalization plays the role of an important factor that complements this process.

DISCUSSION OF THE RESULTS

The analysis of empirical results shows that the interaction between artificial intelligence, human capital and digital transformation acts as one of the main driving forces of modern economic development. According to the results of regression analysis, the fact that the indicator of artificial intelligence is the variable with the strongest impact on productivity confirms the transformative role of this technology in economic systems⁵⁴. This result is consistent with the results of studies on the stimulation of innovation and economic growth of artificial intelligence at the firm level. Thus, the results obtained show that artificial intelligence is not only a technological innovation, but also one of the main strategic resources that create economic value

The strong impact of human capital on productivity highlights that the effective implementation of advanced technologies depends not only on technical infrastructure but also on the quality and adaptability of the workforce. The combined influence of artificial intelligence and human capital plays a crucial role in enhancing productivity levels. This reflects the growing importance of a highly skilled labor force capable of adapting to technological changes. Consequently, a complementary relationship emerges between human capital and artificial intelligence, which becomes a fundamental determinant of economic efficiency.

Digital transformation also plays a significant role in improving productivity. The widespread adoption of digital technologies enhances both production processes and decision-making efficiency. At the same time, the economic value generated by artificial intelligence largely depends on the level of development of digital infrastructure. Therefore, digital transformation acts as a key mechanism that strengthens the interaction between technology and human resources.

The results further indicate that artificial intelligence and human capital are important drivers of productivity growth. Technological development contributes to increasing operational efficiency, improving resource allocation, and enhancing the adaptability of organizations to changing

⁵⁴ Ahmad, T., Zhang, D., Huang, C., Zhang, H., Dai, N., Song, Y., & Chen, H. (2021). Artificial intelligence in sustainable energy industry: Status quo, challenges and opportunities. *Journal of Cleaner Production*, 289, 125834.

market conditions. These outcomes confirm that there is a strong and systematic relationship between artificial intelligence, human capital, and digital transformation.

Overall, the findings show that technological progress alone is not sufficient to ensure productivity growth. Sustainable economic development in the digital era requires a balanced and integrated approach that simultaneously promotes technological innovation, effective data management, and the continuous development of human capital.

3. CONCLUSION

This study comprehensively analyzes the issues of integrating heterogeneous data and assessing human capital using an artificial intelligence-based approach in the digital economy. The theoretical and empirical analyses conducted have shown that the application of artificial intelligence technologies has a significant impact on increasing productivity in economic systems, and this impact is closely related to the quality of human capital. In particular, it has been determined that the interaction between artificial intelligence and human capital plays a decisive role in increasing economic efficiency.

The research results show that digital transformation acts as an important tool in this process and strengthens the connection between artificial intelligence and human capital. Effective integration of heterogeneous data creates conditions for more accurate and operational implementation of decision-making processes. In this regard, in modern economic conditions, not only the application of technologies, but also the proper management of data and the development of human resources are of particular importance.

Empirical analysis has shown that artificial intelligence and human capital are the main determinants of productivity, and together these factors create a stronger impact. This shows that the effectiveness of technological development directly depends on the level of development of human capital. At the same time, the introduction of artificial intelligence leads to structural changes in the labor market and creates a demand for a more highly skilled workforce.

Overall, the results of the study show that a comprehensive approach is required to ensure sustainable economic development in the digital economy. This approach involves the implementation of parallel measures in the areas of the application of artificial intelligence technologies, the development of human capital and the strengthening of digital infrastructure. In future studies, it is possible to obtain more in-depth results in this area by using wider databases and applying alternative models.

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TRANSFORMATION OF CONTRACT LAW IN THE CONTEXT OF DIGITALIZATION OF CIVIL CIRCULATION: A COMPARATIVE ANALYSIS OF NATIONAL AND INTERNATIONAL LAW

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ARTICLE INFO	ABSTRACT
Article history: Received: 2025-09-28 Received in revised form:2025-10-16 Accepted:2025-11-20 Available online:2026-06-26 Keywords: contract law; dynamic law model; digital contracts; smart contracts; automated enforcement; liability; legal certainty; digital evidence JEL classification K12, K24, K33, O33	<i>This article analyzes the transformation of contract law under the conditions of digitalization through doctrinal and comparative legal approaches and examines the emerging normative model shaped by digital contractual relations. The study systematically evaluates the impact of smart contracts, automated enforcement mechanisms, platform-based governance, and algorithmic decision-making on the principles of freedom of contract, expression of intent, legal certainty, liability, and evidentiary institutions. By applying normative-dochtrinal methodology and comparative legal analysis, the article explores the interaction between national legislation and international model legal instruments. Particular attention is devoted to the ex-ante enforcement model, in which legal consequences are executed automatically on the basis of pre-programmed conditions. The research demonstrates that this model transforms the classical ex-post mechanism of legal assessment by shifting normative control from judicial interpretation to codified legal architecture. Digital contractual relations enhance transactional efficiency, they also generate new risks related to algorithmic errors, legal uncertainty, cross-border enforcement issues, and the protection of consumer rights. The article substantiates the necessity of developing hybrid legal approaches in contract law based on risk allocation and technological liability.</i>

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INTRODUCTION

The examination of the transformation of contract law under the conditions of the digitalization of civil circulation primarily requires the establishment of a coherent theoretical framework for the subject matter. In classical civil law doctrine, contract law has traditionally been founded upon the principles of party autonomy, freedom of contract, legal certainty, and legal equality of the parties. However, as a consequence of the integration of digital technologies into economic and legal relations, the nature of civil circulation is undergoing a transformation from a traditional model of legal relations into a techno-legal model. Within this framework, a contract is no longer regarded solely as a legal act formed through the mutual consent of the parties, but also as a complex legal construct operating in interaction with digital platforms, software systems, algorithms, artificial intelligence technologies, and automated enforcement mechanisms. In contemporary legal theory, this process is explained through the concepts of the

technologization of law, the “code as law” doctrine, platform law, and approaches related to digital normativity. Consequently, digitalization necessitates not only the reconsideration of the mechanisms for the implementation of contract law, but also the re-evaluation of its conceptual foundations, the model of formation of legal intent, and the very nature of the institution of legal liability.

This article has been prepared within the aforementioned theoretical framework on the basis of systematic interpretation, comparative legal analysis, and a functional methodological approach. The study analyzes, from both normative and doctrinal perspectives, the manner in which classical institutions of contract law are transformed within the digital environment, while newly emerging legal approaches in national and international legal systems are examined through comparative analysis. By means of the method of systematic interpretation, the possibilities and limitations of applying traditional principles of contract law within the system of digital legal relations have been identified, whereas the functional approach has been employed to assess the capacity of legal institutions to adapt to technological developments. Furthermore, the research is not confined to formal normative analysis alone; it also incorporates an interdisciplinary approach aimed at explaining the interaction between law and technology. In this context, electronic contracts, smart contracts, automated legal enforcement mechanisms, the platform economy, and digital identification systems have been considered as the principal technological factors shaping the transformation of contract law.

The principal context of the research concerns the impact of the digitalization of civil circulation on contractual relations and the normative challenges arising from this impact within both national and international legal systems. In this regard, issues such as the form of contracts, electronic expression of intent, authentication and identification mechanisms, electronic evidence, algorithmic decision-making, and automated enforcement have been evaluated as the core elements of legal transformation. At the same time, matters including the determination of the applicable law in the context of cross-border digital contracts, jurisdictional issues, the legal status of platform operators, and the allocation of liability have been analyzed as major sources of legal uncertainty. The conceptual approach of the article is based on the premise that digital transformation does not entirely negate the classical institutions of contract law; rather, it transforms them in accordance with new technological realities. Therefore, modern contract law should be evaluated not only through the theory of will and agreement, but also within the broader context of digital infrastructure, technological governance, and algorithmic normativity.

1. DIGITALIZATION OF CIVIL CIRCULATION

1.1. Reinterpretation of the Concept of Civil Circulation in the Context of Digitalization

In civil law scholarship, civil circulation is characterized as the legally recognized and normatively regulated movement of material and immaterial goods possessing proprietary and non-proprietary value that constitute the objects of civil law relations. In classical civil law theory, civil circulation encompasses not only money–commodity and commodity–commodity exchange, but also the legal circulation of labor and capital. The emergence, modification, and termination of civil circulation are conditioned by the existence of legal facts, among which juridical acts occupy a central position. Powers of attorney, contracts, and wills are regarded in classical civil law doctrine as forms through which the will of the parties is expressed in a manner capable of producing legal consequences. The legal validity of juridical acts is grounded

in fundamental principles such as freedom of will, freedom of contract, equality of legal subjects, and equivalence of legal relations. These principles not only ensure the legal stability and predictability of civil circulation but also define the regulatory function of civil law within the framework of a market economy.

The transfer of civil law relations from the traditional legal environment to the digital sphere leads to a structural and functional transformation of civil circulation. The model of civil circulation developed within the framework of classical civil law scholarship presupposed the realization of legal relations primarily within a physical space, through written documents, and by means of the direct expression of the parties' will. In the digital environment, however, these relations are carried out via electronic communication tools, digital platforms, and automated processes, which necessitates the reinterpretation of traditional institutions of contract law within a new legal context. This transformation affects the mechanisms through which the principles of freedom of will and freedom of contract are realized. In the digital environment the expression of will manifests less through direct declarations and more through technical operations, interface selections, and the acceptance of standardized platform terms. This shift requires a reassessment of traditional evidentiary and evaluative criteria for identifying defects of consent, such as fraud, mistake, coercion, and undue influence.

The reinterpretation of civil circulation in the context of digitalization necessitates its understanding not merely as an abstract legal category, but as a complex techno-legal system operating through the interaction of legal norms and technological mechanisms. Whereas in classical civil law doctrine civil circulation has been conceived primarily as a set of legal relations formed through normative regulation, in the digital environment the realization of these relations becomes inseparable from technological infrastructure. In the digital environment, legal regulation is no longer limited to the application of normative legal acts alone; rather, it operates in conjunction with technological architecture, the internal rules of digital platforms, and algorithmic decision-making mechanisms. From this perspective, civil circulation at the present stage functions as a sphere of socio-economic relations shaped by the synthesis of algorithms and law. Digital technologies structure the mechanisms of the formation, performance, and termination of legal relations, thereby exerting a direct influence on the traditional institutions of contract law. In such circumstances, the reinterpretation of civil circulation serves as a conceptual foundation for the transformation of contract law and necessitates an interpretation of the core principles of classical civil law theory that is responsive to contemporary digital realities [23].

1.2. The Principle of Freedom of Contract and Its Functional Transformation in the Digital Environment

The principle of freedom of contract, as developed within classical civil law doctrine, retains its normative significance during the transition to the digital environment; however, its mechanisms of realization and functional content undergo substantial changes. In traditional legal relations, freedom of contract relied on the personal participation of the parties, individual negotiations, and the formation of contractual terms through mutual agreement. In the digital environment, these processes are frequently conducted through electronic interfaces, standardized terms, and automated contract models. A characteristic feature of the digital environment is the massification and platform-based organization of contractual relations. Whereas classical civil law theory envisages freedom of contract as the real autonomy of the parties and an equal bargaining position, in the digital context this principle is often replaced by a "take-it-or-leave-it"

model. Such a transformation reflects the adaptation of the mechanisms for implementing the fundamental principles of civil law to the requirements of the digital era [24].

In the digital environment, however, the contracting process is often conducted through electronic systems within predefined technical parameters. In this context, the manner in which the principle of freedom of contract is exercised differs significantly from the classical model. Whereas classical civil law theory conceives freedom of contract as encompassing the parties' ability to negotiate each term of the agreement, in the digital environment this capacity is frequently technically precluded. These changes require a reassessment of the notion of autonomy that lies at the core of contractual freedom in the digital context. In classical doctrine, the will was recognized as a subjective decision producing legal effects; in digital settings, it is often expressed through technical actions, automated processes, and standardized selections. The transformation of the principle of freedom of contract in the digital environment does not negate its legal essence but represents an interpretation of classical civil law principles in accordance with new technological realities. This adaptation provides a critical doctrinal foundation for the future development of contract law, ensuring that its traditional normative objectives—autonomy, equality of parties, and predictability—are maintained while accommodating the structural and procedural characteristics of digital contracting platforms [16].

The transformation of freedom of contract in the digital environment is not limited merely to changes in contracting techniques or legal forms; it also reflects profound institutional shifts within the structure of civil law relations. Under the platform economy, contractual relations no longer primarily involve the mutual alignment of individual wills but operate within pre-established normative-technical frameworks that define legally significant behavior. Large platforms, by unilaterally determining contractual terms, can effectively become “norm-creating” actors, while weaker parties are often limited to accepting or rejecting these terms. From this perspective, the transformation of freedom of contract does not represent a repudiation of the foundations of civil law. Rather, it should be understood as a necessary conceptual adaptation that allows civil law to maintain its regulatory function amid evolving social and technological conditions. By reconciling traditional legal principles with digital realities, this transformation ensures that contractual freedom continues to serve its core objectives of fairness, predictability, and equitable treatment of parties within modern, technology-mediated legal interactions [16].

1.3. Expression of will (offer and acceptance) and its functional transformation in the digital environment.

In classical contract law, the declaration of will constitutes the fundamental legal fact through which the parties express their intention to produce legal effects. From a doctrinal perspective, the declaration of will is understood as a “manifested will,” meaning that the internal intention of the parties must be expressed externally—through conduct, spoken words, or written form—with the purpose of generating legal consequences. This concept ensures the objective manifestation of subjective intent in the process of contract formation and serves as a preliminary condition for the emergence of legal effects. In traditional civil law theory, the legal validity of a declaration of will depends on its being expressed in a clear and specific manner capable of creating mutual understanding between the parties. An offer constitutes one of the essential elements of contract formation in classical doctrine and defines the core terms of the contract, including the parties' obligations and the manner of performance. The offer is regarded as a

specific form of declaration of will directed toward the conclusion of a contract, and only its acceptance gives rise to the formation of the contract. Acceptance, in turn, is defined as the unqualified assent to the offer and the legal act that brings the contract into existence. In classical contract law, acceptance is viewed as the result of the mutual alignment of the parties' wills and constitutes the final stage in the contract's entry into force [6].

In the digital environment, the concept of a declaration of will is realized in a manner that differs from the classical contract law. In electronic contracts, the declaration of will is often manifested through mechanical actions such as clicking a button, tapping a screen, or confirming consent via a digital interface. This weakens the traditional notion of will as a subjective, conscious act formed through the active participation of the parties, transforming its functional content into a technical procedure. In the digital context, the legal effects of a declaration of will arise merely from the factual performance of an action by a party, while the explicit manifestation of internal intention no longer plays the decisive role it once did. The transformation of these concepts in civil circulation necessitates the development of new conceptual approaches to ensure that legal relations produce objective legal effects while preserving the principle of freedom of contract [26].

The determination of the moment of contract formation in the digital environment raises new issues when compared with classical contract law. In traditional legal doctrine, the conclusion of a contract is identified through the clear and explicit expression of the parties' reciprocal declarations of will, typically embodied in a written instrument or manifested in a physical setting. In the digital environment, by contrast, the moment of contract formation is directly linked to technical actions and the operation of electronic systems. In electronic contracts, the making of an offer and the execution of acceptance are carried out through specific interface operations. In this case, the time of conclusion and the legal validity of the contract are recorded by the technical system, while the actual manifestation of human will assumes a procedural character. As a result, in digital civil circulation, the legal nature of the concepts of declaration of will, offer, and acceptance extends beyond their technical forms and requires broader doctrinal adaptation. Since the precise determination of the moment of contract formation is decisive for the emergence of legal consequences and the performance of the parties' obligations, the principles of classical contract law must be reinterpreted in accordance with the realities of the digital environment. This approach serves to preserve the principles of legal certainty and stability within the context of the transformation of contract law [3].

2. MECHANISMS FOR THE FORMATION AND PERFORMANCE OF CONTRACTS IN THE DIGITAL ENVIRONMENT

2.1. Electronic Contracts and Smart Contracts: Concept, Legal Nature, and Criteria of Distinction

Electronic contracts represent a form of modern civil circulation implemented through digital technologies, preserving the fundamental principles of classical contract law while significantly transforming their technical mechanisms of application. According to classical doctrine, a contract is an obligation arising from the mutual and corresponding expression of will of the parties (offer and acceptance), which may be expressed in written or oral form; the conclusion and performance of the contract are accompanied by the parties' active legal conduct, their initiative aimed at fulfilling agreed terms, and an awareness of legal responsibility. Within this

model, the legal validity of a contract is grounded in such classical criteria as freedom of contract, certainty of agreement, and compliance with legal norms. By contrast, in electronic contracts these legal relationships are established through the Internet and other electronic communication means, and the parties' will is expressed through formal technical operations such as clicking, interface-based confirmations, electronic messaging, or the acceptance of terms selected on digital platforms. In this context, the legal nature of electronic contracts depends not only on the existence of a valid expression of will, but also on the reliability of identification and authentication mechanisms, as well as on the assurance of data security as integral techno-legal elements [8].

While classical contract doctrine grounds the legal validity of a contract in the freedom of will and mutual agreement of the parties, in electronic contracts these principles are realized through technological procedures, resulting in a transformation in the form of the expression of will. Although electronic contracts do not differ from traditional contracts in terms of their legal nature, their formation and performance mechanisms are primarily carried out through technical actions—such as click-based consent, interface confirmations, or electronic signatures—which render the manifestation of will more formal and procedural in character. In this context, the criteria for distinguishing electronic from traditional contracts are based on elements such as the execution mechanism, the technical infrastructure employed, and the methods used to confirm the parties' consent. From a practical perspective, for example, a user's act of clicking an "I agree" button on an online platform or confirming a contract through an electronic signature is generally considered sufficient for the conclusion and legal validity of the contract. At the same time, the moment of contract formation and the emergence of legal effects are recorded by technical systems, thereby transforming evidentiary mechanisms and increasing the legal significance of electronic logs, timestamps, and other digital traces. Consequently, these differences do not alter the legal essence of contracts, but necessitate a doctrinal reinterpretation of the manner in which they are formed and performed in the digital environment, while also contributing to the enhancement of legal certainty and predictability [9].

Smart contracts, as a more advanced form of electronic contracts, ensure the automatic generation of legal effects upon the occurrence of pre-programmed conditions, thereby replacing traditional mechanisms of contractual performance with algorithmic processes. From the perspective of classical contract law, this model gives rise to a number of doctrinal challenges, as the expression of will no longer appears solely as a subjective and conscious legal act, but rather as the outcome of programmed code, while the parties' freedom of conduct is constrained by predetermined technical parameters. In this respect, the legal nature of smart contracts is defined by the interaction between normative and technological components: the codification of will, the automation of performance, and the dependence of outcomes on technical infrastructure significantly distinguish these arrangements from the classical model of contractual relations. This situation necessitates a doctrinal reconsideration of the core institutions of contract law—namely, freedom of will, contractual performance, and liability mechanisms—within the digital environment. Consequently, smart contracts emerge as a hybrid legal phenomenon that reflects the ongoing transformation of contract law and calls for the development of new normative approaches to ensure legal certainty, stability, and the effective regulation of digital civil circulation [9].

2.2. *The Form of the Contract, and Issues of Identification and Authentication* ***(Electronic Signatures, Platforms, Algorithms)***

In classical contract law, the form of a contract constitutes one of the fundamental conditions for the establishment of a legal relationship and is ensured through a written document, a physical signature, and compliance with formal requirements prescribed by law; within this framework, the written form plays a decisive role in objectifying the parties' will, ensuring legal certainty, and facilitating evidentiary assessment. The execution of a contract on a physical medium with a handwritten signature functions as a comprehensive mechanism that enables the identification of the parties, guarantees the authenticity of the expression of will, and allows for the reliable proof of legal consequences in the event of a dispute, thereby conferring both substantive and procedural functions upon the notion of form. In the digital environment, however, this concept undergoes a significant transformation, being replaced by the institutions of electronic documents and electronic signatures; consequently, legal effect is no longer dependent on a material carrier but rather on criteria such as the integrity, immutability, and technical traceability of data. Although the use of electronic signatures, particularly advanced electronic signatures, establishes a functional equivalent of the traditional written form requirement, the dependence of identification and authentication processes on certification infrastructures and platform-based mechanisms expands the scope of legal regulation, and in this context, issues of identification and authentication emerge as central elements in the transformation of contract law, with the result that the form of a contract evolves from a purely legal category into a techno-legal mechanism shaped by the interaction between law and technology [17].

In the classical doctrine, the form of a contract serves not only as a fundamental guarantee for the emergence of legal effects but also as objective evidence of the conscious and free expression of the parties' will, a function traditionally realized through written documents and physical signatures; thus, form operates as an integrated legal institution ensuring the validity of the contract, the stability of its content, and the certainty of the parties' identity. In the digital environment, these functions are performed through electronic documents and electronic signatures, which, under contemporary legal approaches, are considered functionally equivalent to the written form; in particular, cryptography-based electronic signature mechanisms enable both the identification of the signatory and the preservation of data integrity, thereby allowing classical legal functions to be effectively replicated in a technological context. At the same time, because identification and authentication processes are no longer governed solely by normative requirements but are increasingly dependent on certification authorities, cryptographic algorithms, and platform-based technical solutions, the legal validity of a contract becomes contingent not merely upon the existence of a document but upon its compliance with technical reliability criteria, and consequently, the concepts of contract form, identification, and authentication are reinterpreted through a synthesis of legal-normative and technological elements in the transition from classical contract law to the digital environment [25].

In classical contract law, identification and authentication are ensured through the physical presence of the parties, the affixing of handwritten signatures, and the submission of written documents, within which the signature functions not merely as a technical attribute but as legal evidence confirming the authenticity of the expression of will and the conscious intention to enter into a contractual relationship. In the digital environment, however, these functions are carried out through more complex technological mechanisms; since the expression of will in electronic contracts is often manifested through actions such as clicking, interface confirmation,

or platform-based operations, additional authentication tools are required to verify that such actions can indeed be attributed to a specific individual. In this regard, electronic signature systems, particularly advanced and qualified electronic signatures, ensure identity verification through cryptographic methods and contribute to the objectification of the intention to enter into a contract, thereby functionally replacing the role performed by handwritten signatures in classical legal doctrine. Consequently, a new functional relationship emerges between contract form and the institutions of identification and authentication in the digital environment, and the legal validity of a contract becomes conditioned not only upon the existence of an expression of will but also upon its reliable technical verification, demonstrating that contract law in the context of digitalization requires new normative approaches and doctrinal adaptation.

2.3. Automated Execution and Liability Issues: The Collision Between Human Intent and Algorithmic Decision-Making

Automated execution mechanisms in the digital environment transform the performance of contractual obligations from a model based on active human conduct into a technical-legal system operated through pre-programmed algorithms. In this context, execution no longer depends on subsequent acts of will of the parties but on the automatic operation of coded conditions, thereby shifting legal regulation structurally from conduct to code. Whereas in classical contract law the performance of obligations is shaped by the party's will, the principle of good faith, and the legal assessment of specific circumstances, in smart contracts this stage is predetermined in technical terms, and once the stipulated conditions are met, legal effects are realized automatically without human intervention. As a result, the execution mechanism evolves from an interpretatively open and flexible model into a rigid functional process governed by algorithmic conditionality. This transformation creates a fundamental tension with the classical legal construction of contractual liability, since traditional doctrine links liability to fault, breach of the principle of freedom of will, or non-performance, whereas under automated execution legal consequences arise not directly from human conduct but from the decisions of a technical system. This, in turn, generates uncertainty as to the attribution of liability and reinforces a shift from the classical notion of fault toward new categories such as functional control and risk allocation. Consequently, automated execution cannot be regarded as either a purely legal or a purely technical process; rather, it constitutes a hybrid mechanism formed at the intersection of human will and algorithmic decision-making, requiring the reconstruction of contractual liability on the basis of new doctrinal models [31].

The implementation of automated execution mechanisms systematically weakens the traditional subjective foundations of the liability regime in contract law and shifts the focus of legal assessment from human conduct to technological processes. In the classical model, liability is grounded in the party's will, fault, and unlawful conduct; however, under algorithmic execution, both the performance of the contract and the emergence of legal effects occur through the automatic application of pre-established technical rules, with subsequent human intent no longer playing a decisive role. This situation limits the functional effectiveness of the traditional "will-fault-breach" triad and necessitates the development of new approaches to determining liability. In particular, within smart contracts, the party's will is expressed only at the initial stage—through acceptance or adoption of the code—while subsequent outcomes are determined by the internal logic of the software. This complicates the attribution of harm or unlawful consequences and raises the issue of allocating liability among the contracting party, the software developer, the platform operator, or the technological risk itself. In such a framework, the concept of liability

moves away from subjective criteria and is reconstituted on the basis of objective factors such as risk allocation, functional control, and the predictability of outcomes. Thus, automated execution does not abolish the classical notion of liability but reshapes it in accordance with the realities of the digital civil circulation [18].

The widespread application of automated execution mechanisms turns the interaction between human will and algorithmic decision-making into one of the central doctrinal challenges of contract law and necessitates its reassessment within a new normative framework. In classical contract law, performance is dynamic in nature and remains open to legal interpretation in light of the parties' conduct and changing circumstances, whereas in smart contracts legal will is primarily expressed at the initial stage—during the coding of contractual terms—and thereafter execution proceeds automatically on the basis of algorithmic determinism. This significantly reduces the role of the human factor in the performance process and narrows the scope for traditional legal mechanisms, including interpretation, adaptation, and intervention. As a consequence, the normative foundations of liability are also transformed, since legal effects arise not from subsequent human conduct but from the operation of a pre-defined technical structure. This leads to a weakening of the subjective character of liability and its reassessment on the basis of objective criteria such as functional control, technological risk allocation, and the capacity to influence algorithmic design. Thus, the classical model of liability based on human will loses its full explanatory adequacy in an algorithmic environment. Ultimately, automated execution can be regarded neither as a purely technical process nor as a legal act in the traditional sense; it operates as a hybrid legal mechanism formed at the intersection of human will and algorithmic decision-making, thereby requiring new normative approaches and doctrinal adaptation in the context of the digitalization of contract law [21].

3. NORMATIVE ADAPTATION OF CONTRACT LAW AND FUTURE DIRECTIONS

3.1. Problems in the Regulation of Digital Contractual Relations in National Civil Legislation

In national civil legislation, the regulation of digital contractual relations primarily emerges as a pressing issue against the backdrop of tensions between the classical legal meaning of contractual form and contemporary technological realities. Under traditional civil law doctrine, the written form is regarded as the principal guarantee of legal validity, evidentiary force, and the objective manifestation of the parties' will, with a physical document and a handwritten signature performing these functions. In the digital environment, however, the notion of written form is functionally reconfigured through electronic documents, electronic communications, and electronic signature regimes. Although statutory equivalence between electronic and paper-based form may be established in certain cases, practical implementation frequently exposes frictions between formalistic legal requirements and technological flexibility. Problems relating to contract form are therefore inseparable from the rules of proof: whereas the classical system relies on a written instrument as the superior means of proof that stabilizes the content of the parties' intent, evidentiary in digital contracts turns on authenticity, immutability, and reliable attribution to a particular subject. The legal effect of an electronic signature, the status of certification authorities, the trustworthiness of time-stamping, and the integrity of data carriers become key criteria for assessing evidentiary weight, thereby extending proof procedures

beyond traditional judicial reasoning into the domain of technical expertise and algorithmic verification. Doctrinally, this transformation of form and evidentiary regimes necessitates a rearticulation of the principles of legal security and predictability: parties must be able to rely on the stability and enforceability of their digital agreements, while regulation must avoid ossifying into a formalism that unduly impedes technological innovation. The central challenge for national civil law is therefore to preserve the protective functions of written form and proof while conceptually recognizing their functional digital equivalents — an approach that secures contractual validity and, at the same time, affords the normative flexibility required by a dynamic digital economy [22].

Legislative and jurisdictional issues governing cross-border contracts concluded on digital platforms can be resolved only through international cooperation and a measure of harmonisation among national legal systems. Contracting parties are typically subject to choice-clauses embedded in online platforms' terms of use, but the validity of such selections is limited from the perspectives of coercion, transparency and consumer protection—particularly where a weaker party (a consumer or small supplier) accepts standard terms without genuine negotiation. Moreover, because servers, operators and data are located in different states with divergent judicial systems and procedural rules, determinations as to which court has jurisdiction and which substantive law applies (choice of forum / choice of law) demand decisions that are not merely theoretical but grounded in enforceability and practical execution. Arbitration may offer a partial solution—its awards benefit from relatively reliable recognition and enforcement under the *Convention on the Recognition and Enforcement of Foreign Arbitral Awards* (United Nations, 1958) [35] - but arbitration is not always suitable given the need for judicial oversight, cross-border enforcement challenges, and the protection of consumer rights. Allocating liability for platforms and third parties (cloud providers, oracles, developers, certification authorities) is even more complex because the execution of smart contracts and algorithmic decisions often operates as a “black box.” Technical standards for judicial expert appraisal of code and behaviour remain underdeveloped: how and on what basis will courts evaluate source code or blockchain logs, who will detect programming defects and by what procedures, and by which criteria will the fairness of an algorithmic outcome be assessed—these questions complicate evidentiary value and expert testimony. At the same time, personal data processing and cybersecurity breaches can directly affect contractual performance: unlawful data transfers, sudden unavailability of servers, or corrupted oracle inputs may frustrate performance and therefore require special rules for allocating liability. Principles of intermediary immunity can further complicate matters by limiting platform accountability and potentially weakening effective remedies for injured parties. Addressing these problems requires coordinated investment in normative, technical and procedural instruments. At the normative level, national legislation should provide clear rules on choice of law and forum selection, a special legal status for smart contracts and mechanisms for treating code as admissible legal evidence, and principles for platform responsibility and third-party risk allocation, while mandatory protective rules should apply to consumer contracts. Technically, robust time-stamping, immutable audit logs, certified oracles and independent third-party audits will strengthen proof and enhance the objectivity of expert analyses. Procedurally, standardised protocols for judicial technical experts, secure mechanisms for confidential in-camera examination of source code, availability of interim relief, and expedited channels for cross-border legal assistance will facilitate practical enforcement. Finally, international coordination (based on UNCITRAL model laws, eIDAS and other

regional instruments) and the development of industry standards will situate national measures in a comparative context; market-based instruments such as insurance schemes and “liability-by-design” conditions may also allocate risks more equitably. Together, these measures can substantially improve the predictability and enforceability of cross-border digital contracts [7].

In the Republic of Azerbaijan, the choice of the substantive law applicable to cross-border contracts concluded via digital platforms and the determination of the court competent to adjudicate related disputes are governed by statute. The principal normative basis is the **Law on Private International Law** [5], which expressly recognises the parties’ autonomy to choose the municipal law applicable to their contract: Article 24 permits the parties to agree that “the rights and obligations arising from the contract, its interpretation, performance, non-performance, termination, consequences of improper performance and invalidity, as well as remedies and assignment of claims related to the contract, shall be regulated by the law of the country chosen by the parties” (Art. 24.1), and further provides that parties may choose the law applicable to the contract as a whole or to specific parts of it (Art. 24.2) and that such choice may be made at any time, including at or after conclusion of the contract, or be subsequently modified by mutual agreement (Art. 24.3). This autonomy extends to contracts concluded on digital platforms and thus permits platform-mediated choice-of-law clauses, but the legal effectiveness of any such choice presupposes the genuine and express manifestation of the user’s will; otherwise the selection may be merely formal. Complementary to this rule, **Article 390 of the Civil Code** [2] affirms the fundamental principle of freedom of contract—providing legal support for party autonomy in selecting the applicable substantive law—while doctrinally distinguishing between genuine contractual autonomy and adhesion contracts (standard form contracts) commonly used in platform settings, a distinction that frequently underpins challenges to the validity of party-made choice-of-law clauses in cross-border electronic contracts. The primacy of **mandatory rules** is addressed in Article 5 of the Law on Private International Law, which provides that, irrespective of the law chosen, the overriding mandatory norms of the Republic of Azerbaijan shall apply (Art. 5.1) and that, where appropriate, the mandatory rules of another State with a close connection to the case may be given effect to the extent possible (Art. 5.2); this rule is particularly important in consumer settings, since a foreign law chosen by a platform that would diminish a consumer’s protection may be disregarded by Azerbaijani courts—an approach analogous to the EU doctrine of “overriding mandatory provisions.” Further protective norms are found in the **Law on Protection of Consumer Rights** [19]: Articles 3 and 8 secure the consumer’s right to full and clear information about contractual terms and render void contractual clauses that unduly restrict consumer rights; in the context of click-wrap platform agreements, lengthy, opaque or non-negotiated clauses must therefore be scrutinised for compliance with these provisions. Finally, the **Law on Arbitration** [1] provides a practical procedural mechanism: in the absence of an agreement governing the law applicable to an arbitration agreement, the arbitral tribunal is free to determine the law governing the arbitration agreement (Art. 25.5), a rule that means tribunals may apply an alternative law where platform choice-of-law clauses are absent or their validity is doubtful. So, these provisions form a normative framework that recognises party autonomy while subjecting cross-border digital contracts to consumer protection, mandatory rule, and public-policy constraints and providing procedural means (including arbitration) for resolving choice-of-law and enforcement issues.

The regulation of digital contractual relations is beset by a range of systemic problems at both the national and international/model-law levels. In the domestic legal order of the Republic of

Azerbaijan a principal difficulty stems from the fact that the Civil Code remains rooted in classical contract law concepts—written form, handwritten signature and a document embodied on a physical medium—and the legal qualification of contracts concluded in the electronic environment is not always specified with sufficient normative precision. Questions such as the legal nature of electronic offer and acceptance, the determination of the moment of contract formation, the time of receipt of electronic notices, and the characterization of manifestations of will produced by automated systems therefore require interpretive clarification and a consistent doctrinal approach. Moreover, procedural assessment of electronic evidence, the reliability of identification and authentication mechanisms, and choice-of-law and jurisdictional conflicts in cross-border digital contracts raise complex private-international law issues. At the international level, the UNCITRAL Model Law on Electronic Commerce (1996) [32] and the UNCITRAL Model Law on Electronic Signatures (2001) [33] promoted the principles of functional equivalence and technological neutrality and recognised the legal force of electronic records and signatures; however, their implementation has taken diverse transpositional forms across States, producing fragmented harmonisation. Divergent national regimes for types of electronic signatures and their legal consequences, varying interpretations of the “written form” requirement, and differences in approaches to the “original” status and evidentiary value of electronic information generate legal uncertainty in transnational contractual relations. The non-mandatory (dispositive) character of these model laws means there is no single binding international standard, and UNCITRAL’s Model Law on Electronic Transferable Records (MLETR) [34] — which seeks to secure legal recognition for electronic transferable documents (e.g. electronic bills of lading, negotiable instruments) — confronts practical divergences in the operationalisation of its “reliable control” concept and in the technical criteria adopted by States, thereby complicating legal recognition in areas such as finance and transport. Similarly, while the EU’s eIDAS Regulation [12] establishes a legal framework for electronic identification and trust services, practical mutual recognition, conformity assessment and the application of technical standards among Member States remain problematic, and the regional scope of eIDAS limits its automatic applicability in other legal systems. In sum, at both the national and international levels the core challenge is the absence of a unified legal approach, terminological clarity and coordinated techno-legal standards sufficient to secure legal certainty and interoperability in digital contracting.

3.2. A Comparative Analysis of International and Regional Legal Approaches

The regulation of digital contractual relations in the sphere of international law is aimed at the formation of common legal standards under conditions where states possess different legal systems and varying levels of technological development. Since contracts concluded via the Internet frequently involve the legal jurisdictions of more than one state, it is essential that their legal validity be recognized in a consistent manner across different legal systems. For this reason, international organizations adopt model and framework instruments that guide states in developing national legislation. Unlike classical international treaties, these instruments do not create directly binding legal obligations; rather, they establish normative frameworks that influence the development of domestic legal systems. For instance, the model law adopted by the United Nations Commission on International Trade Law on electronic commerce [32] promotes the legal recognition of electronic records in commercial transactions, the model law on electronic signatures [33] establishes the principal legal criteria for recognizing the legal validity of electronic signatures, and the model law on electronic transferable records [34] provides a

framework for the legal recognition of transferable electronic documents such as electronic bills of lading and electronic promissory notes. In legal practice, the influence of these instruments has led many states to introduce specific legislative provisions governing the conclusion of electronic contracts, the use of electronic signatures, and the legal validity of electronic documents. The central objective of the international legal approach is to preserve the classical principles of contract law regardless of technological change. These principles include equality of the parties, freedom of will, and freedom of contract. For example, when two companies conclude a contract via the Internet, their legal rights and obligations are regarded as equivalent to those arising from a contract concluded in written paper form. The theoretical foundation of this approach is the doctrine of functional equivalence [15]. According to this doctrine, the law evaluates not the technical form of a tool but the legal function it performs. Thus, if traditional contract law requires a written form, in the digital environment this requirement may be satisfied when information is preserved with integrity and remains accessible for subsequent reference. The same reasoning applies to signatures: if an electronic signature reliably identifies a person and confirms that person's intention to agree to the contract, it may legally perform the same function as a handwritten signature. Practical examples include contracts concluded through electronic signatures in online banking systems or the acceptance of contractual terms by users through electronic confirmation in online commerce platforms. Digitalization also enables states to employ different technological mechanisms, such as certified electronic signatures, biometric authentication methods, or blockchain-based smart contracts. However, this technological diversity may also generate legal uncertainty, as states regulate these mechanisms in different ways, which can create difficulties in cross-border contractual relations. Consequently, the international legal approach seeks to maintain a balance between two objectives: preserving technological neutrality and regulatory flexibility on the one hand, while ensuring a minimum level of legal certainty on the other. The UNCITRAL model laws were developed precisely for this purpose; they do not comprehensively regulate all aspects of digital contracts but rather establish a minimum set of legal standards that states may adopt. As a result, digital contract law at the international level should not be viewed as a fully closed and uniform normative system, but rather as an evolving legal framework that is gradually shaped and supplemented by national legal systems. This approach corresponds to the global nature of the digital economy, where legal regulation is based less on rigid uniformity and more on functional compatibility and shared legal principles [28].

The European Union's legal approach to digital contractual relations is structured around normative specificity, legal harmonization [10], and institutional coordination, reflecting the logic of regional legal integration. The primary objective for the EU is not only the legal recognition of electronic contracts but also the establishment of a unified digital market (Digital Single Market) among its member states. Consequently, while EU legislation does not entirely abandon technological neutrality, unlike the UNCITRAL approach, it provides a more detailed regulatory model with enforcement mechanisms. Central to this regional approach are legal certainty, mutual recognition, and institutional mechanisms that ensure the effective exercise of rights, thereby fostering trust in digital contract transactions. Within this framework, the eIDAS Regulation [12] serves as a fundamental normative pillar for EU digital contract law, explicitly defining the legal validity of electronic identification tools, electronic signatures, electronic seals, and time stamps, and establishing that advanced and qualified electronic signatures produce the same legal effects as written form. A key regional feature is that eIDAS institutionalizes the

principle of mutual recognition: an electronic identification tool deemed valid in one member state must produce legal effects in other member states, minimizing issues related to form, identification, and evidentiary requirements in cross-border electronic contracts and creating a more predictable legal environment for courts. Simultaneously, the EU's new-generation digital regulations—the Digital Services Act [14] and the Digital Markets [13], expand the regulatory scope of contract law in the context of platform economies and algorithmic governance. Although these Acts do not directly establish contract law norms, they provide a normative framework for the role of digital platforms in contractual relations, the transparency of algorithmic decision-making, the allocation of responsibilities, and the protection of user rights. Thus, the EU approach evaluates contractual relations not solely based on the parties' intentions but also in conjunction with platform power, information asymmetries, and algorithmic influence. Nevertheless, the high level of normative detail and strict compliance requirements may create tensions between agile technological innovation and legal regulation, representing the principal doctrinal dilemma of the EU model [27].

3.3. *The Transition of Contract Law towards the "Dynamic Law" Model:*

Risks, Opportunities, and Prospective Legal Assessment

The transition of contract law to the model of "dynamic law" signifies a movement beyond the framework of traditional text-centred legal regulation—comprising legislation, contractual instruments, and judicial decisions—towards the formation of a legal environment that is integrated with technology, adaptive in nature, and capable of being programmed. Within this model, legal consequences are determined not only "ex post", that is, through legal assessment after the relevant event has occurred, but may also be predetermined and implemented through ex ante execution, a feature that is particularly evident in the context of smart contracts. By ex ante execution is meant the prior codification of contractual terms whereby, upon the occurrence of specified conditions, legal consequences are automatically effected; for example, the automatic activation of a penalty mechanism in the event of delayed payment. This approach is grounded in the principle of functional equivalence: where classical legal functions such as the expression of intent, signature, document retention, and performance are reliably ensured through technological means, they should be regarded as legally equivalent to their traditional forms. As a consequence, law manifests itself not merely in textual form but also as a "codified norm", while platform rules, algorithmic systems, and digital protocols acquire normative force. This model gives rise to significant practical advantages: automation reduces transaction costs, accelerates contractual performance, enhances reliability in cross-border transactions, and establishes a stronger evidentiary basis through mechanisms such as audit logs and cryptographic signatures. Nevertheless, this transformation also generates new legal challenges, the resolution of which requires code audits—namely, the independent verification of the legal and technical compliance of software systems—as well as the human-in-the-loop approach, that is, the preservation of human oversight at critical stages of decision-making. At the same time, explainable algorithms and legal-technical certification mechanisms play a fundamental role in ensuring legal certainty and reliability. Accordingly, the dynamic law model constitutes not merely a technological innovation, but a complex hybrid legal system that necessitates the reconstruction of legal institutions, procedural frameworks, and liability mechanisms [29].

The implementation of the dynamic law model gives rise to a wide range of novel legal and practical risks, the conceptual, doctrinal, and operational dimensions of which are closely interconnected; at the core of these risks lies the weakening of the principles of legal certainty

and stability. This is primarily because automated execution mechanisms perform contractual obligations on the basis of pre-programmed rules while minimizing human intervention, meaning that legal consequences are structured around an *ex ante* execution model—namely, the automatic application of obligations in accordance with rules predetermined in advance—which correspondingly restricts the scope for subsequent legal interpretation and judicial construction. Consequently, in situations involving indeterminate contractual terms, force majeure events, or commercial customs and usages, the necessity of applying legal analogy and judicial interpretation creates an inherent tension between rigid algorithmic execution and the classical flexibility of legal doctrine. At the same time, the issue of compensating damages arising from algorithmic errors—such as programming defects or unforeseen system behaviour—and technical malfunctions significantly complicates the choice between competing liability principles, particularly fault-based liability (negligence) and strict liability, thereby generating both doctrinal debate and practical uncertainty and making the prediction of legal risks considerably more difficult. From the perspective of evidence and expert assessment, smart contracts and algorithmic systems frequently operate as a “black box”, in the sense that their internal logic lacks transparency, which complicates the explanation of source code, audit logs (immutable digital records), and algorithmic decisions in judicial proceedings; this, in turn, necessitates the development of new evidentiary standards and procedural frameworks, including rules governing the appointment of technical experts, the protection of source code as a trade secret, and the admissibility of blockchain-based audit logs as judicial evidence. Risks relating to cross-border application and socio-economic fairness are equally significant, since the location of digital infrastructures across multiple jurisdictions complicates issues of choice of law and enforcement, while algorithmic bias—namely, unfair outcomes affecting particular user groups as a result of systematic flaws in training data or system design—information asymmetry, meaning that one party possesses more or better-quality information than the other, and the dominant position of digital platforms, whereby market superiority restricts effective alternative choices, collectively weaken contractual freedom in practical terms and, in particular, undermine the effective protection of consumer rights. In order to mitigate these risks, it is necessary to adopt a комплекс approach involving algorithmic impact assessments, explainable algorithms (explainability), the broader application of platform liability, mandatory consumer protection rules, insurance mechanisms, code audits, and instruments of international legal harmonization, including model laws, mutual recognition regimes, and arbitral mechanisms; absent such measures, the large-scale implementation of dynamic law models may seriously affect the principles of legal justice, economic predictability, and social protection [36].

The implementation of the dynamic law model in contract law is not confined solely to theoretical transformations; rather, it also functions as a complex mechanism serving the more efficient, flexible, and reliable realization of legal relationships in practice. The principal advantage of this model lies in the acceleration of contract formation and performance, the reduction of transaction costs, and the higher degree of predictability of legal consequences. In particular, through smart contracts—namely, contractual mechanisms that ensure the automatic performance of obligations upon the occurrence of predetermined conditions—the execution process is carried out more expeditiously than under traditional judicial and enforcement procedures, while the need for additional legal intervention by the parties is minimized; for example, it becomes possible for payment to be executed automatically upon the fulfilment of a specific condition or for resources to be immediately placed at the disposal of the counterparty.

Within this framework, the recording of transactions conducted in the digital environment in a sequential and immutable form enables the reliable tracing of the history of contractual relations and provides the parties with a strong evidentiary basis, while the precise determination of the time and source of transactions further enhances legal certainty. Electronic signatures and other authentication mechanisms provide the technical foundation of legal validity by safeguarding the authenticity and immutability of documents, thereby strengthening confidence in contractual relations. At the same time, the prior verification of contractual terms and the use of standardized models reduce legal risks for the parties and lower the likelihood of disputes arising, with the result that the resolution of potential disputes also becomes simpler and more expeditious. From an evidentiary perspective, digital records and electronic authentication instruments not only serve as an alternative to traditional written documents but may, in many cases, function as more reliable means of proof. Nevertheless, the effective implementation of this model cannot be limited solely to technological capabilities and requires the preservation of legal oversight; in this respect, the retention of human participation in significant decision-making processes, the explainability of the systems employed, and the prior assessment of their legal impact are of particular importance. Furthermore, the application of specialized expert mechanisms for the proper assessment of technical issues in judicial and arbitral proceedings, the protection of data confidentiality, and the establishment of uniform standards further strengthen the level of legal protection. The harmonization of these mechanisms with international legal approaches, in turn, facilitates the cross-border application of digital contracts and enhances their practical effectiveness. Consequently, the dynamic law model functions as a hybrid system that, while ensuring the integration of technology into law, also requires the reconfiguration of legal institutions, evidentiary mechanisms, and approaches to liability, and the principal objective of this system is to ensure a balance between innovation and legal certainty and justice [4].

CONCLUSION

The findings of the research demonstrate that the digitalization of civil circulation is not merely a technological adaptation of classical civil law institutions, but rather a fundamental transformation of their structural and functional essence. At the present stage, civil circulation operates as a hybrid system formed through the interaction between legal norms and technological architecture (algorithms). Within this process, the transformation of the principle of freedom of contract from a model based on individual negotiations to a platform-based “contract of adhesion” model substantially limits the mechanisms through which the parties’ autonomy of will is exercised. Nevertheless, this change should not be interpreted as a denial of the fundamental principles of civil law, but rather as their conceptual adaptation to the realities of the digital era. The sustainability of civil circulation within the digital environment directly depends on the establishment of a new normative balance between classical legal interpretation and algorithmic enforcement mechanisms. The analysis conducted in the first section of the article demonstrates that the traditional model of civil circulation, grounded in physical space, written documents, and direct declarations of intent, has been transformed under the influence of digital technologies into a complex system operating through electronic communication tools, platform-based relations, and automated mechanisms. Although this transformation does not eliminate the legal significance of such fundamental principles as freedom of contract and autonomy of will, it substantially alters their modes of realization by embedding them within technical procedures and standardized contractual frameworks.

Within the context of this transformation, the subjective elements of contractual liability, particularly the notion of “fault,” partially lose their original regulatory significance; legal liability is increasingly reconstructed on the basis of objective criteria such as the allocation of technological risks, control over algorithmic design, and mechanisms of functional governance rather than the individual conduct of the parties. Automated enforcement mechanisms create a hybrid liability regime situated at the intersection of human intention and algorithmic decision-making, thereby making the modernization of classical civil law doctrine on the basis of new objective criteria inevitable for ensuring legal certainty in digital civil circulation. The analysis conducted in the second section demonstrates that smart contracts advance this process even further by transferring contractual performance into the algorithmic sphere and enabling the automatic generation of legal consequences. This development necessitates the reconsideration of the classical institutions of contract law, including freedom of will, contractual performance, and liability mechanisms.

The final conclusion of the research is that, although the civil and private international law legislation of the Republic of Azerbaijan provides fundamental legal grounds for digital circulation, the deeper integration of UNCITRAL Model Laws and regional standards such as eIDAS into national law has become unavoidable for resolving issues of jurisdiction and evidentiary regulation in cross-border platform contracts. The transformation of contract law into a “dynamic law” model entails the transition of legal control from ex post evaluation toward ex ante algorithmic enforcement, which in turn requires the establishment of new procedural safeguards through “human-in-the-loop” mechanisms and explainable algorithms in order to preserve the principle of fairness. Although the automated performance of obligations through smart contracts creates substantial advantages in terms of efficiency, economic effectiveness, and the strengthening of evidentiary reliability, it simultaneously generates new challenges for fundamental legal principles, including legal certainty, judicial interpretation, and the allocation of liability. Therefore, the effectiveness of the dynamic law model can only be ensured not merely through the implementation of technological innovation, but also through the preservation of legal oversight mechanisms, the retention of human intervention at critical stages, the guarantee of algorithmic transparency, and the institutionalization of code auditing at the normative level.

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CUSTOMER EXPECTATIONS AND CUSTOMER SATISFACTION IN THE REAL ESTATE INDUSTRY: A STUDY ON LOCAL AND FOREIGN BUYERS IN AZERBAIJAN

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ARTICLE INFO	ABSTRACT
<i>Article history:</i> <i>Received:</i>2025-09-29 <i>Received in revised form:</i>2025-10-15 <i>Accepted:</i>2025-11-22 <i>Available online:</i>2026-06-26 <i>Keywords:</i> Customer expectations, customer satisfaction, real estate, foreign buyers, Azerbaijan, perceived services, SERVQUAL. <i>JEL classification</i> M31, L85, R31, D12	<i>Long-term success in the real estate sector depends on customer satisfaction. The relationship between consumer expectations and satisfaction levels is examined in this study, with an emphasis on the difficulties faced by foreign purchasers in Azerbaijan in contrast to local buyers. A survey of 200 participants (100 local and 100 foreign purchasers) and in-depth interviews with 10 individuals were used to gather data using the mixed-methods technique. The findings reveal a significant gap between expectations and perceived services, particularly in communication, transparency, legal support, and agent responsiveness. For foreign buyers, who were primarily dissatisfied due to agent responsiveness and legal complications, this gap was notably larger. The study finds that real estate enterprises must adopt a segmented service model, strengthening multilingual support, legal guidance, and better communication channels to overcome this gap, ultimately improving customer loyalty and competitive advantage.</i>

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1. INTRODUCTION

One of the biggest financial and emotional choices a person will ever make is purchasing a home. In order to maintain a positive reputation and sustain a competitive edge, real estate firms now prioritise client happiness (Johnson, 2020).

However, many reports indicate that clients are frequently dissatisfied because the service they receive falls short of their expectations (da Silva, 2022). This problem is especially serious for foreign buyers, who face new laws, language barriers, and cultural differences without the benefit of local knowledge (Smith & Zhang, 2021).

The real estate market in Azerbaijan has been growing steadily, driven by the country's economic development and diversification strategy. Foreign investors and expatriate residents are increasingly entering this market (Aliyev et al., 2019). However, there remains a notable absence of academic research on service quality and customer satisfaction in this specific context (Ganbarov et al., 2020), particularly studies comparing local and foreign buyers.

This study aims to fill this research gap by investigating the factors that influence customer expectations and satisfaction in Azerbaijan's real estate market, focusing on differences between local and foreign buyers. Our central research question is: What is the relationship between

customer expectations and satisfaction in the Azerbaijani real estate market, and how does it differ for local versus foreign buyers?

2. LITERATURE REVIEW

2.1 The SERVQUAL Model

The SERVQUAL model, a popular tool for evaluating service quality developed by Parasuraman, Zeithaml, and Berry (1988), serves as the theoretical basis for this investigation. According to the approach, the difference between a customer's expectations and how they perceive the service they received determines how satisfied they are. It assesses this gap across five core dimensions: reliability, responsiveness, assurance, empathy, and tangibles (Parasuraman et al., 1988). This framework has been validated across numerous industries (Karim, 2020) and has been specifically applied to the real estate sector to measure expectation-perception gaps in property markets (Singh, 2022).

2.2 Communication and Digital Expectations

Previous research has consistently identified clear and frequent communication as critical for building trust and satisfaction in the real estate sector (Lee & Kim, 2022). Modern buyers increasingly expect a digital experience that encompasses online listings, virtual tours, and rapid response to enquiries (Sao, Singh et al., 2025). The transition to digital channels has reshaped expectations about agent responsiveness and the quality of information provided throughout the transaction process.

2.3 Challenges for Foreign Buyers

Foreign buyers face considerably greater challenges when purchasing property in a new country. Studies confirm that this group requires reliable legal assistance to navigate the risks inherent in cross-border transactions (Smith & Zhang, 2021). Foreign buyers hold high expectations for legal transparency and multilingual communication, yet frequently encounter significant shortfalls in these areas (EMZE Law, 2025). Research in Azerbaijan specifically identifies legal complications and inconsistent construction documentation as major factors that can negatively affect buyer satisfaction (BSU Law Review, 2024). The complexity of property ownership regulations and title verification further heightens the vulnerability of this buyer segment (Hakobyan, 2020).

2.4 CRM and Salesperson Behaviour

Customer Relationship Management (CRM) tools have been shown to improve satisfaction and loyalty when implemented effectively in real estate and service contexts (Sao, Mohite et al., 2022). CRM systems enable firms to track buyer needs, streamline communication, and deliver personalized service—factors that are particularly important in high-involvement purchase decisions (Nilashi et al., 2023). Alongside technology, interpersonal factors also matter significantly. Research confirms that salesperson behaviour, including active listening and ethical conduct, directly influences customer satisfaction in property transactions (Albite & Basig, 2025). Moreover, service quality and pricing transparency together remain among the strongest drivers of satisfaction with real estate agencies (Vrbanec Dedeić et al., 2025).

2.5 The Azerbaijani Real Estate Market

Azerbaijan's real estate market has been undergoing rapid transformation, with significant growth in both the residential and commercial sectors in Baku (Aliyev et al., 2019). The government's economic diversification policies have attracted growing numbers of foreign

investors, particularly from Turkey, Russia, and the Middle East (Ganbarov et al., 2020). However, challenges such as housing affordability, limited availability of standardized legal documentation, and inconsistencies in construction quality continue to affect both local and foreign buyers (Hajiyeu, 2020). The absence of a robust service quality framework for real estate agencies creates a gap that this study seeks to address.

3. METHODOLOGY

3.1 Research Design

In order to gather both quantitative data (survey answers) and qualitative data (semi-structured interviews) concurrently, this study used a convergent parallel mixed-methods design (Creswell & Plano Clark, 2017).

This approach provides a comprehensive understanding of the expectation-satisfaction gap by combining the statistical breadth of survey data with the contextual depth of participant narratives.

3.2 Participants and Sampling

The study included individuals who had purchased or rented property in Azerbaijan within the previous two years. Purposeful sampling was used to construct two groups of equal size:

- Group 1: 100 local Azerbaijani buyers.
- Group 2: 100 foreign buyers.

3.3 Data Collection

Quantitative data were collected via an online survey using a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The survey measured both expectations and satisfaction across five service dimensions: Communication, Transparency, Legal Support, Agent Responsiveness, and Overall Satisfaction. Qualitative data were gathered through semi-structured interviews with 10 participants (a mix of local and foreign buyers) to capture detailed narratives about their property purchase experience.

3.4 Data Analysis

For the quantitative analysis, average expectation and satisfaction scores were computed for each dimension and each group. An independent samples t-test was used to compare scores between local and foreign buyers. The satisfaction gap was operationalized as the difference between satisfaction and expectation scores ($\text{Gap} = \text{Satisfaction Score} - \text{Expectation Score}$), following the SERVQUAL gap methodology (Parasuraman et al., 1988). Qualitative interview transcripts were analyzed using thematic analysis to identify recurring themes.

4. RESULTS

4.1 Quantitative Findings

Table 1 presents the average expectation and satisfaction scores along with the computed gap for each service dimension and each buyer group.

Table 1. Average Scores for Expectations, Satisfaction, and the Gap

Service Dimension	Group	Avg. Expectation	Avg. Satisfaction	Gap
Communication	Local Buyers	9.13	6.69	-2.44
	Foreign Buyers	7.33	4.36	-2.97
Transparency	Local Buyers	8.63	6.87	-1.76
	Foreign Buyers	5.60	3.03	-2.57
Legal Support	Local Buyers	8.61	6.51	-2.10
	Foreign Buyers	6.68	3.80	-2.88
Agent Responsiveness	Local Buyers	8.02	6.11	-1.91
	Foreign Buyers	6.54	3.30	-3.24
Overall Satisfaction	Local Buyers	9.03	6.90	-2.13
	Foreign Buyers	6.48	3.25	-3.23

Expectations were not fulfilled in any area, as evidenced by the statistics showing a negative satisfaction gap for both groups across all dimensions. Crucially, the discrepancy is significantly greater for overseas purchasers across all dimensions, with the biggest disparity noted in Agent Responsiveness (Gap = -3.24) and Overall Satisfaction (Gap = -3.23).

4.2 Qualitative Findings

Semi-structured interviews yielded three principal themes that contextualize the quantitative findings:

Theme 1 – Language and Communication Barriers: The absence of English-language assistance from agents was a major source of annoyance for foreign customers. "My agent sometimes did not answer, and when he did, the information was not clear," said one participant. I felt disoriented. Local purchasers also mentioned communication problems, although these had less to do with language hurdles and more to do with irregular updates.

Theme 2 – Legal Process Confusion: The most often mentioned obstacle for overseas purchasers was legal complexity. "I had to hire my own lawyer because I did not trust the agent to explain the legal details," stated one interviewee. It was a significant concern and an additional expense. Despite acknowledging their lack of legal expertise, local purchasers continued to ask brokers for further advice.

Theme 3 – Trust and Transparency Deficits: Earlier in the process, confidence was damaged by a widespread lack of honesty in price and paperwork, according to many international parties. Local purchasers expressed unhappiness with the clarity of information offered by agencies, while being better familiar with market rules.

5. DISCUSSION

The main research issue of the study is substantially supported by the findings. Azerbaijan's real estate market has a sizable expectation-satisfaction gap, which is consistently greater for foreign purchasers in every parameter analysed. These findings are consistent with the SERVQUAL framework: the largest gaps are observed in dimensions most critical to foreign buyers –

Assurance (proxied by Legal Support) and Empathy (proxied by Communication), which map onto two of the model's five core dimensions (Parasuraman et al., 1988).

The substantial gap in Legal Support for foreign buyers (-2.88) confirms the findings of Smith and Zhang (2021) regarding the risks faced by cross-border buyers and aligns with practical documentation of legal complications in the Azerbaijani property market (EMZE Law, 2025; BSU Law Review, 2024). The inability of local agencies to meet these needs creates distrust that cascades into lower overall satisfaction ratings.

The large communication gap for both groups, and especially for foreign buyers (-2.97), supports the work of Lee and Kim (2022) and Sao, Singh et al. (2025). The problem is not only linguistic; it also reflects mismatched expectations about communication frequency and information quality. The qualitative findings further reinforce this, with foreign buyers describing a sense of disorientation that was absent among local participants.

The findings are also consistent with research on CRM effectiveness: agencies that fail to implement systematic communication and follow-up protocols lose opportunities to close the expectation gap (Sao, Mohite et al., 2022; Nilashi et al., 2023). The study demonstrates that a uniform service model is inadequate for a market serving both local and international buyers. Real estate companies seeking to attract foreign clients must develop segmented service capabilities, including multilingual support, standardized legal guidance, and dedicated agent protocols.

These results contribute to the existing knowledge by applying the SERVQUAL framework to the Azerbaijani real estate context, which has been relatively underexplored in the academic literature (Ganbarov et al., 2020; Aliyev et al., 2019). They confirm that the expectation-satisfaction dynamics documented in other emerging markets are present and intensified in the Azerbaijani context.

6. CONCLUSION

This study offers convincing proof of a sizable expectation-satisfaction gap that affects both domestic and foreign purchasers in Azerbaijan's real estate market. Due to language problems, a lack of acquaintance with local legal procedures, and poor communication from real estate brokers, the difference is even more noticeable for international purchasers. These findings have direct implications for real estate firms, regulators, and policymakers in Azerbaijan, as well as for researchers studying service quality in emerging market contexts.

7. LIMITATIONS

7.1. Sample Size and Composition: The 200 participants in the sample might not be entirely representative of Azerbaijan's overall real estate buyer community. Additionally, selection bias may be introduced by purposeful sampling.

7.2. Limited Qualitative Depth: Because there were only 10 interviews, there might not have been enough theme saturation to adequately explain quantitative results across the range of foreign buyer nations covered.

7.3. Single Stakeholder Perspective: The study captures only the buyer's perspective. Including real estate agents, legal advisors, or agency managers would provide a more balanced view of service delivery challenges.

8. RECOMMENDATIONS

8.1. Specialized Agent Training: Provide specialised training for agents working with foreign customers that emphasises intercultural communication, English language competency, and knowledge of property law as it relates to foreign individuals.

8.2. Standardized Service Protocol for Foreign Clients: Establish a specific onboarding procedure for international purchasers that consists of a multilingual documentation guarantee, a step-by-step legal checklist, and a specialised agent.

8.3. CRM System Investment: Use CRM tools to manage transaction milestones, organise communication processes, and make sure buyers are informed on a regular basis during the purchasing process.

8.4. Strategic Partnerships: Create alliances with international legal firms and relocation service providers to lower transaction-related anxiety and give overseas purchasers with a complete, reliable service package.

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THE ROLE OF ORGANIZATIONAL CULTURE IN ENHANCING THE RELATIONSHIP BETWEEN HUMAN RESOURCE MANAGEMENT PRACTICES AND ORGANIZATIONAL PERFORMANCE: AN EMPIRICAL STUDY ON COMMERCIAL BANKS IN BAGHDAD

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ARTICLE INFO	ABSTRACT
Article history: Received:2025-10-09 Received in revised form:2025-10-14 Accepted:2025-11-20 Available online:2026-06-26 Keywords: Human Resource Management (HRM) Practices, Organizational Culture, Organizational Performance, Commercial Banks, Mediating Variable. JEL classification M12, M14, G21, L25	This research was conducted to understand how an organization's Culture acts as a Mediator between its Human Resource Management (HRM) practices and its overall success (organizational performance). The study used a descriptive-analytical method to compare 100 randomly-selected employees working in different commercial banks, using the Yamane formula to create a 10% level of significance. For this project, a survey instrument with three major sections was utilized: HRM (25 items), Culture (25 items), and Performance (35 items) with sufficient levels of both Validity and Reliability (overall Cronbach's alpha = 0.886). Results showed all HRM practices in Commercial Banks were regarded to be a high (M=3.56, relative importance=71.2%) level of HRM practices. There were higher levels of HRM practices regarding Incentive Systems than all other HRM practice dimensions. Results revealed that Organizational Culture was considered to be moderate (M=3.39, relative importance=67.8%) in nature. The highest rated dimension of Collaborative was followed by Performance Culture. There was a statistically significant positive relationship between HRM practices and organizational performance identified ($r=0.716$). Based on the results of Structural Equation Modeling (Multi-group SEM) all statistically significant indirect effects were proven ($p=0.008$). Recommendations include strengthening Cooperative, Performance, and Innovation cultures; enhancing Performance Appraisal systems; and implementing HRM practices to each type of Commercial Bank.

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1. INTRODUCTION

Today's banking environment is changing rapidly. This is due to rapid technological advancements and increased expectations from customers for innovative product offerings, as well as a growing competitive challenge (both new entrants and incumbent banks) within the industry. In the midst of all these changes, how organizations manage their staff has become an increasingly significant factor that impacts their ability to achieve success in the marketplace.

Human resources represents the driving force for all of an organization's success. Therefore, HR is centrally located in the organization and works regularly with both internal and external stakeholders to develop strategies related to recruiting staff, overseeing employee progression and developing employee skill sets over time (Arokiasami et al., 2024). Numerous studies have shown that the quality of decisions made by HR (including how carefully employees are hired; whether employee training/skills development are focused on; whether pay and incentives motivate employees; and whether clarity exists regarding how to progress) positively influences overall performance outcomes in organizations. More specifically, this success is not empirical; instead, it can be observed through meeting specific performance metrics when employees' capabilities and resources meet the bank's mission (Salman et al., 2024; Phiri & Phiri, 2022).

However, today's banking institutions have difficulty converting individuals' investments into an ongoing advantage. If you pay close attention to what is planned versus what happens on the ground, you will see a disconnect. Culture tends to lag behind the rules. Many organisations have experienced high turnover among employees; basically, people have become unfaithful to the organisation as if they were simply old, worn-out fabric. Initiatives designed to improve the quality of life for employees often become routines that provide no true substance for employees. They represent a check-the-box mentality, and do not cause an appreciation for the people doing the work. While HR has implemented many very exciting initiatives which do drive results, there is an obstacle in the way of those results. Think of this obstacle as wiring that connects at some level, but lies below the surface. Mindsets are created from this wiring; behaviours are developed from the soil of the norms shared by co-workers and the daily behaviours common to the workplace. A company's shared beliefs about how employees complete their work create a relationship between the employee's personal values and the team's objectives by building trust and developing behaviours that promote continued loyalty, as noted by the research of Yang et al. (2024). Without these behaviours established, even the best employee initiatives are at risk of disintegration as if they were built on shifting ground.

The fact that so little has been researched regarding management is especially true for Arab nations, where few in-depth studies have focused on how the culture of the workplace has an effect on the relationship between human resource strategies and the outcomes achieved. This lack of research is most clearly depicted in the banking industry, where quick paced routines, stringent safety procedures, risk related pressures, and challenging interactions between employees and customers impact the daily work experience of employees working in a bank. The central research question for this study is: "How do planned HR strategies improve bank performance by virtue of the company values?" From this overarching question comes other objectives: to review current human resources strategies and their outcomes; to discover the most prevalent organizational culture attributes such as teamwork, creativity, and goal orientation; to identify differences in employee workplace culture by age, gender, and/or job level; and to identify practical steps to enhance overall organizational performance.

The significance of this research lies in its contribution to both theory and practice by revealing the influence of organizational culture on Arab countries' banks. The research employed SEM to evaluate the complex inter-relatedness of the causes and effects of organizational culture within banks, filling a significant gap in Strategic Management literature. In addition to adding to the theoretical understanding of how organizational culture influences the success of banks in the Arab World, the research provides operational utility by providing bank supervisors with a systematic methodology to view how workplace values relate to financial returns attributable to

investment in people management. The research highlights three main themes: the relationship between human resource practices and business performance; the relationship between organizational culture and human resource practices; and the impact of both of the above factors on business performance. While numerous individuals were involved in the research from different levels of employment, the only individuals that participated in the research study were bankers who worked in private banks located in Baghdad, Iraq. The timeframe for the research was also limited to 2025 through 2026; therefore, the data was collected from 2025 to 2026.

1.1 Literature Review

1. Human Resource Practices and How They Affect Organizations

Scholars wishing to study the relationship between workplace management and employee performance have conducted investigations around the world using many different methods to analyse data. An example of researchers examining workplace management using a real-life case study is Phiri and Phiri, who analysed a specific organisation: Zambia's National Assembly. Instead of randomly forming theory-based hypotheses or intuitively reaching conclusions, Phiri and Phiri performed statistical tests to validate their assumptions about best practices within the National Assembly. By examining the results of their statistical analyses, Phiri and Phiri were able to demonstrate that training, tracking of progress and providing recognition and support for employees did not simply provide subjective or anecdotal evidence supporting organisations being 'good' or great,' but rather demonstrated statistically significant correlation with successful employee performance.

In 2024, Salman and his group, considered an example of Sonelgaz of Algeria, studied how different human resource practices affect performance in the workplace. Hiring workers, providing training and education, and creating safe workplaces were many of the direct factors that contributed to achieving results. One of the key performance indicators that stood out was the way people in leadership positions behaved and how their actions impacted the delivery of services to people; this indicated that human resource methods can impact customer service levels. While different factors will influence performance at various organizations or industries, the impact of human resources methods on employee productivity was confirmed in practical settings.

The field of Human Resource Management (HRM) has only recently begun considering other perspectives such as sustainability and technology advancements in the way HR functions. In 2021, Abbas looked at the hospitality industry in Egypt to demonstrate that implementing a green-minded approach to managing people can have a positive influence on three areas - the financial performance of the firm, the well-being of employees, and the environmental footprint of the firm. Afterwards there was an interesting piece of work by Al-Shammari (2022) that focused on an agency in Kuwait responsible for delivering services to youth that showed average scores based on comparisons between HR systems and overall success. In the midst of these average scores, however, there was some very promising data that indicated there is a significant statistical correlation between superior HR systems and improved outcomes. Without this correlation there really is no choice but to keep moving forward as long as progress is important..

2. Culture and leadership in organizations

Reference of performance, the workforce's key areas of performance can also be related to deeper factors like the culture in a workplace environment and the behavior of leaders in an

organization. Juma and Mbarek (2021) studied three different types of organize culture from different factories throughout the Libyan context, provided the following insight regarding performances in reference to these cultures. Juma and Mbarek's study aimed to provide evidence for three primary styles of organizational culture, focused on outcomes, working with others, and experimentation, however it ultimately discovered the link between emotional support and a goal oriented environment - both positively impacted increased productivity, while innovations have some affect overall the correlations of high expectations and high trust have had the most significant impact as per Juma and Mbarek based upon their data. By understanding that behaviours come from within an environment as much as from organizational policy, another example that culture is shaping people's daily behaviours and actions without anyone knowing.

The behaviour of any group is influenced by the leadership more than most people can even imagine. Diab and Mahdy (2022) looked at how acting with integrity contributes to establishing stronger workplace norms within universities. Building positive workplace cultures at Sohag University was not about rules or policies, but rather being a good role model of ethical behaviour by those in leadership positions. When the leaders of a team displayed ethical behaviour, the team members followed their example, resulting in greater stability within their workplace. As trust was established through example as opposed to authority, the level of resistance between departments was reduced naturally rather than through any coercive means. In this manner, a more consistent and predictable workplace was established, where mutual respect prevailed over coercive pressure as the primary influence..

3. Synthesis And Research Gap

Looking closer at past work shows patterns in how research was done plus what ideas keep appearing - this supports the setup used here. Most scholars agree the descriptive-analytical method works well (Abbas, 2021; Al-Shammari, 2022; Diab & Mahdy, 2022). Instead of other tools, nearly every project uses survey questionnaires with Likert-type ratings when studying management styles or workplace actions. On topic trends, findings often link human resource methods - which shape outcomes - to how organizations perform overall (Abbas, 2021; Phiri & Phiri, 2022; Salman et al., 2024).

Still, one clear missing piece stands out after looking through past work. Earlier efforts took place in very different places - from North Africa to the Gulf - and looked at many fields like government offices, hotels, factories, schools. Yet almost none focused on how banks operate inside Iraq. Because of this hole, the present project steps in, filling both a location-based and time-related void by exploring how workplace values shape outcomes in Baghdad's bank system. Through such focus, fresh understanding grows, shaped directly by local norms, money systems, and management styles found here.

2. METHODOLOGY

2.1. Operationalization and Measurement of Variables

Starting with people, not paperwork - this part looks at how jobs are managed inside companies. Not just rules and forms, but real ways workers get support to grow. Backed by ideas from Stall long ago and newer work by Salman's team lately. Their view? Staff aren't cogs; they think, feel, want meaning, seek progress. So the questions asked weren't about hours logged or tasks done. Instead, they focused on whether the workplace notices what humans truly need. When answers

came in, they showed if systems help people thrive. All tied back to bigger aims the group wants to reach.

Using insights from Arokiasamy et al. (2024) alongside work by Agha (2025), HRM was broken down into six clear parts that can be measured. Each participant evaluated their organization through these specific areas of practice. Though framed differently, the core aspects stayed consistent across responses. One after another, people rated how things like hiring or training played out where they worked. These pieces together formed a full picture of human resource management in practice. Instead of vague impressions, actual functions became the focus of judgment. Because structure mattered, each dimension stood apart yet contributed to the whole. From leadership support to performance reviews, every domain had its place

Starting with how people join, this part looked at whether hiring methods worked well or not. It checked if choices felt fair while bringing in strong applicants. Instead of just filling spots, it paid attention to matching skills with what the company actually needed. Getting the right fit mattered more than speed or convenience. Placement wasn't random - it tied personal strengths to real goals.

Starting off, this part looked at how well the company spots where skills are missing. Rather than just listing courses, it checked whether tailored learning options were offered. Instead of one-size-fits-all sessions, customized workshops made a difference. Mentoring played a role too, giving workers guidance over time. Not only that, but preparing future leaders was also weighed in. Progression paths weren't left to chance - they were mapped out. Overall, growth wasn't assumed; it was supported through structure. (Salman et al., 2024).

What gets measured here is how clearly people understand what's expected. Clarity around review processes shows up through their eyes. Feedback that helps grow skills matters a lot. When performance lags, whether help actually arrives makes a difference.

A fair paycheck matters more when it lines up with what others get nearby. Though pay is key, folks also watch how health coverage stacks up against other companies. Time off counts too, especially if rules allow enough rest without penalty. Some notice gaps between policy promises and real-world access.

From Arokiasamy and team in 2024, employee relations looked at how well the company built a fair, welcoming, and secure setting for staff. With attention to real steps taken, it checked whether efforts were already in place to stop mistreatment and bias. Instead of just reacting, the focus landed on actions that help people work together better every day. What mattered most was not promises but actual practices shaping daily interactions across teams.

A clear set of rules shapes how people behave at work. When these guidelines hold steady, they tend to support smooth daily operations. Fairness shows up when everyone faces the same expectations. Consistency matters just as much as transparency in practice. Rules gain purpose when they guide actions without confusion. Their real value appears during routine tasks, not only in crises. How policies are written affects whether staff follow them naturally. A system works better when it feels balanced to those within it.

What lies behind measuring HRM is turning big ideas into something you can count. Through focusing on key roles, the method gives shape to abstract theories. It becomes possible, then, to see whether HRM truly supports employees - meeting their personal growth and emotional needs. At the same time, it checks if staffing aligns with what the company actually requires to move forward.

2.1.2. The Mediating Variable: Organizational Culture

Getting how Organizational Culture works as a middle factor meant shaping it through employee mindset and shared values in banks. Instead of treating culture like fixed rules, the tool used ideas from Herris (2023) and Imran et al. (2022) to see it as something alive, shaped by inner connection. What mattered most? Whether staff truly fit in, took on company beliefs, then matched their own aims with what the bank wanted - this part leaned on Lee (2025) and Arokiasamy et al. (2024).

So, questions about this middle factor looked at key parts of the bank setting - things like surroundings, actions, people involved, how work is set up; each piece shaped what went into the survey

A shared sense of purpose often shapes how deeply someone feels tied to a workplace. When personal values line up with company aims, commitment tends to grow quietly but steadily. Effort becomes natural rather than forced because meaning is already present. Staying with the organization over time then feels less like a choice, more like an outcome. What matters most isn't loyalty stated aloud, but shown through consistent presence.

Starting off different each time, this part looked at how things feel inside the workplace. Because of what shapes culture - according to Herris from 2023 - the review focused on everyday conditions people face. Clear guidelines from management were checked first, followed by whether roles helped rather than hindered workers. Relationships between team members came into view next; these included signs of mutual respect, calm interactions, and fairness across levels. Trust showed up where communication stayed open, while balance in treatment revealed equal footing among coworkers. Leadership behavior mattered just as much when judging honesty, care for personal limits, and making room for new ideas without fear.

What keeps workers sharp? A workplace that prizes results tends to push people toward better output. This part looked at how shared habits shape effort. Instead of just showing up, staff aim higher when expectations are clear. Meeting client demands happens faster when values align with action. Doing things right matters more when it is built into daily routines. Quiet dedication often shows in consistent service quality. Yoon & Suh found patterns linking internal attitudes to real-world performance.

Starting with how people stay, this part looked at workplace habits that shape pride and connection on the job. A setting where fewer call out sick often keeps more staff long term. That steady presence turns quiet dedication into real strength for banks facing fierce competition (Cohen, 2024).

Starting with clear cultural markers, this approach measures how workplace habits shape results. Instead of guessing, it uses specific traits to track patterns across teams. From there, numbers reveal links between staff management and company outcomes. What emerges is a picture of influence - subtle, yet measurable. Through focused lenses, behavior connects to bottom-line effects. Not every factor shows at first glance, still some stand out consistently.

2.1.3. The Dependent Variable: Organizational Performance

What shows up in how well an organization runs comes from more than just money numbers. Instead of relying only on profit or revenue, this study used ideas from Lo and Chung (2024), along with Abu-Mahfouz and others (2023), to shape its approach. A group's success turns out to be less about isolated results, more about shared actions stretching through every team. When people across units move together, that pattern reveals whether the place can handle shifts

around it - tech changes, market pressure, outside forces - and still get strong results. How things add up depends heavily on these combined behaviors working behind visible outcomes.

Noticing how performance checks shift with strategy styles and manager views, the form aimed to show bank results clearly. Questions grouped into four core ideas, pulled from known business studies

Hitting targets became the starting point for measuring success. Backed by findings from Etzioni (2023), it looked at how well the bank met goals already set for strategy and daily work. For these questions, people rated results compared to regular check-ins used across the organization.

Out here, how well a bank handles outside operations really shows up in resource use. Following Cutler and team in 2023, this look wasn't just about grabbing scarce assets but working them smartly once inside. Success meant turning those hard-to-get inputs into steady gains without waste. The real test? Keeping things running smoothly by adding lasting worth through sharper external moves.

Not just about numbers, this angle saw the bank as a living network of people and roles. Instead of focusing only on output, it checked how smoothly goals were met with what was available. Smooth operations mattered more than speed, especially when pressure built up across teams. Effort counted, but so did calm - how work flowed without wearing anyone down too much.

Starting off differently each time keeps things fresh. Banks must balance many moving parts at once, something Quinn and Cameron showed clearly back in 2024 through their framework on conflicting needs. Agility shows up when shifts happen fast - how quickly a bank adjusts tells part of the story. Market reactions reveal more than plans ever could. Stability matters just as much, especially when pressure builds. Working together across levels isn't automatic; it takes effort from everyone involved. Front desks to top offices all play roles in meeting different people's demands. Expectations come from both inside and outside the building. How well those are met shapes long-term standing.

Starting with goal achievement and blending in how resources are used, this method builds on social well-being while folding in the ability to shift with market changes. Outcomes take shape through real-world testing, forming a full picture of performance across banks. Each piece adds depth, making results both solid and clear under shifting conditions.

3.RESULTS AND DISCUSSIONS

A look at real-world data comes first, pulled straight from a close-up investigation inside commercial banks. What follows dives into what those numbers actually mean, shaped by careful thinking that matches strong research habits.

3.1. Descriptive Analysis of Strategic HRM Practices

Looking at the initial research query about how Strategic HRM methods connect with company results, we worked out basic summaries like averages and spread of data. These included typical values alongside how much responses varied. What mattered most stood out through ranking by impact. People's level of consent also shaped the picture. Each piece helped show patterns without assuming cause.

Table 1: Descriptive Statistics for Strategic HRM Practices (n = 100)

Rank	Dimension	Mean	SD	Relative Importance	Agreement Level
1	Incentive Systems	3.80	0.361	76.0%	High
2	Training and Development	3.77	0.391	75.4%	High
3	Strategic Recruitment	3.51	0.412	70.2%	High
4	Career Path Management	3.50	0.479	70.0%	High
5	Employee Participation & Empowerment	3.21	0.540	64.16%	Moderate
Total	Overall HRM Practices	3.56	0.231	71.2%	High

Looking at table 1, strategic HRM practices in commercial banks are widely used - average score hits 3.56. Reward setups come out on top, showing how much weight these institutions place on incentives to drive effort and output. Skill growth through training stands nearly as high, revealing a clear push toward keeping abilities sharp over time. At the bottom, staff involvement in choices lags behind, sitting only at medium levels despite its importance. When workers have little say, their connection to work weakens, possibly dulling the impact of broader human resource efforts meant to lift performance.

3.2. Organizational Culture Analysis

To answer the second research question regarding the role of organizational culture, similar descriptive analyses were conducted.

Table 2: Descriptive Statistics for Organizational Culture Dimensions

Rank	Dimension	Mean	SD	Relative Importance	Agreement Level
1	Collaborative Culture	3.82	0.930	76.4%	High
2	Performance Culture	3.53	0.930	70.4%	High
3	Creative Culture	3.31	0.930	66.2%	Moderate
4	Learning and Development Culture	3.27	0.740	65.4%	Moderate
5	Social Culture	3.03	0.750	60.8%	Moderate
Total	Overall Organizational Culture	3.39	0.360	67.8%	Moderate

Looking at table 2, the average score of 3.39 shows organizational culture across the banks sits around the middle. Teamwork and getting results stand out most clearly, shaping how things get done day to day. Still, fresh ideas, ongoing growth, and community focus tend to lag behind. Because of this, the way these institutions operate feels more fixed than flexible. When change comes fast - like it does in banking - that stiffness could become a problem over time.

3.3. Hypothesis Testing: Demographic Differences

3.3.1. Gender Differences (t-test)

Table 3: Independent Samples t-test Results by Gender

Variable	Gender	n	Mean	SD	t-value	p-value	Decision
Organizational Culture Impact	Male	54	3.45	0.32	1.311	0.042	Significant
	Female	46	2.90	0.22			

Looking at Table 3, statistically significant differences were observed ($p < 0.05$), with male respondents reporting higher perceptions, this may reflect disparities in organizational inclusion, role distribution, or access to decision-making processes.

3.3.2. Educational Qualification

Table 4: Descriptive Statistics

Education	Mean	SD
Bachelor	147.68	24.22
Diploma	147.87	23.06
Master	162.61	19.25
PhD	147.13	23.09

Looking at Table 4, you see averages and how spread out the data points are for each education level. These numbers describe the main features of the variable studied. Grouped by schooling background, the values show patterns across different learners. A closer look reveals typical results alongside variation within each group. Each row reflects a segment's central tendency and dispersion together.

Holding a master's degree? That group scored highest on average - around 162.61 - and their answers didn't swing around much, just 19.25 points apart typically. Unlike them, bachelor's holders, diploma graduates, and those with doctorates landed nearly shoulder to shoulder, all hovering between 147.13 and 147.87. Their spreads weren't tight like the master's bunch, instead stretching roughly 23 to 24 units wide. While one cluster stood out clearly, the rest blurred into each other, almost indistinct. Precision marked the top tier; everyone else looked scattered by comparison.

Table 5: ANOVA Results and Scheffe Test

F	p-value	Decision
4.068	0.019	Significant

Comparison	Mean Difference	p-value	Result
Master vs Bachelor	14.93	0.01	Significant

Table 5 shows what came out after running an ANOVA, then using Scheffe's method to dig deeper. Numbers inside help spot differences between groups without guessing. A first look at the numbers shows clear variation between groups since the p-value sits below 0.05 at 0.019, with an F of 4.068. Since that result does not reveal specific contrasts, further checking happened using Scheffe's method to track down precise group differences. Down at the bottom of the table, there's a clear gap - 14.93 - with a p-value of 0.01 when comparing Master's and Bachelor's degree holders. Put another way, how much education someone has does make a measurable difference, especially noticeable when you look closely at those two groups alone. That contrast shapes most of what the data shows.

3.3.3. Job Title (Hierarchical Analysis)

Table 6: Correlation Analysis

Job Title	Correlation (r)
General Manager	0.82
Deputy GM	0.51
Department Manager	0.29
Division Head	-0.08
Employee	-0.45

Table 6 it shows *r* values, which reflect how tightly linked certain factors are, such as HRM methods and company results, depending on job level. These numbers shift based on where people sit in the organization's structure. Each position tier reveals a slightly different pattern of connection. You can spot trends by comparing them side by side. The link might grow stronger or weaker moving up or down the ladder. What stands out is how each role interprets these relationships uniquely.

Finding one stands out when you look close. Another point becomes clear only after stepping back a bit

At the peak of the hierarchy, views tilt clearly upward. The General Manager sees clear success in how things are run - confidence sits high at 0.82. A step down, that belief softens. For the Deputy General Manager, the link drops to 0.51 - not low, yet less certain. Go one level further, and the picture fades more. Department Managers show only a faint trace of agreement, just 0.29.

Down near the bottom of the org chart, things shift unexpectedly. Not just weaker - flipped. For Division Heads, the link nearly vanishes, sitting at minus 0.08. It drops further among regular employees, hitting minus 0.45. What looks like support from above feels different on the ground. Instead of helping, it starts to get in the way. Practices meant to boost results begin to weigh down daily work. The deeper you go, the more they seem to block rather than assist. Perception shifts sharply where execution actually happens. Those doing the job see less value, more friction. Efforts that aim upward drift apart from what works below.

Here's what stands out. Management thinks the rules are working well - clear win, they say. Yet down in the trenches, workers see no real advantage. Some actually feel worse off because of those same policies. What leaders celebrate, staff often question. The split in perception isn't small - it's wide. One group sees progress. The other sees paperwork piling up. Belief at the top doesn't match experience on the ground. That disconnect shows clearly in the numbers. Not alignment. A rift. Hard to ignore when laid side by side like this. Expectations float high above daily reality. Workers aren't feeling the upside leadership assumes is obvious. Confidence from above meets skepticism below. Proof sits in plain sight across the rows. Little common ground appears. Instead, two different stories emerge from the same data. Trust in policy varies sharply by rank. Higher up means more faith. Closer to work means less. This gap? It speaks volumes without saying a word.

Table 7: Integrated Regression and ANOVA Results

Analysis Type	Variable	Coefficient (B) / F-value	p-value	Decision
Multiple Regression	HRM Practices	0.65	0.001	Significant
	Job Title	-0.41	0.003	Significant
	Interaction (HRM × Job Title)	-0.18	0.009	Significant
ANOVA	Years of Experience	2.964 (F)	0.055	Not Significant

Table 7 shows how company structure and past roles shape the link between strategic human resource methods and how well organizations do. What stands out is that leadership levels matter when applying these practices. Experience shifts outcomes more than expected. The patterns suggest older systems respond differently under new management. Results depend heavily on where decisions are made within the chain. Past involvement in planning affects current success rates too.

Looking at the numbers, HRM methods clearly lift how well organizations perform - the link is solid, with a value of 0.65 and tight statistical support. Yet here's something odd: people lower in rank tend to see those same HR efforts as less effective, shown by a drop tied to job level, sitting at -0.41 with clear significance.

What stands out most is the clear statistical link - negative in direction - between HRM perceptions and job level ($B = -0.18$, $p = 0.009$), pointing to rank shaping views. Because of this, distance grows between leaders and frontline staff. Where executives see HR efforts as fitting well with company aims, workers on the ground often view them as disconnected or unhelpful. That mismatch isn't just about opinion - it reveals deeper cracks in structure and understanding, ones capable of dulling the impact of human resource initiatives across the organization.

Yet the ANOVA findings show experience level doesn't noticeably shift how workers view things ($F = 2.964$, $p = 0.055$). So time spent on the job might not shape opinions about HR methods or outcomes after all. On the flip side, where someone stands in the company structure seems to carry more weight than how long they've been there.

What stands out here is how crucial it is to match HR management approaches at every level of leadership. Not syncing them creates gaps - gaps that weaken outcomes. Clear communication and follow-through matter just as much as the plans themselves. When pieces fit together smoothly, results tend to last longer. Performance gains often come not from big shifts but steady alignment.

4. CONCLUSIONS

A fresh look at how people management shapes bank results shows that what happens inside organizations matters just as much as the strategies they use. Not every method works the same way across different settings. What stands out is how workplace habits quietly shape outcomes behind the scenes. Instead of acting alone, human resource choices often depend on shared beliefs within a team. These patterns emerge clearly when real data replaces assumptions. Culture does not simply reflect strategy - it reshapes it along the way.

Not surprisingly, HRM practices show up clearly across the organization, doing more than just filling roles - they lift overall results. What stands out? Incentive setups plus learning opportunities carry real weight, shaping how work gets done. Performance isn't an afterthought here - it drives choices. Yet when it comes to staff having a say, progress lags behind. Authority stays tight, rarely spreading down through teams.

Above average, yet not strong, the workplace atmosphere leaned more on teamwork and hitting targets than on fresh ideas or growth through knowledge. Because of this balance, financial institutions get things done quickly but often miss building space for bold change or future strength.

Notably, outcomes differ across groups when looking at roles and education levels. Surprisingly, leaders rate HR practices as strong - yet staff farther down the ladder see things differently. That mismatch? It might slow progress when putting plans into action.

Fewer insights emerged from time on the job, showing that standing within the company and how people think matter more than how long they have been there.

One thing becomes clear from the research - how well human resource methods work depends heavily on company values and consistency through different job levels. Not just that, getting

employees more involved makes a difference, especially when combined with a mindset geared toward new ideas. What also matters is closing the gap in how leaders and staff see things. Without these pieces fitting together, long-term success in banks might stay out of reach.

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INTEGRATING MODERN TECHNOLOGIES WITH BPM: WAYS TO ACHIEVE EFFICIENCY AND SUSTAINABILITY

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ARTICLE INFO	ABSTRACT
Article history: Received:2025-08-29 Received in revised form:2025-09-18 Accepted :2025-10-19 Available online:2026-06-26 Keywords: BPM; Technology integration; Process optimization; Risk management. JEL classification M15, L23, O33	<i>This article explores integrating modern technologies with BPM and how it can be a game changer for organizations. Tools such as Power BI and Python are shown to be effective in optimizing processes, minimizing time loss, and aligning workflows with organizational goals. The study analyzes the stages of BPM in detail - process discovery, analysis, redesign, and implementation - and shows how this approach creates effective decision-making, operational agility, and long-term sustainability. Furthermore, it demonstrates how data-driven automation reduces human error and provides real-time visibility into performance bottlenecks. The results highlight the importance of BPM in the modern business environment and the strategic role that technology plays in these processes.</i>

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1. INTRODUCTION

A process is fundamentally understood as a series of interrelated activities to achieve a specific goal. This concept transcends various domains, from everyday tasks to complex scientific and industrial systems. A process follows a structured sequence, progressing from an initial phase toward a desired outcome through deliberate, organized actions. The management and continuous optimization of processes are pivotal in enhancing operational efficiency, ensuring that objectives are reached effectively, within a defined time frame, and often, with minimal resources. [9]

Business Process

A business process is a structured sequence of activities to achieve specific objectives within an organization. These processes involve the efficient use of resources to transform inputs into outputs that deliver value to customers or contribute to organizational goals. Each process is defined by clear boundaries, measurable outcomes, and a systematic workflow that ensures consistency and effectiveness.

The proper management of business processes plays a vital role in enhancing organizational performance. By streamlining activities, minimizing inefficiencies, and focusing on continuous

improvement, organizations can achieve greater productivity, reduce operational costs, and maintain a competitive edge in a dynamic market environment [1], [5].

2. BPM: THE HIDDEN POWER OF MODERN BUSINESS

What is Business Process Management (BPM)?

Business Process Management (BPM) is a systematic approach used to optimize, automate, and improve the efficiency of organizational workflows. Its main goal is to ensure that every step in a process adds value, helping organizations achieve their objectives more effectively. By utilizing various methodologies, tools, and practices, BPM enhances processes, aligns them with organizational goals, and addresses inefficiencies and bottlenecks [2].

In simpler terms, BPM acts as the foundation for modern business operations. For example, by incorporating advanced technologies such as workflow automation and data analytics, BPM helps organizations establish standardized procedures across departments. This not only enables smoother workflows but also ensures efficient resource utilization and improved overall performance.

Why is BPM Crucial in Modern Times?

In today's fast-paced and ever-changing business landscape, BPM plays a vital role in helping organizations stay agile and competitive. For instance, during the COVID-19 pandemic, companies with robust BPM frameworks quickly adapted by restructuring workflows to accommodate remote work and address supply chain disruptions. This adaptability highlights the importance of BPM in ensuring operational resilience during uncertain times [8].

Additionally, BPM integrates modern technologies such as artificial intelligence (AI) and robotic process automation (RPA) into traditional business models. These technologies help organizations identify inefficiencies, optimize workflows, and create opportunities for continuous improvement.

BPM also incorporates performance metrics into workflows, allowing organizations to measure progress and prioritize areas for development or investment [2].

In summary, BPM has become an indispensable tool for businesses, enabling them to adapt to change, embrace innovation, and achieve their strategic goals more effectively.

3. A GENERAL OVERVIEW OF RISK AND RISK MANAGEMENT

Risk - Risk is the result of uncertainties that have the potential to negatively or positively affect an organization's objectives [6]. This concept includes not only negative consequences but also the creation of new opportunities [6], [3].

Identifying and analyzing risks helps organizations anticipate future problems and build defense mechanisms [7]. Once a risk is identified, it is no longer a threat but rather a manageable process. This case ensures that organizations are prepared for potential problems and develop sustainably [7].

Risk Management

Risk management is a systematic approach that aims to minimize the impact of potential threats by identifying them in advance [6]. Through this process, organizations maintain their stability and create new opportunities for development by using resources more effectively [4].

Risk management generally consists of four main stages:

- ❖ **Risk identification:** identifying and recording potential threats [6].
- ❖ **Risk analysis:** assessing the likelihood and consequences of risks [4].
- ❖ **Risk Classification:** making appropriate decisions to reduce, avoid, transfer, or accept risks [7]
- ❖ **Monitoring and control:** continuous monitoring of the effectiveness of adopted strategies and revising them as necessary [6].

Table 1. Risk Management Strategies [11]

RISK MGMT. STRATEGY	DEFINITION	EXAMPLES
Mitigation	To reduce the probability of a risk and/or the impact that an occurrence of the risk may bear. Risk limitation aims at the implementation of controls that dampen the effects of risk occurrences, while not completely alleviating them	• Standardized process routing • Formalized exception handling • Complete kit processing • Collaboration, checks & balances
Avoidance	To eliminate the probability of a specific risk before its occurrence. This strategy is normally realized by trading the risk for other risks that are less threatening or easier to deal with.	• Process redesign
Transfer	To shift risk or the consequences caused by the risk from one party to another. Also called “risk sharing”. Risk transfer may involve the purchase of an insurance policy, or the outsourcing of risky project parts.	• Process Outsourcing • Insurance Policies
Acceptance/ Assumption	To adapt to the risk when it becomes a problem. The enactment of a risk contingency plan is required in this strategy.	• Adaptation to regulatory requirements

Each stage allows the organization to maintain control and proactively approach potential threats in the risk management process [4]. Risk management is not only about solving problems but also helps maintain long-term stability and evaluate potential opportunities [7].

4. RISK AND RISK MANAGEMENT IN BPM PROJECTS

Business Process Management (BPM) involves a lifecycle that spans multiple phases, from analysis to control, each presenting its unique challenges and risks. Managing these risks effectively is crucial to ensure the success of BPM initiatives.

Risks in BPM

BPM, as a methodology to optimize, automate, and manage processes, is inherently exposed to various risks. These risks are as follows:

1. **Human-related Risks:**
 - Skill gaps among employees and resistance to adopting new processes [11].
 - Ineffective communication and collaboration among stakeholders, leading to misunderstandings and delays [11].
2. **Management-related Risks:**
 - Poorly defined process objectives or lack of alignment with organizational goals [11].

- Weak leadership or inadequate engagement of stakeholders [11].
- 3. **Technology-related Risks:**
- Misalignment between chosen technologies and organizational infrastructure [11]
- Dependence on unstable or incompatible systems.

Table 2. Lifecycle-specific Risks in BPM Projects

Lifecycle Phase	Specific Risks
Analysis	❖ Lack of alignment between process goals and organizational strategy [11]. ❖ Overemphasis on technical aspects, neglecting organizational risks [12]. ❖ Failure to account for cross-departmental interdependencies [11].
Design	❖ Inaccurate mapping of analysis results into process models [12]. ❖ Exclusion of stakeholder feedback during design phases [12]. ❖ Inadequate preparation for future contingencies in design [12].
Implementation	❖ Poor integration with existing systems and infrastructure [11]. ❖ Ambiguity in stakeholder role assignments [11]. ❖ Overemphasis on technical elements, leading to gaps in organizational readiness [12].
Execution	❖ Resistance from employees to adopt new workflows [11]. ❖ Lack of clear communication during process changes [11]. ❖ Difficulties in cross-functional collaboration [12].
Monitoring	❖ Lack of a clear monitoring framework [12]. ❖ Mismatched performance metrics with process goals [12]. ❖ Delays in detecting performance deviations [12].
Control	❖ Absence of standardized evaluation policies [12]. ❖ Misinterpretation of control data due to inconsistent formats [11]. ❖ Failure to use audit results for continuous improvement [12]

Managing Risks in the BPM Lifecycle

1. Risk Identification: Identifying potential risks early through structured techniques ensures proactive management [12]. For instance, brainstorming and root-cause analysis can help uncover hidden vulnerabilities.

2. Risk Analysis and Prioritization: Assessing risks based on impact and likelihood allows resource allocation to high-priority risks [11].

3. Risk Mitigation Strategies:

Avoidance: Redesigning processes to eliminate specific risks [11].

Mitigation: Implementing stricter controls and monitoring mechanisms to reduce risk impacts [12].

Transfer: Leveraging outsourcing to delegate certain risks to external vendors [11]

4. Acceptance: Preparing contingency plans for residual risks that cannot be eliminated [12]

5. Monitoring and Adjustment: Continuous monitoring ensures risk management strategies remain effective. Frameworks such as COBIT help align process monitoring with organizational goals [11].

By addressing risks at every phase, organizations can ensure their BPM initiatives remain resilient, adaptable, and goal-oriented.

5. THE STRATEGIC ROLE OF TECHNOLOGY IN OPTIMIZING BUSINESS PROCESSES

Risk management in business processes is a crucial tool for enhancing organizational sustainability and achieving strategic objectives. However, alongside the effective management of risks, the role of technology in these processes is also of critical importance.

Technology provides significant capabilities at every stage of risk identification, analysis, monitoring, mitigation, and resolution. Therefore, the role of technology in business processes should be examined in greater depth.[10]

The Role and Benefits of Technology in Business Processes

Technology plays a fundamental role in optimizing business processes and achieving strategic goals. Modern technologies enhance the speed of business processes, ensure accuracy in operations, and enable more efficient utilization of resources. For instance, artificial intelligence (AI) and robotic process automation (RPA) streamline repetitive tasks, allowing human resources to focus on more strategic objectives [10].

The most prominent aspect highlighting the significance of technology in business processes is its ability to strengthen data-driven decision-making. Through data analytics, organizations can identify weak points in their processes, optimize resource management, and respond promptly to customer demands. Additionally, cloud technologies and digital collaboration platforms facilitate effective communication and coordination among work teams, ensuring the seamless flow of processes.

These technologies not only make business processes more agile and resilient but also play a vital role in risk management and ensuring long-term development. Ultimately, integrating technology into business processes is an indispensable requirement for achieving a competitive advantage. [10]

6. APPLYING TECHNOLOGY IN BPM: EXTENDING THE ANALYSIS

In the previous section, we explored the fundamentals of Business Process Management (BPM) and the strategic advantages its integration with technology can provide to organizations. At this stage, we shift our focus to a practical case study, evaluating the specific outcomes derived from BPM implementation. This study, centered on optimizing market analysis processes, investigates how BPM methodologies were applied, the challenges encountered, and the effectiveness of technology in resolving these issues. This practical approach provides a deeper understanding of BPM's efficiency and the role of technology in enhancing process performance [9].

Core Applications of BPM

During the study, BPM was implemented through the following key phases:

- **Process Discovery:** Mapping the current state ("AS-IS" model) revealed critical inefficiencies, such as coordination gaps in data flow, redundancy in processes, and unnecessary data entry. These issues contributed to resource wastage and decision-making delays. [9]
- **Process Analysis:** The analysis identified major problems, including time loss due to manual data handling tasks, inconsistencies caused by data presented in various formats, and a lack of standardization. These shortcomings amplified inefficiencies in workflows. [9]

- **Process Redesign:** A “TO-BE” model was developed, proposing the automation of repetitive tasks, data standardization, and the integration of data flows into a unified structure.[9]
- **Implementation:** The newly designed processes were successfully integrated into the work environment and optimized with the support of technology. [9]

These phases allowed for the identification and resolution of pre-existing inefficiencies, demonstrating the practical benefits of BPM. [9]

Addressing Key Challenges with Power BI and Python

a. Power BI: Enhancing Data Visualization and Decision-Making

The need for Power BI became evident as traditional methods led to time losses, inadequate data analysis, and unstructured data presentations. Power BI emerged as an indispensable solution to these issues.[9]

The application of Power BI provided the following benefits:

- **Interactive Dashboards:** Data was presented visually and interactively, accelerating decision-making processes for users.[9]

Automated Reporting: Automatically generated reports ensured data was presented more efficiently and accurately. [9]

- **Data Integration:** Integration of diverse data sources into a single platform improved the quality of analysis and transparency of processes. [9]

b. Python: Automating Processes and Ensuring Consistency

Python was crucial for automating repetitive and time-consuming tasks. Manual data collection and processing caused delays and errors, making Python’s application essential for resolving these challenges.[9]

The application of Python achieved the following:

- **Data Collection:** Data from various sources was collected accurately and efficiently.
- **Transformation:** Collected data was standardized and made suitable for analysis.
- **Error Reduction:** Automation minimized human intervention, leading to more reliable and accurate.[9]

7. RESULTS

This study highlights the advantages of combining BPM and technology for organizational improvement. The key outcomes are as follows:

- **Increased Efficiency:** Automated processes accelerated workflows and enabled more efficient resource utilization.[9]
- **Improved Decision-Making:** Structured and accurate visual data presentations facilitated higher quality and faster decision-making.[9]
- **Sustainable Development:** Processes became more flexible and adaptive, laying a strong foundation for continuous optimization in the future.[9]

This research demonstrates how integrating BPM with technology is not only effective for addressing current challenges but also instrumental in achieving long-term strategic goals.

8. CONCLUSION

This study confirms the important role that combining Business Process Management (BPM) with modern technologies plays in the successful operation of organizations. The results obtained show that the implementation of BPM creates conditions for more efficient, agile, and strategic process management.

The article highlights the impact of technologies such as Power BI and Python and demonstrates that these tools effectively automate repetitive tasks, standardize data, and accelerate decision-making. The main conclusion from this study is that BPM is not limited to technical and operational benefits.

It also enables organizations to better manage risks, use resources more efficiently, and maintain long-term competitiveness. Thus, BPM emerges as an important tool not only for solving current problems but also for achieving sustainable development and strategic goals. The widespread adoption of this approach by organizations in the future will play a crucial role in shaping a sustainable and agile work environment.

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THE IMPACT OF ARTIFICIAL INTELLIGENCE ON MANUFACTURING FLEXIBILITY: AN ANALYTICAL STUDY OF THE GENERAL COMPANY FOR AUTOMOTIVE AND EQUIPMENT MANUFACTURING IN IRAQ

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ARTICLE INFO	ABSTRACT
Article history: Received:2025-08-29 Received in revised form:2025-09-18 Accepted :2025-10-19 Available online:2026-06-26 Keywords: Cognitive automation, adaptive manufacturing systems, industrial intelligence integration, cyber-physical production, algorithmic optimization in industry, flexible production architectures. JEL classification L23, O33, M11, L62	This research seeks to highlight the smart technologies available at the General Company for Car and Equipment Manufacturing and to demonstrate the extent of their deployment in the manufacturing sector. To achieve this goal, a virtual model was designed to reflect the impact of artificial intelligence on manufacturing flexibility and its different dimensions, which are machine flexibility, volume flexibility, and handling flexibility. Based on this model, a set of main and sub-hypotheses were formulated to test the nature of the relationship between the study variables. The research adopted the descriptive-analytical approach and used a questionnaire as the main tool for data collection. An electronic questionnaire was distributed to a purposive sample consisting of (23) individuals from experienced leaders and engineers at the General Company for Car and Equipment Manufacturing in Alexandria (the research field). For data analysis, a number of statistical methods were employed, including Cronbach's alpha coefficient to measure reliability, the arithmetic mean, standard deviation, in addition to simple linear regression analysis to test the hypotheses. The research arrived at a set of results, the most prominent of which is the existence of a positive impact of artificial intelligence on manufacturing flexibility in general, with a strong impact appearing in handling flexibility, compared to a weaker impact on both machine flexibility and volume flexibility.

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INTRODUCTION

The importance of technology application is increasing in various fields, and among these fields is the impact of artificial intelligence on manufacturing flexibility. The automotive industry is one of the sectors that greatly benefits from the application of smart technologies to enhance its

efficiency and improve the quality of its products. In this context, our research aims to study the impact of artificial intelligence on manufacturing flexibility in the General Company for Automotive Industry in Iraq, specifically in the city of Alexandria.

This research will focus on three main aspects of manufacturing flexibility: machine flexibility, volume flexibility, and material handling flexibility. We will analyze the variable of flexibility and its related dimensions, and how they are affected by artificial intelligence in terms of efficiency in production processes.

Through this research, we will seek to understand how smart technologies, such as artificial intelligence, can be used to improve manufacturing flexibility and increase the company's ability to adapt to changing challenges in the automotive market. This will help in directing efforts towards improving processes and enhancing competitive advantage. The research includes four chapters: methodology, theoretical framework, practical framework, and conclusions and recommendations.

1. RESEARCH PROBLEM

As technology advances and artificial intelligence becomes widespread in the manufacturing sector, business organizations, especially [specify what kind of companies, e.g., SMEs or automotive manufacturers], have begun to leverage smart technologies to enhance their manufacturing processes and make them more flexible. Nonetheless, the application of artificial intelligence to gain manufacturing flexibility has numerous challenges to such companies as [high costs, skill gaps, data security concerns]. The analyzed firm is not an exception. Thus, the issue needs to be thoroughly researched to learn how artificial intelligence influences the flexibility of manufacturing and what challenges can be expected by the companies when implementing the use of these modern technologies. In order to explore the origins of the issue and solve these problems, the following questions are developed:

(0) Does the company in question implement artificial intelligence systems and applications into the field of work?

- Does artificial intelligence have an effect on manufacturing flexibility?
- Do we have any weaknesses that prevent this technology to be implemented properly?

2. IMPORTANCE OF RESEARCH

The subjects of artificial intelligence and enterprises possessing manufacturing adaptability are regarded as current and engaging themes within the domain of modern management concepts. Whether at the scholarly theoretical plane or practical execution, there is persistent discourse and conversation concerning these dual matters. Moreover, advancements and novelties in the area of artificial intelligence and organizations with production adaptability are constant and ceaseless. Thus, examining these two topics and connecting them is of considerable import from the perspective of researchers. The importance of the investigation encompasses the ensuing facets:

- The analysis assists in illuminating the extant clever technologies within the firm and the degree of their utilization in the realm of production.
- The work aids in broadening comprehension regarding the effect of artificial intelligence upon manufacturing agility.

- The conclusions derived from the research may help foster technical progress and enhance production methods.

Research Objectives

Based on the problem questions raised, the main objectives of the research can be identified as follows:

- Determine the extent to which the company under study relies on artificial intelligence systems and applications in its field of work.
- Identify the extent of the impact of artificial intelligence on the manufacturing flexibility of the company under study.
- Reveal potential weaknesses in the field of its application.

3. HYPOTHETICAL RESEARCH FRAMEWORK

Systematic processing requires designing a hypothetical framework that defines the relationships and influences between the research variables to provide a clear and expressive picture of the research idea that the study is trying to reach. Figure (1) illustrates the hypothetical research framework.

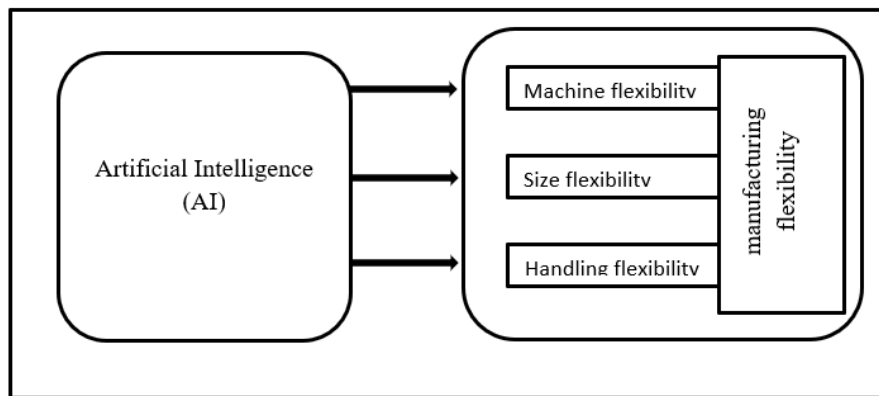


Figure (1) Hypothetical research chart

Research Hypotheses

Based on the research questions, objectives, and its planned hypothesis, the main hypothesis is formulated as follows:

3.1.1. Main Hypothesis: There is a significant meaningful impact of artificial intelligence on manufacturing flexibility. This main hypothesis branches into the following sub-hypotheses:

- Sub-Hypothesis 1: There is a statistically significant impact of artificial intelligence on machine flexibility.
- Sub-Hypothesis 2: There is a statistically significant impact of artificial intelligence on volume flexibility.
- Sub-Hypothesis 3: There is a statistically significant impact of artificial intelligence on handling flexibility.

4. RESEARCH POPULATION AND SAMPLE

The research community included all employees of the General Company for Automotive and Equipment Industry in Iraq, which comprises approximately 175 employees. A purposive sample was selected from this community, representing the management and engineers working in the factory, with a total of 23 individuals, to represent them and survey their opinions on the level of the company's interest in the research variables. The number of retrieved questionnaire forms after distributing them to all members of the community was 23 valid survey forms, which represents 100% of the total research sample.

5. RESEARCH TOOL

The survey was used as a primary tool to collect data about the research problem. It included two dimensions: the first dimension represented personal information (social gender, age, educational qualification, years of service), while the second dimension consisted of questions related to research variables. It included 20 items formulated according to a five-point Likert scale. Table 1 illustrates the variables, the number of items for each variable, and the sources used to construct these items.

Table (1): Questionnaire Construction Scale

Main variables	number of items	source of scale
Artificial Intelligence	10	(Ajam, 2018)
Manufacturing flexibility	10	(Sultan, 2015) (Purwanto et al,2015)
Total	20	

Source: Prepared by the researchers based on the sources mentioned in the table.

6. STATISTICAL METHODS USED

The researchers relied on a set of statistical methods and measures to analyze the data, as follows:

- Cronbach's Alpha Test: To determine the reliability of the questionnaire items.
- Percentage: A mathematical method used to compare two or more quantities of the same type and equals the quotient of the part divided by the whole multiplied by 100%.
- Weighted Mean: To measure the level of responses of the sample and to know the level of the variables in order to conduct analysis and comparison.
- Standard Deviation: To know the level of dispersion in the sample responses.
- Simple Linear Regression analysis: To measure the effect of the independent variable on the dependent variable

7. CONCEPT AND DEFINITIONS OF ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is an area of computer science that seeks to create software and apparatus able to mimic human conduct and intellect. It covers diverse domains such as games, sophisticated apparatus, neural networks, language handling, and robotics. Its inception dates to 1951 when the Ferranti Mark I at the University of Manchester generated the initial AI application for playing chess (Singh, 2019: 566-567).

AI is a fairly recent domain that involves coding computers to play games, comprehend and react to natural language, replicate neural networks similar to those present in people, and

display responsiveness (hearing, sight, motion, and engagement with the setting) comparable to humans (robots) (al-qahtani, 2019: 1). It concentrates on formulating novel programming techniques intended to allow computers to execute responsibilities and reach judgments that progressively approach human capacities (Saleh, 2009: 34).

The initial application of the phrase "artificial intelligence" is credited to John McCarthy in 1956 at a scientific gathering at Dartmouth University. He described AI as the discipline of designing intelligent machines, especially computer applications, in a manner that rivals humans' capability to execute specific functions. ROJAS defined it as the science aiming to develop programs or machines that can ponder and resolve issues more effectively than people (ROJAS, 2015: 2). It has likewise been referenced as an intricate data system with the proficiency to undertake human jobs comparably, such as thinking, reasoning, and acquiring knowledge (Almalki, 2023: 96).

Types of Artificial Intelligence

Scientists have classified artificial intelligence into three categories (Almalki, 2023: 96):

Weak or Narrow Artificial Intelligence: This type of AI is considered the simplest and most widespread. It is limited to performing a single task for which it is programmed and does not go beyond that. It does not attempt to mimic the human mind but focuses on specific, well-defined tasks.

Strong or General Artificial Intelligence: In this type of AI, technologies evolve to a level that makes them equivalent to the human mind and capable of performing diverse tasks. This type allows learning from data, experiences, and expertise, enabling systems to make autonomous and independent decisions similar to humans.

Super Artificial Intelligence: This type of AI is considered one of the most dangerous forms and is still under experimentation. It aims to develop machines that surpass human intelligence and learning capabilities. Such AI could potentially be used in all areas of human intelligence.

7.1. Goals of Artificial Intelligence

According to a study conducted by the Arab British Academy in 2019, it was confirmed that Artificial Intelligence contributes to many aspects, including (Al-Ashwal, 2022: 102):

- Developing software capable of performing human functions: This allows devices to perform tasks that require human thinking, such as logical inference, which enhances device intelligence and makes them more productive.
- Simulating human capabilities: Artificial intelligence seeks to imitate and possibly surpass human capabilities in various areas, such as problem-solving, knowledge acquisition, and decision-making.
- Addressing problems that require extensive expertise: AI systems can be trained and provided with vast amounts of data and expertise, enabling them to deal with complex challenges that are difficult for humans to solve.
- Enhancing human-device interaction: Artificial intelligence plays a vital role in improving communication between humans and machines, whether through dialogue between people or between users and computing platforms. This includes areas such as spoken language analysis, user interface design, and collaborative robotics.
- Increasing the ability of devices to process data in a manner similar to human thought: Artificial intelligence aims to create machines capable of processing information, acquiring understanding, and solving problems in ways that resemble human cognition, including parallel processing and flexible skill acquisition.
- Deep understanding of the mechanisms of the human mind: By studying and understanding the processes occurring in the human mind, AI research can contribute to a deeper appreciation of human intelligence itself.

This can later be used to better develop AI technologies and potentially create devices that surpass human mental capabilities.

Dimensions of Artificial Intelligence

9.3.1. Expert Systems

I've always found it wild how expert systems basically pretend to be a specialist in whatever field you need. They use computer technology that gotten really advanced, to think and analyze stuff at a level close to what a actual human expert can do (Alshare, 2019: 2). Its not just about handing you information the whole point is helping people like me think through problems and make better decisions. Software is what makes all this possible, it carries the expert knowledge and handles tasks that would of been way too complex otherwise. The rules you put into these systems is what drives everything; they take that inputted knowledge and uses it to make decisions that gets you to whatever goal you was trying to reach in the first place (Ajam, 2018: 92).

Neural Networks

Artificial neural networks are computational frameworks motivated by the operation of the human mind. They echo the brain's approach to studying and resolving issues. Made up of linked elements called neurons, these components handle data in a parallel fashion, akin to what happens in the human cerebrum (Cross et al., 1995: 1976).

An artificial neural network comprises several tiers of neurons. The initial tier (input level) takes in the preliminary data and forwards it through various concealed tiers for handling and alteration until it gets to the concluding tier (output level), which furnishes the final outcome. The neural network progresses via exposure to data by modifying the intensity of links amongst neurons. The more information and coaching the network encounters, the better its precision in tackling problems and making judgments.

Because of their capacity to gather knowledge from data, neural networks are employed in a broad array of uses, like scientific exploration, health-related choosing, monetary review, automatic translation, and visual and auditory perception (Sadanand et al., 2023: 300).

9.3.2. Intelligent Agents

In the field of artificial intelligence, the term "intelligent agents" refers to software entities or computer systems that possess the ability to make intelligent decisions and interact with their surrounding environment. An intelligent agent analyzes and processes information, taking appropriate actions based on defined goals and current conditions (Nurhafihz et al., 2021: 1021).

The intelligent agent relies on an internal knowledge base about a specific process to make decisions and execute tasks in a way that achieves the user's objectives (Kot & Leszczyński, 2019: 30). Russell & Norvig (1995: 31) view an intelligent agent as an entity capable of perceiving its environment through sensors and taking appropriate actions to interact with that environment (Baltzan & Phillips, 2008: 46). Baltzan & Phillips (2008: 46) also believe that intelligent agents are software applications that facilitate company tasks, particularly in relation to buying and selling operations. These applications also alert users when important events occur.

8. THE CONCEPT OF MANUFACTURING FLEXIBILITY

Production agility holds a vital position in boosting enterprise effectiveness and results, as well as in adopting lean production methods, as shown by many prior investigations. The common grasp of agility is the capacity of entities to embrace internal and external shifts and the resources accessible to them to manage evolving situations and unexpected or unplanned shifts. This raises the hazard aspect to secure the entity's endurance and rivalry in the marketplace.

Therefore, there exists no solitary unified meaning of production agility among academics and authors because of the distinct character and functions of entities and the shifting era. Nevertheless, some concur that production agility is the extent of readiness and swiftness with which an entity can adjust to alterations in market and surrounding settings (Cox, 1989: 69).

Production agility is characterized as the capability of a production framework to successfully adjust to shifts in the ambient setting by altering item specifics and making methods. Furthermore, it also relates to the power to create a range of goods with varying specifications and layouts according to market and client demands" (Sultan, 2015: 8).

Lastly, it has been recognized as an essential production capacity, holding the force to tangibly impact the competitive and trade standing of the concern" (Tan & Lim, 2019: 309).

Rooted in the foregoing, we can characterize production agility as the power to conform and alter making procedures and supply chains swiftly and effectively to satisfy evolving market requirements and varied obstacles.

8.1. The Importance of Manufacturing Flexibility

Flexibility in manufacturing is a concept that I am often thinking about- more than ever. It essentially means that factories are able to change rapidly when the products that they are producing require change, and all the sums that the environment throws at them or the odd changes in the process. I observed how it could so easily reorganize all your production materials in such a way that they can make all sorts of various products without compromising on quality, and they can make such shifts without busting their budget, or falling behind schedule either.

What bothers me most is that it also causes companies to turn their entire priorities upside down - commercial, competitive, strategic, all that. They are able to stroll into markets in a manner that no one even imagined possible. And then there is the disruption, that every factory has to deal with at some time. It is flexibility that enables companies to sail through them issues without everything coming to a standstill, largely due to the fact that the appropriate machines is being used correctly at the correct time and place (Jain et al., 2013: 5948).

Goals of Manufacturing Flexibility

It actually benefits you, as I understand, to make more flexibilities in manufacturing so that you can end up achieving a bunch of different goals simultaneously (Al-Nimah, 2023: 13).

First thing it makes me have is a much better understanding of what strategic and operational plans is already in place such as, flexibility makes you really dig into their plans and identify where things can be made more flexible. Then there is the entire concept of preempting the occurrence of problems even during the manufacturing, which I believe is immense. When you have an idea of what challenges you are going to face you are in a position to correct them early enough and all just flows better.

I also found it make you dig more into the most important matters and the processes that in fact promotes flexibility, so as to determine how to attain adaptability even more than it already is. And on top of that it makes you get straight into the obstacles directly in your path - what is inhibiting the flexibility, would be something that I think is simply critical in case you want to continue improving and remain agile.

Another thing that I have found very interesting is how it assists in constructing and testing structures to make decisions, as well as the tools that aid that process. These tools are what will assist you in reacting quicker when the things around you continuously keep on changing. Then, as a cap to it all, the entire thing falls into place when you realize what the most significant ones are that can make flexibility easier to develop in manufacturing- as soon as I know what that factors is, it becomes a lot easier to concentrate my effort in the right areas.

Factors Supporting Manufacturing Flexibility

Production agility is something I genuinely believe makes a massive difference — it let companies put out really high quality products that customers actually wants, and they can do it fast and without wasting resources (Singh & Solke, 2018). From what I've read in earlier research, most of the focus been on figuring out what elements leads to achieving that agility, and from what I seen it mostly comes down to two big things.

The first one is strategic integration, which to me just means making sure your production plans is lined up with everything else the business is trying to do. When it all connects together properly I noticed that production activities ends up naturally supporting the bigger goals of the whole company instead of just running on its own.

Then there's organizational structure, and honestly this one feels like the foundation of everything else. Its basically all the components that gives the organization what it need to function properly and lets the people inside it do their jobs well (Mkhaimer et al., 2015: 7). Things like who's leading, how information is managed, and how the whole structure is actually built — all of them plays a role. What I find most interesting is how a clear organizational layout make it easier for people to speak up, work together, and make good decisions, and without them three things I don't think agility is something any company could really achieve.

10.4 Dimensions of Manufacturing Flexibility

Rivalry in the present marketplace necessitates that entities possess the aptitude for ongoing adjustment and novelty. Exchanges concerning agility and invention are vital to commercial discussions, particularly in fields such as the vehicle sector. Firms need to modernize their technologies, either via internal exploration and progress or by utilizing outside expertise. The firm's proficiency to embrace these shifts is pivotal, mirroring its potential to recognize, incorporate, convert, and utilize outside knowledge in its novelty procedures (Sanchez et al., 2019: 2).

Numerous investigators and academics, including Khoobiyan et al. (2017: 1561), Raj & Jain (2013: 126-127), Mayer et al. (1995: 28), Stockton & Bateman (2023: 6), Abdul Karim & Muhammad (2019: 452), and Ngamsirijit (2008: 21), have concurred upon the subsequent aspects of production adaptability:

Volume Flexibility

Production volume adaptability is one of the most vital forms of agility in manufacturing processes, and it has garnered heightened focus since the late 1980s. Numerous theoretical and empirical investigations concentrate on boosting the system's capability to adjust to volume shifts as a measure of their operational effectiveness at various output levels.

Scholars characterize volume adaptability as the capacity to swiftly and affordably transition from small-scale to large-scale output and the reverse (Meredith & Shafer, 2011: 35). Abdul Karim & Muhammad (2019: 452) likewise define it as the power of a production framework to modify output quantity swiftly and capably in reaction to alterations in market needs or manufacturing circumstances.

8.1.1. Machine Flexibility

Equipment adaptability describes the capacity of a machine to execute diverse jobs on the identical apparatus. Typically, dedicated machines are the least adaptable, since they are engineered to carry out just one particular function. Conversely, versatile or broad-scope machines exhibit greater adaptability, possessing the potential to complete numerous distinct procedures.

Machine adaptability facilitates the manufacturing of minor quantities of goods, cutting down inventory expenditures and boosting effective equipment usage, whilst also enhancing the standard of the end item (Talib and Awadi, 2020: 11). It is the aptitude to conduct a selection of functions utilizing the same hardware or apparatus without needing to expend substantial duration and funds on altering configurations or setting up for every fresh operation. Fundamentally, effectiveness depends on streamlining manufacturing processes and lessening downtime so that peak output can be attained with minimal means and expenses (Khoobiyan et al., 2017: 1561).

Material Handling Flexibility

This concept relates to the number of possible paths between processing centers and the variety of materials that can be transported through these paths without significant errors or drastic changes in system performance (Lucas & Kirillova, 2011: 19). Stockton & Bateman (1995: 28) define material handling flexibility as the ability of a material handling system to adapt and handle a diverse range of products efficiently and effectively within the production system. This flexibility can be crucial for companies operating in a rapidly changing industrial environment or producing a variety of products.

Abdul Karim & Muhammad (2019: 452) define material handling flexibility as the ability to move materials efficiently and effectively, both within and outside the production process, by organizing and coordinating specialized processes and technologies designed to ensure a smooth flow and continuous supply chain.

9. MEASURING QUESTIONNAIRE RELIABILITY

Questionnaire reliability refers to the consistency of the questionnaire in yielding the same results if applied multiple times at different time intervals. To ensure this, Cronbach's alpha, the most commonly used measure of reliability, was employed. Cronbach's alpha ranges from 0 to 1, and according to Hair et al. (2014: 90), the minimum acceptable value for reliability is 0.60. Table (2) displays the results of the questionnaire reliability measurement.

Table (2) Measurement of Questionnaire Reliability

Scale	Number of Items	Reliability Coefficient
Artificial Intelligence Scale	10	0.63
Manufacturing Flexibility Scale	10	0.84
Overall Scale	20	0.82

Source: Prepared by the researchers based on the outputs of the SPSS V.26 program.

As observed in Table (2), all coefficients are greater than 0.60, indicating high and statistically significant reliability. Therefore, these scales can be reliably used to survey the opinions of the sample.

10. RESULTS OF DESCRIPTIVE STATISTICAL ANALYSIS OF THE STUDY VARIABLES

10.1. Results of Descriptive Statistical Analysis of the Independent Variable (Artificial Intelligence) and its Dimensions

Table (3) Results of Descriptive Statistical Analysis of the Independent Variable (Artificial Intelligence) and its Dimensions

Dimension		Item	Mean	Standard Deviation	Relative Importance
Expert Systems (ES)	1	Expert systems contribute to knowledge acquisition in specialized areas that support manufacturing decisions.	4.26	0.689	85.2
	2	Expert systems in machines act as a consultant expert for the user in decision-making.	3.61	0.783	72.2
	3	Expert systems contribute to knowledge acquisition in specific areas that can enhance manufacturing flexibility.	3.91	0.515	78.2
Total			3.93	0.414	
Neural Networks (NN)	1	Neural networks assist the organization in analyzing large amounts of information to create characteristics in specific situations in manufacturing processes.	3.78	0.671	75.6
	2	Neural networks function similarly to human nerves and the brain's way of processing information.	3.39	0.839	67.8
	3	Neural networks rely on the learning characteristic as in human cases and the ability to derive meanings from the adopted data.	3.26	0.81	65.2
	4	Neural networks provide the organization with multiple options due to their high ability to analyze information.	3.61	0.941	72.2
Total			3.51	0.508	
Intelligent Agents (IA)	1	Intelligent agents assist in making decisions on behalf of the manufacturing process manager in specific situations.	3.61	0.988	72.2
	2	Intelligent agents reduce the time used by the user to reach the desired goal.	4.13	1.058	82.6
	3	Intelligent agents help the organization make decisions based on their stored knowledge base.	4.00	0.905	80
Total			3.91	0.799	
Overall AI			3.75	0.403	75

Table (3) shows that the mean value of this variable reached (3.75), which is greater than the hypothetical mean (3), confirming that the sample's answers tend towards agreement. The standard deviation value of (0.403) is less than (1), indicating homogeneity in the research sample's answers. The relative importance of this variable was (75%), reflecting the research sample's agreement on the dimensions of artificial intelligence, which are (expert systems, neural networks, intelligent agents). These dimensions recorded mean values of (3.93), (3.51), and (3.91) respectively, with standard deviations of (0.414), (0.508), and (0.799). Figure (2) illustrates the distribution of artificial intelligence dimensions according to their relative importance.

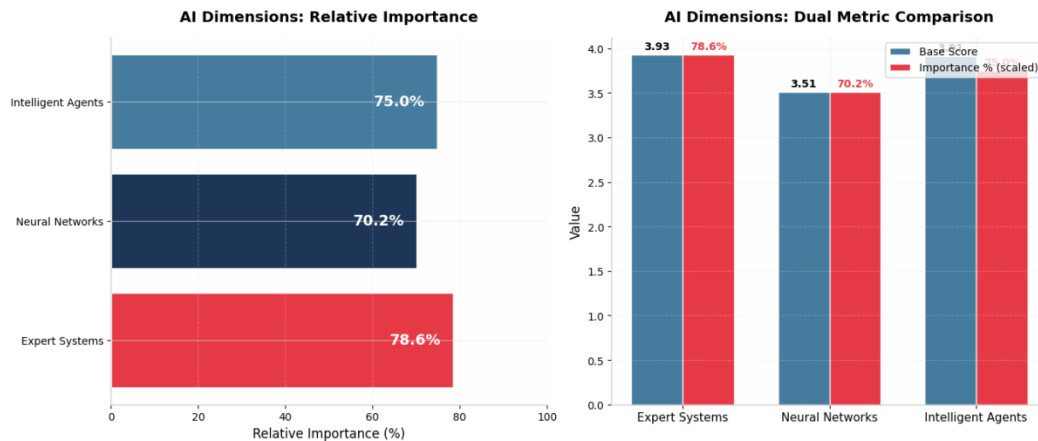


Figure (2) Distribution of the relative importance of artificial intelligence dimensions

Figure (2) illustrates that expert systems emerged with a relative importance of (78.6%), ranking highest among the dimensions constituting artificial intelligence. Conversely, the dimension of neural networks recorded the lowest level of importance at (70.2%).

10.2. Results of the descriptive statistical analysis of the dependent variable (manufacturing flexibility) and its dimensions

Table (4) Results of the descriptive statistical analysis of the dependent variable (manufacturing flexibility) and its dimensions.

Dimension		Item	Mean	Standard Deviation	Relative Importance
Machine Flexibility (MF)	1	The company owns machines that can perform multiple manufacturing processes within the factory.	3.74	0.915	74.8
	2	Machines can transition from one process to another without incurring additional operating costs.	3.61	0.656	72.2
	3	Machines can be set up and prepared for production quickly.	3.7	0.926	74
Total			3.68	0.693	73.6
Machine Flexibility (MF)	1	The company has the capability to offer different sizes of diverse products from time to time.	3.91	0.848	78.2
	2	The company has the ability to increase production volume while maintaining or improving quality levels.	3.74	0.915	74.8
	3	The company has the ability to easily change production volume in the manufacturing process.	3.7	0.926	74
Total			3.78	0.715	75.6

Material Handling Flexibility (HF)	1	The current handling equipment or machinery is compatible with the requirements of the current production system.	3.13	0.869	62.6
	2	The current handling system has high capabilities that enable easy transportation and movement of materials from one place to another.	3.17	0.834	63.4
	3	The handling system can easily connect each machine to another.	3.39	0.941	67.8
	4	The material handling equipment or machinery can be quickly changed or replaced.	3.3	0.822	66
Total			3.25	0.723	65
Overall			3.53	0.557	70.6

From Table (4), it is clear that the mean value of this variable reached (3.53), which is greater than the hypothetical mean (3), confirming that the sample's answers tend towards agreement. The standard deviation value of (0.557) is less than (1), indicating homogeneity in the research sample's answers. The relative importance of this variable was (70.6%), reflecting the research sample's agreement on the dimensions of manufacturing flexibility, which are (machine flexibility, volume flexibility, routing flexibility). These dimensions recorded mean values of (3.68), (3.78), and (3.25) respectively, with standard deviations of (0.693), (0.715), and (0.723). Figure () illustrates the distribution of manufacturing flexibility dimensions according to their relative importance.

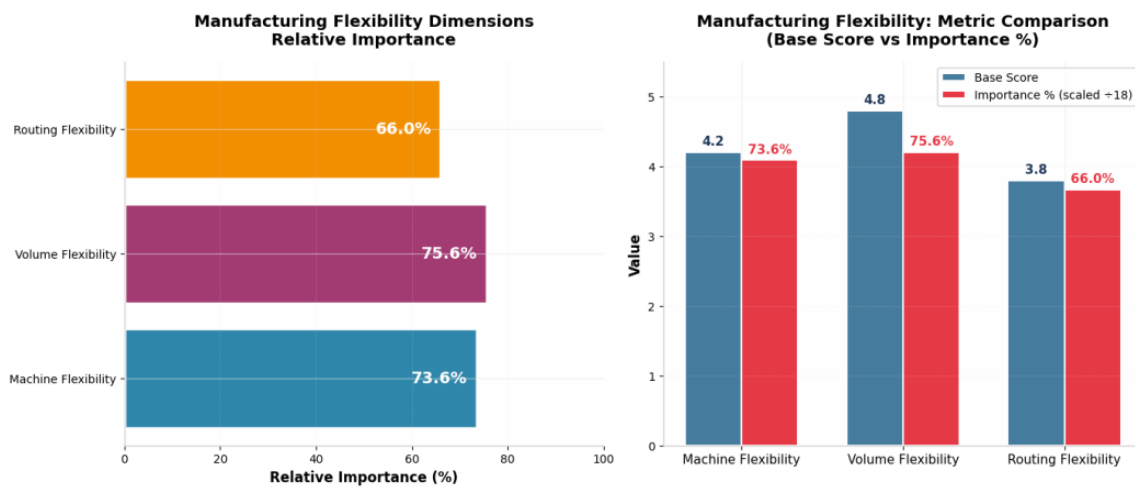


Figure (3) Distribution of the relative importance of manufacturing flexibility dimensions

It is clear from Figure (3) that the volume flexibility dimension came with a relative importance of (75.6%), which is the highest rank among the constituent dimensions of manufacturing flexibility, while the routing flexibility dimension recorded the lowest level of importance (66%).

11. RESULTS OF TESTING THE HYPOTHESES OF INFLUENCE BETWEEN RESEARCH VARIABLES

This section aims to test the main research hypothesis related to examining the influence between the research variables: (artificial intelligence), the independent variable, and (manufac-

turing flexibility), the dependent variable, and the hypotheses branching from it using simple linear regression analysis. The results are as shown in Table (5).

Table (5) Results of the Simple Linear Regression Test for the Main Hypothesis and its Sub-hypotheses

Dependent Variable (Manufacturing Flexibility) Y	Results of the Simple Linear Regression Test						
	Independent Variable (Artificial Intelligence)	Coefficient of Determination R ²	Regression Coefficient (Effect) β	Calculated t-value	Calculated F-value	Significance Level P	Nature of the Relationship
Machine Flexibility	Artificial Intelligence	0.097	0.535	1.503	2.259	0.148	Not Significant
Volume Flexibility	Artificial Intelligence	0.022	0.265	0.694	0.481	0.495	Not Significant
Material Handling Flexibility	Artificial Intelligence	0.302	0.986	3.015	9.091	0.007	Highly Significant
Manufacturing Flexibility	Artificial Intelligence	0.211	0.634	2.367	5.604	0.028	Highly Significant

Source: Prepared by the researchers using (SPSS V.26) software

From Table (5), for the main hypothesis, the value of the coefficient of determination (R²) reached (0.211). This indicates that artificial intelligence contributes to 21.1% of the variance occurring in manufacturing flexibility. The remaining percentage of 78.95% is attributed to other factors do not present in the model. The regression coefficient (β) reached a value of (0.535). This value suggests that any improvement in artificial intelligence systems within the researched factory by one unit leads to a 53.5% improvement in manufacturing flexibility. The calculated t-value reached (2.367), which is greater than its tabular counterpart at a significance level of (0.02). Meanwhile, the calculated F-value reached (5.604), which is greater than its tabular counterpart at a significance level of (0.02) and less than the significance level of 0.05. This confirms that focusing on artificial intelligence systems leads to increased manufacturing flexibility, meaning the main hypothesis is accepted: (There is a statistically significant effect of artificial intelligence on manufacturing flexibility).

As for the sub-hypotheses of the main hypothesis, the results of the simple linear regression test showed the following:

Regarding the initial sub-hypothesis, it is apparent that the regression model possesses a very weak merit, as the coefficient of determination (R²) reached (0.097). This suggests that artificial intelligence only accounts for 9.7% of the variation in the (machine flexibility) metric. The residual 90.3% is ascribed to other elements not present in the evaluation framework. The regression factor (B) achieved a magnitude of (0.535); nevertheless, it is not at an adequate point of importance to assert that this element exerts a notable influence on machine flexibility. The computed T-value attained (1.503) with a significance threshold of (0.150), which exceeds the significance benchmark of 0.05. Concurrently, the computed F-value reached (2.259), which is smaller than its tabulated equivalent at a significance level of (0.148) and greater than the significance benchmark of 0.05. Consequently, it is not statistically important. This signifies a lack of association between artificial intelligence and machine flexibility, thus dismissing the supposition.

Pertaining to the second sub-hypothesis, it is clear that the regression model has a very weak standing, as the coefficient of determination (R²) arrived at (0.022). This implies that artificial intelligence solely clarifies 2.2% of the dispersion in the (volume flexibility) measure. The leftover 97.8% is credited to other constituents absent from the tested structure. The regression factor (B) attained a figure of (0.265); yet, it is not at a 3- adequate degree of consequence to state that this

component has a significant bearing on the dependent measure. The calculated T-value reached (0.694) with a significance level of (0.495), which surpasses the significance benchmark of 0.05. Simultaneously, the computed F-value reached (0.481), which is lower than its tabular counterpart at a significance level of (0.495) and exceeds the significance benchmark of 0.05. Therefore, it is not statistically relevant. This indicates no impact between artificial intelligence and volume flexibility, thereby refuting the assumption.

The measure of the coefficient of determination (R^2) reached (0.303), showing that artificial intelligence explains 30.3% of the variance occurring in routing flexibility. The remaining 69.7% is credited to unfamiliar elements not present in the structure. The regression coefficient (β) reached a value of (0.986), implying that every enhancement in artificial intelligence by a single unit causes a 98.6 enrichment in routing flexibility. The calculated t-value reached (3.015), which surpasses its tabular equivalent at a significance level of (0.007). Meanwhile, the calculated F-value reached (9.091), which is greater than its tabular counterpart at a significance level of (0.007) and less than the significance benchmark of 0.05. This validates that a focus on artificial intelligence systems results in a favorable improvement in routing flexibility, meaning the first sub-hypothesis is sustained: (There is a statistically significant effect between artificial intelligence and routing flexibility).

CONCLUSIONS

The study shows that the company does not ignore the implementation of AI systems in its factory, showing a definite desire to embrace technological changes. Nonetheless, this focus is not spread equally on all AI dimensions. A majority of resources and attention are on the expert systems and relatively less attention is given to neural networks. This selective investment implies that the company puts more emphasis on some AI technologies depending on the perceived contribution to improving manufacturing flexibility.

In general, the factory is doing a good job manufacturing flexibly, but there are dimensions that are more robust than others. Flexibility of machines and volumes seems to dominate, which is a sign of a planned management initiative to expand the capability of operations and responsiveness to production needs especially in terms of efficiency in equipment and production throughput.

The findings also suggest that AI has a positive effect on the flexibility of manufacturing, but this effect has a different magnitude depending on dimensions. The impact of AI on routing flexibility is the greatest, and machine and volume flexibility respond to it more humbly. This gap indicates that the full AI technologies potential is not achieved in various areas of operation.

Lastly, the factory shows a high emphasis on viable AI solutions, such as big data analytics, machine learning, and robotics, as result-oriented solutions to streamline production performance. However, it might be required to move further than the existing technologies and use some more advanced AI applications in case the company wants to become even more flexible in the future.

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GREEN LEADERSHIP, DIGITAL TECHNOLOGY INTEGRATION, AND GUEST OUTCOMES IN BAGHDAD'S HOSPITALITY SECTOR: TOWARD A SUSTAINABILITY-AUTHENTICITY-TECHNOLOGY (SAT) FRAMEWORK

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ARTICLE INFO	ABSTRACT
Article history: Received: 2025-11-20 Received in revised form:2025-12-05 Accepted:2025-12-30 Available online:2026-06-26 Keywords: green leadership; digital sustainability integration; guest satisfaction; hotel loyalty JEL classification L83, Q56, M14, O33	<i>Environmental accountability has emerged as a crucial strategic issue in Baghdad's hotel industry, which is currently experiencing rapid reconstruction and economic recovery after periods of conflict. However, the ability to translate green leadership to genuine results for guests has not been fully explored so far considering the importance of digital technology in the Iraqi hospitality sector. We aim to understand how green leadership and digital sustainability are interwoven and how these two are related to guest satisfaction and loyalty intentions in classified hotels in Baghdad. We will also explore whether the perception of sustainability authenticity (SPS) and digital-human alignment serve as intervening mechanisms within these relationships. Researchers used survey data from 250 hotel guests in Baghdad who were at five, four, and three-star sustainability-compliant and green properties in four cultural groups. They used different statistical methods and found a strong correlation between green leadership visibility and guest satisfaction ($\rho = 0.64$, $p < 0.001$). Sustainability authenticity perception mediates the relationship between leadership and loyalty (indirect $B = 0.24$), and digital-human alignment (indirect $B = 0.17$) are important factors that influenced these findings. The highest satisfaction is associated with sustainability perception and integration intensity ($SI = 4.71$). In the context of the Sustainability-Authenticity-Technology (SAT) framework, green leadership is an authenticity signal and is the message of digital-human communication. Baghdad hotels need to ensure coherent integration, which is not only a good fit for the new tourism market but also incorporates different technologies into the environmental narrative.</i>

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1. INTRODUCTION

Baghdad's hospitality sector has a unique place in the contemporary Middle Eastern tourism sphere. As the city of Iraq's capital is in the midst of post-conflict reconstruction and economic growth, the city's classified hotels are being required to serve a wide range of tourists (business travelers, diplomatic delegations, cultural tourists, and reconstruction workers), and it is also becoming increasingly necessary for the organization to take environmental responsibility into account (Hawela et al., 2025; Alshimmari & Shneikat, 2025). Whereas environmental responsibility was once largely absent from the discourse about service quality in the hotel

industry in Iraq, it is gradually being incorporated into the consideration of international and regional customers as well as into the way in which they want to choose, decide on, and return to a hotel. On the other hand, a measured but growing number of artificial intelligence apps, Internet of Things infrastructure, and AI-driven concierge platforms have been installed in Baghdad's hotel properties, and their interactions are changing the way services are presented to them (Spektor et al., 2023; Roy & Pagaldiviti, 2023).

A relation between green leadership and digital technology in enhancing guest satisfaction and loyalty in the Arab and Iraqi hospitality context is still not clear. Previous studies have demonstrated that a transformational leadership strategy aimed at sustainability has a positive impact on employee behavior (Muftiyanto & Jatmika, 2025; Chan et al., 2024) and that organizational citizenship behavior related to environmental concerns leads to good guest experiences (Cordeiro et al., 2024; Salama, 2024). Furthermore, in hospitality digitization research, the prevalence of digital technologies is linked to better service perception, but the degree to which digital technology is used is to be determined by the context and preparedness of the staff (Giannitsas et al., 2026; Pastor, 2025). Nevertheless, theoretical models of these two research streams, especially related to the institutional culture and operational dynamics of Baghdad's hotel sector, have yet to be developed.

This study fills in the gap by presenting the SAT framework which is based on social exchange theory, social identity theory and planned behavior. In this framework, sustainability authenticity (SPS) is the key pathway through which green leadership is perceived for guest loyalty. Digital-human alignment is a secondary transmission channel for the impact of technology investment on customer satisfaction. Cultural origin clusters and digital exposure are also considered as boundary conditions for the strength of the relationships among Baghdad's diverse guest population. Based on survey data from 250 hotel guests in three property classes in Baghdad, the study aims at five related objectives: (1) to quantify the relationship of green leadership visibility to guest satisfaction; (2) to investigate whether SPS mediates the leadership-loyalty relationship; (3) to examine digital-human alignment as a mediator between integration intensity and satisfaction; (4) to assess cultural origin cluster as a moderator of the leadership-SPS relationship; and (5) to assess digital exposure level as a moderator of the integration-loyalty relationship. The paper is organized as follows: Section 2 sets the literature review and five testable hypotheses; Section 3 introduces the SAT Framework; Section 4 explains the methodology; Section 5 summarizes the empirical results; Section 6 offers theoretical and practical suggestions; and Section 7 concludes.

2. LITERATURE REVIEW AND HYPOTHESES

2.1 Green Leadership in the Hospitality Context

Green leadership is differentiated from its transformational predecessor in that it is a very clear and practical goal of ecological stewardship as a terminal value and a real goal (Alshimmari & Shneikat, 2025). While transformational leaders generally define a vision of organizational excellence, green transformational leaders place strong motivation, idealized influence and intellectual stimulation on environmental outcomes to form an organization's identity rather than as an optional duty to them (Hassan Abdou, 2025). This distinction is empirical; guests perceive and reward these leadership orientations differently and find green transformational leadership environments more satisfying than non-green ones, as shown in Table 4 of the present study.

The central factor influencing guests is behavioral role modeling. When hotel managers in Baghdad are demonstrated to engage in sustainability and to share in sustainability activities (say, by communicating eco-friendly activities during check-in, doing community-oriented environmental events or publicly recognizing workers who come up with resource-saving ideas) they convey authentic attributes to the guests (Aboramadan et al., 2022). Staff who observe that behavior will adopt it as a way of being and be able to reproduce it in their interactions with guests as genuine and not just a matter of appearance (Abedelrahim et al., 2024). And in the case of green leadership, staff autonomy is important, in that they can adapt sustainability offers for their guests as they see fit, thus turning the same policies to fit their own lifestyle (Hasanein & Elrayah, 2025). This is especially important in Baghdad, where the quality of customer service remains very much at the center of guest experience.

Comparative analysis across leadership styles consistently confirms the superiority of explicitly green transformational approaches in shaping hospitality guest outcomes (Nazarian et al., 2026). The results in Section 5 demonstrate that green transformational leadership is associated with the highest mean satisfaction score and the strongest recommendation rate among all leadership styles examined, supporting the following hypothesis:

Hypothesis 1 (H1): Green leadership visibility is positively associated with guest satisfaction index scores in Baghdad's classified hotels.

2.2 Digital Technology Integration and Sustainable Practice

Today's hotel digitization involves different levels of operations: physical assistance robotics, AI-driven interaction, and algorithmic management (Spektor et al., 2023; Roy & Pagaldiviti, 2023). Table 3 shows the adoption for all the different types of properties in Baghdad, and shows that five-star international hotels have considerably higher digital penetration—AI chatbot adoption rates reach 78% and voice recognition control 80% in comparison to three-star ones—this is indicative of the investment gap in Baghdad's hotel industry, where international properties are embedded with digital infrastructure more than independent mid-tier hotels.

Digital tools and sustainability practices are in a unique strategic challenge in the Iraqi context. Technologies that are operationally able to save resources only yield environmental benefits when they are communicated, contextually framed and linked to guest experience (Low et al., 2025; Sun et al., 2025). A climate control system that quietly controls room temperature does not make any impact on resource use; the same system is accompanied by real-time dashboard notifications that convert abstract efficiency into a human-driven sustainability experience. This distinction, we will call it digital-human connection, is crucial to understand why technology would help to spread green leadership narratives in Baghdad's hotels through the lens of technology. Table 5 shows that properties that have high digital sustainability integration perform better than their lower-integration peers in SI and SPS metrics.

Hypothesis 2 (H2): Digital-human alignment mediates the relationship between digital sustainability integration intensity and guest satisfaction in Baghdad's classified hotels.

2.3 Sustainability Authenticity as a Central Mechanism

As guests respond to a hotel's sustainability claims, they do so with implicit verification— they look at if what they observe is in line with the hotel's promises, whether it is a good example of leadership action in line with policy documents and whether the behavior of staff is rooted in genuine environmental values rather than regulatory compliance or superficial reputational management (Yilmaz, 2025; Yikilmaz et al., 2025). When they conclude positive, guests associate

better service with the hotel and feel more emotional attachment to it. This process is more relevant in Baghdad's hospitality system where Arab Gulf States guests are aware of high-quality sustainability practices in other countries and therefore have a more developed evaluation process based on a higher level of knowledge of these. The mediation results in section 5 show that SPS is indicative of 52% of the total impact of green leadership visibility on likelihood-to-revisit as in hospitality literature (Chedrawi et al., 2025; Guerra-Lombardi et al., 2025).

Hypothesis 3 (H3): Sustainability authenticity perception (SPS) mediates the relationship between green leadership visibility and guest loyalty intention in Baghdad's hotel market.

2.4 Cultural and Technological Moderators

The theory of planned behaviour and value-belief-norm theories both suggest that cultural conditioning is involved in individuals' response to environmental messages and how they interpret them (Guerra-Lombardi et al., 2025). In the diverse population of guests in Baghdad with a strong emphasis on individualist and collectivist cultures, Western/European guests are more sensitive to direct, leader-like messages, whereas Iraqi Arab Nationals and Arab Gulf States visitors are more sensitive to group-level environmental behaviour and ecological narratives (Giannitsas et al., 2026; Doctorarastoo et al., 2026). Digital exposure adds to a second boundary condition through a familiarity-driven route: the many technological activities we have to cope with in our daily life and the knowledge of how the environment can be a source of satisfaction are more likely to make us more satisfied in a cohesive integration ecosystem (Pastor, 2025).

Hypothesis 4 (H4): The cultural origin cluster moderates the relationship between green leadership visibility and sustainability authenticity perception, with stronger positive associations observed among guests from individualist (Western/European) backgrounds relative to collectivist-oriented Arab guest segments.

Hypothesis 5 (H5): Digital exposure level moderates the relationship between integration intensity and guest loyalty intentions, with stronger effects observed among high-exposure guests.

3. THEORETICAL FRAMEWORK: THE SAT FRAMEWORK

3.1 Conceptual Architecture and Three Core Propositions

SAT is a holistic view of the Sustainability-Authenticity-Technology (SAT) model in the middle of the scale for social exchange theory, social identity theory and planned behavior to understand how green leadership and digital technology impact guest performance in hospitality settings. In Baghdad, such a model is particularly relevant as it integrates the international sustainability certification pressure and cultural expectations of a predominantly Arab guest base and the connection between authenticity, technology and leadership is very important. Proposition 1 (Leadership-Authenticity Pathway): Green leadership visibility is what the guests perceive as authentic: This is reinforced by a behavioral modeling process that involves managerial ecological behavior in front of the front line and how it is reflected in their actions to ensure they are pro-environmental action and thus create the visible quality signals that can be perceived by guests as an authentic commitment to the organization. The path to the digital sustainability integration is influenced by cultural factors in Baghdad: Western/European guests are more sensitive to leader-specific individualist signals and Iraqi Arabs and Gulf States visitors need to be given more group-normative feedback to update their SPS estimates.

Proposition 2 (Technology-Alignment Pathway): The digital sustainability integration intensity leads guests to a higher level of satisfaction but that in turn is largely mediated by the coherence that is perceived between automated system outputs and employee accounts of the internal environment; digital-human alignment. When Baghdad's hotels are infused with sustainability information that staff can translate into culturally relevant information like Islamic environmental stewardship principles for Arab guests or quantitative efficiency metrics for Western business travelers, the effect is much larger than either channel alone. This pathway is moderated by digital exposure level.

Proposition 3 - Reciprocal Amplification Effect: The two pathways are multiplicative but not additive in the case of congruence. Both SPS and integration intensity are at a higher level, and the satisfaction and loyalty outcomes are higher than what either pathway predicts independently, a result that is well tested statistically ($\Delta R^2 = .064$, $p < .001$). This logic is at odds with the management approach to green leadership and digital transformation as parallel but independent strategic paths, which is also the case for Baghdad hotel operators who tend to compartmentalize these two areas of investment.

3.2 Positioning Within Existing Theory

The SAT Framework builds existing hospitality organizational behavior models in three principal ways. The first is to bring authenticity perception (best researched in consumer behavior and tourism identity research) to the green leadership literature, which has previously considered employee-level processes like the behavior of employees for citizenship, engagement, and environmental engagement (Alshimmari & Shneikat, 2025; Hassan Abdou, 2025). Second, it considers digital-human alignment as an active mediating construct, rather than as a productivity-based metric (Spektor et al., 2023; Low et al., 2025). Third, it considers cultural origin and digital exposure as boundary conditions, which recognizes that Baghdad's hotel guests are mixed in their response to the same sustainability message from different cultures (Nazarian et al., 2026; Giannitsas et al., 2026).

4. METHODOLOGY

4.1 Research Design

This study has used a cross-sectional descriptive survey approach that is based on post-positivist epistemology. This design captures naturalistic perceptions from hotel stay exposure instead of manipulated situations to create the highest ecological validity (Zhang & Wang, 2026). In order to do this, we combined on-site questionnaire administration during hotel lobby and guest floor use in Baghdad and after checkout digital form distribution through QR code-linked instrumentation to capture participants' participation and reduce single-method bias. For primary inference, we used Spearman's rho and chi-square non-parametric statistics as the objective to investigate the distribution of loyalty intention distributions as they are more than one digit in number and as we found non-normality for loyalty intention distribution to be a common feature of the sampling distribution. This approach to data collection was organized at the guest relations and front office levels of the properties, and the collection of data has been done to ensure that the instrument was delivered in a low-congestion time to the guests for the best quality of response.

4.2 Sampling Strategy and Justification

The target audience was hotel guests who visited at least two consecutive nights in Baghdad to find sustainable properties with real sustainability commitments, with digital technology deployment levels. Two types of sampling criteria were used: (1) property selection with a leadership level of involvement in sustainability programming and technology systems (from minimal IoT to complete AI integration) and (2) respondent inclusion with at least 18 years of age, at least two nights in Baghdad, and at least one meeting with staff-led sustainability programs or digital services.

The $n = 250$ sample size was calculated with power analysis, which indicated that detecting small to moderate effect sizes ($f^2 = 0.02$) with $\alpha = .05$ and power ≥ 0.80 was required in at least 200 cases when various aspects of the prediction and interaction were considered (Baczynska et al., 2024). A further 50 cases served as a buffer for incomplete responses and preserved analytic cell viability when aggregating property classification criteria, cultural origin cluster, and digital exposure tier. Table 1 shows the sample composition and provides a glimpse of the demographics of the international and regional hotel customers in Baghdad.

Table 1. Sample Demographic Composition (n = 250)

Variable	Category	n	%
Travel Purpose	Business	122	48.8
	Leisure	88	35.2
	Mixed (Bleisure)	40	16.0
Occupancy Duration	≤ 3 nights	102	40.8
	4–7 nights	87	34.8
	> 7 nights	61	24.4
Cultural Origin Cluster	Iraqi Arab National	96	38.4
	Arab Gulf States (GCC)	70	28.0
	Western/European	50	20.0
	Asian & Other Regions	34	13.6
Property Classification	Five-Star International	88	35.2
	Four-Star Sustainability-Compliant	94	37.6
	Three-Star Basic Green Policy	68	27.2
Digital Exposure Level	High (> 5 functions)	112	44.8
	Moderate (3–4 functions)	83	33.2
	Low (1–2 functions)	55	22.0

Note. Digital exposure level is based on the count of distinct technology functions used during the stay. The Iraqi Arab National cluster includes both Baghdad-resident and non-Baghdad domestic travelers. The Arab Gulf States cluster encompasses guests from Bahrain, Kuwait, Qatar, Saudi Arabia, the United Arab Emirates, and Oman

4.3 Survey Instrument

The questionnaire was organized into five categories: demographic profiling, digital function exposure inventory, green leadership visibility perception items, service quality and sustainability satisfaction ratings, and loyalty intentions. Green leadership perception items were based on validated frameworks based on role modeling, empowerment, and ecological communication alignment (Aboramadan et al., 2022). Satisfaction was assessed with multi-item 5-point Likert scales that combined traditional service dimensions with sustainability-weighted criteria (Wee, 2025) for a total Satisfaction Index (SI) of 1–5 for within-study analyses. A complementary 10-point scale that combines multiple service dimensions was calculated for leadership and communication mechanisms as well. The pilot testing with $n = 20$ guests drawn from Baghdad hotels corroborated item comprehension and internal consistency of all constructs

(Cronbach's $\alpha > .85$ for all constructs). Bilingual forward and backward translation procedures ensured semantic equivalence between the Arabic and English versions of the instrument (Hassan et al., 2024).

4.4 Analytical Strategy

Descriptive statistics were constructed for all continuous constructions. Spearman's rho was used to evaluate bivariate association. Chi-square tests were performed to examine categorical association between integration levels and loyalty brackets. Mediation was estimated to be using bias-corrected bootstrapping with 5,000 resamples (Chedrawi et al., 2025). Moderation was measured by hierarchical regression in which interaction terms are entered after the main effects to separate the incremental variance explained. Data cleaning excluded the responses with more than 20% missing values and verified the identity of the responses by timestamp-IP matching. Ethical approval was obtained from the Research Ethics Committee at Mustansiriyah University's Faculty of Tourism Sciences, and all participants were informed before the data were collected.

5. RESULTS

5.1 Descriptive Statistics

Table 2 gives descriptive statistics on the key studies. The overall satisfaction score (SI) of 4.32 (SD = 0.39) and Sustainability Perception Score (SPS) of 4.30 (SD = 0.41) are good indicators of a favorable guest evaluation environment as the participating properties. The smaller Digital-Human Alignment Rating mean (4.11, SD = 0.56) compared with the Green Leadership Visibility Score of 4.18 (SD = 0.44) indicates that the level at which guests are satisfied with leadership commitment is more variable but the level of digital sustainability information that consumers in Baghdad are equipped with is more variable and will be an important aspect of the mediation analysis that we will analyze in the next section.

Table 2. Descriptive Statistics for Study Constructs (n = 250)

Construct	Mean	SD	Range
Satisfaction Index (SI) [1–5]	4.32	0.39	3.0–5.0
Sustainability Perception Score (SPS) [1–5]	4.30	0.41	2.9–5.0
Green Leadership Visibility Score [1–5]	4.18	0.44	2.5–5.0
Digital-Human Alignment Rating [1–5]	4.11	0.56	2.3–5.0
Integration Intensity Score (composite) [0–10]	8.15	1.02	5.0–10.0
Likelihood-to-Revisit (LTR) [%]	78.4	14.7	40–100
Likelihood-to-Recommend (LTC) [%]	80.2	13.9	45–100
Observed OCB Frequency (acts per stay)	2.4	1.1	0–5

Note. SI and SPS were measured on 1–5 Likert scales anchored to Baghdad hotel stay contexts. OCB = organizational citizenship behavior (voluntary pro-environmental acts observed per stay). The Integration Intensity Score is a composite of digital function breadth and environmental visibility, scored 0–10. LTR = likelihood to revisit; LTC = likelihood to recommend

Table 3 presents digital technology adoption rates across Baghdad's hotel classifications, demonstrating systematic increases with property tier across all function categories. These data served as the empirical referent for the digital exposure level classification variable used throughout the analyses.

Table 3. Digital Technology Adoption Rates by Property Classification in Baghdad Hotels

Technology Function	3-Star (%)	4-Star (%)	5-Star (%)
AI Chatbot Customer Service	42	65	78
Voice-Recognition In-Room Control	38	58	80
Food Delivery Robotics	15	34	55
Automated Cleaning Systems	12	29	48
Algorithmic Occupancy Forecasting	25	60	77

Note. Values represent the percentage of guests who encountered each technology function during their stay. Five-star properties include internationally affiliated hotels operating in Baghdad's commercial and diplomatic districts.

Table 4 presents guest satisfaction and loyalty metrics by perceived leadership style within Baghdad's sampled hotels, confirming the superiority of green transformational approaches across all outcome indicators. SI values in Table 4 reflect the supplementary 10-point composite scale.

Table 4. Guest Satisfaction and Loyalty Metrics by Perceived Leadership Style — Baghdad Hotels

Perceived Leadership Style	SI Mean (1–10) ^a	SD	LTC > 80% (%)
Green Transformational	9.2	0.5	87
Transformational (Non-Green)	8.6	0.7	78
Servant Leadership	8.8	0.6	80
Ethical Leadership	8.4	0.8	74
Transactional Leadership	7.5	1.0	60

Note. ^a SI values reflect the supplementary 10-point composite scale for comparative purposes. Leadership style classifications are derived from guests' narrative characterizations of managerial behaviors observed during their stay. LTC = Likelihood-to-Recommend.

5.2 Hypothesis Testing

5.2.1 H1: Green Leadership Visibility and Guest Satisfaction

It can be seen in Spearman's rho analysis that there is a strong positive relationship between green leadership visibility and the guest satisfaction index ($\rho = 0.64$, $p < .001$) that supports H1 and is the strongest bivariate relationship in our study and held across all three types of properties in Baghdad's hotel market. The effect was more pronounced in the five-star international properties ($\rho = 0.71$, $p < .001$) where guests are usually treated to full-fledged leadership-driven sustainability rituals and less so in three-star properties ($\rho = 0.52$, $p < .001$) where leadership visibility is limited in operation. Table 5 presents the satisfaction index scores disaggregated by digital sustainability integration level, contextualizing the leadership effect within the broader technological landscape.

Table 5. Satisfaction Index (SI) and Sustainability Perception Scores (SPS) by Digital Sustainability Integration Level — Baghdad Hotels

Integration Level	SI Mean [1–5]	SPS Mean [1–5]	p-value (SI vs. SPS)
High Integration (Score > 8)	4.61	4.54	< .001
Moderate Integration (Score 6–8)	4.29	4.23	< .001
Low Integration (Score < 6)	3.96	3.88	< .01

Note. Integration level is based on the composite Integration Intensity Score (0–10). p-values reflect Spearman's rho tests of the SI–SPS correlation within each integration tier.

The bias-corrected bootstrapping mediation analyses (5,000 resamples) supported both H2 and H3. For H3, the SPS partially mediated the relationship between the visibility of green leadership and likelihood of revisiting: the total effect was $B = 0.46$ ($p < 0.001$) and the indirect pathway through SPS was $B = 0.24$ (95% CI [0.14, 0.36])—representing approximately 52% of the total effect. The direct effect was still significant ($B = 0.22$, $p < 0.001$) and the indirect pathway was still

significant (but not as much as the direct pathway). For H2, digital-human alignment somewhat mediated the integration intensity-satisfaction relationship, and the indirect pathway was still significant (95% CI [0.09, 0.27]). Table 6 summarizes the mediation results.

Table 6. Mediation Analysis Results — Baghdad Hotel Sample

Pathway	Total B	Indirect B	Direct B	95% CI
GL Visibility → SPS → LTR (H3)	0.46***	0.24***	0.22***	[0.14, 0.36]
Integration → Alignment → SI (H2)	0.38***	0.17***	0.21***	[0.09, 0.27]

Note. *** $p < .001$. GL = Green Leadership; SPS = Sustainability Perception Score; LTR = Likelihood-to-Revisit; SI = Satisfaction Index. Bootstrapping with 5,000 resamples.

5.2.3 H4 and H5: Moderation Analyses

Hierarchical regression analyses with interaction terms confirmed the moderating effect of cultural origin cluster (H4) and digital exposure level (H5). The relationship between green leadership visibility and cultural origin cluster strongly predicted SPS ($B = .18$, $p < .05$) and simple slopes ($b = .65$, $p < .001$) were obtained for Western/European guests and $b = .42$ for Arab Gulf States that supports H4. The higher-slope results for Western/European guests are in line with the individualist nature of the cultural origin cluster and make authenticity cues of a leader more diagnostic than those of the Arab majority in Baghdad. The digital exposure level (H5) interaction was significant ($B = .24$, $p < .01$) and high-exposure guests had a steeper slope than low exposure guests ($b = .21$). Tables 7 and 8 summarise regression model summary and significant moderation effects.

Table 7. Hierarchical Regression Summary — Moderation Models, Baghdad Hotel Sample

Predictor	Model 1 β	Model 2 β	Model 3 β	p-value
Green Leadership Visibility (GL)	.51***	.48***	.46***	< .001
Cultural Origin Cluster	—	.22***	.21***	< .001
GL × Cultural Origin (Interaction)	—	—	.18*	< .05
Integration Intensity	.44***	.41***	.40***	< .001
Digital Exposure Level	—	.27***	.25***	< .001
Integration × Digital Exposure (Interaction)	—	—	.24**	< .01
ΔR^2 (Interaction terms)	—	—	.064***	< .001

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. Standardized coefficients (β) reported. Model 1 = main effects only; Model 2 = main effects + moderators; Model 3 = full model including interaction terms. $n = 250$.

Table 8. Summary of Significant Moderation Effects — Baghdad Hotel Sample

Moderator Variable	Interaction β	p-value	Key Pattern in Baghdad Context
Cultural Origin Cluster	GL × Culture = .18	< .05	Steeper slope: Western/European > Arab Gulf States guests
Digital Exposure Level	Integration × Exposure = .24	< .01	Strongest slope for high-exposure guests in 5-star Baghdad properties
Cultural Origin Cluster	Alignment × Culture = .15	< .05	Higher sensitivity: Arab Gulf States guests to Arabic-language sustainability messaging
Digital Exposure Level	SPS × Exposure = .19	< .05	LTR sustained only at moderate-to-high digital exposure tiers in Baghdad hotels

Note. Moderation effects derived from hierarchical regression analyses. GL = Green Leadership visibility. All interaction terms entered after main effects. Cultural origin cluster treated as a categorical moderator with Western/European as the reference category.

5.3 Interaction Effects: Sustainability × Technology

SPS and integration intensity explained an additional 6.4% of the variance beyond the main effects ($\Delta R^2 = .064$, $p < .001$). This confirms that sustainability perception and technology deployment are both complementary with respect to Baghdad's hotel environment. Table 9 shows the cell means after high/low SPS and integration. The highest satisfaction ratings (SI = 4.71; LTC = 87.2%) were only achieved when both the SPS and integration intensity were high in combination, and even the best technical systems are unable to significantly increase SI when sustainability cues lack authenticity (SI decreases to 4.18 in high-integration/low-SPS conditions). This is very relevant to Baghdad's five-star hotels, which have over the past few years spent big on an AI-driven digital system but not enough on human service behavior to ensure that they are not just making automated sustainability claims.

Table 9. Satisfaction Index (SI) and LTC by Combined Sustainability Perception and Integration Level — Baghdad Hotels

SPS Level	Integration Level	SI Mean [1–5]	LTC Mean (%)
High (> 4.3)	High (Score > 8)	4.71	87.2
High (> 4.3)	Low (Score < 7)	4.43	81.5
Low (< 3.6)	High (Score > 8)	4.18	76.4
Low (< 3.6)	Low (Score < 7)	3.89	61.9

Note. The highest SI (4.71) and LTC (87.2%) occurred exclusively when both SPS and integration intensity were simultaneously high, confirming the multiplicative amplification proposition of the SAT Framework. LTC = Likelihood-to-Recommend

Table 10 illustrates that digital-verbal messaging achieves the highest satisfaction scores, averaging 9.2 on a 10-point composite scale, and garners the most substantial rate of guests expressing strong recommendation intentions at 64%. This figure remains significantly superior to those of other communication methods. Notably, this insight is particularly striking considering that hotels in Baghdad have traditionally relied on interpersonal service excellence as their primary differentiator in quality. These findings suggest that this relational strength can be augmented not supplanted by effective digital sustainability communication.

Table 10. Guest Satisfaction and Loyalty by Sustainability Communication Channel — Baghdad Hotels

Communication Mode	SI Score (1–10) ^a	High LTC (> 80%) %
Combined Digital + Verbal Messaging	9.2	64
Digital Interface Integrated Suggestions	8.4	58
Verbal Invitations by Staff Only	8.1	44
Static Signage Only	7.9	37
No Sustainability Communication	6.5	18

Note. ^a SI values reflect the supplementary 10-point composite scale for comparative purposes. LTC = Likelihood-to-Recommend. Data derived from the Baghdad hotel sample ($n = 250$).

5.4 Hypotheses Summary

All five hypotheses received empirical support, collectively validating the three central propositions of the SAT Framework within the context of Baghdad's classified hotel sector. Table 11 consolidates the hypothesis outcomes alongside key statistical evidence.

Table 11. Hypothesis Test Outcomes Summary — Baghdad Hotel Sample

H	Hypothesis Statement	Outcome	Key Statistical Evidence
H1	Green leadership visibility positively predicts guest satisfaction (SI) in Baghdad's hotels	Supported	$\rho = 0.64, p < .001$
H2	Digital-human alignment mediates Integration Intensity $\rightarrow$ SI	Supported	Indirect $B = 0.17$, 95% CI [0.09, 0.27]
H3	SPS mediates Green Leadership Visibility $\rightarrow$ LTR (partial mediation)	Supported	Indirect $B = 0.24$, 95% CI [0.14, 0.36]
H4	Cultural origin cluster moderates GL Visibility $\rightarrow$ SPS relationship	Supported	$B = .18, p < .05$; Western/European slope steeper
H5	Digital exposure level moderates Integration Intensity $\rightarrow$ LTR relationship	Supported	$B = .24, p < .01$; high-exposure slope strongest

Note. All hypotheses tested on the Baghdad hotel sample ($n = 250$). SPS = Sustainability Perception Score; LTR = Likelihood-to-Revisit; SI = Satisfaction Index; GL = Green Leadership. Bootstrapping with 5,000 resamples for mediation analyses.

6. DISCUSSION

6.1 Theoretical Contributions

The SAT Framework's main theoretical contribution is to posit the role of authenticity perception as the mechanism that green leadership plays in creating loyalty results. Long-standing hospitality leadership research has focused on the leader-to-employee pathway and the role of green transformational leadership in staff organizational citizenship behavior, intrinsic motivation and environmental engagement (Alshimmari & Shneikat, 2025; Hassan Abdou, 2025). Our findings in Baghdad are a further extension of this literature and suggest that guest-facing authenticity perception (SPS) is a theoretically and empirically separable construct that partially mediates the leadership-to-loyalty pathway, which has not been formally discussed in hospitality organizational behavior research in the context of Iraq.

Since the results indicate a partial rather than full mediation of the leadership-loyal relationship in this study, it is not clear whether SPS is sufficient to see more than one side of this relationship that would be important in future studies. In the hospitality context in Baghdad, these can be indicative of the quality-of-service innovation, the Arabic language environmental storytelling, Islamic ecological value alignment (which is not captured in current hospitality scenarios) and co-creation experiences that send leadership signals to guests. SPS is also consistent with self-determination theory: those who attribute sustainable behavior to intrinsic organizational commitment rather than instrumental compliance are more likely to associate the property with the person and to have longer loyalty responses, which might be especially true of Iraqi Arab National guests, who are much more motivated by their institutional trustworthiness in the sense that they can be evaluated more critically about the institution.

The second theoretical contribution—digital-human alignment as a mediating framework—posits the technology adoption literature and behavioral hospitality research in ways applicable to Baghdad's digitizing hotel sector. Current research has presented digital investment as a means of explaining operational efficiency, but the present perspective is to consider it as a communication infrastructure that is built to help to connect automated activities to human service in the world of the hospitality industry (Low et al., 2025; Sun et al., 2025). Rather than focusing only on accuracy or efficiency of AI outputs, Baghdad's hotels should evaluate sustainability-relevant AI outputs to the extent to which they enable staff to make meaning (in a bilingual narrative training context) which needs to be done deliberately.

Third, the reciprocal amplification result– the maximum satisfaction is when SPS and integration intensity are in conjunction above threshold values– is an important feature for interaction research in service management. The value of the interaction term is large over the magnitude of the main effect variance, suggesting that research that does not incorporate this interaction could underestimate the effect of the combined investments in sustainability and technology. For Baghdad's hotel operators, this implies that the returns on digital sustainability investment are dependent on prior or concurrent investments in green leadership visibility– and this finding is at odds with the common managerial conception of them as assets that are not continuous but products of one another but can be deployed as one and all.

6.2 Practical Implications for Baghdad's Hotel Sector

The findings have impactful implications for hospitality management in Baghdad in a variety of areas. First, green leadership visibility should be considered a measurable behavior variable that can be quantified in terms of frequency and context, since the data confirm a direct positive impact of leadership visibility on satisfaction levels. Baghdad properties in the three-star category may get the best per unit satisfaction effect of more leadership visibility, as the interaction analysis shows leadership partially compensates for lower integration intensity, which is a strategically important finding for the mid-tier hotels that can still be capital constrained in the post-reconstruction context in Iraq.

Second, digital interface investments should be conditioned on whether staff are ready to interpret and contextualize system outputs for Baghdad's multicultural guest segments. Expanding the scope of technological function without a fair investment in interpretive training may not yield high returns. Training programs should integrate technical operations with narrative communication skills: training staff to translate resource-saving metrics into culturally relevant ecological stories, whether in terms of Islamic stewardship principles for Arab guests or quantified environmental impact for Western and Asian business travelers.

Third, communication strategies need to vary by channel and be sensitive to the cultural composition of each property's guest mix. Table 10 shows that the combination of digital and verbal communication is the most effective in terms of satisfaction and loyalty. Baghdad's hotels serving mainly Arab Gulf States guests should frame sustainability messages in terms of collective participation, shared environmental responsibility, and regional identity, which is consistent with collectivist culture. Properties with more Western/European guests may also employ more individualist, leader-centered messaging with the same effect.

The post-departure communication phase, in turn, must be studied as the loyalty-building mechanism for Baghdad hotels. A collection of sustainability contribution reports for each property that describe a guest's resource-saving contribution and contextualize it within the property's collective environmental outcomes during the stay, therefore, provides additional authenticity for the SPS-LTR relationship post-stay (Chedrawi et al., 2025). For Baghdad hotels, who are working to build international reputation in a competitive regional market, this way of seeing things as low-cost differentiation vehicles in comparison with more established sustainability-certified competitors in neighboring Gulf cities can be helpful.

7. CONCLUSION

7.1 Summary of Findings

We investigated the effects of green leadership and digital technology on hotel guests' satisfaction and loyalty using a cross-sectional survey of 250 hotel guests across three property types in Baghdad, Iraq. All five hypotheses in the SAT Framework were confirmed. Green leadership visibility directly and positively contributed to satisfaction ($\rho = 0.64$, $p < 0.001$); sustainability authenticity perception partially mediated leadership-loyalty pathway (indirect $B = 0.24$, $CI [0.14, 0.36]$); digital-human alignment mediated the integration intensity-to-satisfaction relationship (indirect $B = 0.17$, $CI [0.09, 0.27]$); cultural origin cluster moderated the leadership-SPS relationship ($B = 0.18$, $p < 0.05$), Western/European guests were the most steeply slope and digital exposure level moderated the relationship between integration and loyalty ($B = 0.24$, $p < 0.01$). The relationship between SPS and integration intensity was found to be in the same direction ($\Delta R^2 = 0.064$) and authenticity and technology are complementary to each other in Baghdad's classified hotel environment.

7.2 Contributions to Theory and Practice

The SAT Framework advances hospitality organizational behaviour theory by characterising authenticity perception as the primary mediating mechanism in the green leadership-loyalty pathway, representing digital-human alignment as a second-order transmission mechanism and advocating that authenticity and technology are complementary and mutually reinforcing as a means for best guest satisfaction. We argue that these propositions are well grounded in the special institutional, cultural, and operational context of Baghdad and could be considered as the basis for future work on hospitality and other service opportunities in the Arab world and beyond. This framework also underscores practitioners in Baghdad's rapidly changing hotel market that coherence in leadership signals, staff behaviour, and technological messaging leads to guest outcomes that neither investment stream can achieve independently.

7.3 Limitations and Future Research Directions

This study has a number of limitations. The cross-sectional nature of the research makes it difficult to draw causal conclusions; longitudinal research with the same guests over multiple visits would enhance claims about directionality and allow us to observe changes in perceptions of sustainability authenticity as Iraq's green hospitality sector develops. Self-reported information on leadership visibility and sustainability perceptions is likely to lead to social desirability bias that may be reduced by observational and ethnographic methods. While the sample from Baghdad was demographically varied compared to other regional studies, it was restricted to one city; conducting similar studies in other Iraqi cities such as Basra, Erbil, and Najaf, as well as in broader Middle Eastern hospitality settings, would help to explore the limits of the cultural moderation findings.

In the future work, the implications of the SAT Framework should be examined in more than just the service sector in Iraq: religious tourism (especially as Najaf and Karbala are located abroad), airport and conference facilities. Longitudinal research based on experience sampling can be used to study how within-person perception of authenticity changes during the guests' journey. Arabic-language online guest reviews in Iraqi hotel-listing platforms could be used as external test cases for SPS, and large samples could be replicated in an unbiased manner. Finally, the theoretical framework could be applied to complexity leadership theory (Brown et al., 2026) to have better insights into how the adaptive co-creation of leaders, staff and guests contributes to the emergence of authenticity perceptions in Baghdad's fast-changing hospitality sector.

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META MARKETING IN THE FMCG SECTOR: DRIVING SUSTAINABLE DEVELOPMENT THROUGH IMMERSIVE DIGITAL STRATEGIES

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Article history: Received:2025-11-09 Received in revised form:2025-11-21 Accepted:2025-12-20 Available online:2026-06-26	<i>Digital technology has evolved rapidly, resulting in a new form of marketing known as "meta marketing," which represents a revolutionary way of doing business in today's rapidly changing marketplace, especially for marketers working within the highly competitive Fast-Moving Consumer Goods (FMCG) industry. This study aimed to conceptually explore how organizations utilize technology such as the Metaverse, augmented reality (AR), virtual reality (VR), and artificial intelligence (AI) to create meta marketing strategies, while promoting sustainable development. This will include investigating how using immersive, interactive marketing environments can motivate consumer engagement, trust, and purchasing behaviours, while at the same time, through lessening physical consumption of resources and improving digital communications, developing initiatives that encompass environmental sustainability. Using existing literature and applying theoretical frameworks, this research advances knowledge by developing a conceptual framework that connects the advancement of technological innovation with achieving sustainable outcomes as a business performance indicator. Overall, this study provides evidence that the use of Meta marketing presents FMCG companies with an opportunity to gain a competitive advantage while meeting sustainability challenges.</i>
Keywords:	
Meta Marketing;	
FMCG;	
Sustainable Development;	
Metaverse;	
Consumer Behavior.	
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M31, M37, O33, Q56	

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1. INTRODUCTION

Companies that conduct business in the fast moving consumer goods (FMCG) market face both intense competition and pressure to be resource efficient in the market place, and thus firms in this industry are moving towards new marketing strategies due to the increased focus on sustainable practices. Meta-marketing is an example of an innovative concept in the literature that combines the use of digital technology with sustainable business practices via immersive technologies such as the non-physical experience of virtual products (Metaverse), augmented reality (AR), and virtual reality (VR). The literature indicates that by using immersive marketing, organizations are able to develop interactive consumer experiences that are also individualized by allowing consumers to personalize their experiences without depending on physical resources and thus support environmental sustainability (Muneesawang & Yawised, 2025;

Bashar et al., 2025). In addition, companies are utilizing the Metaverse to develop product interaction, simulated experiences and branding to provide an opportunity for consumers to engage in a more active manner while also utilizing more environmentally responsible consumption behaviours (Srivastava & Sahu, 2023; Sharma & Garg, 2025). Empirical studies suggest that FMCG firms will utilise meta-marketing to enhance supply chain effectiveness, reduce waste and communicate sustainability efforts in a more effective way through platforms that are transparent and supported by data (dos Santos, 2024; Ndigwe et al. 2026).

Further evidence supportive of the use of immersive technology to change marketing strategies stems from a number of systematic reviews, such as the ones conducted by Faruk et al. (2025) and Fan et al. (2025). However, although there are numerous potential benefits related to the use of new immersion technologies, the application of meta marketing techniques in the fast-moving consumer goods (FMCG) sector is still at a relatively nascent stage due to prevalent barriers associated with technology uptake, consumer confidence, or integration into existing business models (Kaman & Deshmukh, 2025; Barbosa, 2025). Therefore, there exists an urgent need to investigate the extent to which meta marketing strategies facilitate sustainable development amongst FMCG organisations as an important mechanism for creating alignment between digital transformation and sustainability objectives in today's evolving marketing ecosystem.

2. LITERATURE REVIEW

Growing academic interest on how Metaverse technologies have impacted marketing has positioned meta-marketing as one of the new digital strategies today. Yadav, Pandey & Sharma's (2024) systematic literary review of current literature revealed that food manufacturers would be better positioned to grow their business by leveraging Metaverse-based marketing to reach consumers through a new method of engaging them through the immersive and interactive experiences that they create in these brand ecosystems, even if they have not yet developed a viable Metaverse marketing application in the field of Fast Moving Consumer Goods (FMCG). According to Faruk, Ejarder & Jannat (2025), the introduction of Metaverse marketing represents a shift in how firms create customer experiences by utilizing virtual environments as a mechanism for engaging customers and communicating sustainability. As they relate their research findings to FMCG, Fan et al. (2025) report using meta-analytic research methodologies to demonstrate that Augmented, and Virtual Reality Enhances how and when consumers interact and make purchase decisions, which is of particular relevance to Fast Moving Consumer Goods with relatively low levels of consumer involvement and high levels of purchase frequency.

Bashar et al. (2025) present a detailed approach to creating sustainable digital marketing from a sustainability perspective. They argue that using immersive technologies can help achieve environmental goals by minimizing the use of physical resources and allowing for a digital substitution of traditional marketing channels. Similarly, Srivastava & Sahu (2023) suggest that the Metaverse promotes green marketing and encourages eco-friendly consumer behaviours through virtual simulations and experiential learning. Furthermore, Ghasemzadeh & Antucheviciene (2025) describe how businesses can optimise their marketing-related to sustainability using advanced analytical techniques to align marketing strategy with sustainability targets. There has also been much work published on consumer behaviour within meta marketing environments. Yin & Do (2025) demonstrate how virtual reality significantly influences consumer attitudes, trust, and engagement; all of which are essential for FMCG

brands wanting to establish long-term relationships with customers. Sharma & Garg (2025) expand on this point by suggesting that intelligent technologies embedded in the marketing ecosystem can encourage more sustainable consumption behaviours, especially when consumers receive transparent and interactive information about products. Finally, Ndigwe et al. (2026) illustrate through empirical research, with examples from developing nations, that FMCG brands can utilize immersive marketing to increase both engagement and awareness of sustainability issues among consumers.

Although there have been many advancements in recent years, many studies have pointed to critical gaps in Metaverse research. According to Barbossa, as of 2025, there is still little knowledge on the link between Metaverse branding and measurable sustainability results. This is particularly true in sectors that operate on a mass scale such as fast-moving consumer goods (FMCG). Lowry et al. suggest that while the Metaverse will disrupt consumer goods industries, there are still significant unresolved issues around scale, access, and ethical considerations. Dos Santos states that barriers to trust and adoption may impede meta-marketing strategies' ability to influence purchase intent in FMCG markets.

3. RESEARCH OBJECTIVES

To explore the implementation of Meta marketing strategies in FMCG companies and analyze their role in promoting sustainable development.

4. RESEARCH GAP

Even though there is a lot of research already completed on the use of meta marketing as well as using immersive technologies in the fast-moving consumer goods (FMCG) industry, significant gaps still exist in terms of understanding how they can be put into practice to promote sustainable development. The understanding of consumers' behaviours while in a metaverse environment is not yet fully understood, and research conducted so far has not provided insights into consumer's purchasing behaviours concerning trust and adoption, nor how it will influence consumers' purchasing decisions (Yin & Do, 2025, dos Santos, 2024). In addition to this, there has not been a framework created to connect the adoption of meta-marketing with measurable outcomes such as sustainability or business operational performance (Kaman & Deshmukh, 2025; Lowry et al., 2025).

5. RESEARCH METHODOLOGY

The goal of this study is to take an analytical approach by researching how to implement Meta Marketing in sustainability efforts by Fast Moving Consumer Good (FMCG) companies using a conceptual or theoretical research methodology. This study will rely heavily on reviewing and synthesizing literature related to Meta marketing, immersive marketing technologies, consumer behaviour, and sustainability. A variety of academic sources of information (i.e., and peer-reviewed journals, conference papers, and industry reports) were reviewed and examined to gather the constructs, relationships, and theoretical foundations needed to create a conceptual framework for the study. The study draws on theory from well-established models/theories such as the S-O-R green marketing model. The study will produce a conceptual model for how rapidly developed marketing strategies, also known as meta marketing, create or influence a customer's engagement and trust and also impact their decision to be a sustainable customer.

6. CONCEPTUAL FRAMEWORK

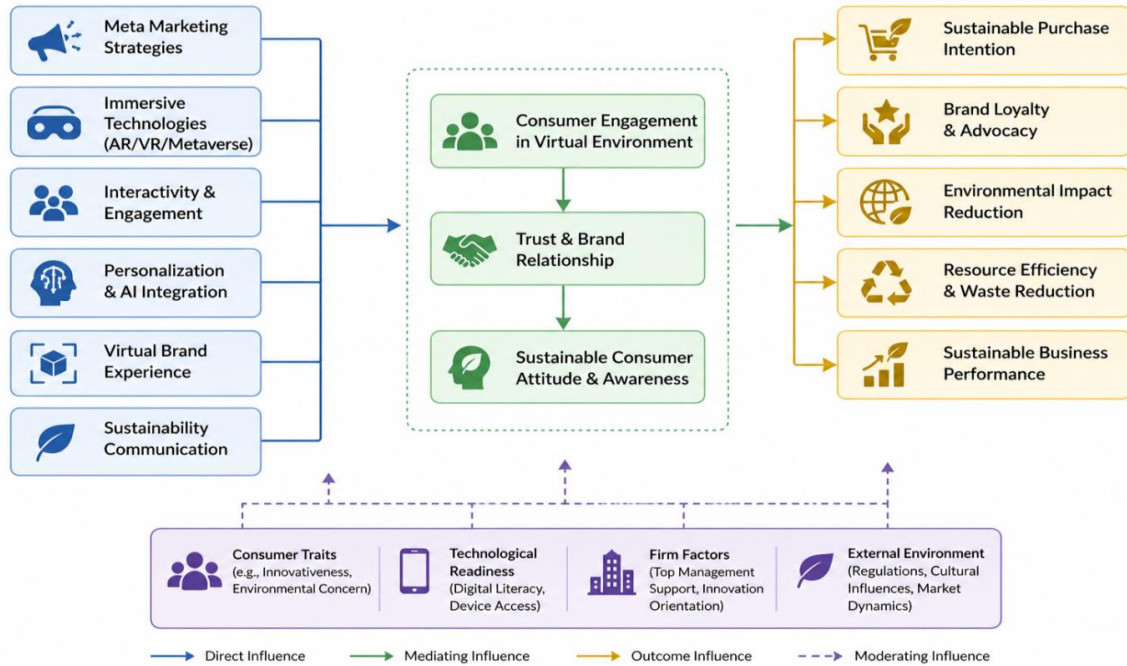


Figure 1: Conceptual Framework (Self Sourced).

7. MODEL DISCUSSION

A proposed conceptual framework explains how Meta marketing is contributing to sustainable development within the FMCG sector by combining technology, behavioural, and environmental dimensions. The proposed framework highlights many examples of immersive technologies (AR/VR and metaverses), personalization via artificial intelligence, interactive, and sustainable communications as primary drivers forming the experiences consumers have within virtual environments. Consistent with the S-O-R theory, the digital stimuli from immersive, interactive experiences will affect consumers internally, creating emotional connections and ultimately influencing their trust towards the brand, creating the basis of a positive relationship between the brand and consumer in a digital ecosystem (Yin & Do, 2025; Muneesawang & Yawised, 2025). There is both empirical and meta-analytical support to indicate those consumers that have more immersive and more interactive experiences will be more engaged with the brand as well as feel more emotionally connected, further driving the strength of their relationship to the brand and importantly influencing their decision-making process (Fan et al., 2025; Faruk et al., 2025).

The model further emphasizes that consumer trust and engagement play significant roles in creating sustainable attitudes toward consumers and awareness of sustainability, acting as mechanisms through which marketing strategies can lead to behavioral results. Past research has shown that consumers are more likely to engage in environmentally friendly purchasing behaviors when they have access to interactive and transparent sustainability information (Srivastava & Sahu, 2023; Sharma & Garg, 2025). The resulting attitudinal changes lead to desired outcomes such as sustainable purchase intention, brand loyalty, reduced environmental impact, and enhanced resource efficiency, which contribute to sustainable business performance

for the FMCG industry (Bashar et al., 2025; Ndigwe et al., 2026). Additionally, the framework recognizes that the consumer's individual characteristics, the consumer's level of technological readiness, the organization's level of support for the consumer, and the overall external environment will enhance or diminish the relationships expressed in the model. Prior studies indicate that digital literacy, innovation orientation, and the regulatory environment significantly impact the adoption and effectiveness of immersive marketing approaches (Lowry et al., 2025; Barbosa, 2025). Thus, the model provides a well-rounded explanation of how to strategically implement Meta marketing initiatives to achieve sustainability goals while recognizing the complexities and multidimensionality of consumer behavior and organizational dynamics in the FMCG sector.

Meta Marketing Strategies and Immersive Technologies

Meta marketing strategies make use of AR/VR and the metaverse to provide consumers with fully immersive and interactive experiences that go beyond what can be done with traditional digital marketing. By enhancing a user's perceived presence and experiential value, these technologies offer deeper levels of cognitive and emotional engagement. Numerous scholarly studies have demonstrated that immersive environments enhance a consumer's level of involvement and retention of memories, thus giving brands a powerful tool to leverage storytelling and sustainability messaging when connecting with consumers. For instance, according to Flavián et al., (2019) AR can enhance consumer experiences with a brand or product using interactivity and vividness. In addition, Dwivedi et al., (2022) cite the disruption that the metaverse has on the marketing ecosystem.

Interactivity, Personalization, and Consumer Engagement

Both interactivity and AI-driven personalizations are two key drivers of consumer engagement in the virtual realm. Engagement is a multi-dimensional construct consisting of cognitive, emotional, and behavioral dimensions and hollebeek et al. (2014) state that consumer engagement is one of the most important predictors of brand loyalty and value co-creation. Furthermore, "consumer engagement will be elevated through AI personalization by providing unique content relevant to an individual (Huang & Rust, 2021). Lastly, by increasing the perceived control and enjoyment of a user within an immersive environment, interactivity can ultimately lead to better engagement outcomes (Yim et al., 2017).

Trust and Brand Relationship as Mediators

The relationship between engagement and behavior is mediated by trust, and this becomes significantly more essential when discussing virtual environments because of the higher levels of uncertainty and perceived risk. Trust is a fundamental building block of long-term partnerships as highlighted in Morgan and Hunt's (1994) Commitment-Trust Theory, and in the virtual world, trust is a significant predictor of purchase intention (Gefen et al., 2003). Furthermore, immersive experiences in the Metaverse can develop stronger emotional connections and trust toward brands (Javornik, 2016).

Sustainable Consumer Attitudes and Awareness

Consumer perceptions of sustainability as well as their pro-environmental attitudes can be amplified by engaging them through immersive experiences. These pro-environmental attitudes represent an important antecedent of sustainable purchase behaviour. According to White et al. (2019), sustainability marketing must close the gap between attitudes and behaviours to be successful. Immersive storytelling and simulation (for instance, visualizing the impact of

environmental damage) can help a consumer to relate to more abstract issues of sustainability by presenting them in a tangible way (Ahn et al., 2016). This will help consumers internalize sustainability values more strongly.

Behavioral and Business Outcomes

Outcomes identified by the model include:

- Intention to Buy Sustainably: Related to consumer trust in a brand and their awareness of its sustainability (Joshi & Rahman, 2015).
- Brand Loyalty and Advocacy: Resulting from consumers' level of engagement with a brand and their relationship with it (Hollebeek et al., 2014).
- Reduced Environmental Impact: Resulting from consumer behaviour changes and informed decision making (Peattie, 2010).
- Efficient Use of Resources and Reduced Waste: Achieved through the use of digital consumption models and experience with virtual products.
- Sustainable Business Performance: Companies that include sustainability in their digital strategy have better long-term performance than other companies (Eccles et al., 2014).

Other Factors

Consumer Traits

Individual differences such as innovative thinking and concern for the environment greatly impact the level of involvement and acceptance of immersive technology (Rogers, 2003).

Technological Readiness

The ability to use digital tools and access various devices determines how well a metaverse strategy will work (Parasuraman, 2000).

Organizational Factors

Organizational support, the inclination to innovate within an organization, and leadership's level of commitment to success impact the success of implementing an initiative (Teece, 2018).

External Environment

The environment (laws, cultural environment, etc.) in which a metaverse initiative takes place, as well as its ability to operate within that environment (market conditions), both influence the level of adoption and subsequent outcomes of a metaverse initiative (Kotler et al., 2021).

8. MANAGERIAL INSIGHTS

To support the development of a sustainability-driven business model in an FMCG company, managers must strategically shift en-masse away from traditional, mass marketing practices toward an experience and sustainability-oriented approach using immersive technologies such as augmented reality (AR) and virtual reality (VR) that create an interactive brand experience that can lead to higher levels of consumer engagement and stronger emotional connections that impact both purchase decisions and loyalty to brands (Fan et al., 2025; Muneesawang & Yawised, 2025). To achieve this, companies need to integrate their digital efforts with sustainability goals by using virtual/augmented environments to reduce the use of physical promotional materials, thus reducing waste, while also using these same environments to

communicate transparently about the sources of products and their environmental impacts (Srivastava & Sahu, 2023; Bashar et al., 2025).

In addition, establishing consumer confidence is essential for success in virtual ecosystems; therefore, managers need to address concerns about privacy, authenticity, and security in order to increase the likelihood that customers will use these systems. As a result, management should focus on developing secure systems, adhering to ethical data usage, and having transparent communication strategies that enable long-lasting relationships with customers (Yin & Do, 2025; dos Santos, 2024). Organizational readiness is also critical to help companies implement their meta marketing strategies; therefore, companies must develop their internal capabilities (such as digital skill sets, infrastructure for technology development, and an innovative culture) in order to implement successful meta marketing efforts (Ndigwe et al., 2026). Effective collaboration between marketing, IT, and sustainability teams is necessary in order to support successful immersive marketing initiatives that are aligned with a company's sustainability strategies.

Managers should account for local laws, cultural standards, technology availability, and other external factors that affect meta marketing strategy across various markets (Barbosa, 2025; Sharma & Garg, 2025). Additionally, firms need to have performance metrics that not only reflect their financial successes but also their ecological successes (e.g., reducing their carbon footprint, improving resource efficiency, and raising consumer awareness) so that they can measure the true long-term effects of meta marketing and make decisions based on data. In other words, in order for firms to gain a competitive advantage from using meta marketing in FMCG products, they must take a holistic management approach that incorporates technology, consumer research, and sustainability principles into meta marketing execution; thus, supporting their efforts to develop sustainably.

9. CONCLUSION

To summarize, using the Meta marketing approach allows for FMCG (Fast Moving Consumer Goods) organizations to combine digital innovation with progress on sustainability goals in new and meaningful ways. While creating a unique experience; companies can connect better with their consumers through the use of emerging technologies (the Metaverse, augmented reality and artificial intelligence), as well as reduce their carbon footprint via dematerialized marketing initiatives. Additionally, the findings indicate that meta marketing generates effectiveness through the ability of technologists to shape consumers' attitudes, to create brand trust and to drive sustainable consumer behaviour. The use of meta marketing requires the goal of aligning interests, readiness of the organization to adopt meta marketing, and focus on establishment of sustainability into core business practices. Therefore, as the FMCG industry continues to respond to environmental concerns and the challenges of digital disruption, the implementation of meta marketing practices provides a critical mechanism for long-term competitive advantage and responsible business growth.

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GREEN ENERGY MARKETING UNDER GOVERNMENT INCENTIVE SCHEMES: STRATEGIC RESPONSES OF ENERGY FIRMS

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ARTICLE INFO	ABSTRACT
Article history: Received:2025-07-12 Received in revised form:2025-07-29 Accepted:2025-08-30 Available online:2026-06-26 Keywords: green energy; government incentives; renewable energy marketing; corporate strategy; renewable policy JEL Classification Q42, Q48, M31, L94	Government incentive schemes have become a pivotal driver of renewable energy growth worldwide, prompting varied strategic responses from energy firms. This study examines how companies adapt their marketing and investment strategies under such incentives, drawing on international examples and data from the last decade. The findings indicate that robust incentive policies (e.g. feed-in tariffs, tax credits, renewable portfolio standards) are correlated with significantly faster growth in renewable energy capacity and encourage firms to pivot towards green energy offerings. Energy firms respond by increasing renewable investments, rebranding with sustainability themes, and leveraging incentives in marketing campaigns to attract consumers and investors. However, the effectiveness of incentives in altering firm behavior is not uniform – some policies lead to transformative change, while others have had limited impact or unintended consequences. By analyzing renewable energy trends in key countries alongside firm-level strategy shifts, the paper highlights the critical role of stable, well-designed incentives in enabling a clean energy transition. It also underscores that firms combining incentive-driven investment with authentic sustainability marketing can achieve competitive advantages. The insights contribute to understanding how public policy and corporate strategy intersect in the renewable energy sector, offering recommendations to policymakers and industry leaders for fostering more effective collaboration in the pursuit of climate and energy goals.

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1. INTRODUCTION

Governments around the world have increasingly implemented incentive schemes to accelerate the transition to green energy. These incentives, ranging from feed-in tariffs and tax credits to renewable energy targets, auctions, and grants, aim to improve the economic attractiveness of renewable technologies and reduce investor uncertainty. Their aggregate influence is visible in global electricity trends: renewable sources accounted for around 30% of worldwide electricity generation in 2023 and are expected to continue rising under sustained policy support (IEA,

2024). By the early 2020s, more than 130 countries had adopted some form of renewable energy target or support mechanism (REN21, 2023). Yet the central academic question is not simply whether incentives matter, but how they reshape firm strategy across different market and institutional settings.

A growing body of research has examined the effectiveness of renewable energy incentives, but the literature remains fragmented across policy evaluation, sustainability transitions, and corporate strategy. Many studies confirm that well-designed incentives can substantially boost renewable deployment. For instance, Nicolini and Tavori (2017) found that feed-in tariff subsidies in Europe were highly effective, estimating that a 1 Euro-cent increase in FIT rates led to an 18-26% increase in renewable electricity capacity. Cross-country panel analyses likewise show that market-based instruments, fiscal incentives, R&D support, and policy targets can significantly expand renewable capacity (Liu et al., 2019). Kilinc-Ata (2016) compared policies across the EU and the United States and concluded that feed-in tariffs, competitive tenders, and tax incentives generally outperformed quota-based obligations. These findings indicate that incentives affect investment behavior, but they say less about the strategic pathways through which firms respond.

Other studies show that incentives do not operate mechanically and may produce uneven outcomes when market conditions, institutional credibility, or implementation capacity are weak. Jenner et al. (2013) found that broader electricity-market conditions sometimes mattered more than formal incentives, while Karneyeva and Wustenhagen (2017) showed that abrupt policy change can undermine investor confidence even when renewable technologies are becoming more competitive. This line of research suggests that firms respond not only to the nominal existence of incentives, but also to their durability, predictability, and compatibility with market structures. In other words, the strategic effect of policy depends on both incentive design and policy credibility.

This study therefore adopts a more explicit conceptual lens. It treats government incentives as strategic signals that influence firms through three mechanisms: first, economic repricing, by changing expected project returns; second, strategic legitimization, by making green investment and green branding more acceptable to investors, regulators, and customers; and third, capability formation, by encouraging firms to build new organizational routines, partnerships, and business models around renewables. On that basis, firm responses are expected to cluster into four pathways: portfolio reallocation, market communication and branding, business model innovation, and regulatory positioning. This framework moves the paper beyond the general claim that incentives influence firm behavior and clarifies the channels through which that influence unfolds.

The marketing dimension is especially relevant but often undertheorized in the energy-policy literature. When incentives reduce end-user costs or expand renewable market visibility, firms gain new grounds for price framing, sustainability framing, and investor communication. In liberalized retail markets, installers and utilities can translate incentives directly into customer-facing messages such as rebates, tax advantages, or long-term bill savings. In less competitive or more state-directed systems, marketing is directed less at final consumers and more at investors, regulators, and public legitimacy. This distinction helps explain why green energy marketing is more pronounced in some countries and more muted in others, even when incentives are strong.

A notable strategic response among incumbent energy firms is the acceleration of diversification into renewable technologies. Hockerts and Wustenhagen (2010) describe a dynamic of greening

Goliaths versus emerging Davids, where incumbents gradually adopt sustainable innovations that new entrants embrace earlier. In energy markets, that pattern is visible in the way established utilities and fossil-fuel-based firms entered wind, solar, and related services once incentives made such investments financially and reputationally attractive. Examples such as RWE, NextEra Energy, and Orsted show that incentives can trigger not only incremental project additions but deeper strategic repositioning.

At the same time, incentives can also generate superficial or opportunistic responses. Some firms expand renewable assets mainly to capture temporary subsidies, overstate their environmental transformation in corporate communication, or lobby selectively for incentives while resisting broader climate regulation. Recognizing this variation is part of the paper's contribution. Rather than assuming a uniform corporate reaction, the study distinguishes between substantive strategic adaptation and symbolic adaptation. The empirical goal is therefore to identify how different incentive environments shape the depth, form, and credibility of firm responses.

Materials and Methods

This research employs a mixed-method design that combines comparative trend analysis with structured qualitative case studies. The empirical period is 2015-2024, a decade during which many jurisdictions intensified renewable energy policy support and firms had enough time to translate those signals into observable strategic responses. The study proceeds in two connected steps: first, a cross-country examination of renewable energy growth under different policy regimes; second, a structured analysis of how major energy firms adapted their portfolios, market communication, and organizational strategies under those regimes.

For the quantitative component, data were compiled from IRENA, IEA, national energy reports, and firm disclosures. Five focal countries were selected for detailed comparison: Germany, the United States, China, India, and Russia. They provide meaningful institutional variation, from highly supportive and stable policy environments to comparatively weak or inconsistent ones. Rather than relying only on the raw number of incentive schemes, the revised analysis uses a policy intensity index that combines three dimensions of support: financial attractiveness, implementation stability, and market coverage. Each dimension was scored on a common scale using policy documentation and prior literature, then aggregated into an index to capture the practical strength of the incentive environment more realistically than a simple policy count.

The policy intensity index was then compared with renewable capacity growth across a broader sample of 20 countries. The regression should be read as exploratory rather than causal. Its aim is to test whether stronger policy environments are systematically associated with higher renewable expansion after controlling for GDP per capita and initial fossil-fuel dependence. This design does not eliminate endogeneity: countries that are politically more favorable toward renewables may also be more likely to adopt stronger incentives. Accordingly, the regression is used to identify patterned association, not to claim definitive causal effects. This limitation is stated explicitly because policy ambition and market outcomes co-evolve.

For the qualitative component, the paper applies a structured comparative case-study logic rather than using firm examples only illustratively. Cases were selected to capture variation in ownership type, national policy setting, and degree of renewable transition. The analysis focuses on four dimensions derived from the conceptual framework: (1) portfolio reallocation toward renewables, (2) marketing and communication responses, (3) organizational and business model reconfiguration, and (4) strategic positioning toward regulation and policy. Evidence was

triangulated across annual reports, public strategy statements, industry analyses, and secondary academic sources to strengthen consistency.

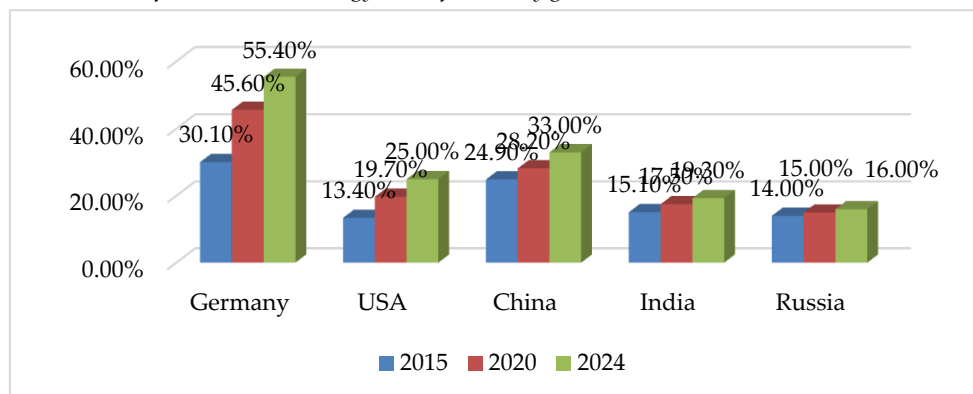
To ensure reliability, multiple sources were cross-checked for each data point and interpretive claim. Renewable generation and capacity statistics reported in the tables were verified against IRENA and national or company-level reporting. Policy descriptions were compared with IEA or IRENA policy databases and official announcements. Firm-specific evidence on strategic responses was not limited to installed capacity; it also included investor communication, public sustainability positioning, and documented organizational changes such as new renewable divisions, asset restructuring, acquisitions, and partnership models. This broader evidence base supports the paper's claim that incentives affect both investment behavior and market communication.

Methodologically, the study remains bounded in scope. The sample is modest, policy scores inevitably involve researcher judgment, and firm-level marketing responses are assessed through disclosed communication and strategic materials rather than through a dedicated content-analysis dataset. Even so, the combined design offers a more rigorous basis than a purely descriptive account because it links a transparent conceptual framework, a more nuanced policy measure, and a structured case protocol. The purpose is not to estimate a final causal model for all energy markets, but to explain recurrent strategic patterns and their policy conditions.

Results and Discussion

The cross-country comparison reveals a consistent positive association between stronger incentive environments and faster renewable energy expansion, but it also shows that policy strength matters more than the mere existence of multiple instruments. Countries with high policy intensity, meaning incentives that were financially meaningful, durable, and broad in market reach, achieved the strongest gains. Germany, for example, increased the renewable share of electricity generation from about 30% in 2015 to roughly 55% by 2024 under a long sequence of stable support mechanisms. By contrast, Russia, where renewable support remained narrow and weak, moved only marginally. The contrast suggests that firms respond most strongly when incentives alter expected returns and reduce uncertainty at the same time.

Graph 1. Renewable energy share of electricity generation in selected countries (%).



Source: Compiled from IRENA and national energy reports (2016–2025).

The renewable share includes all renewable sources in gross electricity generation. Germany's rapid increase reflects the combined effect of long-term support, credible implementation, and a

market environment in which firms could invest with confidence. The United States benefited from tax incentives and state-level mandates, but the fragmented architecture of support produced more uneven responses across regions. China combined strong subsidies, quotas, and state direction, generating extraordinary scale. India expanded quickly in selected segments, especially solar, yet inconsistent implementation reduced the translation of policy intent into system-wide transformation. Russia's near-flat trajectory illustrates the limited strategic response that emerges when incentives remain weak or narrow.

The United States also made notable progress, increasing renewable generation from roughly 13% to 25% of its electricity between 2015 and 2024 (Graph 1). U.S. growth was fueled by a combination of federal tax incentives (the Production Tax Credit for wind, Investment Tax Credit for solar) and state-level Renewable Portfolio Standards (RPS) that required utilities to integrate more renewables. The effect of these incentives can be seen in the surge of wind farms across the Great Plains and solar farms in states like California and Texas. By 2024, wind and solar together made up around 24–25% of U.S. electricity – a significant rise, albeit from a low base (Zheng, 2025). The relatively moderate overall share compared to Europe indicates that while incentives helped, the U.S. started with a heavily fossil-dependent grid and an uneven patchwork of policies (some states with strong support, others with none). It wasn't until the 2020s and the passage of the 2022 Inflation Reduction Act (with extended and expanded clean energy tax credits) that the U.S. got a more comprehensive federal push. We see early impacts of that in the uptick around 2023–2024, and further effects are expected beyond 2024.

China's case is extraordinary in sheer scale. With aggressive government mandates and subsidies, China's installed renewable capacity skyrocketed. The share of renewables in generation (including its vast hydroelectric output) rose from roughly 25% in 2015 to over 33% in 2024 (Graph 1). This understates the growth of non-hydro renewables: China went from about 170 GW of wind and solar capacity in 2015 to an astounding 1.41 TW (1410 GW) by end of 2024 (China Daily, 2025). Such an achievement was only possible due to strong state-led incentive programs: feed-in tariffs for both wind and solar were introduced in the mid-2000s and maintained for many years, providing guaranteed returns to developers. Additionally, direct subsidies and cheap financing from state banks helped domestic companies flourish in manufacturing and deploying renewables. By 2019, China started replacing FITs with competitive auctions as costs fell, but it also imposed renewable portfolio quotas on grid companies to ensure they kept integrating new green power. The strategic behavior of Chinese firms under these incentives was to scale up as fast as possible – solar and wind developers, often state-owned enterprises themselves, rushed to build projects to capture tariff benefits before deadlines or quota requirements. While this led to some inefficiencies (e.g. occasional curtailment when grid upgrades lagged), it undeniably positioned China as the global leader in renewable energy. Experts note that China's consistent and large-scale policy support, including subsidies, renewable quotas, and tax incentives, has strongly incentivized clean energy investment and enabled this rapid growth (Zheng, 2025). The government's clear long-term targets (peaking carbon by 2030, neutrality by 2060) also signaled to firms that backing renewables was not just profitable but also politically favored – a crucial consideration in China's economic environment.

India presents a more mixed outcome. Renewable electricity share increased only modestly from about 15% to 19% over 2015–2024 (Graph 1), despite India setting ambitious goals (e.g. 175 GW of renewables by 2022) and having various incentives on paper. The Indian government offered

feed-in tariffs at the state level in the early 2010s and later shifted mostly to auctioning renewable energy projects to get lower prices. It also provided some tax breaks (such as accelerated depreciation for wind/solar investments) and mandated renewable purchase obligations for utilities. However, implementation challenges (grid integration, financing hurdles, policy flip-flops) limited the impact. Many planned projects were delayed or faced curtailment due to grid constraints. As a result, while India achieved impressive growth in capacity (especially in solar, which grew from virtually nothing to over 70 GW by 2024), its overall electricity mix didn't shift as dramatically as China's or Germany's.

The incentives were enough to launch new enterprises and bring down renewable costs substantially – India now holds some of the world's lowest solar tariffs from its auctions – but not sufficient to overcome systemic issues in the power sector. Energy firms in India did respond to incentives by participating in large government auctions and forming partnerships to invest in renewables, yet many conventional generation companies remained hesitant given the financial strains of distribution companies and occasional changes in contract terms by authorities. This points to the fact that incentives must be backed by strong institutional frameworks to yield the desired outcome.

To sharpen the comparison, Table 1 is complemented by a policy intensity index that captures not only how many policy tools existed, but how forcefully they operated in practice. This adjustment responds to a common weakness in comparative policy studies: two countries may each have several instruments on paper, yet their strategic effect on firms can differ substantially because of differences in fiscal generosity, duration, enforceability, and coverage. The revised metric therefore provides a better bridge between policy design and corporate response.

Table 1. Major renewable energy incentive schemes in selected countries (2015–2024).

Country	Key Incentive Schemes (2015–2024)
Germany	Feed-in Tariffs (FIT) under the EEG (2000–2016) guaranteeing above-market prices for renewables; Auction system (since 2017) for wind/solar with market premiums; Low-interest loans for green energy via KfW bank; EU ETS (indirectly raising fossil costs).
USA	Federal Tax Credits (PTC for wind, ITC for solar) renewed multiple times (e.g. 2015, 2019, 2022) providing 20–30% investment savings; State RPS in 29 states requiring X% renewables by target years; Net Metering policies in many states enabling residential solar credits; Grants/Loans (DOE programs) for clean energy projects.
China	Feed-in Tariffs for wind (since 2006) and solar (since 2011) guaranteeing fixed rates (phased down by 2021); Central Subsidies for solar farms and distributed PV (with annual quotas); Renewable Portfolio Quotas (from 2019) obligating provinces/utilities to meet minimum green power percentages; Cheap Credit & Land provided by government for renewable projects; Grid Priority Dispatch for renewables mandated by policy.
India	Feed-in Tariffs at state level (2010s) for wind/solar (gradually replaced by auctions); Competitive Auctions (National Solar Mission, etc., since ~2015) procuring large solar/wind capacities at falling tariffs; Accelerated Depreciation and tax holidays for renewable energy investments; Renewable Purchase Obligations (RPO) requiring utilities to buy certain % of renewables; Net Metering and capital subsidies for rooftop solar in some states.
Russia	Capacity Auction Program (since 2013) for renewables – tenders that guarantee capacity payments for approved wind/solar projects (limited scale); Import Duty Exemptions for renewable equipment (to reduce costs); [No nationwide FIT or green certificate system] – reliance mainly on a few state-led projects and general power market.

Source: Compiled from IEA/IRENA Policies Database and national policy documents.

This table outlines the primary mechanisms by which governments incentivized renewable energy, but the strategic relevance of these mechanisms differs by policy quality. Germany relied on credible long-term price support and then auctions with continued market certainty. The United States combined tax incentives with state obligations, creating a strong but geographically uneven opportunity structure. China used administered pricing, quotas, and direct state backing, producing exceptionally high strategic pressure to build renewables. India introduced several instruments, but implementation inconsistency weakened their aggregate effect. Russia's limited measures generated only narrow incentives and therefore modest strategic change.

Germany's policy approach illustrates why intensity matters. Its earlier feed-in tariff regime and later auction system differed in design, yet both supplied investors with relatively clear long-term expectations. That continuity supported capability building across utilities, developers, manufacturers, and financiers. The result was not just project growth, but a durable industrial ecosystem in which firms could plan beyond short subsidy windows.

In the United States, incentives were often indirect (through the tax code) and varied by jurisdiction. This fragmented approach led to booms in certain regions; for example, the Production Tax Credit (PTC) made wind energy highly attractive in the Midwest and Texas, areas with strong wind resources, leading companies like NextEra, Avangrid, and others to install tens of gigawatts of wind capacity. Simultaneously, state RPS programs spurred utilities in states like California, New York, and many others to sign long-term contracts with renewable energy developers. A strategic response from firms in the US was the rise of specialized renewable developers who aggregated tax equity financing (to monetize those tax credits) and built projects for utilities or corporate buyers. Many traditional utilities, for their part, lobbied against some state mandates initially, but as public support grew and the economics improved, even utilities in conservative states began to voluntarily add wind/solar, partly to take advantage of federal incentives and partly to brand themselves as forward-looking. The recently introduced federal incentives under the Inflation Reduction Act are prompting nearly all utilities and energy companies in the US to incorporate significant renewable expansions in their plans for the late 2020s.

China's incentives, listed in Table 1, show a top-down strategy: using fixed tariffs and quotas to directly control outcomes. One distinguishing feature in China is that state-owned enterprises (which dominate the power sector) were essentially instructed and subsidized to build renewables. The strategic response here is less about individual firm marketing – since consumers have little choice of provider – and more about meeting government-set targets to gain favor and secure funding. Nonetheless, Chinese companies did innovate under this regime, for example by dramatically scaling up manufacturing capacity for solar panels and wind turbines to drive down costs, which in turn allowed the government to reduce feed-in tariff levels over time. By the early 2020s, China shifted to competitive bidding for new projects as the industry matured. Chinese firms, unlike Western ones, didn't need to market green power to end-users (who have no alternative supplier in most cases), but they did highlight their renewable build-out in corporate communications to signal alignment with national priorities and to access international capital (green bonds, etc.). Essentially, in China the incentives aligned corporate strategy with national strategy, making renewable expansion a patriotic and profitable endeavor backed by policy.

The situation in India involved several overlapping policies (Table 1). Initially, generous feed-in tariffs attracted many independent power producers and even foreign investors to India's wind and solar sector around 2010–2015. The strategy of firms like Suzlon (wind) or various solar project developers was to lock in long-term tariff contracts with state utilities. However, as some states began renegotiating contracts or delaying payments due to financial issues, it undermined confidence. The government's shift to auctions around 2017 led to record-low tariff bids, which while good for cost reduction, squeezed developer margins. Some firms, in a rush to win auction allocations, underbid and later struggled with project viability. This highlights an unintended consequence: fierce competition under auctions (an incentive mechanism) can lead firms to act strategically in ways that aren't always sustainable, such as relying on future equipment cost drops or government bailouts. The more successful strategic responses in India came from companies that diversified and integrated – for example, large conglomerates like Adani and Tata stepped into renewables, using their deep pockets to handle thin margins and their political clout to ensure projects reach completion. These firms leveraged government incentives as one piece of a broader strategy, bundling cheap solar with other services or using renewables to meet their own industrial needs.

The regression analysis provides additional support for the association between policy strength and renewable expansion. When policy intensity is used instead of a simple scheme count, the relationship remains positive and statistically significant. This does not prove causality, but it strengthens the argument that stronger and more credible incentives are systematically linked to larger renewable build-out than weaker and less reliable ones.

Table 2. New renewable capacity added (2015–2024) and policy intensity in selected countries.

Country	Renewable Capacity Added 2015–2024 (GW)	Policy Intensity Index (0–10)*
Germany	+66 GW (approx.)	8.5
USA	+220 GW (approx.)	7.5
China	+1240 GW (approx.)	9.0
India	+90 GW (approx.)	6.0
Russia	+10 GW (approx.)	2.0

Source: Computed from IRENA, policy databases, and the author's comparative scoring of incentive intensity.

The policy intensity index produces a clearer ranking than a simple policy count. China, Germany, and the United States score highest because their incentive systems combined meaningful economic support with implementation capacity. India's mid-range score reflects the coexistence of ambitious policy instruments and institutional bottlenecks. Russia's low score is consistent with its limited commitment to renewable transformation. The pattern reinforces the argument that what firms respond to is not policy volume alone, but the practical strength and credibility of the support environment.

China's 1240 GW addition dwarfs the others, reflecting not only strong incentives but also the country's vast electricity demand growth and centralized execution capacity. Germany and the United States, starting from smaller bases, still made substantial additions under comparatively high-intensity policy environments. India's added capacity, though significant in absolute terms (+90 GW), remained below its ambition, consistent with its middling policy-intensity score and implementation bottlenecks. Russia's negligible growth aligns with its weak support environment. These outcomes fit the broader literature: countries with stronger and more credible support systems tend to achieve faster renewable deployment, although the efficiency of each policy package still depends on institutional and market conditions.

To formalize this relationship, we ran an exploratory regression on a sample of 20 countries with renewable capacity growth per capita from 2015 to 2024 as the dependent variable. The explanatory variables were the policy intensity index, GDP per capita in 2015, and fossil-fuel share in 2015. Because policy adoption and renewable expansion may influence each other over time, the model should be interpreted as associational. Its value lies in showing that even after accounting for structural baseline differences, stronger policy environments still correlate with stronger renewable growth.

Table 3. Regression results – determinants of renewable capacity growth (2015–2024) across 20 countries.

Variable	Coefficient (β)	Significance
Policy intensity index	+10.8	$p < 0.01$
Intercept	-5.4	(n.s.)
GDP per capita (2015, \$1000s)	+0.15	(n.s.)
Fossil fuel share (% , 2015)	-0.32	$p < 0.05$
$R^2 = 0.68$, $N = 20$ countries.		

Note: The dependent variable is renewable capacity added per capita (watts/person). The policy intensity index aggregates financial attractiveness, implementation stability, and market coverage of renewable support measures. Coefficients significant at 99% and 95% confidence are indicated where relevant. The index should be interpreted as a structured comparative proxy, not as a perfect causal measure of policy strength.

The regression outcome supports the hypothesis that policy intensity has a positive and statistically significant association with renewable deployment. The result is more convincing than the earlier scheme-count approach because it recognizes that an additional minor instrument is not equivalent to a major long-term fiscal or pricing commitment. Substantively, the finding suggests that firms respond most strongly when incentives are deep enough to affect capital allocation, not merely when policy menus become longer.

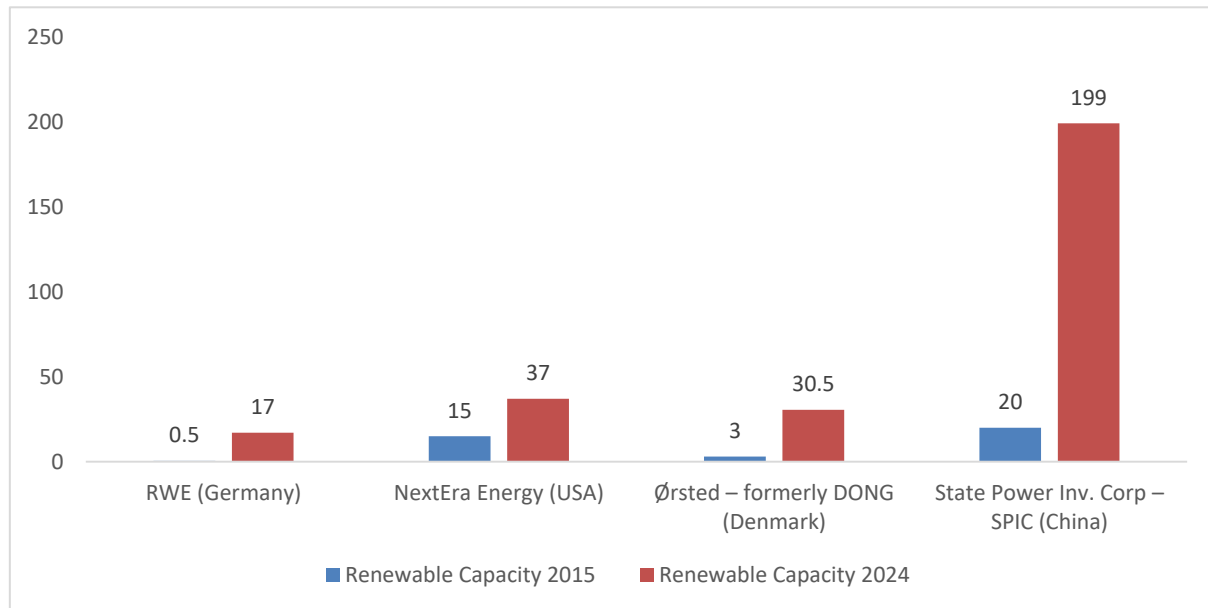
Interestingly, GDP per capita was not a decisive factor in this regression, once policy and initial energy mix were accounted for. This implies that even less wealthy countries can achieve strong renewables growth if they have the right policy incentives – a heartening implication for emerging economies. The negative coefficient on initial fossil fuel share (significant at $p < 0.05$) suggests that countries starting with very high fossil dependence tended to see smaller renewable increases, possibly due to entrenched industry interests or higher technical barriers. This highlights a classic challenge: incumbency and path-dependence can slow the transition, reinforcing why incentives often need to be coupled with other measures (like phasing out fossil subsidies or introducing carbon pricing) to shift the trajectory.

From a strategic perspective, the quantitative results imply that firms read policy environments as signals about the future profitability and legitimacy of green investment. Higher-intensity regimes create stronger expectations of market growth, encourage earlier portfolio shifts, and lower the perceived risk of building internal capabilities around renewables. This is precisely the mechanism expected in the conceptual framework introduced above.

Strategic Responses of Energy Firms. Government incentive schemes elicited four broad categories of strategic response: portfolio reallocation, market communication and branding, business model innovation, and regulatory positioning. Framing the evidence in this way makes the firm-level analysis more systematic and better aligned with the paper's theoretical ambition. It also allows the marketing dimension to be evaluated as one strategic pathway among others, rather than as a loosely descriptive add-on.

Investment and Portfolio Shifts: The most direct response to incentives is reallocating capital toward renewable energy projects. When policy support improves relative returns and reduces uncertainty, firms shift capital expenditure, acquire renewable developers, create specialized subsidiaries, and exit carbon-intensive assets. This pattern is visible across the selected firms, although the pace and depth of transition differ depending on national policy credibility and firm starting position.

Graph 2. Growth in renewable energy capacity for selected energy companies (2015 vs 2024).



Source: Company annual reports and industry data (2015–2025).

RWE, NextEra, Orsted, and SPIC illustrate the diversity of incentive-driven portfolio responses. In Germany, RWE's transformation was linked to a policy environment that made renewable revenues increasingly bankable. In the United States, NextEra turned federal tax credits and state-level contracting demand into a scalable development model. Orsted used long-term offshore wind support schemes to remake its corporate identity and asset base. SPIC responded to state-backed quotas and planning priorities by expanding at extraordinary scale. Across all four cases, incentives affected not only investment volume but also the internal organization of growth.

The companies in Table above exemplify how incentives have catalyzed rapid renewable energy expansion by firms. RWE, a German power company, effectively reinvented itself in the span of a decade. Germany's feed-in tariffs initially benefited new independent producers more than big utilities, and RWE was actually slow to embrace renewables in the 2000s. But around 2016–2018, facing pressure from both policy (nuclear phase-out, coal carbon costs) and market trends, RWE executed a major strategy shift: it transferred its conventional generation to a subsidiary and acquired the renewable assets of rival E.ON/Innogy. This was facilitated in part by the stable cash flows that German renewables offered under the EEG law's tariffs. Now with auctions, RWE continues to invest heavily – as noted, by 2024 RWE owned about 17 GW of renewables (RWE, 2025). This strategic pivot was directly influenced by Germany's incentive regime making renewables a safe bet. RWE's executives often cite that without the assured revenues from

policies, it would have been much harder to justify abandoning coal, but with them, renewables became the growth engine of the company.

In the United States, NextEra Energy represents a success story of a company riding the wave of incentives. As the parent of Florida Power & Light (a utility) and NextEra Energy Resources (a wholesale generation developer), NextEra leveraged the federal PTC and ITC to invest in wind farms and solar farms in dozens of states. They mastered the use of tax equity financing – essentially bringing in investors who could use the tax credits fully – and by doing so, NextEra could build more projects than its own balance sheet would allow. Over 2015–2024, NextEra more than doubled its renewable capacity (Cleanview, 2025). The firm's strategy has been to aggressively pursue long-term power purchase agreements (PPAs) with utilities and corporations for renewable energy, locking in customers who are themselves motivated by state RPS requirements or sustainability goals. This illustrates how incentives that apply at one level (e.g., state RPS obligating utilities) cascade into business for firms like NextEra, which market themselves as reliable partners to fulfill those needs. In marketing materials, NextEra often touts itself as the world's largest generator of wind and solar energy – a branding that resonates with investors looking for clean energy exposure. The stable policy environment for renewables (PTC/ITC were extended multiple times) gave NextEra confidence to invest tens of billions of dollars in capacity, shaping it into a predominantly renewable-energy company in terms of generation mix by 2024.

Ørsted in Denmark (formerly DONG Energy) is another striking case. DONG was once a conventional oil and gas producer and coal-burning utility. EU renewable energy directives and national policies in Denmark and the UK (two of its key markets) provided heavy support for offshore wind through tariffs and contracts for difference. Ørsted took a calculated strategic turn to focus on offshore wind, leveraging these incentives. It divested its oil & gas business and reinvested in wind farms, which were subsidized by governments willing to pay premium rates for clean power. By 2015, Ørsted had a few gigawatts of offshore wind (e.g., in the North Sea); by 2024, it had around 30 GW installed or under construction (Ørsted, 2024). This was made possible because the incentive schemes (often long-term fixed-price contracts) reduced revenue risk. Ørsted also became adept at marketing its image as a green energy leader, which helped its stock price and allowed it to raise capital for further expansion. It is now often cited as a model of an incumbent successfully transitioning under the right mix of incentives and vision.

In China, a slightly different scenario, State Power Investment Corporation (SPIC) – one of the big five state-owned power generators – massively increased its clean energy capacity from an estimated ~20 GW in 2015 to about 199 GW by 2025 (SPIC, 2025). This includes not just wind and solar, but also hydro and some nuclear, given China's definition of "clean energy." The driving force was clearly government targets and incentives, effectively mandates. SPIC and peers responded to central government quotas by pouring investment into renewables; not doing so would mean failing to meet government expectations. Their strategy wasn't about marketing to consumers (who are captive) but about aligning with policy to secure government approvals and funding. For example, SPIC might accelerate solar farm development in a province to ensure it meets the quota, even if short-term profits are slim, trusting that the state will allow cost recovery through regulated tariffs or subsidies. The outcome is a colossal build-out that no private company in a purely market-driven context would attempt so quickly. It reflects how under strong incentives (or directives), firm strategy can prioritize scale and political compliance over immediate financial return, a dynamic somewhat unique to China's system.

Besides these large firms, there are countless smaller renewable energy companies whose very existence and growth strategy are predicated on government incentives. Many solar installers, wind turbine manufacturers, and project developers formed in the 2010s to seize the opportunity created by incentives. These companies' strategy often involves specializing in navigating policy bureaucracy: knowing how to apply for feed-in tariff contracts, interconnection queue management, or maximizing grant usage. In countries like Germany, thousands of small and medium enterprises emerged in the renewable sector (engineering firms, installers, etc.), essentially an ecosystem fostered by the guaranteed market the government created. In marketing themselves, they often emphasize credentials like being approved under certain subsidy schemes or their experience with regulatory compliance, which is a selling point to customers who want a hassle-free way to benefit from government programs.

Marketing and Branding: The evidence shows that the marketing component is strongest where firms interact directly with customers, investors, or competitive stakeholders. Incentives create usable marketing content by lowering end-user costs, improving the visibility of green products, and giving firms credible policy-backed claims about future clean-energy expansion. In retail and investor-facing markets, companies translated incentives into communication strategies built around affordability, sustainability, and long-term reliability.

Three marketing patterns stand out. First, firms used price-framing, emphasizing rebates, tax credits, premium payments, or lower lifetime electricity bills. Second, they used legitimacy-framing, presenting themselves as aligned with national climate goals and policy priorities. Third, they used investor-relations framing, highlighting renewable pipelines, certified green revenues, and alignment with ESG-oriented capital. These communication strategies were not peripheral; they helped firms convert policy support into customer acquisition, investor confidence, and reputational advantage.

The form of marketing varied by market structure. In competitive retail settings such as parts of the United States, installers and utilities used incentives in direct consumer messaging, for example by advertising the reduced net cost of rooftop solar or the value of net metering. In more centralized systems such as China, communication was directed less to households and more to regulators, lenders, and capital markets. European incumbents often focused on corporate rebranding and public legitimacy, linking their renewable investment narratives to broader sustainability commitments. This variation resolves the apparent tension in the title: green energy marketing is present, but it operates through different audiences and channels across policy regimes.

At the same time, the analysis indicates that marketing effects are most credible when backed by substantive strategic change. Firms that combined visible renewable investment, organizational restructuring, and transparent communication gained stronger legitimacy than firms whose marketing claims outpaced their operational transformation. This distinction helps separate genuine strategy from greenwashing and shows why incentives can generate both authentic and symbolic responses.

Innovation and Business Model Adjustments: Incentives also stimulated innovation in technology, organizational practice, and revenue models. Firms developed leasing models, distributed-energy services, storage integration, and new partnership structures in order to monetize policy support more effectively. In several markets, policy did not just increase renewable deployment; it changed how firms defined the product they sold, shifting from commodity electricity toward integrated low-carbon energy solutions.

A salient strategic innovation is the emergence of energy-as-a-service models. With many incentives supporting distributed energy (rooftop solar, batteries, EV charging), some firms chose to not just sell equipment but sell services: leasing solar panels (the company retains ownership to capture tax credits and sells the power or savings to the homeowner), or offering “solar PPAs” to households where the rate is fixed below utility price thanks to net metering credits. These models were pioneered by firms like SolarCity (USA) and have been replicated elsewhere. They rely on policy mechanisms (tax credits, net metering) to be viable. The firms essentially built an entire business around making it easy for customers to utilize incentives without upfront cost – a clever response that unlocked a segment of consumers who would not otherwise invest in renewable technology.

Another example is how some utilities have transformed their generation business model. Traditionally, utilities earned returns on capital investments like power plants via regulated rates. With incentives and mandates for renewables, utilities in many regions started to invest heavily in renewables and rate-base those investments (ensuring a return). In places like the USA, even vertically integrated utilities in the Southeast (not originally subject to RPS) have proposed large solar builds because they know regulators will approve them to meet anticipated federal or investor demands. Their long-term strategy now includes significant renewable ownership, which was not the case before these incentives and societal pressures existed.

In markets with high renewable penetration due to incentives, companies also had to innovate operationally. For example, energy firms in Germany and California had to develop advanced forecasting and balancing techniques to handle the variability introduced by so much wind and solar. Some utilities started offering new products like battery storage integration for customers, or time-of-use rates to encourage demand shifting – indirectly prompted by the need to manage incentive-driven renewable intermittency. These can be seen as strategic adaptations ensuring reliability and profitability in a grid dominated by incentivized renewables.

There are also defensive and political responses. Firms with major fossil-fuel exposure sometimes sought to slow, reshape, or selectively absorb the transition by lobbying against certain incentive designs, contesting net-metering rules, or advocating compensatory support for legacy assets. Including these responses in the framework is important because it shows that incentive schemes do not simply trigger linear adaptation; they also reorganize bargaining power and strategic contestation within the sector.

The discussion yields several insights. First, government incentives redirect corporate strategy not only by improving project economics but also by changing what is perceived as legitimate, scalable, and investable. The combined evidence from country trends and firm cases suggests that incentives matter most when they alter both the financial and strategic horizon of firms. This gives the paper a stronger theoretical contribution than a simple confirmation that policy affects behavior.

Second, specific incentive types generate different strategic pathways. Feed-in tariffs and long-term contracts reduce revenue uncertainty and are especially conducive to early portfolio expansion. Auctions intensify cost competition and encourage scale, operational discipline, and selective consolidation. Tax incentives encourage financial structuring and partnership models that can mobilize outside capital. These differences show that policy design shapes not only deployment levels but also the organizational form of corporate adaptation.

Third, the marketing dimension should be understood as an endogenous part of strategic response rather than as a separate communications issue. Firms do not merely advertise after

investment decisions are made; they use policy-enabled narratives to attract customers, reassure investors, build legitimacy, and differentiate themselves in increasingly green-sensitive markets. The empirical evidence in this paper is still interpretive rather than content-analytic, but it is sufficient to show that marketing is a recurring and strategically meaningful response pathway.

Fourth, the durability of corporate transformation depends on whether incentives create lasting capabilities and business logic. In firms such as Orsted and NextEra, renewable expansion became embedded in long-term strategy. In other settings, support generated shorter-term or more opportunistic behavior. The implication is that policy success should be assessed not only by megawatts installed, but by whether firms internalize green growth as a durable strategic orientation.

From a theoretical standpoint, the findings extend work on environmental regulation and corporate strategy by showing that incentives operate through a combination of repricing, legitimation, and capability formation. This complements the greening Goliaths versus emerging Davids perspective by clarifying when incumbents move from defensive delay to strategic repositioning. The paper therefore contributes a mid-range analytical framework that connects policy design to distinct categories of firm response.

The study also reinforces the importance of policy credibility. Firms evaluate not just the generosity of current incentives but the probability that those incentives, or their functional equivalents, will remain in place long enough to justify organizational commitment. Stable policy regimes support deeper transformation; volatile regimes encourage caution, short-termism, or symbolic compliance. This insight has direct implications for policymakers seeking not only deployment, but genuine strategic transition within the energy sector.

CONCLUSION

Government incentive schemes for green energy have proven to be major catalysts of renewable deployment and strategic change in the energy industry. Using a revised conceptual framework and a more nuanced empirical design, this paper examined how incentives shape firm behavior through economic repricing, strategic legitimation, and capability formation across the period 2015-2024. Several conclusions follow.

1. Policy strength matters more than policy count - Countries with stronger, more stable, and broader incentive environments achieved larger renewable expansion than countries with weaker support. Replacing a simple scheme count with a policy intensity index improves the interpretation of the quantitative evidence and better captures the real strategic signal facing firms.
2. Firm responses follow identifiable strategic pathways - The evidence is best understood through four recurring pathways: portfolio reallocation, market communication and branding, business model innovation, and regulatory positioning. This gives the paper a clearer theoretical contribution by specifying how incentives are translated into corporate action rather than merely observing that a relationship exists.
3. Green energy marketing is real but context dependent - The marketing dimension is strongest in settings where firms compete for customers, investors, or reputational legitimacy. Incentives provide content for price-based, legitimacy-based, and investor-oriented communication, but the form and intensity of marketing vary across liberalized, coordinated, and state-led energy systems.

4. Policy credibility determines the depth of strategic change - Firms undertake deeper organizational transformation when support mechanisms are credible over time. Where policy is unstable or inconsistently implemented, firms are more likely to adopt narrow, opportunistic, or symbolic responses. This helps explain why similar policy instruments can yield different market outcomes across countries.
5. The paper's contribution is analytical rather than causal - The study offers a structured explanation of recurrent patterns linking incentive design to firm strategy, but it does not claim definitive causal identification. The regression is exploratory, the policy intensity index remains a comparative proxy, and the marketing evidence is based on structured case interpretation rather than large-scale content analysis. Being explicit about these limits strengthens the credibility of the findings.
6. Implications for policy and management - Policymakers should prioritize not only the introduction of incentives but also their durability, enforceability, and strategic coherence. Energy firms, meanwhile, benefit most when they treat incentives as a window for capability building and credible repositioning rather than as temporary subsidy opportunities. The strongest competitive gains appear where firms combine investment, organizational change, and believable green communication.

In conclusion, government incentives do more than stimulate additional renewable capacity. They reshape the strategic field of the energy sector by influencing which investments look profitable, which business models appear viable, and which corporate narratives gain legitimacy. When designed credibly and implemented consistently, incentive schemes can align private strategy with public climate goals. When weak or unstable, they generate only partial adaptation. That distinction is central to understanding both the promise and the limits of incentive-led green transition.

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THE 8S METHODOLOGY IN QUALITY MANAGEMENT

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ARTICLE INFO	ABSTRACT
<i>Article history:</i> Received:2025-06-27 Received in revised form2025-07-13 Accepted:2025-08-15 Available online:2026-06-26 <i>Keywords:</i> Toyota Production System (TPS), 8S, Kaizen, Just-in-Time (JIT). <i>JEL classification</i> L15, M11, L23	<i>In modern manufacturing The Quality improvement methods and techniques have been investigated in different fields of manufacturing during the last decades. The Quality in Manufacturing areas are some of the key differentiators between competing entities in the business environment and the marketplace. Therefore, improving quality in production or services standards is the one of the main aim companies. The companies applied the Kaizen system for continues improvement. The KAIZEN process aims at continuous improvement of processes not only in manufacturing sector but all other departments as well. Implementing Kaizen tools is not the responsibility of a single individual but involves every member who is directly associated with the organization. The 8S methodology in quality management focuses on organizing and maintaining a clean and efficient workspace to enhance productivity and efficiency, reduce waste and quality cost. The Application of 8S principles has also positive impact for protection of Environment by reducing waste in production.</i>

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1. INTRODUCTION

The purpose of the study – In modern manufacturing, by applying the quality control and improvement techniques such as 8S, enterprises are to achieve maximum efficiency with minimum waste and continuous improvement of the quality of products and services and also without harming the environment, human health and safety. The research aim of the study was to assess the application of 8S tool, to investigate its application in a manufacturing management and to achieve a culture of a clean, safe, productive environment, quality improvement, elimination of wastes, minimizing of total cost, enhancement of equipment production performance, to increase the quality and elimination of cost of quality. 8S will assist the organization to actively detect potential equipment failures before it can occur and assist in the reduction of product defects and improve total quality. Application of new 8S methods in manufacturing are the one part of Total Quality Management.

1.1 Objectives of the study

The two objectives of the research are as follows:

1. To study all steps of 8S and introduce the new 8S technique to identify cost of quality in quality control.

2. To calculate Total Quality Cost, assess poor product quality costs and identify the root causes of costs.

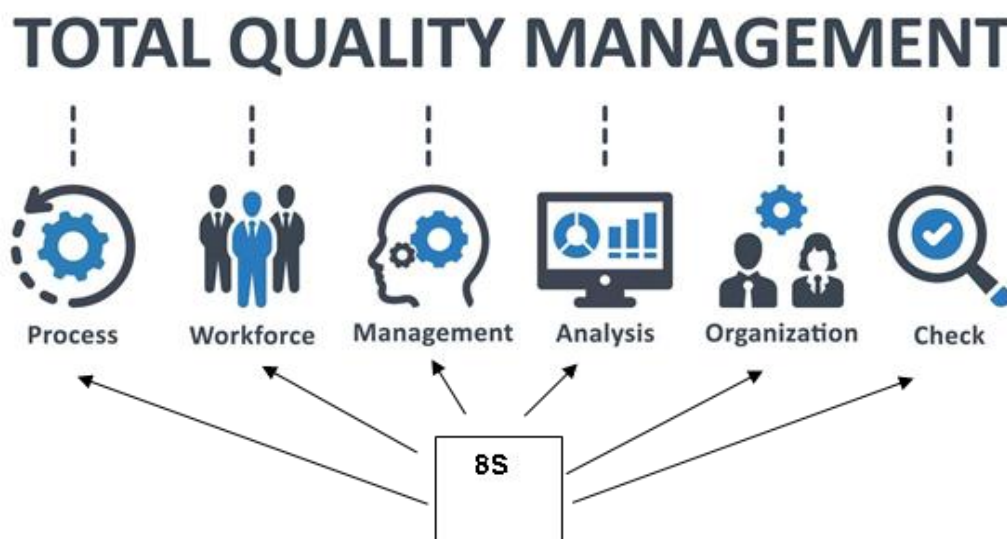
The applied significance of the study – Definition and Reducing of cost of quality, improving quality and enhancement of equipment production performance.

Scientific innovation of the research – The definition and calculation of all quality cost by application of 8S methodologies leading to reducing of production cost and minimizing wastes and enhancement of equipment production performance.

One of the most important aspects in manufacturing is the minimization of defects, elimination of costs, reducing injuries, improving productivity, efficiency and the perseverance of quality in the involved processes and products [11].

The latest 8S indicates the quality assurance which can be defined as part of the quality management focusing more on the proactive activities implemented towards providing confidence that a product or service will fulfil requirements for quality. The first main case for quality control is the consideration of raw materials quality prior entering it to production process. Thus, quality control can be considered as a subset of quality assurance which is also a subset of quality management in general (Figure 1). Finally, quality inspection is part of quality control focusing on the actual inspection techniques which are being carried out either during the processes or most commonly when the product is already finished in order to evaluate its quality.

Figure 1. Relationships between process, management, workforce, analysis, organization, checking with 8S.



The 8S - standardization refers to standardize all process in management system including all department activities. Lean manufacturing which one part of quality improvement, originally developed by Toyota to minimize waste and optimize processes, has evolved significantly with technological integration and the demands of contemporary industrial environments. The 8 S is one of the main aspect of Lean manufacturing. The lean principles, indicates such as waste reduction, continuous improvement, and value maximization, followed by a discussion of widely used lean practices like 8S, Kaizen, Just-in-Time (JIT), and Kanban's.

Today, quality control is more than just a checkpoint. It serves as the backbone of operational excellence and is integral to maintaining competitive advantage. The implications of quality control in modern manufacturing include:

Enhanced Product quality: Consistent quality control processes result in products that meet customer expectations, thereby reducing returns and bolstering brand loyalty.

- **Total Cost Reduction:** By catching defects early such like raw materials, auxiliary materials, spare parts, companies can avoid the extensive costs incurred from rework or product recalls.
- **Production Process Optimization:** Continuous monitoring and adjustments lead to refined production processes which boost overall efficiency and productivity.
- **Regulatory Compliance:** Meeting international and local quality standards is essential for both market access and customer trust.

2. THE STEPS OF THE 8S METHODOLOGY (EIGHT S)

1S (Sort)

It is the first step of the 8S approach, in which the organization needs to retain what is needed and eliminate unwanted materials from the workplace. To remove unused hand tools, raw materials, auxiliary materials mainly expired chemicals materials, spare parts, any damaged and unusable equipment and any other parts.

2S (Set in order)

This second step is to set items in order, to improve the flow of work and easily identify tools and materials. The objective of this step is to arrange the work in an orderly way and to encourage the use of visual aids to reduce the time spent searching for items.

3S (Shine)

Once the unwanted or unused tools, raw materials, spare parts have been removed and the workplace has been set in order, the next step is to tidy and clean up the production, storage and all related places, machine, tools, spare parts. This step includes eliminating all forms of dirt, contamination, and untidiness from the workplace.

4S (Standardize)

1. To obtain, prepare and continuously improve the manual, site operation procedures, testing a commissioning procedures, Maintenance procedures, Health, Safety and Environment Procedures, instructions, strategy, plans, related drawings, strategy for company goals.
2. Standardize the product and service quality parameters and continuously improve it based on people health, safety and protection of environment.

5S (Sustain)

In order for an organization to ensure an effective culture of neat and tidy workplace, it should intermittently monitor performance to identify deviations. This would help to put measures in place that ensure that progress is sustained. customer satisfaction and for all organization activities.

6S (Safety)

1. Personnel safety and 2. Process safety 3. Environmental safety

The safety is a tool for effective safety management, including the prevention of hazards, fatal accidents, injuries, and deaths.

7 (Spirit as the seventh 'S')

The impact of organizational culture and the crucial element of respect for employees, choosing to include 'spirit or morale or rising desire on each employee' as the seventh step of the methodology highlights support for the people factor in the workplace.

8S (Save of Quality Cost 'SQC')

The application of KAIZEN in manufacturing for improvement of product and service quality cause increased cost of quality. So by application of Six Sigma DPO (Defect per opportunity) companies can analyses and decrease the cost of quality. First old data analysis related with poor quality and then analyzing of source of poor quality based on each defect opportunity the cost of quality is going to be decreased.

3. THE COST OF QUALITY.

28 years later in 2022, a Gartner survey revealed that one out of every three companies do not use *any* emerging technologies to manage their cost of quality (First Production Quality Cost Slope). Only 18% were using an QMS, one of the prime enablers of a culture of quality [2]. The cost for first production cost covering first natural quality cost of product.

In modern business the aim is achieving the optimal balance between quality and cost is a major challenge, and this balance is called the quality-cost trade-off problem. So below is given the Slope of First production cost PCS. The PCS has the first quality change on each product. The formula for Production Cost Slope is PCS_{ij}:

$$PCS_{ij} = \frac{\Delta CPQ_{ij}}{\Delta PCQ_{ij}} \quad (1)$$

ΔCPQ_{ij} – Cost of First Production Quality, $\sum (\Delta PCQ_{ij})$ – First Production changes of Quality,

The second quality slope indicates the periodical changes on product quality such us adding chemicals, increase of sampling and analyzing, staff trainings, improvement of preventive maintenance, application of modern technologies, improvement of working conditions, delivery of raw materials with high quality and another one. So the second formula indicates changes on quality. The formula for Cost Slope of Improved Quality is IQCS_{ij}:

$$IQCS_{ij} = \frac{\Delta CIQ_{ij}}{\Delta QIC_{ij}} \quad (2)$$

ΔCIQ_{ij} – Cost of Improved Quality, ΔQIC_{ij} – Quality Improvement Changes,



Figure 2. Slope of quality changes and improvement

Company produces 500mm diameter, wall thickness 2mm piping with 6-meter length. The one 6 meter piping without painting has the cost 50\$. This is the ΔCPQ_{ij} – Cost of First Production Quality, ΔPQ_{ij} – First Production changes of Quality is 5 (using welding rod, coal, cutting disc, purification, using cooling oil, using knife). But after requirement from customer the quality changes for pipe quality improvement are required and new coal, and new knife were used instead of old ones. So ΔCPQ_{ij} increased to 80\$ and ΔPQ_{ij} increased to 7. This is the practical application.

Six Sigma allows you to figure out the cost of quality by estimating the following [11]:

The cost of production of the wasted original product, the cost of the recall, Scrapping or rework, Additional work done to rectify the original product, the resultant cost of the recall, the cost of manpower working with the product before, during and after the recall, the cost of losing business, Bad publicity, their impact on stock price and The delay in working on another product or another feature for the same product.

Here are some of the main points to remember:

- cost of quality is not the cost of producing a quality product or service, but the cost of not doing so. It includes all the costs associated with preventing, detecting, and correcting defects and errors in the processes and outputs of an organization.
- Cost of quality can be used as a strategic tool to measure, monitor, and improve the quality performance and customer satisfaction of an organization. It can also help identify the root causes of quality problems and prioritize improvement actions. [7]
- Cost of quality (Natural Cost Slope) can be calculated by adding up the four categories of quality costs: prevention costs, appraisal costs, internal failure costs, and external failure costs.

Additionally, the cost of quality can be represented by the sum of two factors: the cost of good quality and the cost of poor quality equates to the cost of quality — as shown in the equation below:

Mathematically:

Cost of Quality (CoQ) = Cost of Good Quality (COGQ) + Cost of Poor Quality (COPQ)

1. **COGQ = Prevention Cost (PC) + Appraisal Cost (AC)**
2. **COPQ = Internal Failures Cost (IFC) + External Failures Cost (EFC)**

The final formula is:

$$3. \quad \text{COQ} = \text{COGQ} + \text{COPQ} = (\text{PC} + \text{AC}) + (\text{IFC} + \text{EFC})$$

Understanding and optimizing CoQ can help businesses reduce waste, improve efficiency, and enhance profitability.

The cost of good quality is represented as CoGQ, The cost of poor quality is represented as CoPQ, The prevention cost is represented as a PC, AC represents the appraisal costs, IFC represents the internal failure costs and EFC represents the external failure costs.

4. CLASSIFICATION OF COST OF POOR QUALITY

The cost of poor quality (COPQ) refers to the costs of providing poor quality products or services. The cost of poor quality is divided into three categories:

1. **Appraisal costs** incurred to ascertain the degree of conformance to quality requirements.
2. **Internal failure costs** related to defects found before the customer receives the product or service.
3. **External failure costs** associated with defects found after the customer receives the product or service.

Furthermore, quality-related activities that incur costs may be divided into prevention, appraisal, and internal and external failure costs [11]. According to Gartner [2], an astounding 46% of a company's cost of quality is actually the cost of *poor* quality—the failures spotted onsite (internal failures) and by the customer (external failures).

3. Prevention Cost

PC - Prevention Costs are expenditures made intentionally to keep defects from occurring in the first place, preceding the actual production cycle. There's more to prevention "costs" than many realize. To understand what they are—and what exactly they prevent—we need to turn to quality guru Armand Feigenbaum's idea of the "hidden factory". According to Feigenbaum (who developed the Total Cost of Quality formula that captures the costs of good and bad quality), every factory has an evil parasitic twin. The activities classified under prevention costs share the goal of defect avoidance before a production run begins. The prevention activities are: Quality Training for Employees, Supplier Quality Assurance, Investment in Process Capability, The acquisition of Robust Equipment Design, Preventative Maintenance Programs and Quality Data Analysis and Reporting Systems.

Prevention Costs = (Number of potential problems x Cost to fix each problem) x (Probability of each problem occurring)

4.1. Types of Preventive Costs

As in project management, preventive measures are often taken in order to avoid cost overruns, schedule delays, and other potential problems. Some examples of preventive costs to avoid internal failure costs in project management include: **Hiring a Project Manager: Risk Assessment, Staff Training, Upkeep Costs and Ongoing Costs.**

Prevention costs can be difficult to calculate, but they are an important part of any project management budget. By including prevention costs in your budget, you can help ensure your project stays on track and that potential problems are identified early and dealt with before they escalate into costly rework or delays.

4.1.2 Strategy for Reducing of prevention cost

Prevention costs are those that are incurred to keep the project on track and avoid problems. They are often seen as necessary evils, but they don't have to be. By taking a few simple steps, you can reduce the prevention costs in your project and improve your bottom line.

1. Allocate Competent Resources

Allocate competent resources during the project initiation phase. This ensures that you have the right people working on the project from the start and that they are familiar with the project's goals and objectives.

2. Track Spending

Track forecasted vs. actual spending to control project costs. This helps you to identify areas where you are overspending and makes it easier to adjust your budget accordingly.

3. Use Job Strategy

You can boost productivity through a job rotation strategy. This involves rotating employees through different tasks so that they are better able to understand the project as a whole and identify potential problems. By taking these steps, you can reduce the prevention costs in your project and improve your bottom line.

4.2. Appraisal Cost

AC - Appraisal Costs involve the expense of inspecting, testing, and auditing products or processes to ensure conformance to specifications. These costs are incurred during the production process to identify defects. Appraisal costs are a specific category of quality control costs. Companies pay appraisal costs as part of the quality control process to ensure that their products and services meet customer expectations and regulatory requirements. These costs could include expenses for field tests and inspections. A classic appraisal cost would be what is spent to inspect materials delivered from suppliers. For example, let's say a music retailer gets a shipment of guitars from a major manufacturer.

Other examples of appraisal costs include:

Inspecting work-in-process materials, inspecting finished goods, the supplies used to conduct inspections, the inventory destroyed as part of the testing process, Supervision of the inspection staff, Depreciation of test equipment and software, Maintenance of any test equipment and

Appraisal cost include below ones:

Inspection of Incoming Materials, In-Process Testing and Monitoring and Final Audits and Equipment Maintenance

4.2.1 Strategies to Reduce Appraisal Costs

1. Implement Quality Management Systems (QMS)

Automation and Data Analysis: Leverage data analytics to identify trends and areas for improvement, minimizing unnecessary inspections.

2. Improve Training and Processes

Employee Training and Standard Operating Procedures (SOPs): Develop clear SOPs to streamline inspection processes and reduce time spent on evaluations.

3. Optimize Supplier Relationships

- **Supplier Audits and Partnerships:** Build strong relationships with suppliers to foster a culture of quality, which can lead to fewer defects.

4.3. Internal Failure Costs

IFC - Internal Failure Costs arise when a product or service fails to meet quality standards before it is delivered to the customer, such as the expense associated with scrap or rework. Internal failure cost refers to a type of cost of quality related to product failures discovered by an organization before any product leaves the manufacturing unit or factory. Determining such costs helps companies understand the extent to which the manufactured products meet the set quality standards. Given below is a list of such costs that businesses must be able to monitor:

- 1. Rework and Rectification,**
- 2. Wasted Resources,**
- 3. Delayed Deliveries,**
- 4. Increased Inspection Costs,**
- 5. Loss of Employee Morale,**
- 6. Opportunity Costs,**
- 7. Scrap,**
- 8. Failure Analysis,**
- 9. Supplier Side Cost,**
- 10. Retesting and**
- 11. Modifying Process:**

Example: The company spends \$80,000 on rework, \$50,000 on scrap, \$20,000 on retesting, and \$30,000 on downtime. The total internal failure costs are \$180,000.

4.3.1 Identifying Common Sources of Internal Failures

Identifying the common sources of these failures is not just a reactive measure; it's a proactive strategy that can save considerable time and resources. By understanding where and how these breakdowns typically occur, organizations can implement targeted improvements that bolster their bottom line and elevate their market position. Here's an in-depth look at common sources of internal failures:

1. Insufficient training of workers. Poor responsibilities,
2. If required eliminate the night shift activities for final product packaging,
3. Poor morale of employees, and lack of personnel and equipment performance assessment,
4. The lack of application of Modern Supply Chain Management,
5. Ineffective and inefficient quality control processes
6. Poor product design
7. Lack of standardization of processes such as product standards and lack of strategy, plans and procedures,
8. Poor supplier quality, Equipment Failure, Lack of Communication, Insufficient Resources and Unclear Objectives and Goals

4.3.2 Strategies to Reduce Internal Failure Costs

Implementing effective strategies can help minimize internal failure costs. Here are some key approaches:

1.Process Optimization

2.Standardization: Establish clear procedures to reduce variability in production.

3.Preventive Maintenance: Regularly maintain equipment to prevent breakdowns.

4.Quality Management Systems (QMS) 1. Training: 2. Data analysis: 3. Periodical performance assessment.

5.Continuous Improvement. Lean Management and Feedback Loops: Create systems for continuous feedback to identify and address issues promptly.

4.4. External Failure cost

EFC - External Failure Costs occur when a product defect is discovered after the item has been shipped to the customer. These external costs include warranty claims, product recalls, liability costs, and damage to brand reputation. An External Failure Cost is an expense incurred when customers discover defects in the product or service once it is delivered to them. It highlights the financial impact of post-delivery quality issues for businesses to address and minimize such occurrences. The transparency of customer behavioral against product and service quality must be analyzed in today modern environment where we have climate changes, consciously changed and improved technology, and political and geopolitical changes.

4.4.1 Strategies to Reduce External Failure Costs

To minimize external failure costs, companies can implement several strategies:

1. Improve Quality Control: Regular Inspections and Quality Audits to conduct to ensure compliance with quality standards.
2. Enhance Training and Development: Employee Training and Process Improvement: Encourage a culture of continuous improvement to enhance product quality.
3. Utilize Customer Feedback: Voice of the Customer: Actively seek and analyze customer feedback to identify areas for improvement and Responsive Adjustments: Make necessary adjustments based on customer insights to prevent future issues.
4. Implement Quality Management Systems (QMS): Automated Tracking: Use QMS software to monitor quality metrics and identify trends in defects. Data Analysis: Analyze quality data to pinpoint recurring issues and address root causes.

Additional activities to Reduce Total Cost of quality

- Identifying the systemic issues beforehand and take early corrective measures so that not much expense is made to deal with it at a later stage.
- In case entities plan to implement a change, they must consider change management tools to understand the repercussions of bringing about that change. These tools help figure out if the transition would be smooth or involve rough transformation for which the entities may have to remain prepared beforehand.
- Identifying operational errors and making sure they do not occur at a later stage. This is because such errors involve huge damage control cost, thereby making it a huge expense for the firms. Conducting training programs help entities have professionals who can identify and prevent such errors.

- Implementing various risk management techniques to avoid errors at advanced stages. To achieve this, the entities can ensure thorough audit management, proper financial reporting, and compliance with regulatory requirements.
- Enhancing or setting standards for suppliers' quality is an essential step that one may take to reduce quality costs. Specifying benchmark performance and enhancing communication with the supplier is a must to make sure they are providing standard quality supplies based on the quality standards that a firm ensures for its finished products.
- Process standardization. The first step in reducing quality costs is standardizing your processes.

IMPORTANCE

The determination of the cost of quality remains to be critical and varies for different organizations. If this cost is not measured and quantified, the organizations working in the competitive industries would never gain the upper hand and survive the ever-changing dynamic environment. Therefore, measuring it is necessary as it helps the business maintain a healthy and positive bottom line.

Some of the advantages of incurring the cost of quality include:

- It helps the organization to chalk out wrong and poor-quality output.
- It helps in problem-solving, wherein it performs cost and benefits analysis on quality and process improvement initiatives.
- The model or cost of quality helps in a single-point evaluation of quality performance.
- It further evaluates the costs of failures and appraises them accordingly.

Example: In manufacturing company for Total Quality costs:

Total Quality Activity	Monthly Cost
Training Programs	\$6,000
Supplier Audits	\$4,000
In-Process Inspections	\$5,000
Scrap & Rework	\$18,000(Previously the cost were \$ 22,000)
Customer Warranty Claims	\$8,000
Audit Prep Time	\$2,500
Manual Documentation	\$3,500
Equipment Downtime	\$10,000 (Previously the cost were \$14,000)
Service activities	\$2,000
<u>Total Cost of Quality</u>	<u>\$59,000</u>

CONCLUSION.

With ever increasingly evolving business environment, intensified awareness and concerns of Health, Safety and work environmental issues, additionally the lack of raw materials and spare parts, geopolitical and economic issues have prompted organizations to use various efficiency improvement tools. It is clear that one of the lean methodology tools does have significant positive impacts on organizations performance when effectively implemented. The new Lean 8S Methodology can have positive outcome the organization performance. It is noticeable that the goal of 8S function is broad and diverse. When successfully applied, the work environment improves reduce waste in different forms, organize work areas, promotes hygiene as well as

team cohesion, the complete gains of 8S cannot be envisioned in firms, if the obstructions related, completely understood, addressed and removed. The lean 8S methodology has become the base for any lean method to be applied for quality improvement and reducing total production cost. 8S methodology is a continuous improvement tool for increase total quality and should be constantly monitored and evaluated.

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BANK PERFORMANCE DURING AND AFTER THE COVID-19 PANDEMIC: EVIDENCE FROM THE AZERBAIJANI BANKING SECTOR

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ARTICLE INFO	ABSTRACT
Article history: Received:2025-09-05 Received in revised form:2025-09-11 Accepted:2025-10-18 Available online:2026-06-26 Keywords: ROA; ROE; COVID-19; Banking; Profitability JEL classification G21, G01, G32, I18	<i>This article examines the financial performance of Azerbaijani banks over the period 2019–2024 that corresponds to the COVID-19 pandemic and thereafter. The paper examines the volatility of profitability, credit risk, and post-pandemic recovery dynamics using profitability ratios including Return on Assets (ROA), Return on Equity (ROE), and the Loan Loss Provisions to Total Loans (LLP/Total Loans). It appears that during 2020-2021, there was a significant drop in performance indicators. In that period, ROA, ROE ratios deteriorated, while LLP/Total Loans ratio increased remarkably, due to higher provisions deriving from higher credit risk and precautionary provisioning.</i> <i>The results show that the indicators vary across banks depending on the sensitivity to shocks, risk-exposure and asset quality. Beginning from 2022, profitability figures improved, provisions decreased, credit risk dropped back to normal levels and asset quality improved.</i> <i>By 2023-2024, positive and stable performance was observed in most banks, due to improved borrower creditworthiness and macroeconomic stability.</i>

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1. INTRODUCTION

The COVID-19 pandemic was one of the history's global occasions that brought substantial changes in all areas, as well as global financial system. Due to increased macroeconomic instability, credit risk, and liquidity pressures, banking sector was also exposed to crisis. Assessing the performance of banks is essential as they are of high importance in the maintenance of economic stability.

In 2020, Azerbaijan experienced a dual crisis deriving from both pandemic and global volatility. We analysed the profitability changes and credit-risk trends of Azerbaijani banks for the pandemic and post pandemic periods that correspond to the years of 2020-2021 and 2022-2024 respectively. The analyses were conducted with key profitability ratios: Return on Assets (ROA), Return on Equity (ROE), and the Loan Loss Provisions to Total Loans (LLP/Total Loans) ratio.

ROA demonstrates how much net income does one dollar of asset brings, shortly, asset utilization, while ROE measures how much net income does one dollar of shareholder capital brings in. The LLP to Total Loans ratio reflects the proportion of loss provisions in the total loans, so it provides insight into risk management of banks during uncertain periods.

During 2020-2021, uncertainty and diminished payment capacity of customers led to lower profitability and higher provisioning. These indicators became promising beginning from 2022, due to normalized credit activity and improvements in macroeconomic conditions.

The topic of this paper has high importance nowadays and contributes to the literature on banking performance in emerging markets with ratio-based analysis during shock periods.

2. LITERATURE REVIEW

In the literature, profitability indicators are used to assess efficiency and financial situation of banks. During the pandemic, research on banking suggests that main profitability indicators exhibited visible volatility. Elnahass et al. (2021) states that the pandemic crises affected banking sector profitability and stability negatively across many countries. Other studies also come to the same conclusion that higher credit risk and provisioning caused downward movement of profits during pandemic. The studies also showed that, due to government support and improved economic conditions, many banking systems began to recover in the following years.

The pandemic effect in emerging economies was talked more than developed economies as those countries have less financial diversification and the sector is more vulnerable. The research by Naceur Ben Naceur and Mohamed Goaied states that in emerging banking systems the profitability is highly correlated with asset quality, capital strength and macroeconomic conditions.

Eugene F. Brigham and Joel F. Houston demonstrate that with the help of profitability ratios raw financial statements data can be transformed into meaningful indicators.

Lawrence J. Gitman and Chad J. Zutter emphasize that investors and analysts compare companies using ratio analysis across time and within industries by standardizing financial information.

Mahir Karimli (2023), in his study analyses the **profitability performance of major Azerbaijani banks** focusing on financial indicators including **ROA, ROE, and net profit margins**. According to the results, diversified income and strong capitalization and sources positively influence profitability.

Fariz Hasanov, Nigar Bayramli, & Ahmed Nayef (2018), using econometric analysis studied the **determinants of bank profitability in Azerbaijan**. With the help of ROA and ROE, the study shows that **capitalization and cost efficiency positively influence profitability**, while **higher loan loss provisions and credit risk reduce bank performance**. The study provides important insights into the structural characteristics of the Azerbaijani banking sector.

3. METHODOLOGY

A quantitative, descriptive and comparative research has been conducted to assess financial performance and asset quality of the Azerbaijani banks during 2019-2024. This period covers pre-pandemic period, pandemic and recovery stage.

Financial ratio evaluation rather than econometric modelling has been applied to, focusing on trend analysis, and convergence patterns over time.

The sample is eight selected commercial banks, and they are chosen based on their size and continuity of operations. The data were annual, officially confirmed bank statements that are disclosed and published to the public by the banks and regulatory publications by the Central Bank of Azerbaijan.

In the research, three main financial indicators have been employed: ROA (Return on Assets), which measures how effectively bank utilizes their asset to earn profits; ROE (Return on Equity) which reflects shareholder profitability and LLP/Total Loans (Loan Loss Provisions to Total Loans) which is a proxy for possible credit losses and asset quality.

The following techniques have been applying here in the study: trend analysis, comparative analysis, crisis-phase comparison, and convergence analysis.

This study does not demonstrate intra-year volatility, as it relies on ratio analysis, and it does not implement econometric models. That's why our findings are not casual, but interpretative.

4. BANK PERFORMANCES DURING AND AFTER COVID-19

The COVID-19 pandemic affected the whole world, and naturally, it revealed itself in the Azerbaijan's banking sector as well. To measure the effect numerically, we chose eight distinguished banks in the country and analyzed their statements. Bank performance is assessed using several profitability ratios, and as the main performance indicators, here in the study we took ROA, ROE, LLP/Total Loans.

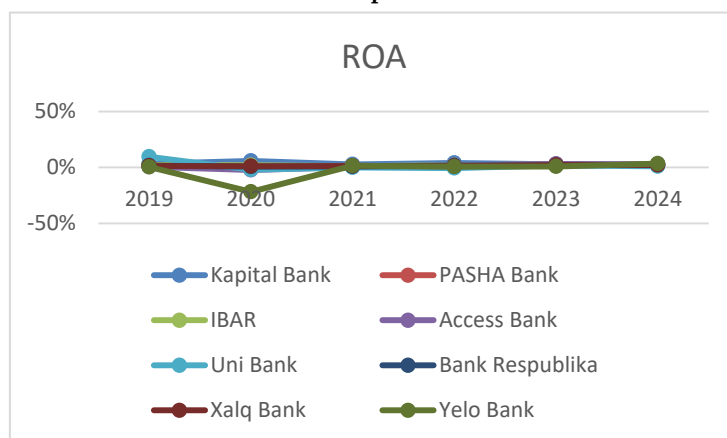
4.1 Return on Assets (ROA)

ROA is one of the top essential ratios that measure bank profitability by dividing annual net income to the annual total assets.⁵⁵ We took eight main banks of the country, reviewed their annual financial statements, calculated the ratio throughout the years for each bank and with the help of the graph below analysed the trend of the Return on Assets (ROA) from 2016 to 2024.

Table 1.

ROA						
Banks	2019	2020	2021	2022	2023	2024
Kapital Bank	3%	6%	3%	4%	3%	2%
PASHA Bank	1%	1%	1%	1%	3%	3%
IBAR	2%	2%	1%	2%	3%	2%
Access Bank	1%	-2%	0%	2%	3%	3%
Uni Bank	10%	-2%	0%	-1%	2%	1%
Bank Respublika	2%	1%	1%	2%	2%	2%
Xalq Bank	1%	1%	1%	1%	2%	2%
Yelo Bank	0%	-22%	2%	1%	1%	3%

Graph 1.



Source: Central Bank of The Republic of Azerbaijan.

⁵⁵ Brigham, E. F., & Ehrhardt, M. C. (20XX). Financial Management: Theory & Practice. Cengage Learning.

Evidence from profitability analyses shows variation among banks in ROA performance during the pandemic period (Karimli, 2025). The moderate and positive ROA in most banks indicates stable profitability before COVID-19. The highest one belongs to the Uni Bank which suggests strong profitability before the shock. Kapital Bank, Bank Respublika, Access Bank and PASHA Bank show 1-4% returns which is a sign of stable returns.

In 2020, COVID-19 shock is clearly visible. So that, due to high loss provisions, tense relations with pandemic-sensitive sectors, ROA of Yelo Bank dropped to almost -22%. That of Uni Bank and Access Bank also turned to negative figures.⁵⁶

In the same period, Kapital Bank indicator is positive and the highest among others. Others show only slight positive and close to zero figures. It means, better-capitalized large banks have higher resilience than others.⁵⁷

Until 2021, Yelo Bank recovered from strong negative to positive territory. Uni and Access Bank also recovered and almost they all together stabilized around 1-3% in that period. This is explained with effective loan restructuring, eased provisioning and economic reopening.

Period of 2021-2023 is distinguished for its stability. From 2022 onward, more stable and convergent period began, and sharp movements diminished. Due to better asset quality, improved lending strategy and stronger macroeconomic conditions, by 2024 more balanced profitability is observed.

To sum up the ROA indicator, we can say that Kapital Bank and Uni Bank have the best consistency among others, Yelo Bank had the strongest recovery, while at the same time was the most volatile one. PASHA Bank, Xalq Bank and Bank Respublika were the steadiest ones with small ROA.

4.2 Return on Equity (ROE)

The table below demonstrates the ROE ratio of those eight banks from 2019 to 2024, while the graph describes the movement visually. ROE ratio is obtained by dividing net income to total equity which indicates the level of returns to shareholders.⁵⁸

Table 2.

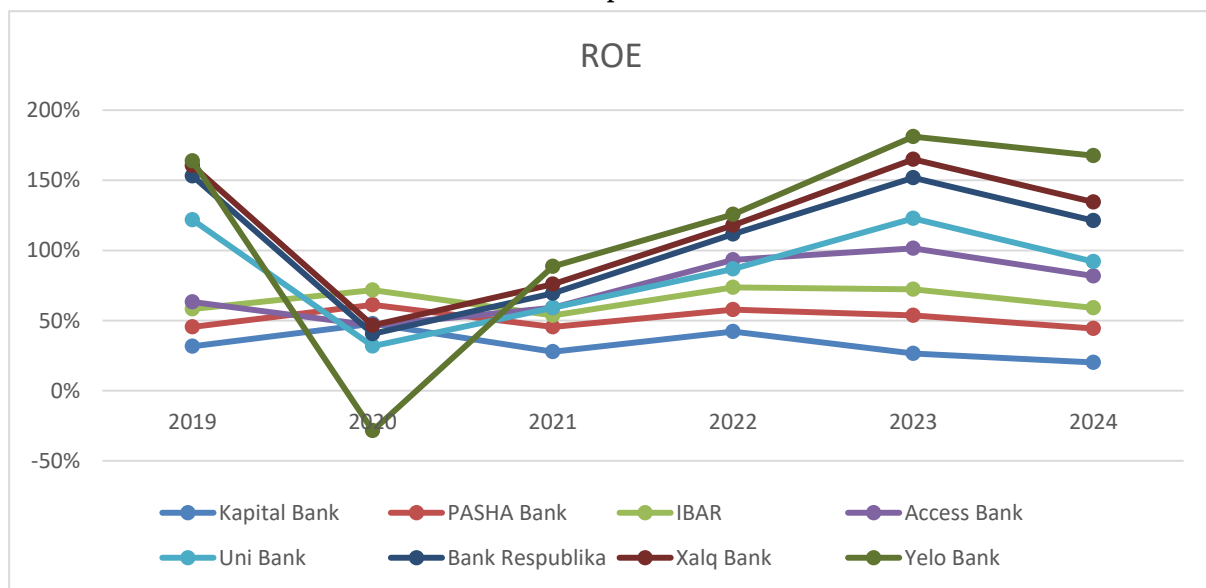
ROE						
Banks	2019	2020	2021	2022	2023	2024
Kapital Bank	32%	48%	28%	42%	27%	20%
PASHA Bank	14%	13%	18%	16%	27%	24%
IBAR	13%	11%	8%	16%	19%	15%
Access Bank	5%	-25%	5%	20%	29%	23%
Uni Bank	59%	-15%	0%	-7%	21%	10%
Bank Respublika	31%	9%	10%	25%	29%	29%
Xalq Bank	7%	6%	6%	6%	13%	13%
Yelo Bank	3%	-75%	13%	8%	16%	33%

⁵⁶ Al Zafir, & Sudarjah, I. G. A. (2025). Credit risk, COVID-19, and bank profitability in Indonesian conventional banks. European Journal of Business and Management Research.

⁵⁷ Aliyev, S. (2021, May 3). The Azerbaijani banking sector during pandemic and war. Baku Research Institute.

⁵⁸ Elnahass, M., Soliman, A., & Abdel-Gawad, H. (2023). COVID-19 Pandemic Impact on the Banking Sector: A Cross-Country Analysis. Journal of Banking & Finance, 152, 106-859.

Graph 2.



Source: Central Bank of The Republic of Azerbaijan.

In the graph, we observe that, in 2019, there is an utterly strong ROE levels in most banks. Among them, that of in Xalq Bank, Bank Respublika and Yelo Bank is prominent as they have the highest ROE figures-around 150-160%. The ratio in Uni Bank is also high with around 120%. The rest maintain their lower, still positive levels. This can be explained with high profitability, also can be due to relatively low equity bases prior to pandemic.⁵⁹

In 2020, there is a clear impact of pandemic on banks, especially, Yelo Bank was affected more with -30%. Other banks also show prominent decline to around 30-70%, and this is the result of losses or probably, higher provisions. Kapital Bank is distinguished among others with its stable performance over the years. In 2020 the ROE was at its highest point, later diminished slightly but still stayed stable.

Compared to ROA, ROE figures are more volatile, because, relative to total assets, total equity is smaller, so, changes in profitability are reflected in ROE more prominently.

In 2021, Yelo Bank goes back to positive levels fast. IBAR, Xalq Bank, Bank Respublika demonstrate strong recovery momentum. So, because of stabilized credit portfolios, decreased provisioning and economic reopening, majority of banks return to moderate-50-90% ROE levels.⁶⁰

During 2022-2023, ROE levels of Yelo Bank, Xalq Bank, Bank Respublika and Uni bank reached at peak with 150-180%. Access Bank and IBAR also showed considerable improvement. The sector itself moved upward synchronically due to increased lending, better asset quality, lower equity growth relative to net income and macroeconomic recovery.

2024 is a normalization year as in most banks, ROE declined, still higher than that of pandemic period.

⁵⁹ Akbas, F., et al. (2023). Impact of COVID-19 on Commercial Bank Performance: Evidence from Emerging Markets.

⁶⁰ Azərbaycan Respublikasının Mərkəzi Bankı. (2020). Koronavirus (COVID-19) pandemiyası ilə əlaqədar kredit təşkilatlarının müvəqqəti tənzimləmə Qaydası.

4.3 LLP/Total Loans

The Loan Loss Provisions to Total Loans (LLP/Total Loans) ratio is as an indicator of credit risk and asset quality in the banking sector. It measures the proportion of provisions allocated by banks to cover possible loan losses relative to their total loan portfolio. A higher LLP ratio generally indicates increased credit risk and potential diminish in asset quality, while a lower ratio indicates improved loan performance and reduced expected losses (Beatty & Liao, 2014; Demirgüç-Kunt et al., 2021).

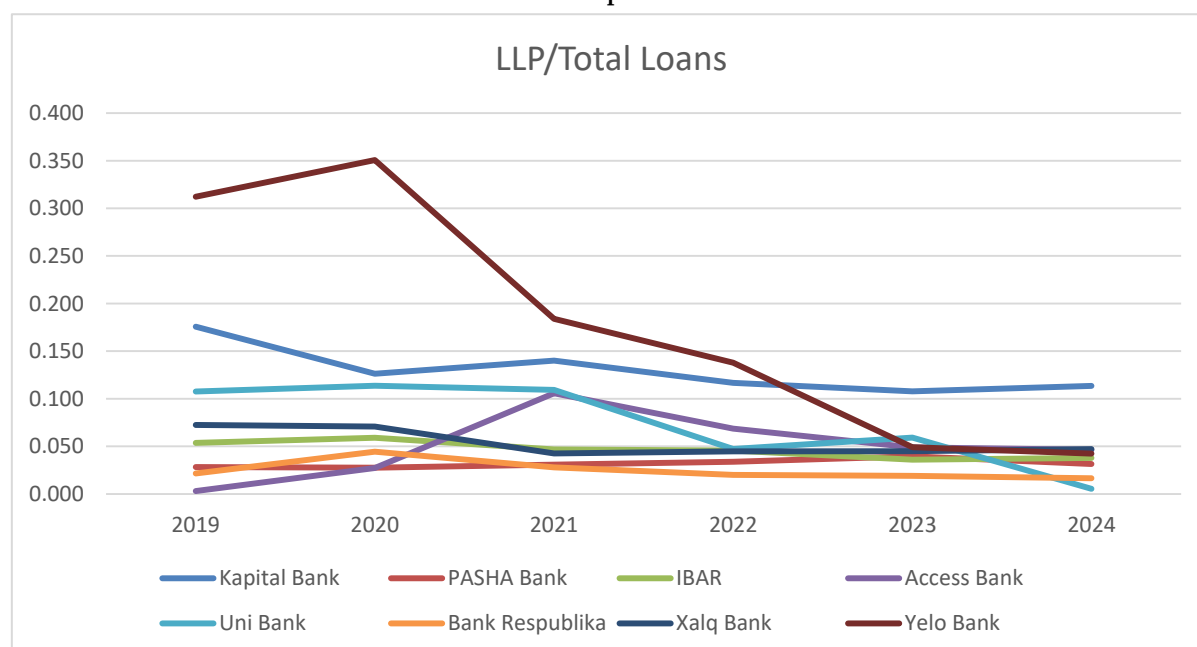
Table 3.

Banks	2019		2020		2021		2022		2023		2024	
	Allow. LL	Total Loan	Allow. LL	Total Loan	Allow. LL	Total Loan	Allow. LL	Total Loan	Allow. LL	Total Loan	Allow. LL	Total Loan
Kapital Bank	319869	1821222	274782	2175951	371475	2652560	368193	3157769	460114	4271823	590952	5211208
PASHA Bank	66921	2363909	74038	2682856	96164	3123469	114470	3388059	125893	3181044	115750	3690825
IBAR	122745	2288549	150265	2547283	145305	3104073	162455	3563513	181438	5040577	241032	6365771
Access Bank	1711	565362	12858	473205	69972	661362	56804	828797	50294	1026453	54304	1171516
Uni Bank	54810	509368	64221	565502	80794	739841	41837	886951	62449	1055441	63970	11919077
Bank Respublika	10668	495562	21836	492742	21409	769069	20866	1043967	22258	1172458	24376	1480504
Xalq Bank	138185555	1904984666	108172800	1527837764	60994275	1431324208	80009945	1788732074	85208770	1895498081	91973122	1954838736
Yelo Bank	130457	417810	142491	406227	95219	517921	95325	691285	39084	794977	40548	956157
Total	138892736	1913446448	108913291	1537181530	61874613	1442892503	80869895	1802292415	86150300	1912040854	93104054	1985633794

Table 4.

LLP/Loans						
Banks	2019	2020	2021	2022	2023	2024
Kapital Bank	0.176	0.126	0.140	0.117	0.108	0.113
PASHA Bank	0.028	0.028	0.031	0.034	0.040	0.031
IBAR	0.054	0.059	0.047	0.046	0.036	0.038
Access Bank	0.003	0.027	0.106	0.069	0.049	0.046
Uni Bank	0.108	0.114	0.109	0.047	0.059	0.005
Bank Respublika	0.022	0.044	0.028	0.020	0.019	0.016
Xalq Bank	0.073	0.071	0.043	0.045	0.045	0.047
Yelo Bank	0.312	0.351	0.184	0.138	0.049	0.042

Graph 3.



Source: Central Bank of The Republic of Azerbaijan

This chart shows the **Loan Loss Provisions to Total Loans (LLP/Total Loans)** ratio for several Azerbaijani banks from **2019–2024**. Since this ratio reflects expected credit losses and asset-

quality risk, it is a useful indicator of how banks were affected by the pandemic and how they recovered afterward.⁶¹

In general, this ratio among banks shows an upward trend around 2020-2021 due to more uncertainty, loan restructuring and precautionary provisions, while from 2022 a decline follows it. Main reason of that decline is improved creditability of customers, normalization of credit risk, and reduction of loss provisions. It means, after 2021, an asset quality of Azerbaijani banks increased.

The observation shows that, by 2023-2024, majority of the banks cluster in a tense range. Reduced uncertainty, stabilization of the credit environment, normalized provisioning across the sector is the main reason of that convergence.⁶²

All in all, the LLP to total loans ratio shows that, during the pandemic period, there was a high credit risk, especially, during 2020-2021 as there was increased provisions. From 2022 onwards, that ratio declined in most banks and a convergence is observed due to increased asset quality, borrowers' capacity and macroeconomic stabilization.

5. CONCLUSION

This study measured the financial performance of main Azerbaijani banks over 2019-2024 with the help of Return on Assets (ROA), Return on Equity (ROE) and the Loan Loss Provisions to Total Loans (LLP/Total Loans) ratio. Here we covered the pre-pandemic period, pandemic period and recovery period, evaluating how their financial situation and external shocks affected those banks.

According to the findings, the profitability and the risk profile of banks were highly affected by the COVID-19 pandemic. Due to significant volatility, reduced economic activity, higher credit risk and increased uncertainty, during the pandemic years, there was a considerable volatility.

The banking sector is quite sensitive to borrower capacity and macroeconomic shocks. It is visible when we observe the increase in LLP to total loans ratio across many banks. The reason was the increase in provisions and diminish in expected loan portfolio quality.

Beginning in 2022, performance indicators improved gradually, and credit-risk indicators decreased. In the later years, the convergence of these ratios indicates a stabilization of banking operations and a sounder banking environment.

To sum up, although there were short-term disruptions in banking performance, post-pandemic period came with a relatively strong recovery. These results demonstrate the resilience of the banking sector of Azerbaijan.

6. RECOMMENDATIONS

Several recommendations can be proposed in the direction of strengthening banks' risk management. It will also lead to the maintenance of asset quality during economic downturn periods.

First, banking sector should be strengthened from credit risk management side by applying more advanced monitoring systems. Better real-time monitoring system would help banks to

⁶¹ Beatty, A., & Liao, S. (2014). Financial accounting in the banking industry: A review of the empirical literature on loan loss provisions. *Journal of Accounting and Economics*, 58(2-3), 339-383.

⁶² Azərbaycan Respublikasının Mərkəzi Bankı. (2023). Financial Stability Report 2022. Central Bank of Azerbaijan.

determine changes in the creditworthiness of customers at an early stage. In turn, this will reduce the probability of non-performing loans (NLPs).

Second, the implementation of forward-looking and adequate provisioning policies is advised. If banks adopt international credit loss models, they can absorb potential losses during crisis periods and sudden losses can be prevented.

To prevent the accumulation of systematic risk, capital buffers, capital requirements and limits on excessive credit growth should be continued to be used by regulatory authorities.

Furthermore, investor confidence and market discipline can be fostered by improving transparency and risk disclosure practices.

Finally, a wider set of financial indicators such as liquidity ratios, capital adequacy ratios, cost-efficiency indicators, and profitability measures should be applied to expand the empirical analysis. From econometric models panel data regression models, VAR (vector autoregression), or dynamic panel estimators can be employed to capture the relationships between bank performance and macroeconomic variables.

These analyses help to provide better insights into the resilience of banking sector and support evidence-based policy formulation in Azerbaijan

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INDEPENDENT AUDITING: ADAPTATION PROCESS OF INDEPENDENT AUDITING STANDARDS AND THE EXAMPLE OF AZERBAIJAN

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ARTICLE INFO	ABSTRACT
<i>Article history:</i> <i>Received:</i>2025-10-17 <i>Received in revised form:</i>2025-10-30 <i>Accepted:</i>2025-12-01 <i>Available online:</i>2026-06-26 <i>Keywords:</i> <i>Independent auditing standards adaptation;</i> <i>International Standards on Auditing convergence;</i> <i>Audit regulation in Azerbaijan;</i> <i>Audit quality and oversight;</i> <i>Emerging economies' auditing reform</i> <i>JEL classification</i> M42; M48; H83; O16	<i>This article examines how independent auditing standards are adapted to national systems, using Azerbaijan as a case study. Independent audits are essential for reliable financial reporting and investor confidence, yet international standards cannot be simply transplanted without regard to local legal and institutional realities. The central problem addressed is the gap that can arise between formal adoption of such standards and their effective implementation in practice. The study has two main purposes: to outline the core elements and stages of an effective adaptation process, and to assess Azerbaijan's experience in aligning its auditing framework with international benchmarks. Methodologically, the article relies on qualitative analysis of laws, regulations, professional guidance, and international assessments, complemented by academic literature and comparative insights. The findings show that Azerbaijan has made significant progress in translating and applying international standards, strengthening quality assurance, and upgrading professional education, particularly in key sectors such as banking and oil and gas. However, challenges remain in enforcement capacity, regional skills gaps, application to smaller entities, and ensuring auditor independence. The article concludes with policy recommendations and highlights avenues for future empirical and comparative research.</i>

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INTRODUCTION

Independent auditing standards play a central role in safeguarding the credibility of financial reporting and, more broadly, the integrity of capital markets. Independent audit is commonly defined as an objective examination of an entity's financial statements by a qualified external auditor, performed with the aim of expressing an opinion on whether those statements are prepared, in all material respects, in accordance with an applicable financial reporting framework (Hayes, Wallage, & Gortemaker, 2014). By providing "reasonable assurance" that financial statements are free from material misstatement due to fraud or error, independent audits enhance the confidence of investors, creditors, regulators, and other stakeholders in published financial information (Arens, Elder, & Beasley, 2014). This assurance function is particularly important in transition and emerging economies, where market institutions, corporate governance practices, and enforcement mechanisms are still consolidating.

To promote consistent, high-quality auditing practices worldwide, the International Auditing and Assurance Standards Board (IAASB), operating under the auspices of the International Federation of Accountants (IFAC), issues the International Standards on Auditing (ISA). These standards set out the auditor's responsibilities and prescribe key principles for planning and performing audits, assessing risks, gathering sufficient appropriate audit evidence, and forming an audit opinion (IAASB, 2021). Over the past two decades, the ISA have become the de facto global benchmark for audit quality, and many jurisdictions have either adopted them directly or used them as a basis for national auditing standards (IFAC, 2020). Global harmonization of auditing standards is seen as essential for cross-border investment, comparability of financial information, and the integration of national capital markets into the global financial system (Humphrey, Loft, & Woods, 2009). When investors and other users of financial statements can rely on a common set of auditing principles, the cost of information processing is reduced and confidence in transnational financial reporting is strengthened.

At the same time, the movement toward global harmonization has revealed that auditing standards cannot simply be "copy-pasted" from the international level into domestic law and practice. The ISA are high-level, principles-based standards designed for broad applicability across jurisdictions. In practice, their effective implementation depends on the specific legal system, institutional arrangements, market structure, and professional capacity of each country (Nobes, 2013). Legal environments differ significantly in areas such as company law, securities regulation, civil and criminal liability of auditors, and the role of regulators. Institutional settings vary in terms of the strength of professional bodies, the capacity of audit oversight authorities, and the development of educational and quality-assurance systems. Moreover, the size and structure of the audit market, ranging from global networks to small local practices, affect how standards are interpreted and applied (Khumawala & Leung, 2010).

These differences mean that a purely formal or legalistic adoption of ISA, without attention to local conditions, may result in what some authors describe as "symbolic" or "ceremonial" compliance (Suchman, 1995). In such cases, standards are adopted in law or regulation but are not fully embedded in the day-to-day practices of auditors, firms, and oversight institutions. The gap between de jure and de facto implementation can undermine the very objectives of harmonization. For instance, the World Bank's Reports on the Observance of Standards and Codes (ROSC) have documented that in many countries, including transition economies, ISA are formally adopted but audit quality remains uneven due to weak enforcement, limited practical training, and insufficient quality control mechanisms (World Bank, 2015, 2017). Consequently, scholars and international organizations emphasize the need for a deliberate adaptation process that tailors international standards to national legal and institutional realities, while preserving their key principles (IFAC, 2020; Zeghal & Mhedhbi, 2006).

In this context, the notion of "adaptation" of independent auditing standards goes beyond translation or simple legal incorporation. It involves a complex process that includes the alignment of auditing standards with domestic legislation, the clarification of responsibilities among regulators and professional bodies, the development of guidance and training materials, and the design of monitoring and enforcement mechanisms suited to local capacities (Khorwatt, 2021). Adaptation may also require phased implementation, particularly in countries where the audit profession is still developing. This allows firms and practitioners to gradually internalize new requirements, invest in necessary methodologies and technologies, and upgrade their competencies. At the same time, adaptation must avoid excessive national modifications that

could fragment the global framework and weaken comparability. Thus, the challenge is to strike a balance between international convergence and local relevance.

Azerbaijan offers an instructive case for analyzing this adaptation process. As a post-Soviet transition economy with ambitions to integrate into global financial and capital markets, Azerbaijan has undertaken substantial reforms in corporate financial reporting and auditing over the last two decades. The Law of the Republic of Azerbaijan “On Audit Service” and related regulations have been progressively aligned with international best practices, including the adoption of ISA as the basis for national auditing standards (Chamber of Auditors of the Republic of Azerbaijan, 2019; The Law of the Republic of Azerbaijan on the “Audit Service”, 1994/2019). The Chamber of Auditors, established as the professional and regulatory body for auditors, has played a key role in translating ISA, issuing methodological guidance, and organizing professional education and qualification processes (Chamber of Auditors of the Republic of Azerbaijan, 2020; IFAC, 2023). At the same time, external assessments by international institutions have highlighted ongoing challenges in ensuring consistent and high-quality application of these standards in practice (World Bank, 2015, 2017).

According to the World Bank’s ROSC on Accounting and Auditing for Azerbaijan, the country has made notable progress in adopting ISA and strengthening the regulatory framework, particularly since the late 2000s (World Bank, 2015). However, the report also points to issues such as the limited capacity of small and medium-sized audit firms, gaps in practical training for auditors, and the need to further develop quality assurance and public oversight mechanisms. A subsequent update stresses that while the formal framework is increasingly aligned with international requirements, implementation and enforcement require sustained efforts, including improvements in translation quality, more robust monitoring, and closer coordination between the Chamber of Auditors, the Ministry of Finance, and other stakeholders (World Bank, 2017). These findings illustrate the broader theme that the effectiveness of ISA adoption cannot be assessed solely by reviewing legal texts; one must also examine institutional arrangements, professional culture, market incentives, and sector-specific regulatory practices such as those of the Central Bank of Azerbaijan (CBA) for bank audits (CBA, 2019).

The purpose of this article is therefore twofold. First, it aims to provide a conceptual and practical overview of the adaptation process of independent auditing standards in general. This includes an examination of the main stages of adaptation—from legal incorporation and translation to capacity building and quality assurance—and the typical challenges that arise, particularly in emerging and transition economies. By drawing on the international literature on accounting and auditing harmonization, as well as guidance issued by IFAC and the IAASB, the article outlines the key factors that influence successful adaptation and the risks associated with purely formal compliance (IFAC, 2020; IAASB, 2021; Nobes, 2013). Second, the article analyzes the specific experience of Azerbaijan as a case study. It explores how Azerbaijan has approached the adoption and adaptation of ISA, the role played by national institutions such as the Chamber of Auditors and the CBA, and the extent to which the country’s audit practices have converged with international standards in substance, not only in form.

To achieve these objectives, the article addresses the following research questions:

1. What are the core elements and stages of an effective adaptation process for independent auditing standards?
2. How has Azerbaijan adapted ISA to its national legal and institutional environment, and what specific measures have been taken to operationalize these standards in practice?
3. What challenges and gaps remain in Azerbaijan's adaptation process, and what lessons can be drawn for other countries seeking to align their auditing frameworks with global standards?

By answering these questions, the study aims to contribute both to the academic literature on international auditing harmonization and to the practical debate on regulatory reform in emerging markets.

Methodologically, the article is based on a qualitative, documentary analysis of secondary sources in a comparative perspective. The research draws on academic literature on international auditing and accounting harmonization, including books, journal articles, and comparative studies (e.g., Arens et al., 2014; Hayes et al., 2014; Humphrey et al., 2009; Nobes, 2013; Zeghal & Mhedhbi, 2006). It uses primary legal texts of the Republic of Azerbaijan related to audit regulation, such as the Law "On Audit Service" and sectoral regulations (e.g., for banks and investment funds), as well as official documents, quality-control regulations, and methodological guidelines issued by the Chamber of Auditors (The Law on "Audit Service", 1994/2019; CAAR, 2019a, 2019b). In addition, it analyzes international reports and assessments, notably the World Bank's ROSC Accounting and Auditing reports for Azerbaijan and relevant policy papers issued by IFAC and the IAASB (World Bank, 2015, 2017; IFAC, 2020; IAASB, 2021), complemented by CAAR's IFAC membership profile (IFAC, 2023), IAASB materials on the revised auditor's report and quality management (IAASB, 2016, 2020), and sectoral regulations by the CBA (CBA, 2019). The comparative element is addressed by benchmarking Azerbaijan's arrangements against international "good practice" models, particularly EU member states such as Estonia or Lithuania, along dimensions such as legal status of ISA, oversight independence, quality assurance transparency, and education/CPD alignment.

A small empirical vignette is included by examining the CBA's external audit requirements for banks and publicly available information on bank auditors, to illustrate how ISA-aligned expectations are implemented in a critical sector (CBA, 2019; Banker.az, 2022; FED.az, 2022). The article is structured as follows. Section 1 outlines the conceptual framework of independent auditing standards and their adaptation, focusing on the rationale for international harmonization and the main dimensions of national adaptation. Section 2 provides an overview of the evolution of auditing regulation in Azerbaijan and the formal and practical adoption of ISA. Section 3 examines implementation issues, comparative positioning, and the banking-sector vignette. Section 4 summarizes the main findings, discusses policy implications, and suggests areas for future research.

1. CONCEPTUAL FRAMEWORK OF ADAPTING INDEPENDENT AUDITING STANDARDS TO NATIONAL SYSTEMS

Independent audit is generally understood as an objective examination of an entity's financial statements by a qualified external auditor, performed with the purpose of expressing an opinion on whether those statements are prepared, in all material respects, in accordance with an applicable financial reporting framework (Hayes et al., 2014; Arens et al., 2014). Independence—

both in fact and appearance—is central: the auditor must be free from undue influence by management or other interested parties so that users can trust the audit opinion (IFAC, 2020).

Independent auditing standards transform this broad notion of assurance into a structured set of principles and requirements. Their objectives are to: enhance the credibility and reliability of financial reporting; promote consistency and comparability of audit work across firms and jurisdictions; provide a benchmark for audit quality and a basis for supervision and discipline; and protect the public interest by supporting sound corporate governance and market confidence (IAASB, 2021; Humphrey et al., 2009).

The International Standards on Auditing (ISA), issued by the IAASB, embody several core principles. First, they institutionalize a risk-based approach. Rather than applying uniform procedures to all areas of the financial statements, the auditor is required to identify and assess the risks of material misstatement and to tailor audit procedures to these risks (ISA 315, ISA 330). This improves both effectiveness—by focusing on what matters most—and efficiency—by avoiding unnecessary work in low-risk areas (Hayes et al., 2014). Second, ISA emphasize professional judgment and professional skepticism. Because audits are conducted in complex environments with imperfect information, auditors must interpret evidence, evaluate management estimates, and make judgments about materiality, going concern, and internal control. ISA 200 explicitly recognizes the centrality of judgment and skepticism, requiring auditors to maintain a questioning mind and to critically assess audit evidence (IAASB, 2021). Third, documentation is a foundational principle. ISA 230 requires auditors to prepare sufficient and appropriate documentation to enable an experienced auditor, having no previous connection with the audit, to understand the procedures performed, evidence obtained, and significant judgments made. Documentation supports internal quality control, external inspections, and, where necessary, legal defense of the auditor's work (Arens et al., 2014). Finally, independent auditing standards are inseparable from ethics. ISA are designed to be applied together with the International Code of Ethics for Professional Accountants (including International Independence Standards), issued by the International Ethics Standards Board for Accountants under IFAC. Core ethical principles—integrity, objectivity, professional competence and due care, confidentiality, and professional behavior—are prerequisites for the meaningful application of ISA (IFAC, 2020; Humphrey et al., 2009).

Countries have followed different models in bringing ISA into their national systems. A first model is full adoption, where ISA are incorporated “as issued” by the IAASB, sometimes with only minimal additions to address specific legal references. Many smaller and emerging economies have chosen this route to benefit quickly from internationally developed standards and to signal alignment with global best practice (IFAC, 2020; World Bank, 2015). A second model is adaptation with modifications, where ISA serve as the primary reference but national standard-setters introduce changes to reflect local legal requirements on auditor reporting, liability, or specific regulated sectors (e.g., banking and insurance). This approach is more common in countries with well-established legal traditions that seek to preserve certain national features while converging with ISA (Nobes, 2013). A third model is gradual convergence over time, in which existing national auditing standards are progressively revised to reduce differences with ISA, often based on a roadmap supported by IFAC or international financial institutions (Zeghal & Mhedhbi, 2006; World Bank, 2017).

Regardless of the model, several key mechanisms or steps are typical in the adaptation process:

1. **Legal recognition of standards.** For standards to be binding, they must be anchored in law or regulation. Company, banking, and securities laws often specify that statutory audits must be carried out in accordance with national standards, which are themselves defined as ISA-based or identical to ISA. In some jurisdictions, the law directly names ISA as the applicable standard; in others, it delegates authority to a standard-setting body (World Bank, 2015).
2. **Translation and technical interpretation.** In non-English-speaking countries, high-quality translation is essential. IFAC requires formal translation processes, involving bilingual experts and technical reviewers, to preserve the meaning of standards (IFAC, 2020). Even with good translation, national interpretations, FAQs, and guidance are usually needed to clarify complex concepts, such as materiality or the audit of group financial statements (Hayes et al., 2014).
3. **Integration with existing laws and sectoral regulations.** The effectiveness of adapted standards depends on their consistency with broader legal frameworks: company law, banking and insurance regulations, securities legislation, tax law, and sometimes public sector auditing requirements. Conflicts can arise where national law prescribes detailed audit procedures inconsistent with a risk-based approach, or where confidentiality and data-protection rules restrict access to information. Harmonization therefore requires legislative amendments and close coordination among ministries, regulators, and the audit profession (Humphrey et al., 2009; World Bank, 2017).

Formal transposition of ISA into legal texts is insufficient; effective adaptation requires appropriate institutional and regulatory structures. A first dimension concerns standard-setting arrangements. Some countries rely primarily on professional bodies to adopt and update auditing standards, often under a framework set by law. Others vest authority in governmental agencies or establish mixed models, where professional bodies draft standards subject to approval by a public authority (IFAC, 2020; Nobes, 2013). A second dimension is public oversight, quality assurance, and enforcement. Since the early 2000s, international practice has emphasized the need for independent public oversight of the audit profession, separate from professional self-regulation (Humphrey et al., 2009). Oversight bodies typically conduct inspections, enforce compliance with ISA and ethical requirements, and impose sanctions for serious violations. World Bank ROSC assessments repeatedly show that countries with strong, independent oversight and functioning quality-assurance systems achieve more substantive implementation of ISA than those relying solely on self-regulation (World Bank, 2015, 2017). A third dimension is education and continuing professional development (CPD). University curricula, professional examinations, and licensing requirements need to be aligned with ISA-based auditing. IFAC's International Education Standards require that auditors not only understand the content of ISA but can apply a risk-based approach, exercise professional judgment, and uphold ethical standards in practice (IFAC, 2020). Without sustained investment in education and CPD, formal adaptation risks remaining a "paper reform" (Zeghal & Mhedhbi, 2006; Hayes et al., 2014).

The adaptation of independent auditing standards is further shaped by structural legal, institutional, and cultural challenges, especially in emerging and transition economies. Legal and institutional incompatibilities between international standards and domestic legal traditions can create tension with ISA's principles-based, risk-oriented approach (Nobes, 2013). Capacity gaps in regulators and audit firms, particularly small and medium-sized practices, often constrain the ability to implement ISA fully (World Bank, 2015; Khorwatt, 2021). Market structure and

economic incentives can hinder effective adaptation when demand for high-quality audits is limited and fee pressure is strong (Humphrey et al., 2009). Finally, cultural and ethical factors—such as strong relational ties, deference to authority, and tolerance of conflicts of interest—may undermine auditors' independence and professional skepticism (Suchman, 1995; Humphrey et al., 2009). Research on international adoption of accounting and auditing standards shows that factors such as investor protection, rule of law, and professional tradition significantly affect the depth of implementation, not only the formal decision to adopt ISA (Zeghal & Mhedhbi, 2006; World Bank, 2017).

These challenges imply that adapting independent auditing standards is not merely a technical exercise but a broader process of institutional development and cultural change. Successful adaptation requires coherence between standards, laws, institutions, and professional norms. Where such coherence is lacking, the risk is that ISA become a symbolic reference, while actual audit practices continue to reflect older habits, limited capacity, and domestic constraints.

2. EVOLUTION OF AUDITING STANDARDS AND THEIR ADAPTATION IN AZERBAIJAN

Under the Soviet system, Azerbaijan's accounting and control mechanisms were designed for a centrally planned economy rather than capital markets. Accounting served primarily as a tool for state planning and control, with a strong focus on compliance with state norms and budget execution (World Bank, 2015). "Audit" in the Western sense did not exist; instead, financial control was exercised through internal state bodies such as revision commissions and ministerial inspectorates. These bodies verified adherence to plan indicators and state regulations rather than providing independent assurance on financial statements for external stakeholders (Alas, Tuulik, & Turk, 2011). As a result, at independence in 1991, Azerbaijan had no tradition of a private audit profession, no audit firms, and no framework for independent assurance of corporate financial reporting.

The transition to a market economy in the 1990s fundamentally altered these needs. Privatization, the emergence of private enterprises, the development of a banking sector, and growing foreign investment created demand for transparent, reliable financial information. International financial institutions and foreign investors increasingly required audited financial statements, often prepared under International Financial Reporting Standards (IFRS) and audited in line with ISA (World Bank, 2015; Zeghal & Mhedhbi, 2006). The absence of a modern audit framework quickly became a constraint on financial sector development and integration into global markets.

In this context, Azerbaijan began building its audit profession from scratch. A key step was the adoption of the Law of the Republic of Azerbaijan "On Audit Service" in September 1994, which established the legal foundations for audit activity and provided for the creation of the Chamber of Auditors of the Republic of Azerbaijan (CAAR) as the central professional and regulatory body (World Bank, 2017; The Law on "Audit Service", 1994/2019; CAAR, 2020). The Chamber started operations in the mid-1990s, organizing qualification examinations and licensing of auditors, registering audit firms, and issuing initial methodological guidelines.

Over time, the audit profession evolved in several stages. The late 1990s and early 2000s saw the emergence of local audit firms and the entry of some international networks, primarily to serve foreign-owned enterprises and large domestic clients. During this period, audit practice was

shaped by a mix of domestic regulations and imported methodologies from international firms, with limited systematic reference to ISA (World Bank, 2015). The profession gradually developed its own institutional structures, including professional examinations, CPD requirements, and disciplinary procedures managed by the Chamber of Auditors (CAAR, 2020; IFAC, 2023).

From the late 2000s onwards, the trajectory increasingly shifted toward alignment with international standards. Driven by recommendations from the World Bank's ROSC and IFAC's Statements of Membership Obligations, Azerbaijan began to rely more explicitly on ISA and international ethics standards, and to strengthen quality assurance and oversight mechanisms (World Bank, 2015; IFAC, 2020, 2023). This marked the beginning of a more structured adaptation process of independent auditing standards to the national system.

The core legal basis for auditing in Azerbaijan remains the Law "On Audit Service," amended several times, notably in 2004 and later, to expand the scope and refine the regulation of audit activity (World Bank, 2017; The Law on "Audit Service", 1994/2019). This law defines audit services, sets out conditions for practicing as an auditor, regulates the establishment and operation of audit firms, and assigns key regulatory powers to the Chamber of Auditors. Membership in the Chamber and a valid license are required for the provision of statutory audit services.

Auditing activities are also influenced by broader legislation. Company-related requirements for statutory audits appear in the Civil Code and in sector-specific laws that require audits for particular types of entities. For example, the Law "On Banks," the Law "On Insurance Activity," and regulations of the Central Bank and financial markets regulators mandate annual audits for banks, insurers, and other financial institutions, often specifying additional reporting requirements and interaction with regulators (World Bank, 2015; CBA, 2019; E-qanun, 2017). Listed companies and certain public interest entities are required to have their financial statements audited, in line with capital market regulations.

Regarding the legal recognition of auditing standards, Azerbaijan has followed a hybrid path. Historically, the Law "On Audit Service" did not explicitly prescribe the application of ISA as the mandatory standards. Instead, it empowered the Chamber of Auditors to develop and approve auditing standards and methodological guidance (World Bank, 2017; The Law on "Audit Service", 1994/2019). Over time, the Chamber decided to base these national requirements on ISA, effectively adopting them for practical use, especially for significant and public interest audits (CAAR, 2020; IAASB, 2016-2017). By the mid-2010s, the Chamber had translated and formally adopted the IAASB's 2016–2017 ISA Handbook in Azerbaijani and required its application in practice, particularly by audit firms engaged in audits of banks, insurers, large companies, and entities with foreign participation (World Bank, 2017; IAASB, 2016-2017). ROSC and IFAC reports note, however, that the legal framework still did not explicitly state in primary legislation that ISA, as issued by the IAASB (or as endorsed nationally), are the sole mandatory auditing standards; instead, ISA were effectively applied through the Chamber's regulatory acts and licensing conditions (World Bank, 2017; IFAC, 2023). Ongoing legal reforms aim to clarify this linkage and give ISA a stronger statutory basis.

Institutionally, the Chamber of Auditors plays a central role in standard setting, licensing, and oversight. It:

- Drafts and approves auditing standards and related methodological documents, currently based on ISA.

- Organizes qualification examinations, licenses auditors and audit firms, and maintains registers.
- Oversees CPD requirements and ethics compliance.
- Operates the national quality assurance system, including periodic inspections of audit firms (CAAR, 2019a, 2019b, 2020; World Bank, 2017; IFAC, 2023).

While the Chamber combines professional and regulatory functions, there has been a gradual move—encouraged by international recommendations—toward enhancing public oversight and increasing the role of state bodies in supervising the audit profession, particularly for public interest entities (PIEs). Draft legal amendments have envisaged a more explicit public oversight function, possibly within or alongside the Chamber, to align with practices in the EU and other jurisdictions (World Bank, 2017; IFAC, 2020).

Prior to ISA-based reforms, Azerbaijan’s audit environment was characterized by a patchwork of domestic regulations, internal firm methodologies, and inherited Soviet-style control practices. Early national standards and guidelines issued by the Chamber of Auditors were relatively general and did not comprehensively reflect modern risk-based auditing concepts, documentation requirements, or international ethics frameworks (World Bank, 2015). Key deficiencies identified by the 2015 ROSC included: insufficiently detailed auditing standards, limited guidance on auditor independence, lack of systematic risk-based approaches, and gaps in quality assurance and public oversight (World Bank, 2015).

Alignment with ISA unfolded through several reform milestones. The translation and use of ISA in practice began to accelerate in the late 2000s, influenced by IFAC membership obligations and World Bank recommendations. Around 2010, the Chamber of Auditors started to require the application of ISA in audits of major entities and initiated structured translation work (CAAR, 2020; IFAC, 2023). A major step came with the adoption of the Azerbaijani version of the IAASB 2016–2017 ISA Handbook, which the Chamber approved as the main basis for auditing practice (World Bank, 2017; IAASB, 2016–2017). Parallel to this, a package of more than 40 legal and regulatory amendments in 2016–2017 sought to improve the audit environment, strengthen quality assurance, and move toward explicit legal reference to ISA and international ethics standards (World Bank, 2017).

The practical aspects of adaptation included several components: high-quality translation into Azerbaijani under IFAC translation policies (IFAC, 2020; IAASB, 2016–2017); implementation guidance and methodological instructions; and integration into education and training. The Chamber issued methodological recommendations, model forms, and explanatory materials on key ISA topics—such as audit planning, risk assessment, documentation, and the auditor’s report—helping especially smaller firms to adjust their methodologies and working papers to ISA requirements (CAAR, 2019a, 2019b; World Bank, 2017). Universities and professional education programs began incorporating ISA-based auditing content into curricula, and the Chamber revised qualification examinations and CPD courses to reflect ISA and the International Code of Ethics (Alas et al., 2011; CAAR, 2020; AZERTAC, 2023). The Chamber’s quality assurance reviews increasingly used ISA as the benchmark for assessing audit work, thereby reinforcing their practical importance and encouraging firms to align their methodologies accordingly (World Bank, 2017).

3. IMPLEMENTATION, COMPARATIVE POSITIONING, AND PRACTICAL EVIDENCE

3.1 Current State of ISA-Based Practice in Azerbaijan

ISA-based standards are now widely applied in Azerbaijan, particularly for audits of significant entities. The World Bank's 2017 ROSC update notes that the Chamber has essentially adopted ISA as the operative standards for statutory audit, even though full legal codification was still evolving at that time (World Bank, 2017). In practice, ISA are expected to be followed in audits of:

- Banks and other financial institutions, under requirements of the Law "On Banks" and regulations of the CBA, which explicitly expect high-quality, ISA-based audits due to systemic risk considerations (World Bank, 2015; CBA, 2019).
- Insurance companies and investment funds, which face similar expectations given their public interest character (World Bank, 2015; E-qanun, 2017).
- Listed and other public interest entities, where capital market regulators and foreign investors often require ISA-compliant audits, sometimes supplemented by IFRS-based financial reporting.
- Large non-listed entities and foreign-invested enterprises, particularly where lenders or shareholders demand audited financial statements according to international norms (World Bank, 2015, 2017).

For small and medium-sized enterprises (SMEs) and micro-entities, the picture is more mixed. Statutory audit requirements are narrower, and many smaller entities either are not required to be audited or are audited under simpler arrangements. ISA theoretically apply where a statutory audit is required, but the depth and consistency of implementation in small engagements depend on the capacity of local firms and the expectations of clients (Khorwatt, 2021; World Bank, 2017).

The structure of the audit market reflects a combination of international and domestic actors. Large international networks (the "Big Four" and some mid-tier firms) are present and tend to dominate audits of banks, insurers, multinational subsidiaries, and major corporates. Local media reports show that banks' auditors include the Big Four and networks such as Baker Tilly, Grant Thornton, Nexia, and Crowe/Baltic Caspian (Banker.az, 2022; FED.az, 2022). These firms apply globally standardized ISA-based methodologies and contribute to the diffusion of best practices (World Bank, 2015). Alongside them, numerous local audit firms and individual practitioners serve SMEs, local corporates, and public entities. Market concentration is therefore high for PIEs, while the wider market remains fragmented, with many small practices facing resource constraints and fee pressure.

Regarding quality assurance and inspection mechanisms, the Chamber of Auditors operates the national quality assurance (QA) system. It conducts periodic inspections of audit firms, reviews selected audit files against ISA requirements, and issues recommendations or sanctions where necessary. The QA system has been progressively strengthened to better align with IFAC's Statement of Membership Obligations on quality assurance, including the establishment of dedicated quality-control regulations and committees and more structured review cycles (CAAR, 2019a, 2019b; IFAC, 2023). The QA rules have been updated to reflect a more modern, quality-management-oriented approach consistent with the IAASB's new ISQM 1 and ISQM 2 standards (IAASB, 2020).

Nevertheless, the World Bank (2017) and IFAC (2020, 2023) highlight remaining challenges. These include ensuring the effective independence of the QA function from the profession's commercial interests, extending the scope and depth of inspections, and improving transparency of QA outcomes, especially for PIE audits. Capacity constraints, particularly the limited number of inspectors with extensive practical ISA experience, remain an issue. In addition, further legal measures are recommended to formalize public oversight arrangements and clarify the division of responsibilities between the Chamber, state bodies, and financial regulators.

3.2 Key Achievements and Main Challenges

From an adaptation perspective, Azerbaijan's main achievements include:

- **De facto ISA adoption and translation.** CAAR has translated and adopted the 2016–2017 IAASB Handbook and requires its application in practice for statutory audits, especially for PIEs (World Bank, 2017; IAASB, 2016-2017).
- **Strengthened QA and regulatory framework.** CAAR operates a formal QA system under detailed regulations (CAAR, 2019a, 2019b), and sector regulators such as the CBA impose ISA-aligned requirements for external audits of banks (CBA, 2019).
- **Improved methodologies and documentation.** ISA-based reforms have encouraged risk-based audit planning, standardized working papers, and enhanced documentation (World Bank, 2015, 2017).
- **Growth in professional capacity.** Qualification requirements, CPD structures, and university curricula have been aligned more closely with ISA and IFRS, and more auditors hold international professional designations (World Bank, 2017; IFAC, 2023).

At the same time, significant challenges affect the depth and consistency of ISA implementation: constrained enforcement and supervisory capacity within a profession-centered oversight model; uneven professional capacity between large urban firms and smaller regional practices; structural fee pressures in the SME segment; and ethical and independence risks linked to close client relationships and cross-service provision (World Bank, 2015, 2017; Khorwatt, 2021; AZERTAC, 2023).

3.3 Comparative Perspective and Benchmarks

When compared with peer post-Soviet and regional economies, Azerbaijan's progress can be seen as intermediate to advanced, depending on the benchmark. Countries such as Estonia or Lithuania, as EU member states, have rapidly implemented EU audit directives and established independent public oversight bodies; they now have legal systems that explicitly mandate ISA and strong institutional frameworks. Other states in the region have been slower to adopt ISA and maintain more fragmented professional structures (Zeghal & Mhedhbi, 2006; World Bank, 2017).

A comparative lens along key dimensions suggests the following positioning:

- **Legal status of ISA.** In mature EU benchmarks, ISA are mandated in law/regulation with automatic update mechanisms. In Azerbaijan, ISA are applied de facto via CAAR adoption and translation; the Audit Law anchors reliance on international standards but does not yet give ISA the same explicit statutory status (The Law on "Audit Service", 1994/2019; IAASB, 2016-2017; IFAC, 2023).
- **Oversight independence.** EU models typically feature separate independent oversight authorities for PIE audits. Azerbaijan retains a profession-centered model where CAAR

conducts QA and disciplinary actions; independence enhancements remain a reform priority (CAAR, 2019a, 2019b; World Bank, 2017; IFAC, 2023).

- **QA system design and transparency.** EU oversight bodies often publish inspection statistics, common findings, and sanctions. Azerbaijan has the QA framework in place, but public reporting on inspection outcomes is limited (CAAR, 2019a, 2019b).
- **Education/CPD alignment.** Azerbaijan, as an IFAC member, has aligned many elements with IES, but capacity gaps persist outside Baku and among smaller firms (IFAC, 2023; World Bank, 2015, 2017).
- **Implementation of new IAASB standards.** EU jurisdictions have formally implemented ISQM 1/2 and ISA 315 (Revised 2019) with supervisor scrutiny. Azerbaijan's QA rules have been modernized to reflect a quality-management focus, but the visibility of implementation outcomes remains limited (CAAR, 2019a, 2019b; IAASB, 2020).
- **Auditor reporting reforms.** EU PIE audits now routinely include Key Audit Matters (KAMs), with analysis by regulators. Azerbaijan has adopted the revised auditor's report structure and KAM concept through ISA-based practice and training, but systematic evaluation of KAM usage is not yet publicly available (IAASB, 2016; CAAR, 2010; World Bank CFRR, 2016).
- **Market structure.** Azerbaijan is similar to many EU states in that PIE audits are concentrated among global networks, while the broader SME segment is fragmented and fee-sensitive (Banker.az, 2022; FED.az, 2022).

Overall, Azerbaijan sits between full EU-style legal embedding/independent oversight and earlier-stage convergence models. The main convergence gaps relate to formal legal status of ISA, independence and transparency of oversight, and the ability of smaller firms to implement complex standards under economic constraints.

3.4 Practical Vignette: Banking-Sector External Audit Requirements

A concise practical example of substantive ISA-aligned adaptation can be seen in the banking sector. The CBA's "Regulations on Requirements for Conducting External Audit of Local Banks and Branches of Foreign Banks" set explicit conditions for external auditors (CBA, 2019). Key features include:

- **Appointment and notification.** Banks must appoint qualified, independent auditors and notify the CBA by a specified deadline within the audit year (for example, by mid-November). Publicly available notices from banks confirm these timelines in practice (TuranBank, 2023).
- **Reporting timelines.** After completion of the audit, banks must submit the auditor's report to the CBA within prescribed deadlines (e.g., within five months of year-end or within a short period after the audit report is signed), ensuring timely supervisory access to audited financial information (CBA, 2019).
- **Rotation and independence.** The regulation empowers the CBA to require rotation of the external auditor after extended consecutive service (e.g., five years), mitigating familiarity threats. Similar independence safeguards apply to auditors of investment funds and other financial institutions under sectoral regulations (E-qanun, 2017).

In practice, banks tend to engage Big Four or other major international networks as their auditors (Banker.az, 2022; FED.az, 2022). These firms apply standardized ISA-based methodologies, and

the CBA's requirements on appointment, reporting, and rotation create incentives for robust risk assessment, documentation, and transparent reporting, including the articulation of KAMs in the auditor's report in line with the revised ISA 700 series (IAASB, 2016; World Bank CFRR, 2016). This vignette illustrates that beyond formal references to ISA in professional regulations, sector-specific prudential rules can effectively "operationalize" ISA principles and drive substantive implementation in high-stakes segments of the market.

4. CONCLUSION

The analysis in this article shows that adapting independent auditing standards is not a mere technical decision to "adopt ISA," but a multi-dimensional process that unfolds over time and is deeply shaped by national legal, institutional, and cultural contexts. In general, the adaptation of independent auditing standards involves several core elements and stages. It begins with formal legal recognition of standards—through laws or regulations that mandate their use—followed by translation and technical interpretation, particularly in non-English-speaking environments. Next comes integration with existing legal frameworks (company, banking, securities, and tax law) to avoid conflicts and ensure coherence. Crucially, these formal steps must be supported by institutional capacity (standard-setting, oversight, and quality assurance), professional education (university curricula, qualification exams, CPD), and effective enforcement mechanisms that ensure the standards are applied in substance, not just in form. Throughout, the process is iterative: as ISA evolve, national systems must update translations, guidance, and regulations and respond to emerging issues such as new technologies or complex financial instruments.

Azerbaijan's trajectory illustrates this general model, moving from a Soviet legacy with no tradition of independent auditing to an ISA-based framework that increasingly resembles international practice. In the early post-independence period, auditing emerged as a new profession under the 1994 Law "On Audit Service" and the establishment of the Chamber of Auditors. At that stage, national rules and inherited control practices dominated, with limited systematic use of ISA and modest methodological sophistication. Over time, driven by the demands of a market economy, foreign investors, and international financial institutions, Azerbaijan began to align its financial reporting and auditing frameworks with global standards.

The core of this adaptation has been the translation and practical adoption of ISA, led primarily by the Chamber of Auditors. Azerbaijan has translated the IAASB standards into Azerbaijani, approved them as the operative auditing standards, and embedded them in licensing requirements, methodological guidance, and quality assurance reviews. ISA are now applied in audits of banks, insurers, listed and other public interest entities, and many large corporations. Supporting measures include the development of ISA-based university courses, revision of professional examinations, and CPD programs focusing on risk-based auditing, documentation, and ethics. Quality assurance and inspection mechanisms, although still evolving, use ISA and, increasingly, the ISQM framework as benchmarks for evaluating engagement and firm-level quality.

At the same time, Azerbaijan's path has distinctive features. The prominence of the oil and gas sector and major state-owned enterprises created early pockets of ISA-based practice, often driven by international networks and lenders. Regulatory design has centered on a strong professional body that combines standard-setting, licensing, and oversight, with a gradual shift towards more public-interest-oriented supervision. Sectoral regulators such as the CBA have

embedded ISA-aligned requirements into prudential rules, especially for banks, reinforcing independence, reporting, and timeliness. This hybrid approach has enabled relatively rapid professionalization but also raises questions about the independence and capacity of oversight in a context where the profession largely regulates itself.

From a balanced perspective, Azerbaijan has achieved significant progress but still faces important weaknesses. On the positive side, the country has:

- Established a legal and institutional framework for the audit profession.
- Translated and operationalized ISA for a wide range of statutory audits, particularly in higher-risk sectors.
- Improved audit methodologies, documentation, and risk-based approaches in many firms.
- Expanded the pool of qualified auditors and strengthened education and training.

However, several gaps remain. Enforcement capacity is limited, especially in terms of the resources, expertise, and independence of inspection and oversight functions. Professional capacity is uneven: while large firms and Baku-based auditors often achieve high levels of ISA compliance, smaller regional firms struggle with complex standards and resource constraints. Market conditions—fee pressure, limited demand for high-quality audits among SMEs, and low awareness of the value of assurance—undermine incentives for rigorous application of standards. Ethical risks and independence threats, rooted in close client relationships and legacy practices, are not yet fully mitigated by existing safeguards and enforcement.

These strengths and weaknesses have direct implications for financial transparency, investor confidence, and economic development in Azerbaijan. Where ISA are robustly implemented—particularly in banks, major corporates, and entities with significant foreign participation—audits contribute to more reliable financial information, enhance the credibility of reporting, and support access to international capital and credit. This, in turn, reinforces financial stability and can facilitate investment in key sectors such as energy, infrastructure, and manufacturing. Yet, in parts of the economy where audit quality is uneven or audits are absent, information risks remain higher. This duality means that the full potential of independent auditing standards—for example, broad-based SME financing, improved governance in SOEs, and deeper capital markets—has not yet been fully realized.

With respect to the research questions posed in the introduction, the findings can be summarized as follows:

1. **Core elements and stages of effective adaptation.** An effective adaptation process combines legal incorporation of ISA or ISA-based standards; high-quality translation and technical interpretation; alignment with company, financial, and securities legislation; establishment of competent standard-setting and oversight bodies; comprehensive education, qualification, and CPD systems; strong quality assurance and enforcement mechanisms; and a culture of ethics and independence. These elements typically unfold in stages, from initial formal adoption, through capacity building and institutional development, to ongoing updates and refinement.
2. **Azerbaijan's adaptation and specific measures.** Azerbaijan has adapted ISA by empowering the Chamber of Auditors to translate and adopt them, integrating them into licensing rules, methodological guidance, and QA inspections, and embedding them in education and training. Legislative reforms have progressively strengthened the audit framework, and sectoral regulators require ISA-based audits in key industries. The

operationalization of standards has relied on practical tools: translated ISA handbooks, guidance notes, model documentation, ISA-aligned exams, CPD programs, and sector-specific prudential rules in banking and investment funds.

3. **Remaining challenges and lessons for others.** Remaining challenges include limited oversight independence and capacity, uneven professional skills—especially outside major centers—difficulties in applying full ISA to small entities under fee pressure, and persistent ethical and independence risks. For other emerging economies, Azerbaijan’s experience underscores that: (a) de facto ISA adoption via professional regulation can be a powerful interim step; (b) robust QA systems and education are as important as legal reforms; (c) sectoral “flagship” areas (e.g., banks, oil and gas) can drive broader convergence; and (d) sustainable adaptation requires attention to economic incentives and ethical culture, not only technical standards.

Looking forward, Azerbaijan’s journey towards full international convergence will increasingly be shaped by digitalization and technological change. The spread of data analytics, automated controls, and digital reporting systems will alter how audits are planned and executed, potentially helping smaller firms implement ISA more efficiently but also raising new skill requirements and risks. This points to several avenues for future research. Empirical studies on audit quality—using inspection data, financial reporting outcomes, or restatements—could shed light on how far ISA adoption and ISQM implementation have improved practice in different segments of the Azerbaijani market. Surveys and interviews with auditors, regulators, and users of financial statements could explore perceptions of audit value, independence, and the practical challenges of ISA implementation. Comparative studies with peer countries could deepen understanding of which institutional designs and policy choices are most effective in sustaining convergence. Finally, research on the impact of digital tools on audit processes in Azerbaijan—particularly among small and medium-sized firms—would provide timely insights into the next phase of the country’s adaptation to international auditing standards.

In sum, Azerbaijan has moved a long way from a system with no independent audits to one where ISA—and, increasingly, ISQM—shape the practices of a growing and professionalized audit community. The task now is to close the remaining implementation gaps, strengthen institutions and incentives, and ensure that the benefits of high-quality, independent audits extend across the whole economy.

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