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IMPACT OF REGULATORY AND TECHNOLOGICAL DRIVERS ON THE IMPLEMENTATION OF GREEN PORT OPERATIONS IN NIGERIA'S OIL AND GAS EXPORT TERMINALS

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ABSTRACT

Nigeria is the largest oil producer in Africa but the faces serious environmental challenges due to its oil and gas export terminals which are under pressure to embrace sustainable green practices. The study investigated the effect of regulatory and technological drivers on the adoption of green port operations in the Nigerian context of oil and gas export terminals, moderated by top management commitment and mediated by operational excellence. A primary quantitative research design was adopted, using survey data from 384 respondents at key Nigerian terminals. PLS-SEM analysis was used to evaluate the relationships between regulatory drivers, technological drivers, top management commitment, operational excellence, and green port operations. The study showed that regulatory drivers significantly influence operational excellence and green port operations while technological drivers significantly influence operational excellence. Top management commitment was found to moderate the relationship between these drivers and green port operations. All these drivers should be prioritized by policymakers and port operators to increase competitiveness in the global energy market, with full environmental sustainability. The research is original since it integrates institutional theory with internal organisational factors such as top management commitment and operational excellence in explaining green port adoption in Nigeria's oil and gas terminals.

KEYWORDS: Green Port Operations, Nigeria, Regulator Drivers, Technological Drivers, Top Management Committee, Operational Excellence.

1. INTRODUCTION

Nigeria is the largest oil producer in Africa, and its oil and gas export terminals are at the key origin of economic opportunity and environmental challenges (Adeola et al., 2022; Sakib, 2021). Global oil demand rose by 1.5% in 2024, reaching 103.84 million barrels per day, despite a 1% decline in global crude oil production, highlighting the growing energy needs amid production cuts from both OPEC and non-OPEC producers (EIA, 2025). The petroleum industry is still a key driver of the nation's economy, accounting for around 40% of the federal government's Revenues in 2021 (EITI, 2023). However, the extensive network of pipes, terminals and ports many of them along the environmentally sensitive Niger Delta is increasingly under pressure to adopt sustainable, green practices as global expectations about the environmental stewardship and decarbonization rise in port and terminal operations (Abayomi et al., 2021; Umar et al., 2021). Such innovations being worked on include electrification of port operations, digital tracking systems and low emission handling equipment, allowing increased efficiency while lessening the environmental impact of such areas (Oluwakoya, 2024). Full electrification of Nigeria's container transport and port operations could unlock up to $830 million in private investment, reduce air pollution, and enhance operational efficiencies throughout the logistics chain (Svendsen, 2025).

Regulatory reforms, such as the 2021 Petroleum Industrial Act (PIA) that gave a new impetus for the governance of Nigeria's oil and gas industry, are also influencing the push toward green port operations (JPT, 2025). For instance, the NUPRC and the NMDPRA have been given extended powers to implement laws that reduces emissions (Umukoro & Omozue, 2024).

As per Almeida and Okon (2025), combined with the regulatory measures, technological advances like automation, electrification and monitoring through digitalisation keep enabling Nigerian ports to optimise operations and reduce energy consumption and emissions. Kosmajac (2025), demonstrated in the recent milestone agreement between APM terminals Nigeria and the NPA on the electrification of container handling at Onne port-a major step toward making it a green Port. As these regulatory and technological drivers continue to converge, export terminals across Nigeria prepare for a green transition that can improve environmental performance while modernising Infrastructure and boosting global competitiveness in the world economy increasingly shaped by decarbonisation (Jacob & Umoh, 2025; Nwosu, 2025).

Nigeria's export terminals of oil and gas face the dual challenge of modernising old Infrastructure while responding to increasing global demands for environmental sustainability (Aniebo & Mogbo 2024; Theresa et al., 2025). As per Oluwakoya, (2024) and Ahmed (2025), while providing a considerable boost to the national economy, these terminals represent inefficiencies at many points, high emission levels, and outdated technologies that adversely impact operational performance and environmental compliance. The growing pressure for transition toward green port operations namely, the adoption of cleaner technologies and more stringent regulatory compliance is a multidimensional issue that stakeholders face (Ogola et al., 2025). However, although regulator frameworks such as the PIA and the establishment of regulatory bodies like NUPRC and NMDPRA represent steps in the right direction, enforcement on environmental standards remains inconsistent (Ezekwesiri & Ayo-Odewale 2025). Technologically, integration with automation, digital monitoring systems, and electrification of equipment though promise highly effective ways to reduce emission and optimise energy use is restrained by high initial investment and incomplete upgrading of infrastructures. On the other hand, there is an apparent lack of harmony between the operations of Nigeria's export terminals and the international expectation of sustainability limiting this seriously limits competitiveness in the emerging energy market (Shao et al., 2025). The core problem thus revolves around how to navigate these regulatory and technological challenges effectively for a sustainable, efficient, and competitive system of oil and gas export terminals one that balances economic growth with a strong sense of environmental responsibility (Oruwari et al., 2024).

The study is especially timely since it handles critical gaps in the current literature on green port operations, particularly in the context of oil and gas export terminals in Nigeria. Although sustainable practices in the port operation are a topic of discussion globally, there is a major gap regarding the knowledge on what exactly drives the green port adoption in the developing countries especially in Nigeria. Nigeria as the largest oil producer in Africa is in a lot of pressure to be able to go green but there is lack of empirical study that can be able to focus on how regulation and technological forces interplay within the special setting of the oil and gas export terminals in Nigeria. Further research that examines the top management commitment as a moderator and operational excellence as a mediator in adopting green ports in this

respect is little or no. Most of the previous studies have been centred on the western world or developed port environment and therefore not applicable in the exact challenges and opportunities encountered by the Nigerian ports.

The paper challenges a theoretical and research bases especially the Institutional Theory by adding two key variables which have barely been addressed and that are the moderating impact of top management commitment and mediating impact of operational excellence. Although the institutional theory focuses on the impact of external rules on the practice of organizations, it has failed to address the internal processes that may determine the success of regulatory forces. This research paper resolves this shortcoming by proposing that the top management commitment and operational excellence can be instrumental in ensuring that operational pressures that are embodied by external regulations are successfully translated into sustainable practices. Combining these internal conditions, the research undermines the established concept of regulatory compliance and emphasizes that the leadership and the efficacy of operations are the key elements that can promote green initiatives. The current research addresses a very important gap in both the theoretical and methodological knowledge about how operations of green port may be conducted in Nigeria and other developing economies and offers evidence-based recommendations to the policymakers, port operators, and other stakeholders in the industry. In addition, the results will provide viable solutions to mitigating infrastructural, regulatory, and financial challenges towards the conversion to sustainable green operations at Nigerian ports, which will eventually make Nigeria competitive in the energy market and put the country at par with global environmental standards.

2. LITERATURE REVIEW

2.1 Theoretical Framework

The Institutional Theory by DiMaggio and Powell, (1983) focuses on the impacts of the external regulatory forces on the organization practices by implying that organizations will alter themselves to fit the regulatory systems to attain legitimacy and remain in existence (Kauppi, 2022). In Nigeria, the export terminal of oil and gas, regulatory drivers, including the Petroleum Industry Act (PIA) and the recommendations of the NUPRC and NMDPRA are expected to influence the move towards green port operation (JPT, 2025). According to this theory, regulatory pressures cause organizations to adopt environmentally sustainable practices to conform to institutional expectations and avoiding being sanctioned. Nonetheless, in the circumstance of export terminals in Nigeria, such regulations are not being enforced uniformly, which compromises the efficacy of regulatory drivers. Ezekwesiri and Ayo-Odewale (2025) observed that corruption and inadequate capacity to monitor are some of the challenges that regulatory enforcing in developing countries especially in the oil and gas industry is prone to these. This contradiction challenges the strength of the regulatory drivers alone and postulates that other mediators or moderators must be introduced to support the implementation of green practices.

Although institutional theory offers some insight into the impact of regulations on regulating organizations to compliance, it fails to explain the dynamics that occur internally to determine the effectiveness of external forces (Risi et al., 2023). Top management committees are important moderators in this process because they determine the effectiveness of the organizations in implementing and meeting sustainability objectives (Kosmajac, 2025). Moreover, the connection between regulatory drivers and green port operations is mediated by operational excellence because it increases the efficiency of processes and makes certain that technological and regulatory interventions are adapted to the context of the organization (Oluwakoya, 2024). This theoretical framework questions the fact that institutional theory is simple by underlining that, although there has to be regulatory drivers, they cannot act as the only drivers of green port adoption. Internal factors like management commitment and operational efficiency should also be taken into consideration since they are relevant in converting regulatory requirements into real environmental impacts (Oruwari et al., 2024). As much as the institutional theory is used to bring up insights into the regulatory compliance, it should be coupled with internal factors like top management commitment and operational excellence to express fully the dynamics that lead to green port adoption and sustainability.

2.2 Hypothesis Development

Empirical studies such as by Muazu et al. (2021) confirm the beneficial effect of regulatory frameworks on the excellence of operations within the oil and gas industry in Nigeria with a special focus on the enterprise risk management. The research is based on a small group of subsidiaries of NNPC, however, there is no wide industry view that would enhance its applicability. On the same note, Jalundhwala and Londhe (2023) have presented the concept of operational excellence as

regulated in the Indian pharmaceutical industry, but the authors focus their study exclusively on one industry and a specific area, which might not be directly applicable to the more diverse and complex oil and gas industry in Nigeria. Eich and Friedli (2021) discovered that operational excellence is associated with positive regulatory inspection results in the pharmaceutical manufacturing industry, whereas the sample of their research is European, which does not make it applicable to the Nigerian oil terminals. The study by Bernasconi et al. (2025) show that regulatory inspections help in continuous improvement, though their results apply to pharmaceutical facilities directly, which is not directly relevant to oil and gas ports.

H1: Regulatory drivers *positively influence* ***green port operations*** *in Nigeria's oil and gas export terminals*

Empirical studies offer important perspectives on the role of regulatory drivers in operations of green ports. Regulatory pressures were found to be one of the drivers of green innovation in ports by Liu et al. (2025), and the authors noted that they influence sustainable practices. This study is strong in that it is an extensive system review in different contexts across the world but it is not very specific to particular regional application like Nigeria. Similarly, Raza (2020) discovered that regulatory pressure in short-sea shipping improves both the performance in terms of environment and economics, which highlights the positive effects of regulation. Nevertheless, the research is restricted in its attention to the European shipping, which might not be necessarily relevant to the oil and gas terminals in Nigeria. Mahmud et al. (2023) emphasized the significance of the pollution control tools and digitalization in supporting green port practice, especially in Asian ports. It shows strong analysis showing but applicable to the port of Nigerian ports because the regulatory environment is different. Deng et al. (2022) investigated the direct impact of environmental regulations on green port construction in China and their tripartite game model has shown that government-led regulation is effective.

Raza (2020), illustrates that short-sea shipping that is influenced by regulatory pressure is willing to develop green innovations, as is the case with port operations. Although the study confirms the favorable role of technological improvement in the environmental and economic performance, it is limited geographically to the European region and is therefore less applicable to the Nigerian contexts. Mahmud et al. (2023) address the subject of green port management practices implementation in Asia and find that the enablers are automation and digitalization. However, it is limited as it fails to consider the developed Asian ports, which might not have the same infrastructural issues as those of the Nigerian ports. Elhussieny et al. (2023) demonstrate that geospatial technologies could turn Egyptian ports into smart green ones, yet this case study does not fully correspond to the reality in Nigeria regarding technological implementation and enforcement of regulations.

H2: T echnological drivers *positively influence* ***green port operations*** *in Nigeria's oil and gas export terminals*

Empirical studies such as by Hasan et al. (2024) emphasize that the top management support and institutional pressures are crucial in the connection between the environment management accounting and performance. The strength of the study is its sound theoretical framework comprised of institutional theory and knowledge-based view, however, its narrowness of focus to manufacturing SMEs in Yemen limits its use to the oil and gas export industry in Nigeria. In the same vein Ali et al. (2022) examine factors that affect IT innovation adoption, among them top management support, and conclude that such factors have a positive correlation with the successful technology adoption. Although the study has provided important information about organizational factors that drive technological adoption by lacking the discussion on innovation among different global companies and failing to consider port context making it less relevant to green port operations. Zhang et al. (2023) show the influence of foreign experience of top management teams on green innovation, particularly where the environment is highly regulated. Nevertheless, they are less applicable to the oil and gas export terminals in Nigeria because they do not address the green patents of the firms and directly relate to the ports. Munim et al. (2020) relate to the topic of port governance and the adoption of green port management practices with the focus on the role of the top management.

H3: Top management committee *moderates the relationship between* ***technological drivers*** *and* ***green port operations*** *in Nigeria's oil and gas export terminals.*

Empirical studies by Nguyen et al. (2024) underline the supportive role of top management support in the impact on the environmental performance indicating management contributes a crucial role in harmonizing the activities of green practices with organizational objectives, including green training. However, it fails to provide immediate understanding of the role played by the influence of top management in flattening the relationship between regulatory drivers and environmental outcomes. The study by Zhang et

al. (2023) looks into the foreign experience of the top management teams and highlights its positive influence on green innovation in the situation of the regulatory pressure. This study indirectly advocates the fact that the decisions of the top management can facilitate the regulatory effects on green port performance. Nevertheless, it concentrates on the foreign experience that might not be directly applicable to green port operations. Munim et al. (2020) has a more expansive approach to governance, which involves multi-criteria decision-making models that are utilized to suggest models of governance in green port management. The study outlines the way the management models can be used to increase green practices and fails to address the way in which the top management in particular moderates the regulatory drivers in port situations. Hasan et al. (2024) discusses the role of top management in facilitating environmental performance with institutional pressures, suggesting that management support may mediate regulatory effects, although not directly dealing with the green operations of ports.

H4*: *Top management committee moderates the relationship between ***regulatory drivers*** and ***green port operations*** in Nigeria's oil and gas export terminals

Empirical literature such as by Hashmi and Akram (2021) bring forth the indirect role of operational performance in connecting green supply chain management to environmental as well as financial performance, and their study results contain important information on how regulatory pressures contribute to green innovation. The external pressures that are found in the study do not have a direct connection with port operations; therefore, it may not be applicable to the specific context of green ports. Although Wojkowiak and Cyplik (2020) provide a notable survey of the topic of operational excellence in the framework of sustainable development, they focus on Lean and operational enhancement but failing present an explicit relationship between these two aspects and green port operations. This implies a disconnection between implications of environmental factors in operational structures and restrict it to ports. Similarly, Nguyen et al. (2024) show that the top management support can lead to better environmental performance in the power industry in Vietnam but fails to relate it to operational excellence or green port strategies, which restricts their extrapolation to the oil and gas export industry. Munim et al. (2020) present information on governance models of green ports but dwell on multi-criteria decision-making without details on how operational excellence intermediates regulatory drivers.

H5*: *Operational excellence mediates the relationship between ***regulatory drivers*** and ***green port operations*** in Nigeria's oil and gas export terminals

Operational excellence is an important mediating position on how technological advancement is translated into effective green port operations. Liu et al. (2025) explain the role of technological drivers, including automation and digitalisation, in the enhancement of green innovation in the operation of ports. Nevertheless, the analysis does not extend to the mediation of operational excellence in this relationship, which leaves a gap in the knowledge of what goes on within the organizations to support the implementation of green practices. Mahmud et al. (2023) also note that technology has a positive effect on the efficiency of operations, which promotes sustainability, but not the concept of operational excellence as a mediator. Kosmajac (2025) argues on the significance of top management in excellence of operations, but it does not take into account the role of top management as a mediator between technology and green performance. Moreover, Oluwakoya (2024) highlights that operational excellence is central to maximizing the advantages of technological drivers to green port operations, yet does not empirically test the mediating role.

H6: *Operational excellence mediates the relationship between technological drivers and green port operations in Nigeria's oil and gas export terminals.*

2.3. Conceptual Framework

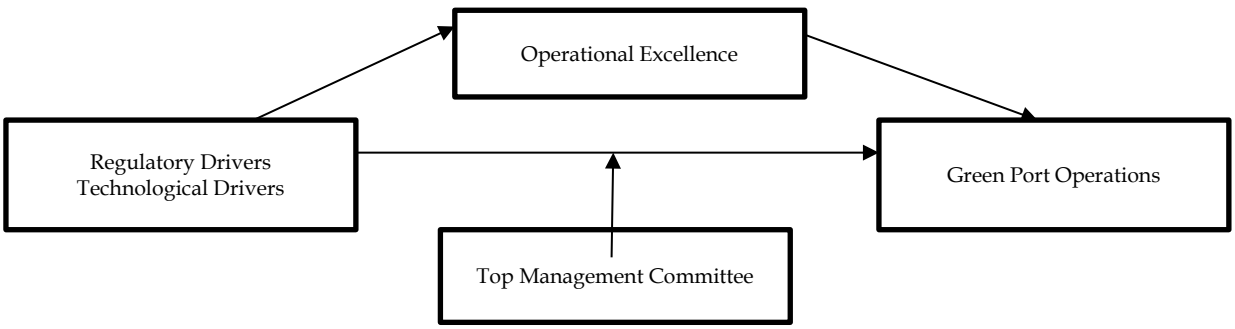

Figure 1: Conceptual Framework of Study.

The conceptual framework questions the current institutional theory because it introduces the implementation of operational excellence and top management commitment as key mediators and moderators in the interrelationship between technological and regulatory drivers and green port operations. The institutional theory mainly concentrates on the outside pressures that influence organizations to conform but the internal processes that can define the effectiveness of the same outside pressures are ignored. Kosmajac (2025) indicates that the top management is an important stakeholder in the application of sustainable practices, but this aspect is seldom discussed in the context of green port operations. Oluwakaya (2024) goes further to propose that the mediator role of operational excellence is necessary in the process of maximising the effectiveness of technological advancement and regulatory compliance. This research criticizes the simplicity of the theory of institutions by highlighting the critical internal variables mediating and moderating the external factors affecting the adoption of green ports.

3. METHODOLOGY

3.1 Research Design

The study adopted a primary quantitative research design, which assesses the relationship between regulatory and technological drivers and green port operations in Nigeria's oil and gas export terminals. The research places significant emphasis on the moderating and mediating influence of top management committees and operational excellence as mechanisms through which green port practices can be developed. The study made use of survey-based data from senior managers and key stakeholders who play a critical role in developing strategies for green practices and sustainability at Nigerian oil and gas export terminals. As per Duckett (2021) quantitative design is acceptable enabling the analysis of the correlation between variables and give solid statistical evidence on how drivers and internal factors affect green port operations.

3.2 Data Collection and Sources

Structured questionnaires were administered to senior management, environmental compliance officers, and operational staff at key Nigerian oil and gas export terminals for collecting primary data. The sample was purposely chosen so that the respondents who had direct access to decision-making related to sustainable practices at the oil and gas export terminals in Nigeria could give pertinent and informed responses. Purposive sampling was done to ensure that respondents had the relevant experience and knowledge critical to understanding the factors that influence green port operations. Data collection was conducted online using survey questionnaires circulated on platforms like LinkedIn, industry groups, and personal networks, targeting various types of respondents involved in operational management, regulatory compliance, and technology integration.

3.3 Sample Size and Calculation

The study aimed for a sample size of 384 respondents, calculated using the Cochrane formula for sample size determination, as per the study of Nanjundeswaraswamy and Divakar (2021). The formula used was:

$$n = \frac{Z^2 \, X \, p \, X \, (1-p)}{e^2}$$

$$n = \frac{1.96^2 \, X \, 0.5 \, X \, (1-0.5)}{0.05^2}$$

Where:

- n = sample size,
- Z = Z value for a 95% confidence level (1.96),
- p = estimated proportion (assumed as 0.5 for maximum variability),
- E = margin of error (0.05),

The survey was distributed to 700 participants to ensure diversity and aiming to attain the desired sample size. However, 400 respondents filled the survey attaining response rate of 57%. The data was further cleaned for missing data which led to the final sample of 380. The non-response bias was addressed in this study using the significant difference between early and late respondents as late respondents are similar in attributes to non-respondents. The insignificant difference between early and late respondent for each variable reflects that non-response bias is not an issue with this study.

3.4 Data Analysis

The data obtained was processed with the help of Partial Least Squares Structural Equation Modeling (PLS-SEM), which helps in studying the relationship between several latent variables and their interdependence at the same time. The analysis was done in two stages. The measurement model was tested in the first phase, which comprised of assessing the reliability and validity of the constructs. This involved the evaluation of the factor loading, Cronbach alpha, and composite reliability in order to warrant the soundness of the constructs. The second stage was dedicated to the structural model, the relationships between regulatory drivers, technological drivers, operational excellence, and green port operations were experimented. The significance of the paths was tested by use of bootstrapping that was used to determine the strength of the relationships. This strategy allowed a thorough analysis of the model and gave an idea of the direct and indirect impact of the variables on green port operations.

4. RESULTS

4.1 Demographics

Table 1: Demographic Profile of Respondants.

Demographic Category	Frequency	Percent	Valid Percent
Gender			
Male	275	71.6%	71.6%
Female	109	28.4%	28.4%
Age			
18-25	102	26.6%	26.6%
25-35	160	41.7%	41.7%
35-45	88	22.9%	22.9%
45 or above	34	8.9%	8.9%
Qualification			
Bachelors	192	50.0%	50.0%
Undergraduate	64	16.7%	16.7%
Masters	96	25.0%	25.0%
Diploma	32	8.3%	8.3%
Total	384	100%	100%

The demographic study of the 384 people who responded to the survey shows that the respondents are mostly males (71.6%) and few (28.4%) are females. Age-wise, the vast majority of 25-35 years old (41.7%), 18-25 years old (26.6%). The lower percentages are in the 35-45 age group (22.9%) and individuals aged 45 years and above (8.9%). This is a sign of a young and middle-aged professional population. As per qualifications, half of the respondents have a background of the Bachelor with 50%, with 25% possessing a Master. The next group of respondents (16.7% undergraduate qualifications and 8.3% diplomas) takes up the remaining part. The results are balanced in terms of gender, age, and education and might indicate that the sample is quite varied with a preference to young professionals with high education.

4.2 Measurement Model using Confirmatory Factor Analysis

Table 2: Construct Validity and Reliability.

Latent Constructs	Indicators	Factor Loadings	Cronbach's Alpha	Composite Reliability	AVE
Green Port Operations	GPO1	0.911	0.895	0.905	0.825
	GPO2	0.933			
	GPO3	0.881			
Operational Excellence	OE1	0.898	0.885	0.889	0.812
	OE2	0.929			
	OE3	0.877			
Regulatory Drivers	RD1	0.879	0.852	0.855	0.772
	RD2	0.905			
	RD3	0.851			
Technological Drivers	TD1	0.789	0.815	0.830	0.730
	TD2	0.903			
	TD3	0.867			
Top Management Commitment	TMC1	0.910	0.901	0.903	0.835
	TMC2	0.934			
	TMC3	0.898			

As per Table 1, it shows the internal consistency and stability of the measurement model, the Cronbach's Alpha and Composite Reliability values. The guideline by Cheung et al. (2024) states that values above 0.7 are said to be good internal consistency indicators. The values of Cronbach's Alpha of all constructs in this study are above the needed level, namely, Green Port Operations (GPO) 0.895, Operational Excellence (OE) 0.885, Regulatory Drivers (RD) 0.852, Technological Drivers (TD) 0.815, and Top Management Commitment (TMC) 0.901. Equally, the Composite Reliability scores lie between 0.830 and 0.905 and this is a further verification of the reliability and stability of the constructs in the study. Moreover, factor loadings greater than 0.6 signify that both indicators are strong representatives of each of their respective constructs that guarantee that constructs are both reliable and valid. This helps to increase the transparency and applicability of the measurement model to justify the strengths of the data analysis.

The extracted average variance of each construct was assessed in regard to convergent validity. According to Hair and Alamer (2022), when the value exceeds 0.5, it demonstrates that the convergent validity is good. All the constructs in this study have values of AVE that are above the threshold with the highest being in the category of Green Port Operations (0.825), Operational Excellence (0.812), Regulatory Drivers (0.772), Technological Drivers (0.730), and Top Management Commitment (0.835). Besides, all the indicators have factor loadings that exceed 0.6 meaning that the constructs are acceptable and clear. The obtained results prove the fact that the measurement model used in the given research is correct and valid, which ensures accuracy of the further data analysis.

Table 3: Discriminant Validity.

Variables	GPO	OE	RD	TD	TMC	TMC×TD
OE	0.495					
RD	0.277	0.718				
TD	0.339	0.547	0.617			
TMC	0.48	0.731	0.608	0.465		
TMCxTD	0.29	0.109	0.109	0.116	0.273	
TMCxRD	0.107	0.276	0.362	0.117	0.486	0.464
GPO= Green port operations, RD= Regulatory Drivers, TD= Technology Drivers, TMC= top management commitment, OE= Operational Excellence						

Table 2 shows the discriminant validity of the constructs in this research, through the HTMT ratio for the determination of potential multicollinearity issues as indicated by Rasoolimanesh (2022), an HTMT ratio less than 0.85 can be taken as adequate discriminant validity between constructs. From this study, the HTMT values on Green Port Operations with Operational Excellence (0.495) and Green Port Operations with Regulatory Drivers (0.277) and those of Technological Drivers with Top Management Commitment at 0.465 are far below the threshold of 0.85. These values show that the constructs are well separated and therefore not strongly correlated; this means each of the constructs contributes uniquely to the model. Also, the HTMT values of Top Management Commitment with Technological Drivers and Regulatory Drivers with values of 0.273 and 0.464, respectively, indicate that whereas there is a relationship between these constructs, they are adequately differentiated.

4.3 Structural Model

Table 4: Structural Model.

	Path Coefficient	T statistics	P values
Operational Excellence -> Green Port Operations	0.317	3.998	0.000
Regulatory Drivers -> Green Port Operations	-0.101	1.390	0.165
Regulatory Drivers -> Operational Excellence	0.525	10.530	0.000
Technological Drivers -> Green Port Operations	0.074	1.196	0.232
Technological Drivers -> Operational Excellence	0.197	3.533	0.000
Top Management Commitment -> Green Port Operations	0.280	3.523	0.000
Top Management Commitment x Regulatory Drivers -> Green Port Operations	0.170	2.808	0.005
Top Management Commitment x Technological Drivers -> Green Port Operations	-0.210	3.927	0.000
Indirect Effect			
Regulatory Drivers -> Green Port Operations	0.166	3.592	0.000
Technological Drivers -> Green Port Operations	0.062	2.889	0.004
Specific Indirect Effect			
Regulatory Drivers -> Operational Excellence -> Green Port Operations	0.166	3.592	0.000
Technological Drivers -> Operational Excellence -> Green Port Operations	0.062	2.889	0.004

The results indicate that regulatory drivers do not significantly influence green port operations (B= -0.101, P= 0.165), but they strongly enhance operational excellence (B= 0.525, P<0.001). The indirect effect of regulatory drivers on green port operations through operational excellence is significant (B= 0.166, P <0.001). It shows full mediation, reflecting regulatory drivers improve green operations only strengthening operational excellence. Technological drivers also reflects insignificant direct effect on green port operations (B= 0.074, P= 0.232), but significantly improve operational excellence (B= 0.197, P<0.001). The indirect effect through operational excellence is significant (B= 0.062, P= 0.004), reflecting full mediation as well. Top management commitment (B= 0.170, P = 0.005) significantly moderates the relationship between regulatory drivers and green port operations. Furthermore, it also significantly moderates the relationship between technology drivers and green port operations (B= -0.210, P= 0.000).

4.4 Model Explanatory Power

Table 5: Model Explanatory Power.

Variables	R-square	R-square adjusted
Green Port Operations	0.312	0.301
Operational Excellence	0.422	0.418

Table 4 provides the model explanatory power through R-squared and adjusted R-squared values for the key variables. The R-squared value for Green Port Operations is 0.312, and the adjusted R-squared is 0.301, revealing that about 31.2% of the variance in green port operations is explained by the model,

with a slight adjustment for the number of predictors. The R-squared value for Operational Excellence is 0.422, and the adjusted R-squared is 0.418, indicating 42.2% of the variance in operational excellence explained by the model with similar adjustments. These results reveal that the variables are moderately.

5. DISCUSSION

The present study aimed to investigate the effects of regulatory and technological drivers on green port operations in Nigeria's oil and gas export terminals, focusing on the moderating role of top management commitment and the mediating role of operational excellence. The findings proved that for H1, the regulatory drivers positively affect the conditions of operational excellence, which is in support of Muazu et al. (2021), who stated that regulations enhance enterprise risk management and operational efficiency. However, there are some limitations since the study conducted by Muazu et al. (2021) only appraised a small subsidiary dataset, which may not indicate the actual situation in the general context. Similarly, H2 illustrates that the regulatory drivers have a positive effect on GPOs, as has been established by Liu et al. (2025), who stated that regulation provides the key impetus that drives green innovation in ports. Nevertheless, the Nigerian context further complicates this since enforcement remains inconsistent, according to Ezekwesiri and Ayo-Odewale (2025), which might have an implication for the generalizability of those results. In addition, H3 supported the hypothesis that technological drivers have a positive impact on GPOs, similar to Mahmud et al. (2023), who established the role of automation and digitalization in enhancing green practices. Whereas these results were fairly robust, it must be remembered that the infrastructural constraints facing Nigeria, as identified by Mahmud et al. (2023), may impede the practical implementation of those technologies. The subsequent hypothesis, H4, was that Top Management Commitment serves as a moderator in the relationship between technological drivers and GPOs. This hypothesis proved valid, in line with Nguyen et al. (2024), where top management always plays a paramount role in the company for environmental support. Similarly, as Zhang et al. (2023) confirmed, management influence in this regard may vary due to experience and cultural backgrounds, which is subject to further research. Moreover, H5 and H6 substantiated the moderation and mediation roles of top management commitment and operational excellence. In turn, these findings are in line with Ali et al. (2022) and Hasan et al. (2024), who emphasized that if there is operational performance and top management support, then innovation is developed.

The research's theoretical challenge: to extend institutional theory by including the role of operational excellence and top management commitment in the adoption of green port operations. The findings confirm that both operational excellence and top management commitment are fundamental mediators and moderators, thus validating the proposed framework. The results challenge the simplicity of institutional theory by showing that regulatory drivers alone cannot sufficiently achieve sustainable practices; there is always a need for internal factors. By incorporating these internal dynamics, the study contributes to theory by offering a more nuanced understanding of how green port practices are developed. This research underlines the importance of considering both external and internal factors in issues of sustainability transitions.

The implications of this study are wide-ranging, particularly for policy, port operators, and other key stakeholders in the oil and gas export sector of Nigeria. Considering the problems that come with enforcing environmental regulations in developing economies, building the capacity of regulatory bodies like the NUPRC and NMDPRA, as well as ensuring compliance on the part of all export terminals in Nigeria, will require serious attention. In addition, this study emphasizes how technological innovation, especially automation and digitalization, can support green port operations. Policymakers should encourage such technological innovation through public-private partnerships and investments in infrastructure. Another critical implication of the present study is the role of top management in driving the adoption of sustainability practices. This suggests that top management support is not only a passive requirement but an active, key driver of change within Nigerian export terminals.

6. CONCLUSION

The findings of the study proved that regulatory and technological drivers were influencing green port operations in the Nigerian oil and gas export terminals. Consequently, it was found that regulatory and technological drivers significantly influenced operational excellence, environmental performance, and sustainability practices. Furthermore, the results indicated that top management commitment played a vital moderating role, and operational excellence

mediated the relationship between regulatory drivers and green port operations. From a regulatory point of view, the study emphasized that strong regulatory enforcement and increased technological investments are rather necessary to encourage green practices in Nigeria's oil and gas export terminals.

6.1 Policy Implications

This research had one theoretical challenge: to extend institutional theory by including the role of operational excellence and top management commitment in the adoption of green port operations. The findings confirm that both operational excellence and top management commitment are fundamental mediators and moderators, thus validating the proposed framework. The results challenge the simplicity of institutional theory by showing that regulatory drivers alone cannot sufficiently achieve sustainable practices; there is always a need for internal factors. By incorporating these internal dynamics, the study contributes to theory by offering a more nuanced understanding of how green port practices are developed. This research underlines the importance of taking into account both external and internal factors in issues of sustainability transitions.

6.2 Limitations

This research had limitations in terms of the geographical area, as the focus would be on oil and gas export terminals in Nigeria. The technological innovations to be implemented may be restricted because of infrastructural bottlenecks and financial constraints existing within the regions. Further studies could consider a wider scope for better results.

6.3 Future Implications

The specific barriers to the adoption of technology at Nigerian ports could be the subject of future research, as well as an assessment of the effectiveness of public-private partnerships in surmounting these barriers. Further, the long-term economic effects of green port operations on the oil and gas sector in Nigeria need to be studied. Research should also be directed at the influence of international regulations on Nigeria's transition to green ports.

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Appendix

Questionnaire

1. Please specify your age:

i) 18-25
ii) 25-35
iii) 35-45
iv) 45 or above

2. Please specify your Gender:

i) Male
ii) Female

3. Please specify your qualifications:

i) Bachelors
ii) Undergraduate
iii) Masters
iv) Diploma

Based on your knowledge and experience, select any one of the options given below each of the following statements.

	Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
Regulatory Drivers					
I believe that the regulations in my organization effectively encourage sustainable practices.					
I think that regulatory changes have improved my organization's operational efficiency.					
I feel that the regulations in my organization promote better environmental outcomes.					
Technological Drivers					
I find that the adoption of new technologies has made my work processes more efficient.					
I believe that technological advancements in my organization are key to improving sustainability.					
I feel that the technologies used in my organization have helped reduce operational costs.					
Operational Excellence					
I constantly seek ways to improve the efficiency of my daily tasks.					
I believe that operational excellence in my organization contributes to higher employee satisfaction.					
I feel that maintaining high operational standards is important for achieving organizational goals.					
Green Port Operations					
I believe that implementing green port practices significantly reduces the environmental impact of my organization.					
I feel that green port operations have improved the overall sustainability of my workplace.					
I think that green port initiatives have enhanced my organization's competitiveness in the market.					
Top Management Committee					
I feel that the top management team actively supports the implementation of sustainable practices in my organization.					
I believe that the top management committee effectively communicates organizational goals to employees.					
I think that the decisions made by top management significantly impact the overall success of sustainability initiatives in my organization.					