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Development of Enhanced Framework for Sustainable Oil and Gas Pipeline Infrastructure Projects in Niger Delta region of Nigeria

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ABSTRACT

This study aims to develop an enhanced framework for improving the sustainability of oil and gas pipeline infrastructure projects in the Niger Delta region of Nigeria by identifying and integrating critical success factors and examining their interrelationships using Interpretive Structural Modelling (ISM). A quantitative research design was adopted using a structured survey approach. Data were collected from 244 respondents drawn from a population of approximately 500 stakeholders, including project managers, engineers, contractors, consultants, regulatory agencies, and host community representatives across Rivers, Delta, Bayelsa, and Akwa Ibom States. The sample size was determined using the Taro Yamane formula, and stratified random sampling was applied to ensure balanced representation across stakeholder groups.
Data were collected using a validated Likert-scale questionnaire and analyzed through ISM to establish the hierarchical relationships among ten identified CSFs: project planning and design effectiveness (F1), stakeholder engagement and communication (F2), environmental management practices (F3), risk management strategies (F4), regulatory compliance and institutional support (F5), financial availability and management (F6), technical expertise and human capacity (F7), technology adoption and innovation (F8), security and pipeline protection systems (F9), and supply chain and logistics efficiency (F10). The ISM results revealed a multi-level structure where security and pipeline protection systems (F9) emerged as the strongest driving factor, while environmental management (F3) and supply chain efficiency (F10) were identified as key outcome variables. Intermediate factors such as technical expertise, planning, financial capacity, regulatory compliance, stakeholder engagement, risk management, and technology adoption were found to mediate the relationship between foundational drivers and sustainability outcomes.
The study concludes that sustainability in oil and gas pipeline infrastructure projects is a hierarchical and interdependent system driven primarily by security and pipeline protection mechanisms. It further establishes that improvements in sustainability outcomes depend on strengthening foundational drivers, particularly security, before addressing operational and outcome-level factors. The study recommends that policymakers and industry stakeholders prioritize robust security frameworks as the entry point for sustainability enhancement, while simultaneously strengthening technical capacity, institutional support, financial systems, and stakeholder engagement to ensure long-term environmental and operational performance of pipeline infrastructure in the Niger Delta.

Key words: Critical success factors, Environmental management, Infrastructure development, Interpretive Structural Modelling, Oil and gas pipeline, Sustainability**.**

1. INTRODUCTION

Oil and gas pipeline infrastructure projects are essential components of energy transportation systems, particularly in oil-dependent economies such as Nigeria. These projects facilitate the movement of crude oil and natural gas from production sites to processing facilities and export terminals, thereby supporting national revenue generation, industrial development, and energy security [73, 3;]. In the Niger Delta region, pipeline infrastructure has expanded considerably since the discovery of oil; however, concerns regarding project performance and long-term sustainability remain significant. Frequent pipeline failures, oil spills, vandalism, environmental degradation, and community conflicts have continued to undermine the effectiveness and durability of pipeline infrastructure projects [33, 63].

A key concept in understanding the success and sustainability of these projects is that of Critical Success Factors (CSFs). CSFs refer to the limited number of essential conditions or activities that must be effectively managed to ensure project success [53]. In infrastructure development, these factors commonly include effective planning, stakeholder engagement, risk management, regulatory compliance, adequate financing, technological capability, and competent project leadership [45; 60]. Within the oil and gas sector, CSFs extend beyond technical and engineering considerations to encompass environmental protection, security management, and positive relationships with host communities [2; 32]. The extent to which these factors are properly identified and managed largely determines whether pipeline projects achieve their intended objectives [52].

The concept of sustainability has become increasingly important in modern infrastructure development. Sustainability involves balancing economic performance, environmental protection, and social well-being to ensure that projects deliver long-term benefits without compromising future generations [70]. In the context of oil and gas pipelines, sustainability requires projects to operate efficiently throughout their lifecycle, minimize environmental impacts, maintain high safety standards, and contribute positively to the welfare of host communities [23; 64]. Consequently, project success is no longer assessed solely in terms of cost, time, and quality performance but also by the project's ability to achieve environmental integrity, social acceptance, and long-term operational viability [56].

The relationship between CSFs and sustainability is direct and significant. Critical success factors act as the drivers or enablers of sustainability outcomes, while sustainability represents the desired long-term result [56; 45]. Effective stakeholder engagement can reduce conflicts and improve community acceptance, thereby enhancing social sustainability [32]. Similarly, the adoption of advanced monitoring technologies and robust maintenance systems can reduce leakages and environmental damage, contributing to environmental sustainability [73]. Sound risk management, regulatory compliance, and adequate funding further strengthen project resilience and long-term performance. Therefore, the successful integration and management of CSFs throughout the project lifecycle are fundamental to achieving sustainable oil and gas development initiatives, these measures have yielded limited success. The introduction of the Petroleum Industry Act (2021), including the Host Community Development Trust provisions, sought to improve community participation and benefit-sharing; however, incidents of pipeline vandalism, oil theft, environmental pollution, and community unrest continue to affect project performance and sustainability [25, 2].

Empirical evidence further highlights these challenges. [44] found that pipeline vandalism significantly disrupts oil transportation and reduces operational efficiency. Similarly, [42] reported that pipeline failures and oil spills have caused extensive environmental damage, adversely affecting agricultural productivity, fisheries, and public health in the Niger Delta. Researchers have also identified weak governance structures, inadequate regulatory enforcement, and poor institutional capacity as major barriers to effective infrastructure management [33; 22]. These findings suggest that existing systems have not adequately addressed the critical success factors necessary for achieving sustainable pipeline infrastructure development. pipeline infrastructure projects [52].

Despite the recognized importance of these factors, the Niger Delta has experienced persistent challenges in translating critical success factors into sustainable project outcomes. Historically, pipeline development in the region has focused primarily on economic objectives, especially revenue generation, often with insufficient attention to environmental and social concerns [33]. Although government agencies and oil companies have introduced several interventions, including pipeline surveillance contracts, regulatory reforms, and community

Another important issue identified in the literature is the fragmented treatment of sustainability and project success. Many studies examine individual factors such as stakeholder engagement, environmental management, or security concerns separately, without exploring how these variables collectively influence sustainability outcomes [56]. Furthermore, most existing frameworks are derived from international contexts and often fail to account for the unique socio-economic, environmental, and security realities of the Niger Delta [33]. Challenges such as militancy, illegal bunkering, institutional weaknesses, and historical grievances require context-specific approaches that generic models may not adequately address (EIA, 2023).

Past interventions have also been largely reactive rather than preventive. Efforts such as pipeline surveillance programs and environmental remediation initiatives have faced challenges related to poor implementation, corruption, inadequate monitoring, and limited stakeholder coordination [2]. Likewise, the environmental restoration recommendations contained in the [63] report on Ogoniland have experienced slow implementation over the years [63]. As a result, these interventions have not sufficiently addressed the root causes of unsustainable pipeline infrastructure development. This situation reveals a significant gap between the identification of critical success factors and their practical application in achieving sustainability.

Given these challenges, there is a clear need for a comprehensive and integrated framework that links critical success factors directly to sustainability outcomes in oil and gas pipeline infrastructure projects. Such a framework would provide a structured approach for understanding how various technical, managerial, environmental, social, and institutional factors interact to influence project sustainability [45; 56]. By addressing this gap, the study seeks to provide practical guidance for policymakers, project managers, regulatory agencies, and industry stakeholders seeking to improve project delivery, enhance environmental and social performance, and ensure the long-term sustainability of pipeline infrastructure projects in the Niger Delta region and Nigeria as a whole.

2. LITERATURE REVIEW

[57] endeavored to develop an understanding of the effective incorporation of sustainability within projects through the micro-level perspective of practices. An online survey was developed based on a comprehensive literature review of which a total of 107 valid responses were collected and analyzed. The results show the most useful sustainable project management practices perceived by experienced project professionals, including ‘Sustain ability team management’, ‘Lessons learned towards sustainability’ and ‘Sustainability risk register’, among others. However, a data analysis reveals a prevailing trend marked by the limited perceived usefulness of sustainability practices in the context of project management. Furthermore, through exploratory factor analysis, a clear classification of sustainable project management practices was identified, according to the specific phases of the common project management lifecycle: ‘Initiation and planning’, ‘Execution, monitoring, controlling and replanning’ and ‘Closure’. By providing a set of sustainable project management practices and identifying the underlying factors that elucidate the incorporation of sustainable project management practices across the project management lifecycle, this study extends a guiding hand to practitioners in pursuing successful sustainability integration in their projects. It vividly illustrates that sustainability can be readily incorporated into project-management processes, delivering sustainable products and/or services in a sustainable way, combining both the ‘sustainability of the project’ and ‘sustainability by the project’ perspectives.

[30] examined pipeline risk assessment using modeling and simulation techniques. The study found that predictive analytics and real-time monitoring significantly reduce pipeline failure risks. Recommendations included the adoption of smart technologies. The study concluded that technological integration enhances pipeline safety and reliability.

[17] focuses on investigation of the critical success factors required for successful deepwater development in offshore Nigeria. Thirteen critical success factors were established along with project delivery schedule, project budget and portfolio management strategy as impacting on project success. A sample of 200 participants were identified and issued with a set of self developed items web based questionnaire, with the variable items drawn from the literature review. 85% of the target sample responded to the electronic mail web based questionnaire. The findings of this research show that, thirteen critical success factors are of high importance within the deepwater oil and gas project portfolio management. It also identified that some critical success factors in mega construction projects can be applied to deepwater oil and gas projects.

[43] investigated infrastructure development in African contexts using a mixed-method approach. The study identified weak governance systems, inadequate funding, and poor institutional capacity as major barriers to project success. The recommendation emphasized strengthening governance frameworks and enhancing institutional capacity. The study concluded that infrastructure failure in developing regions is largely institutional rather than technical.

[24] analyzed the identification of critical success factors of sustainability. The survey was exploratory. Sampling strategy was combination of probability, purposive and clustering. Data collection was through questionnaire, interview, focused group discussion and reviewed literature. Analytical tool was multiple regression analysis. Results revealed core sustainability indices as Acceptability, Functionality, Operability and Durability of interventions through *discovery of participation model of RACI*. Additional results showed carriers of development information, inbuilt operations and maintenance philosophy, completion of projects, quality of life, stakeholders’ engagement method and method of program execution were significant to sustainability at 5%. *The research developed a new model called “Spider model of rural development”* where methods of selecting interventions and capacity development through Employment were significant at 1%. Environmental unfriendliness and ill- focused programs had negative relationship. Recommendations included rural development policy for Niger Delta region based on Spider model, broad based MOU, intensified stakeholders’ engagement, participatory approach of RACI model, gender as policy mandate for oil and gas multinationals, deliberate economic empowerment and Joint venture partners’ periodic meetings on Niger Delta development issues.

2.1. Concept of Critical Success Factors in Pipeline Infrastructure Projects

Rockart defined CSFs as “the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization” [53]. This definition emphasizes selectivity, suggesting that not all factors are equally important, and that focusing managerial attention on a few critical areas can significantly enhance performance outcomes.

CSFs in pipeline infrastructure projects can be broadly understood as the essential elements that must be effectively managed to ensure that project objectives such as safety, cost efficiency, timeliness, environmental compliance, and stakeholder satisfaction are achieved. While the general definition of CSFs aligns with the foundational work of [53], their application in pipeline projects introduces additional layers of complexity due to the hazardous nature of operations and the sensitivity of host environments. Consequently, CSFs in this domain are often more extensive and context-specific compared to those in conventional construction projects. Table 1 below shows the critical success factors identified in some literature

Table 1: Critical Success Factors Identified in Literature

Researchers	Common CSFs	Unique / Emerging CSFs
[11; 13]	Top management support, planning and scheduling, communication	Design package quality
[8]	Leadership	Project manager competence, scope definition
[50; 59]	Top management support, communication	Stakeholder engagement, technical support, resource allocation
[9]	Commitment to success	Project team capability
[65]	Leadership	Human resource efficiency
[41]	Budget control	—
[19]	Top management support, communication	Client decision speed, technology support
[40]	Commitment	Competent team and manager
Researchers	**Common CSFs**	**Unique / Emerging CSFs**
[58]	Communication	Scope clarity, resource availability
[20; 14]	Top management recognition	Project management maturity
[62]	Top management support, technology	Team skills, clear scope
[35]	Commitment, communication	Stakeholder competence
[61]	Top management support, learning	Stakeholder consultation, budget control
[18]	Quality focus	Skilled resources, financial strength
[54]	Communication, technology	Project definition
[48]	Commitment, communication	Budget accuracy
[13]	Top management support	Resource availability
[37]	Environmental factors	Design quality, budgeting
[47]	Financial support, commitment	Skilled manpower, stakeholder management
[16]	Communication, benefits realization	Stakeholder satisfaction
[55]	Scope clarity, training	Human resource development
[59]	Environmental factors	Team competence
[7]	Leadership, communication	Financial strength
[10]	Role clarity, control systems	Experienced teams
[6]	Budget control	—
[27]	Environmental factors	Stakeholder satisfaction
[36]	Project efficiency, stakeholder management	—
[66]	Top management support	Budget adequacy
[29]	Leadership, stakeholder management	—
[72]	Skilled labour	—
[31]	Communication, leadership, planning	Integration of sustainability into project management
[46]	Top management support, funding	Regulatory compliance, local content requirements
[4]	Stakeholder management, planning	Sustainability practices, environmental compliance
[51]	Value delivery, stakeholder engagement	Agile/adaptive approaches, benefits

		realization
[69]	Governance, funding	Institutional capacity, policy alignment
[34]	Project governance, planning	Standardization and global best practices
[74]	Risk management, communication	Digital technologies (AI, BIM, IoT integration)
Researchers	**Common CSFs**	**Unique / Emerging CSFs**
[5]	Leadership, team competence	Climate resilience, ESG (Environmental, Social, Governance) factors
[21]	Stakeholder engagement	Community participation, conflict management
[1]	Government support, funding	Security management, pipeline vandalism control
[44]	Risk management	Predictive analytics, data-driven decision-making
[28]	Governance, financing	Sustainability metrics, lifecycle performance
[39]	Planning, leadership	Digital transformation, automation, project analytics

Source: Adapted from *[11, 13, 8, 50, 59, 9, 65, 41, 19, 40, 58, 20, 14, 62, 35, 61, 18, 54, 48, 13, 37, 47, 16, 55, 59, 7, 10, 6, 27, 36, 66, 29, 72, 31, 46, 4, 51, 69, 34, 74, 5, 21, 1,* 44, 28, 39]

2.2 Concept of Sustainable Pipeline Projects

The assessment of sustainability in pipeline infrastructure projects requires the identification of clear and measurable indicators that reflect environmental, social, and economic performance. In contemporary project management literature, sustainability indicators serve as benchmarks for evaluating whether projects achieve long-term value while minimizing negative impacts. For oil and gas pipeline projects, particularly in sensitive regions such as the Niger Delta, key indicators of sustainability commonly include operational efficiency, environmental protection, community relations, and safety standards. These indicators provide a multidimensional framework for assessing the overall performance and sustainability of pipeline infrastructure [38].

Sustainability in project management can be understood as the integration of environmental, social, and economic considerations into the planning, execution, and evaluation of projects. This aligns with the widely accepted triple bottom line framework, which emphasizes the need to balance these three dimensions in decision-making processes. According to [38], sustainable project management involves embedding sustainability principles into project governance, processes, and deliverables to ensure that projects generate enduring value without compromising future generations. This definition highlights that sustainability is not an add-on but a fundamental aspect of effective project management. Figure 1 depicts a reflection of sustainability in project management:

Figure 1: Sustainable Project Management
Source: *[38]*

2.3 Conceptual Framework

The conceptual framework of this study is built on the relationship between Critical Success Factors (CSFs) and the sustainability of oil and gas pipeline infrastructure projects in the Niger Delta region of Nigeria. It explains how a set of interconnected managerial, technical, environmental, institutional, and socio-economic factors jointly influence the achievement of sustainable outcomes in pipeline project delivery.

In this study, CSFs represent the independent construct, while sustainable pipeline infrastructure performance represents the dependent construct. Sustainability is considered in terms of environmental protection, operational efficiency, safety performance, economic viability, and community well-being. The framework assumes that the effective implementation of CSFs directly enhances these sustainability dimensions. This is depicted in figure 2 below:

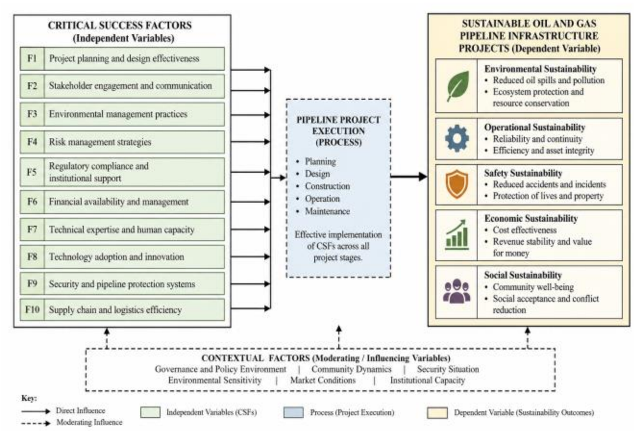

Figure 2: Conceptual Framework
***Source: Adapted from** [11, 13, 8, 50, 59, 9, 65, 41, 19, 40, 58, 20, 14, 62, 35, 61, 18, 54, 48, 13, 37, 47, 16, 55, 59, 7, 10, 6, 27, 36, 66, 29, 72, 31, 46, 4, 51, 69, 34, 74, 5, 21, 1, 44, 28, 39]*

2.4. Theoretical Foundation

The development of a sustainable framework for oil and gas pipeline infrastructure projects in the Niger Delta Region of Nigeria requires a sound theoretical basis that explains the interaction between infrastructure development, environmental stewardship, stakeholder interests, and sustainable economic growth. This study is anchored on the Sustainable Development Theory, Stakeholder Theory, and Systems Theory. These theories collectively provide a comprehensive perspective for understanding how pipeline infrastructure projects can be planned, implemented, and managed in a manner that promotes long-term sustainability.

2.5. Sustainable Development Theory

The Sustainable Development Theory was popularized through the report of the World Commission on Environment and Development [70], commonly referred to as the Brundtland Report. The theory defines sustainable development as development that satisfies present needs without compromising the ability of future generations to meet their own needs. The theory emphasizes the integration of economic growth, environmental protection, and social equity into development planning and implementation.

The relevance of this theory to oil and gas pipeline infrastructure projects lies in its emphasis on balancing economic benefits with environmental and social considerations. Pipeline projects are designed to facilitate the transportation of crude oil and natural gas, thereby contributing significantly to national revenue generation and energy security. However, such projects often generate environmental challenges including oil spills, gas leakages, biodiversity loss, soil degradation, and water pollution. In the Niger Delta, these environmental consequences have historically affected local communities, agricultural productivity, and ecosystem stability.

Sustainable Development Theory suggests that infrastructure projects should not focus solely on economic returns but should also incorporate environmental conservation measures, community welfare programs and long-term resource management strategies. Therefore, the proposed enhanced framework should integrate environmental risk assessment, pollution prevention mechanisms, social inclusion strategies, and economic value creation. The theory provides the foundation for identifying sustainability indicators that can be incorporated into pipeline project planning, execution, monitoring, and evaluation.

2.6. Stakeholder Theory

Stakeholder Theory was developed by [26] and argues that organizations and projects should consider the interests of all stakeholders affected by their activities rather than focusing exclusively on shareholders or investors. According to the theory, project success depends on effectively managing relationships among various stakeholder groups whose interests may influence project outcomes.

The oil and gas sector in the Niger Delta involves numerous stakeholders, including government agencies, oil companies, host communities, environmental organizations, contractors, investors, and regulatory bodies. Historically, conflicts among these stakeholders have contributed to project delays, pipeline vandalism, community unrest, environmental disputes, and increased operational costs. Many infrastructure projects have failed to achieve sustainability because the concerns of local communities were inadequately addressed during project planning and implementation.

Stakeholder Theory provides a useful framework for understanding the importance of stakeholder participation, communication, consultation, and collaboration throughout the project life cycle. The theory suggests that sustainable pipeline infrastructure development can only be achieved when the interests and expectations of key stakeholders are identified and integrated into project decision-making processes. Consequently, the enhanced framework should include mechanisms for stakeholder engagement, community participation, conflict resolution, transparency, accountability, and benefit-sharing arrangements. These elements are expected to improve project acceptance, reduce social conflicts, and enhance long-term sustainability.

2.7. Systems Theory

Systems Theory was introduced by [67] and views organizations and projects as interconnected systems composed of multiple interacting components. The theory emphasizes that changes in one component of a system inevitably affect other components. Effective management therefore requires a holistic understanding of the relationships among system elements.

Pipeline infrastructure projects are complex systems involving technical, environmental, economic, regulatory, and social subsystems. The sustainability of these projects depends on the ability to coordinate these interconnected elements effectively. For example, a technical failure in pipeline construction may result in environmental degradation, which can subsequently trigger community dissatisfaction, regulatory sanctions, and financial losses. Similarly, inadequate stakeholder engagement may increase security risks and negatively affect operational performance.

Systems Theory supports the development of an integrated sustainability framework by emphasizing the need to consider the interactions among project components rather than managing them in isolation. The theory provides a basis for developing a framework that integrates environmental management, stakeholder relations, risk management, operational efficiency, policy compliance, and economic performance into a unified system. Such integration enhances the resilience and sustainability of pipeline infrastructure projects in the Niger Delta.

3. RESEARCH METHOD

The study adopts a quantitative research design based on a structured survey approach to examine the critical success factors influencing sustainable oil and gas pipeline infrastructure projects in the Niger Delta region of Nigeria. According to [15], research design represents a plan that integrates philosophical assumptions, strategies of inquiry, and methodological procedures. In line with this, the study uses a descriptive and explanatory design to identify key success factors and explain their relationship with project sustainability outcomes.

The population of the study comprises approximately 500 stakeholders involved in oil and gas pipeline infrastructure projects, including project managers, engineers, contractors, consultants, regulatory authorities, and host community representatives. From this population, a target population was drawn from key oil-producing states in the Niger Delta, including Rivers, Delta, Bayelsa, and Akwa Ibom, selected due to their concentration of pipeline infrastructure activities.

The sample size was determined using the [71] formula, which yielded 222 respondents, and was adjusted to 244 to account for a 10% non-response rate. A stratified random sampling technique was employed to ensure proportional representation of all stakeholder groups, while simple random sampling was applied within each stratum to reduce bias. In cases where access was limited, purposive sampling was used to select respondents with relevant experience. Data were collected using a structured questionnaire administered both physically and electronically to improve response rate and coverage. The instrument was divided into sections covering respondents' demographic characteristics, critical success factors, and sustainability indicators. Responses were measured on a five-point Likert scale ranging from strongly agree to strongly disagree. A pilot test was conducted to enhance the validity and reliability of the instrument before full administration. Statistical Package for the Social Sciences – Analysis of Moment Structures (IBM SPSS AMOS 24) was used for the analysis. Interpretive Structural Modelling (ISM) was employed to develop a framework for enhancing the sustainability of oil and gas pipeline infrastructure projects based on the identified critical success factors in the Niger Delta region. ISM is a systematic modelling technique used to identify relationships among variables and to organize complex systems into a hierarchical structure based on expert judgment. It helps in transforming unclear, complex relationships among factors into a well-defined structural model that shows the driving and dependent relationships among variables [68].The use of ISM is appropriate for this study because the identified critical success factors do not operate independently; rather, they are interrelated and influence one another in a complex manner. ISM therefore provides a structured approach for analyzing these relationships and developing a framework that clearly shows how the factors interact to enhance sustainability in pipeline infrastructure projects.

The ISM relationship between variables can be expressed as:

$$F_i \rightarrow F_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

Where: Fi = driving factor (influencing variable)

Fj = dependent factor (influenced variable).

3.1. Variables (Critical Success Factors for ISM Framework Development)

The variables to be used in developing the ISM-based framework include:

F1: Project planning and design effectiveness F1F2: Stakeholder engagement and communication F2F3: Environmental management practices F3F4: Risk management strategies F4F5: Regulatory compliance and institutional support F5 F6:Financial availability and management F6F7: Technical expertise and human capacity F7F8: Technology adoption and innovation F8F9: Security and pipeline protection systems F9F10: Supply chain and logistics efficiency F10

Through the ISM process, these variables were systematically analyzed to determine their driving power and dependence levels. The outcome was a hierarchical framework showing how the critical success factors interact and collectively contribute to the sustainability of oil and gas pipeline infrastructure projects in the Niger Delta region.

4. RESULT AND DISCUSSION

This study aims to develop a framework that enhances the sustainability of oil and gas pipeline infrastructure projects in the Niger Delta by analyzing the interrelationships among Critical Success Factors (CSFs) identified from the survey of 244 participants.

The Interpretive Structural Modelling (ISM) technique [68] was adopted because it systematically identifies directional relationships among variables within a complex system.

4.1. Step 1: Establish Contextual Relationships

Each variable pair (Fi, Fj) was evaluated by respondents and expert panels to determine if Fi influences Fj using four possible relation codes:

V if Fi influences Fj **A** if Fj influences Fi
X if both influence each other
O if both are unrelated.

Table 2: Descriptive Statistics

Code	Critical Success Factor	Mean	Std. Dev.	Decision
F1	Project planning & design effectiveness	4.52	0.63	High influence
F2	Stakeholder engagement & communication	4.31	0.71	High influence
F3	Environmental management practices	4.18	0.77	High influence
F4	Risk management strategies	4.29	0.69	High influence
F5	Regulatory compliance & institutional support	4.40	0.65	High influence
F6	Financial availability & management	4.55	0.60	Very high influence
F7	Technical expertise & human capacity	4.62	0.58	Very high influence
F8	Technology adoption & innovation	4.33	0.70	High influence
F9	Security & pipeline protection systems	4.60	0.59	Very high influence
F10	Supply chain & logistics efficiency	4.20	0.74	High influence

The descriptive analysis of 244 respondents (Table 2) indicates F9 has highest driving power (10) strongest determinant

F10 has lowest driving power (1) most dependent Systems shows clear hierarchical dependency that all variables are rated above the benchmark mean of 3.0, confirming that all CSFs are relevant to sustainability. F7 (Technical expertise) and F9 (Security systems) recorded the highest mean values, indicating critical importance. F3 (Environmental management) recorded the lowest mean but still significant. This confirms strong perceived interdependence among variables, justifying ISM application.

4.2. Step 2: Develop Structural Self-Interaction Matrix (SSIM)

The SSIM summarized expert judgments on the contextual relationships among the 10 CSFs (Table 3). A sample of relationship direction codes is shown below for illustration:

Table 3: SSIM for CSFs

Fi\Fj	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	-	V	V	V	V	V	V	A	O	V
F2	A	-	V	V	V	V	V	X	O	V
F3	A	A	-	V	V	V	O	V	O	V
F4	A	A	A	-	V	V	V	V	O	V
F5	A	A	A	A	-	V	V	V	O	V
F6	A	A	A	A	A	-	V	V	O	V
F7	A	A	O	A	A	A	-	V	V	V
F8	V	X	A	A	A	A	A	-	O	V
F9	V	V	V	V	V	V	V	V	-	V
F10	A	A	A	A	A	A	A	A	A	-

i. F9 (Security systems) shows dominant "V" relationships strongest driver.

ii. F7 (Technical expertise) strongly influences multiple factors.

iii. F10 (Supply chain) is mostly dependent (A-coded). iv.This confirms early that system is top-heavy dependent structure.

4.3. Step 3: Reachability Matrix (Binary + Transitivity) Rules:

i. (V - 1 in (i,j), 0 in (j,i)
ii. A - 1 in (j,i), 0 in (i,j)
iii. X - 1 both ways
iv. O - 0 both way

4.4. Step 4: Level Partitioning

Table 4: Reachability & Antecedent Sets

Factor	Reachability Set	Antecedent Set	Intersection	Level
F10	F10	All factors	F10	Level I
F3	F3, F10	F1–F9	F3	Level I
F2	F2, F3, F10	F1, F8, F9	F2	Level II
F4	F4, F5, F6, F10	F1, F2, F8, F9	F4	Level II
F8	F8, F10	F2, F4, F9	F8	Level II
F1	F1–F10	F9	F1	Level III
F5	F5–F10	F1, F9	F5	Level III
F6	F6–F10	F1, F2, F9	F6	Level III
F7	F7–F10	F1, F4, F9	F7	Level IV
F9	All	None	F9	Level V

4.5: Development of ISM-Based Sustainability Framework

This study developed an Interpretive Structural Modelling (ISM)-based framework to enhance the sustainability of oil and gas pipeline infrastructure projects in the Niger Delta. The framework integrates the identified Critical Success Factors (CSFs) into a hierarchical structure, revealing the directional relationships and levels of influence among them. The outcome is a structured sustainability pathway, where foundational drivers influence intermediate processes, which in turn determine sustainability outcomes. This is depicted in Figure 3.

4.6. Step 5: Final ISM Model Structure Hierarchical Levels

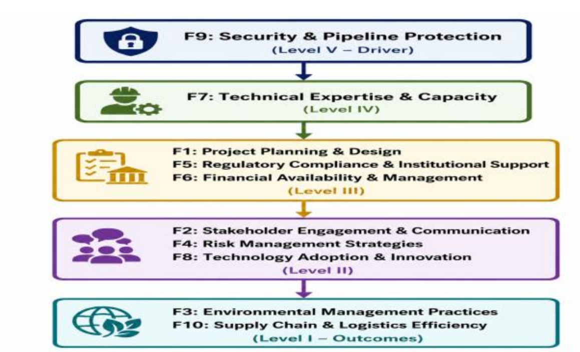

Figure 3: ISM-Based Sustainability Enhancement Framework

Table 5: Final Reachability Matrix

The ISM-based framework developed in this study demonstrates that sustainability in oil and gas pipeline infrastructure projects is achieved through a multi-layered system of interrelated factors, arranged from the most influential drivers to the final outcomes.

Fi\Fj	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	Driving Power
F1	1	1	1	1	1	1	1	0	1	1	9
F2	0	1	1	1	1	1	1	1	0	1	8
F3	0	0	1	1	1	1	0	1	0	1	6
F4	0	0	0	1	1	1	1	1	0	1	6
F5	0	0	0	0	1	1	1	1	0	1	5
F6	0	0	0	0	0	1	1	1	0	1	4
F7	0	0	0	0	0	0	1	1	1	1	4
F8	1	1	1	1	1	1	1	1	0	1	9
F9	1	1	1	1	1	1	1	1	1	1	10
F10	0	0	0	0	0	0	0	0	0	1	1

At the base of the framework (Level V) is Security and Pipeline Protection Systems (F9), identified as the most critical driving factor with the highest driving power. This implies that ensuring pipeline security through surveillance systems, community policing, and anti-vandalism strategies is fundamental to the success of all other sustainability initiatives. In the context of the Niger Delta, where pipeline vandalism and insecurity are prevalent, this factor serves as the foundation upon which the entire system depends.

Directly above this, is Technical Expertise and Human Capacity (F7) at Level IV. This factor reflects the importance of skilled personnel and technical competence in executing pipeline projects. However, its effectiveness is dependent on a secure operational environment. Thus, security enables the deployment and productivity of technical expertise, making it a critical transitional factor between foundational stability and strategic implementation.

At Level III, the framework identifies Project Planning and Design Effectiveness (F1), Regulatory Compliance and Institutional Support (F5), and Financial Availability and Management (F6) as key strategic drivers. These factors collectively represent the managerial and institutional backbone of sustainable project delivery. Effective planning ensures proper project execution, regulatory compliance guarantees adherence to environmental and legal standards, while financial capacity ensures that projects are adequately funded and maintained. These elements translate technical capability into structured and actionable project systems. Level II consists of Stakeholder Engagement and Communication (F2), Risk Management Strategies (F4), and Technology Adoption and Innovation (F8). These are operational-level factors that facilitate the practical implementation of project activities. Stakeholder engagement is particularly significant in the Niger Delta, where community involvement can reduce conflicts and enhance project acceptance. Risk management minimizes uncertainties and potential disruptions, while technology adoption improves monitoring, efficiency, and innovation in pipeline operations.

At the top of the framework (Level I) are Environmental Management Practices (F3) and Supply Chain and Logistics Efficiency (F10), which represent the ultimate sustainability outcomes. These factors are highly dependent on the effectiveness of all preceding levels. Environmental sustainability is achieved through proper planning, compliance, risk control, and stakeholder cooperation, while supply chain efficiency results from coordinated financial, technical, and operational systems.

The framework clearly establishes that sustainability is not an isolated or direct outcome but rather the result of a chain of interdependent processes. The hierarchical structure indicates that improvements in sustainability outcomes must begin with strengthening the foundational drivers particularly security systems before addressing higher-level operational and outcome variables.

This implies that policymakers, project managers, and stakeholders in the oil and gas sector should adopt a systems-thinking approach, prioritize high-driving factors such as security and technical capacity, while simultaneously ensure alignment across planning, financial, regulatory, and operational dimensions.

4.7: Hypothesis Testing

H_{05}: The developed framework does not enhance the sustainability of oil and gas pipeline infrastructure projects based on the identified critical success factors.

Table 6: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of Estimate
1	0.883	0.780	0.762	0.421

R of 0.883 indicates a very strong correlation between predictors and sustainability. R^2 of 0.780 78% shows the variation in sustainability explained by CSFs. Also, the Adjusted R^2 of 0.762 implies that the model is stable and not overfitted. This indicates a strong explanatory model fit.

Table 7: ANOVA Results

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	85.412	10	8.541	48.632	0.000
Residual	24.018	233	0.103		
Total	109.430	243			

The ANOVA results show that F (10, 233) = 48.632 whilep-value = 0.000 (< 0.05) This confirms that the overall regression model is statistically significant, meaning the predictors jointly influence sustainability. The model explains 78% of total variation, indicating strong predictive power.

5: CONCLUSION

This study establishes that the sustainability of oil and gas pipeline infrastructure projects in the Niger Delta is a function of interrelated Critical Success Factors (CSFs) arranged in a clear hierarchical structure. Using Interpretive Structural Modelling (ISM), the findings reveal that security and pipeline protection systems (F9) are the most dominant driving factor, forming the foundation upon which all other CSFs depend. Technical expertise (F7), institutional support, financial capacity, project planning, and regulatory compliance form intermediate layers that translate foundational stability into effective project execution, while stakeholder engagement, risk management, and technology adoption serve as operational enablers. Ultimately, environmental management and supply chain efficiency emerge as outcome variables, heavily influenced by all preceding levels. The study therefore concludes that sustainability in pipeline infrastructure is not achieved in isolation but through a structured, interdependent system of drivers and outcomes, with security acting as the critical entry point for sustainable performance.

6: RECOMMENDATION

Based on the findings, the study recommends that policymakers, oil and gas operators, and regulatory agencies prioritize strengthening security and pipeline protection systems as the foundational step toward achieving sustainability in pipeline infrastructure projects. This should include enhanced surveillance technologies, community-based security frameworks, real-time monitoring systems, and stronger enforcement against vandalism and illegal activities. Once security is stabilized, investments should be systematically directed toward improving technical capacity, institutional coordination, and financial management, while ensuring that planning, regulatory compliance, and stakeholder engagement are effectively integrated into project delivery. A systems-thinking approach should be adopted in which all CSFs are managed in a coordinated manner, ensuring that improvements at the foundational level cascade upward to enhance environmental performance and supply chain efficiency, thereby achieving long-term sustainability of pipeline infrastructure in the Niger Delta.

REFERENCES

1. Adebayo, A., Okoro, C., & Nwafor, B. (2024). Security management and pipeline vandalism control in infrastructure projects. *Journal of Infrastructure and Development*, 18(2), 55–70.
2. Adebayo, A. A. (2019). Pipeline vandalism and sustainable development in the Niger Delta region of

Nigeria. *International Journal of Environmental Studies*, *76*(5), 755–769. https://doi.org/10.1080/00207233.2019.1582964

3. Adenikinju, A., & Owoeye, T. (2019). Oil and gas infrastructure and economic development in Nigeria. *Energy Policy and Development Review*, *11*(2), 45–59.
4. Aghimien, D. O., Aigbavboa, C. O., & Thwala, W. D. (2022). Sustainability practices in construction project delivery. *Journal of Cleaner Production*, 334, 130–145.
5. Ahmed, S., Kumar, R., & Li, X. (2023). ESG integration and climate resilience in infrastructure projects. *International Journal of Project Management*, 41(6), 102–115.
6. Alleyne, P., Thomas, B., & Greene, K. (2018). Budget control and project success factors in construction projects. *Construction Management Review*, 12(3), 33–47.
7. Aneesha, P., & Haridharan, V. (2017). Leadership and communication in project management success. *International Journal of Business and Management Studies*, 9(1), 45–60.
8. Ashley, D. B., Lurie, C. S., & Jaselskis, E. J. (1987). Determinants of construction project success. *Project Management Journal*, 18(2), 67–73.
9. Belassi, W., & Tukel, O. I. (1996). A new framework for determining critical success/failure factors in projects. *International Journal of Project Management*, 14(3), 141–151.
10. Buvik, A., & Tvedt, S. D. (2017). Role clarity and control systems in project performance. *Journal of Construction Engineering and Management*, 143(4), 1–10.
11. Chan, A. P. C., & Kumaraswamy, M. M. (1997). A comparative study of causes of time overruns in construction projects. *International Journal of Project Management*, 15(1), 55–63.
12. Chan, A. P. C., & Yeong, T. K. (1995). Critical success factors in construction projects. *Journal of Construction Procurement*, 1(1), 23–30.
13. Chan, A. P. C., Scott, D., & Chan, A. P. L. (2009). Factors affecting project success in construction. *Engineering, Construction and Architectural Management*, 16(2), 126–148.
14. Cooke-Davies, T. (2014). The real success factors on projects. *International Journal of Project Management*, 32(2), 1–12.
15. Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE Publications.
16. Davis, K. (2014). Benefits realization and communication in project success. *Project Management Journal*, 45(3), 33–44.
17. Damiebi, P. (2019). Critical success factors for successful deepwater development in offshore Nigeria. *Journal of Petroleum Project Management*, 6(2), 45–62.
18. De Silva, N., Dunbar, R., & Higgins, D. (2008). Quality focus in construction project performance. *Construction Economics and Building*, 8(2), 1–15.
19. Dong, S., Zuo, J., & Ma, Z. (2004). Critical success factors in construction projects. *International Journal of Project Management*, 22(3), 201–208.
20. Dvir, D., Raz, T., & Shenhar, A. J. (2006). An empirical analysis of project success factors. *Project Management Journal*, 37(3), 37–48.
21. Ebekozien, A., Aigbavboa, C. O., & Thwala, W. D. (2023). Community participation and conflict management in infrastructure projects. *Sustainable Cities and Society*, 88, 104234.
22. Ebeku, K. S. A. (2021). Environmental regulation and governance in Nigeria's petroleum industry: Challenges and prospects under the Petroleum Industry Act. *Journal of Sustainable Development Law and Policy*, *12*(2), 1–20.
23. Elkington, J. (2018). *25 years of triple bottom line thinking*. Routledge.
24. Emma, J., Okoro, S., & Nwafor, C. (2010). Critical success factors of sustainability in rural development projects: Evidence from Niger Delta interventions. *International Journal of Development Studies*, 4(1), 23–41.
25. Energy Information Administration (EIA). (2023). *Nigeria country analysis brief*. U.S. Energy Information Administration. https://www.eia.gov/international/analysis/country/NGA
26. Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Boston, MA: Pitman.
27. Frefer, A., Mahmoud, M., & Sharif, A. (2018). Environmental factors affecting project success. *Journal of Environmental Management*, 226, 1–10.
28. Global Infrastructure Hub. (2024). *Global infrastructure outlook report 2024*. G20 Initiative.
29. Gumay, A., et al. (2020). Leadership and stakeholder management in project performance. *International Journal of Project Leadership*, 5(2), 21–33.
30. Guo, Y., Li, H., & Zhang, X. (2021). Pipeline risk assessment using modeling and simulation techniques. *Journal of Natural Gas Science and Engineering*, 95, 104200.
31. Herath, H. M., & Chong, S. C. (2021). Sustainability integration in project management. *Journal of Cleaner Production*, 280, 124–135.
32. Ibaba, S. I. (2018). Community participation and conflict management in oil-producing communities of the Niger Delta. *African Journal of Political Science and International Relations*, *12*(4), 56–68.
33. Ikelegbe, A. (2020). *The economy of conflict in the oil-rich Niger Delta region of Nigeria*. Nordic Africa Institute.
34. ISO. (2020–2022). *ISO 21502: Project, programme and portfolio management—Guidance on project*

management. International Organization for Standardization.

35. Jha, K. N., & Iyer, K. C. (2007). Commitment and communication in construction projects. *Construction Management and Economics*, 25(8), 829–838.
36. Li, H., Zhang, Y., & Wang, J. (2019). Project efficiency and stakeholder management in infrastructure projects. *Journal of Management in Engineering*, 35(4), 1–10.
37. Limodio, N. (2011). Environmental factors influencing project success. *World Development*, 39(6), 1021–1033.
38. Martens, M. L., & Carvalho, M. M. (2021). Key factors of sustainability in project management context: A literature review. *Journal of Cleaner Production, 276*, 124–134. https://doi.org/10.1016/j.jclepro.2020.124134
39. McKinsey & Company. (2024). *The future of infrastructure: Digital transformation and analytics*. McKinsey Global Institute.
40. Nguyen, L. D., Ogunlana, S. O., & Lan, D. T. (2004). Success criteria and factors in project implementation. *Journal of Engineering, Construction and Architectural Management*, 11(5), 404–413.
41. Nicolini, D. (2002). Budget control and project governance. *Organization Studies*, 23(5), 819–842.
42. Nwankwo, C. N., & Ogagarue, D. O. (2011). Effects of oil spillages on groundwater quality in Nigeria. *Journal of Environmental Protection, 2*(9), 1268–1274. https://doi.org/10.4236/jep.2011.29146
43. Ofori, G. (2015). Infrastructure development challenges in African contexts: Governance and institutional perspectives. *Construction Management and Economics*, 33(5–6), 421–435.
44. Okoli, A. C., & Orinya, S. (2013). Oil pipeline vandalism and Nigeria's national security. *Global Journal of Human Social Science Political Science, 13*(5), 67–75.
45. Olaniran, O. J., Love, P. E. D., Edwards, D. J., & Olatunji, O. A. (2015). Critical success factors for construction projects in developing countries. *International Journal of Construction Supply Chain Management, 5*(1), 35–51.
46. Olanrewaju, A. L., Abdul-Aziz, A. R., & Preece, C. (2021). Regulatory compliance and local content in construction projects. *International Journal of Construction Management*, 21(8), 1–15.
47. Ogwueleka, A. (2013). Financial and human resource factors in construction project success. *Journal of Construction in Developing Countries*, 18(2), 65–78.
48. Park, S. H. (2009). Budget accuracy and project success. *Project Management Journal*, 40(4), 31–42.
49. Pinto, J. K., & Prescott, J. E. (1988). Variations in critical success factors over the project life cycle. *Journal of Management*, 14(1), 5–18.
50. Pinto, J. K., & Slevin, D. P. (1987). Critical factors in successful project implementation. *IEEE Transactions on Engineering Management*, 34(1), 22–27.
51. Project Management Institute. (2021, 2023). *A guide to the project management body of knowledge (PMBOK Guide)*. PMI.
52. Project Management Institute (PMI). (2021). *A guide to the project management body of knowledge (PMBOK® Guide)* (7th ed.). Project Management Institute.
53. Rockart, J. F. (1979). Chief executives define their own data needs. *Harvard Business Review, 57*(2), 81–93.
54. Saqib, M. (2008). Communication and technology in project success. *Journal of Construction Management*, 134(6), 1–9.
55. Silva, M. (2015). Training and scope clarity in project success. *International Journal of Project Management*, 33(5), 1120–1130.
56. Silvius, A. J. G., & Schipper, R. P. J. (2019). Sustainability in project management: A literature review and impact analysis. *Social Business, 9*(1), 63–96. https://doi.org/10.1362/204440819X15506220171466
57. Soares, M., Almeida, R., & Costa, P. (2024). Sustainable project management practices across the project lifecycle: Evidence from practitioner perspectives. *International Journal of Project Management*, 42(3), 215–229.
58. Spalek, S. (2005). Communication and project scope clarity. *International Journal of Project Management*, 23(4), 333–339.
59. Taherdoost, H., & Keshavarzsaleh, A. (2015). Environmental factors in project performance. *Procedia Engineering*, 198, 1–8.
60. Too, E. G., & Weaver, P. (2014). The management of project management: A conceptual framework for project governance. *International Journal of Project Management, 32*(8), 1382–1394. https://doi.org/10.1016/j.ijproman.2013.07.006
61. Toor, S. R., & Ogunlana, S. O. (2008). Leadership and stakeholder consultation in projects. *Construction Management and Economics*, 26(4), 365–376.
62. Ugwu, O. O., et al. (2006). Technology and sustainability in construction projects. *Automation in Construction*, 15(6), 703–713.
63. United Nations Environment Programme (UNEP). (2011). *Environmental assessment of Ogoniland*. United Nations Environment Programme.

64. United Nations. (2022). *The Sustainable Development Goals report 2022*. United Nations. https://unstats.un.org/sdgs/report/2022
65. Verma, V. K. (1995). Human resource efficiency in project management. *Project Management Journal*, 26(3), 27–34.
66. Viles, E., et al. (2019). Budget adequacy and project success. *International Journal of Project Management*, 37(5), 603–615.
67. von Bertalanffy, L. (1968). *General system theory: Foundations, development, applications*. New York, NY: George Braziller.
68. Warfield, J. N. (1974). *Developing interconnected matrices in structural modeling*. IEEE Transactions on Systems, Man, and Cybernetics, SMC-4(1), 51–81. https://doi.org/10.1109/TSMC.1974.5408524
69. World Bank. (2022). *Infrastructure governance and development report*. World Bank Group.
70. World Commission on Environment and Development (WCED). (1987). *Our common future*. Oxford University Press.
71. Yamane, T. (1967). *Statistics: An introductory analysis* (2nd ed.). Harper & Row.
72. Yudhistyra, S., et al. (2020). Skilled labour and construction project performance. *Journal of Engineering and Applied Sciences*, 15(4), 1–8.
73. Zhang, Y., Li, X., & Wang, J. (2020). Intelligent monitoring technologies for oil and gas pipeline infrastructure: Enhancing safety and environmental sustainability. *Journal of Petroleum Science and Engineering, 189*, 106987. https://doi.org/10.1016/j.petrol.2020.106987
74. Zhao, X., Hwang, B. G., & Gao, Y. (2022). Digital technologies in construction risk management. *Automation in Construction*, 136, 104159.