

END-OF-LIFE PRODUCTS RECOVERY PRACTICES AND SUPPLY CHAIN PERFORMANCE IN OIL AND GAS INDUSTRY IN SOUTH SOUTH

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Abstract: This study examined the relationship between End-of-Life Product Recovery Practices (EPRP) and Supply Chain Performance (SCP) among oil and gas firms in the South-South region of Nigeria, with particular emphasis on the moderating role of organizational policy. This study investigated how four dimensions of End-of-Life Product Recovery Practices (remanufacturing design, product reconfiguration, product recycling, and product redesign) influence key supply chain performance indicators, namely delivery lead time, delivery reliability, and customer satisfaction. The study adopted a quantitative research design using a survey method to collect primary data from oil and gas firms operating within the South-South region of Nigeria. The target population consisted of managers and officers involved in supply chain and operations management across selected oil and gas firms. A structured questionnaire was used as the primary data collection instrument, and a total of 276 valid responses were obtained for analysis. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine the relationships among the constructs, while descriptive statistics were conducted using SPSS software. The findings revealed that the influence of End-of-Life Product Recovery Practices on supply chain performance varies across operational dimensions. Product recycling and product reconfiguration showed significant relationships with delivery lead-time, while product redesign significantly influenced delivery reliability. In addition, product recycling and product reconfiguration demonstrated significant relationships with customer satisfaction, whereas remanufacturing design showed no significant relationship with delivery lead-time and customer satisfaction. The results also indicated that organizational policy plays a moderating role in strengthening the relationship between End-of-Life Product Recovery Practices and Supply Chain Performance, although the magnitude of the moderating effect was relatively weak. The study concludes that while End-of-Life Product Recovery Practices contribute to improving supply chain performance in the oil and gas sector, their effects are generally modest and depend largely on supportive organizational policies and effective supply chain management systems. The study recommends that oil and gas firms strengthen sustainability policies, invest in recycling and product flexibility systems, and integrate recovery practices into broader supply chain strategies in order to achieve improved operational efficiency and environmental sustainability.

Keywords: End-of-Life Product Recovery Practices, Supply Chain Performance, organizational policy, delivery lead time, delivery reliability.

Article History

Received: 20.08.2026
Revised: 11.09.2026
Accepted: 04.10.2026
Published: 26.10.2026

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Cite this article:

Enenchi, K. C., Asiegbu, I., (2026). END-OF-LIFE PRODUCTS RECOVERY PRACTICES AND SUPPLY CHAIN PERFORMANCE IN OIL AND GAS INDUSTRY IN SOUTH SOUTH. *ISAR Journal of Multidisciplinary Research and Studies*, 4(10), 13-28.

1.1 Introduction

The extractive industry remains a key driver of economic growth across the globe. In over 80 countries, it accounts for approximately one-quarter of global GDP (Enviro-literacy, 2018). While technological advances in petroleum exploration and extraction have significantly supported global energy demands, they have also generated severe environmental consequences. In regions such as Nigeria's Niger Delta, over five decades of oil exploration and production have resulted in environmental pollution, ecosystem degradation, health risks, and social inequalities (Ite & Ibok, 2013; Ite & Ite, 2012). These impacts are further aggravated by unsustainable consumption patterns, improper waste disposal, and resource overexploitation (Peñuelas, Sardans, Rivas-Ubach, & Janssens, 2012).

Initially, business organizations and industries operated with little regard for environmental implications, focusing primarily on production efficiency and profit maximization. This linear model was to extract, produce, consume, and dispose, which has historically neglected the principles of resource conservation, recycling, and reuse (Song, Wang, & Cen, 2015; Dubey *et al.*, 2019; El-Kassar & Singh, 2019). However, growing environmental awareness and global advocacy have led to the establishment of stricter environmental policies and corporate sustainability requirements (Mani *et al.*, 2016; Song & Wang, 2018). These regulatory and societal pressures have reshaped business paradigms, and has compelled organizations to embed sustainability into their operational and strategic frameworks. Supply chain management (SCM) has emerged as a central mechanism for achieving this transformation, given its critical role in integrating suppliers, manufacturers, logistics providers, and customers (Mentzer *et al.*, 2001). SCM seeks not only to enhance efficiency and responsiveness but also to foster long-term competitiveness through value creation (Sirmon, Hitt, & Ireland, 2007).

The evolution from traditional to green and sustainable supply chains represents a fundamental shift in business logic. Green Supply Chain Management (GSCM) integrates environmental considerations into every stage of the supply chain, from sourcing and production to logistics and end-of-life management (Li & Zhang, 2018; Tseng *et al.*, 2018). Within this framework, End-of-Life (EoL) product recovery also referred to as EoL logistics has emerged. End-of-Life (EoL) product recovery encompasses processes such as collection, inspection, disassembly, recycling, remanufacturing, and safe disposal of products that have reached the end of their useful life (Thierry *et al.*, 1995; Guide & Van Wassenhove, 2009). EoL recovery aligns with the circular economy philosophy, which promotes the continuous flow of materials through closed-loop systems,

which minimizes waste and maximizes resource efficiency (Yuan *et al.*, 2006; Ellen MacArthur Foundation, 2020).

The current study hopes to fill the knowledge gap in literature where there is dearth of empirical studies on remanufacturing design, and product reconfiguration as dimension of end-of-life product recovery practices, by examining the relationship between end-of-life product recovery practices and supply chain performance in the Oil and Gas Industry in South South. The perceived relationship between them is investigated in the context of organizational policy, which is an organizational factor.

1.2 Statement of the Problem

There is substantial evidence supporting the idea that supply chain performance in terms of delivery led time, delivery reliability and customer satisfaction improves overall organizational sustainability and performance. Studies (e.g., Wang & Chan, 2020; Liao & Deng, 2021; Gupta & Palsule-Desai, 2019; Jabbour *et al.*, 2020) have identified the importance of supply chain performance as a key driver of organizational competitiveness and sustainability. For example, Wang and Chan (2020) found that effective supply chain performance enhances delivery reliability, reduces lead time variability, and improves overall operational efficiency. Similarly, Gupta and Palsule-Desai (2019) emphasized that improved coordination and process efficiency within the supply chain increase customer satisfaction through consistent service delivery. Liao and Deng (2021) reported that firms with strong supply chain performance capabilities are better positioned to respond to market changes, ensuring timely deliveries and operational resilience. In addition, Jabbour *et al.* (2020) demonstrated that sustainable and well-managed supply chains contribute significantly to enhanced customer loyalty and long-term profitability.

It has been observed that the supply chain performance of many oil and gas firms operating in Rivers State remains suboptimal and below industry expectations. A case in hand is that of the major operators such as the Nigerian National Petroleum Company Limited (NNPCL) and Shell Petroleum Development Company (SPDC) have struggled with inefficiencies in their supply chain. Also, reports from the Nigerian Extractive Industries Transparency Initiative (NEITI, 2023) indicate recurring issues such as delays in crude evacuation, poor maintenance coordination, inadequate supplier integration, and weak technological adoption across the oil and gas supply chain. The current research is curious to know what could have accounted for the poor supply chain performance performance (Delivery Lead Time, Delivery Reliability and Customer Satisfaction) experienced by these Oil and Gas firms in Rivers State. Hence, our interest in this study titled "End-of-Life Product

Recovery Practices and Supply Chain Performance in the Oil and Gas Industry in South South”.

1.3 Research Hypotheses

Based on the objectives and research questions, we develop our research hypotheses;

- H₀₁:** There is no significant relationship between remanufacturing design and delivery lead time of oil and gas firms in South South.
- H₀₂:** There is no significant relationship between remanufacturing design and delivery reliability of oil and gas firms in South South.
- H₀₃:** There is no significant relationship between remanufacturing design and customer satisfaction of oil and gas firms in South South.
- H₀₄:** There is no significant relationship between product reconfiguration and delivery lead time of oil and gas firms in South South.
- H₀₅:** There is no significant relationship between product reconfiguration and delivery reliability of oil and gas firms in South South.
- H₀₆:** There is no significant relationship between product reconfiguration and customer satisfaction of oil and gas firms in South South.
- H₀₇:** There is no significant relationship between product recycling and delivery lead time of oil and gas firms in South South.
- H₀₈:** There is significant relationship between product recycling and delivery reliability of oil and gas firms in South South.
- H₀₉:** There is significant relationship between product recycling and customer satisfaction of oil and gas firms in South South.
- H₀₁₀:** There is significant relationship between product redesign relates to delivery lead time rate of oil and gas firms in South South.
- H₀₁₁:** There is significant relationship between product redesign and delivery reliability of oil and gas firms in South South.

H₀₁₂: There is significant relationship between product redesign and customer satisfaction of oil and gas firms in South South

H₀₁₃: Organizational policy as an organizational factor does not moderate the relationship between End-of-Life Product Recovery Practices and Supply Chain Performance among oil and gas firms in South South.

2.0 Theoretical Standpoints

Stakeholder Theory (Freeman, 1984). The stakeholder theory, introduced by Freeman (1984), has become a widely utilized explanatory framework in environmental sustainability literature (Sarkis et al., 2011). Various researchers have provided definitions of "stakeholder" (Mainardes, Alves & Raposo, 2011), but most adhere to Freeman's (1984) definition, which describes a stakeholder as any individual or group affected by a company's commercial activities. These stakeholders can influence or be influenced by an organization's objectives. Stakeholder theory asserts that, beyond shareholders, organizations have obligations to other individuals or groups who may be directly impacted by their actions or who have explicit contractual relationships with them (Alkhafaji, 1989).

Stakeholders expect companies to minimize negative externalities such as water pollution, solid waste, deforestation, and harmful emissions. They also expect companies to take responsibility for correcting any adverse effects caused (Alkhafaji, 1989). If an organization fails to meet these expectations, it risks losing legitimacy, which can threaten its survival. Stakeholder theory suggests that companies produce externalities impacting various stakeholders, both internal and external (Maignan & McAlister, 2003). These externalities often lead stakeholders to exert pressure on companies to mitigate negative impacts and enhance positive outcomes (Björklund, 2010). Although there are many developments and directions in stakeholder theory, its core premise remains that both internal and external groups influence organizational practices (Maignan & McAlister, 2003).

2.1 Conceptual Framework

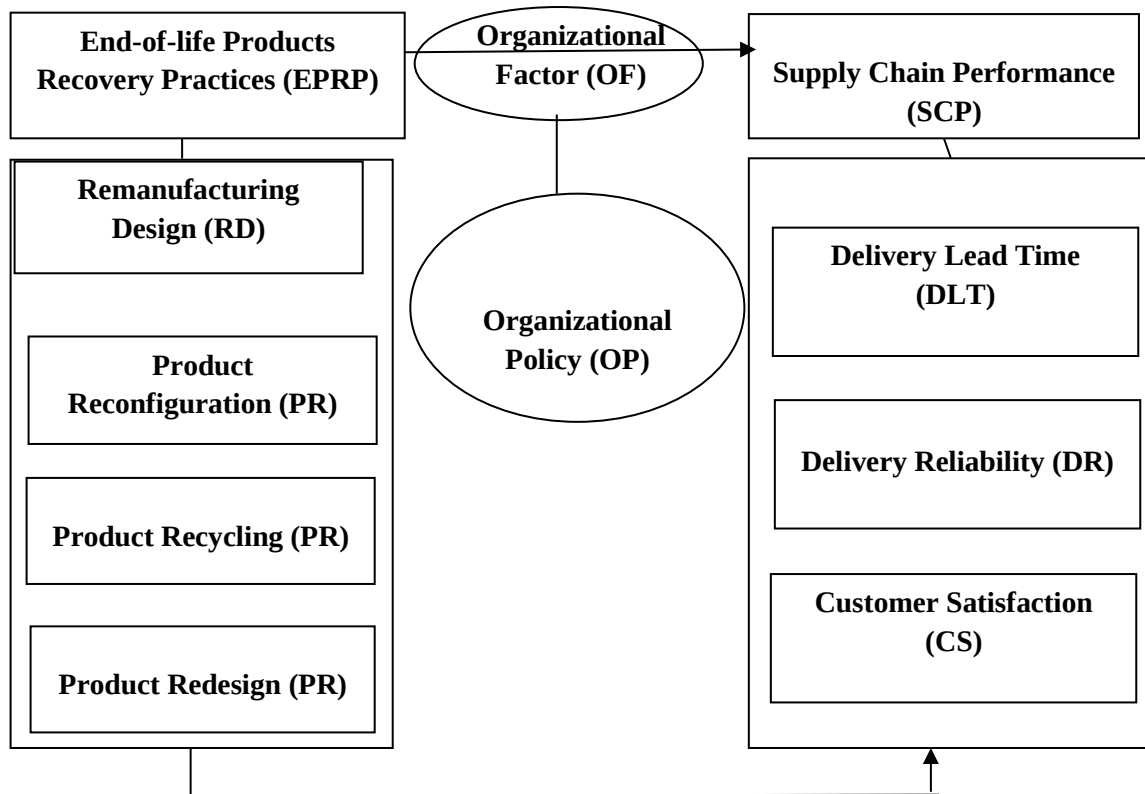


Figure 2.1: The Conceptual Framework of End-of-life Products Recovery Practices and Supply Chain Performance

Sources: Conceptualized by Enechi (2026), and dimensions of **End-of-life Products Recovery Practices** adapted from Srivastava (2008); Govindan et al. (2015); Fleischmann et al. (2000). **Measures of Supply Chain Performance** from (Min & Ko, 2008); Melo et al. (2009); Daskin (2011); Jayaraman, & Luo, (2007); Sarkis, & Zhu, (2018); Shen (2007). **Moderating role of Organizational Policy (OP)** studied previously by Li, & Olorunniwo, (2008); Cannella, et al. (2016); Tibben-Lembke, & Rogers, (2002).

2.2.1 Supply Chain Performance

Market globalization, intensifying competition, and an increasing emphasis on customer orientation are frequently cited as the catalysts for the growing interest in supply chain management (SCM) (Gunasekaran et al., 2001; Webster, 2002). Within this dynamic landscape, effective SCM is recognized as a cornerstone for achieving sustainable competitive advantage through improved inter- and intra-firm relationships (Ellinger, 2000). Supply chains encompass all activities involved in the flow and transformation of goods from raw material sources to end users (Handfield & Nichols, 1999). Numerous benefits such as cost reduction, market share growth, and enhanced customer relationships are attributed to SCM (Ferguson, 2000). However, evidence suggests that these benefits are not universally realized in practice. International studies of manufacturing practices revealed only moderate adoption and perceived effectiveness of SCM (Clegg et al., 2002).

Consequently, interest in developing robust performance measurement systems to evaluate supply chain performance has surged. Performance refers to the outputs that result from the processes of products and services that can be evaluated and compared relatively with goals, standards, past results, and other organizations (Hertz, 2007). Measuring supply chain performance facilitates a deeper understanding of supply dynamics, influences stakeholder behavior, and drives overall performance improvement (Chen & Paulraj, 2004). Neely et al. (1995) define performance measurement as the process of quantifying efficiency and effectiveness in achieving organizational goals. Effectiveness refers to the degree to which customer requirements are met, while efficiency captures the extent to which resources are economically utilized. Performance measurement systems (PMS) represent a comprehensive set of metrics used to quantify both. Several approaches to PMS exist, including the balanced scorecard (Kaplan & Norton,

1992), performance measurement matrix (Keegan et al., 1989), performance questionnaires (Dixon et al., 1990), and design criteria frameworks (Globerson, 1985). Nonetheless, these systems often suffer from limitations such as short-termism, lack of strategic focus, local optimization, and insufficient benchmarking (Neely et al., 1995). Their foundational work has since influenced numerous SCM performance studies (Beamon, 1999; Beamon & Chen, 2001; Gunasekaran et al., 2001, 2004), which indicate that many of these limitations persist in supply chain contexts.

2.2.1 Delivery Lead Time

The concept of Delivery Lead Time (DLT) has evolved significantly over the past decades, reflecting the changing paradigms of global supply chain management. Historically, DLT emerged from the classical production and inventory control literature, where it was treated primarily as a deterministic variable influencing lot-sizing, reorder points, and safety stock decisions (Zipkin, 2000). Early production models viewed lead time as fixed and predictable, emphasizing its role in internal operations rather than as a strategic factor. However, the advent of globalization and increasing supply chain complexity transformed lead time into a stochastic and multifaceted construct, prompting researchers to model it under uncertainty (Disney et al., 2007; Boute et al., 2019). During the 1990s and early 2000s, DLT gained prominence as firms embraced lean and agile manufacturing philosophies. The principles of the Toyota Production System and Just-in-Time (JIT) management underscored lead time reduction as a vital route to operational excellence (Schonberger, 2007).

2.2.1.2 Delivery Reliability

The globalization of markets and the proliferation of Just-in-Time (JIT) systems during the 1990s redefined Delivery Reliability (DR) from a narrowly operational construct into a strategic performance driver (Christopher, 2000; Naylor et al., 1999). The Toyota Production System exemplified this paradigm shift by embedding delivery reliability as a core element in supplier evaluation and partnership systems, aiming to minimize disruptions and inventory buffers (Schonberger, 2007). Consequently, delivery reliability became recognized as a function of logistics efficiency and also, as a determinant of overall supply chain competitiveness and resilience. DR is the ability of a firm or an integrated supply chain to consistently deliver products or services on or before the committed delivery date, in the right quantity and condition (Beamon, 1999; Gunasekaran et al., 2001). It reflects the degree of alignment between actual delivery outcomes and customer expectations or contractual agreements (Mentzer & Konrad, 1991; Chopra & Meindl, 2016). DR functions as an operational indicator and also, as a measure of organizational credibility and responsiveness within the broader competitive landscape

2.2.1.3 Customer Satisfaction

Customer satisfaction (CS) remains a foundational concept in logistics and supply chain management, and it represents a vital indicator of organizational success and competitiveness (Mentzer, Flint, & Kent, 2001; Anderson, Fornell, & Lehmann, 1994; Beamon, 1999). It embodies the degree to which customers perceive their expectations to have been met or surpassed by a firm's products or services (Oliver, 1980, 1997). A satisfied customer experiences a sense of consumption-related fulfillment and contentment (Oliver, 1997), positioning CS as both an outcome of service performance and a strategic driver of firm longevity. Over the decades, scholars have continuously refined the understanding of this construct (Cardozo, 1965; Anderson & Mittal, 2000; McCollough, Berry, & Yadav, 2000), yet consensus remains elusive (Giese & Cote, 2000).

2.2.2 End-of-life Products Recovery Practices

In recent decades, environmentally conscious manufacturing (ECM) and product recovery have transitioned from optional corporate practices to integral components of global sustainability agendas. Increasing environmental awareness, stringent governmental regulations, and evolving customer expectations have collectively redefined corporate responsibilities toward resource conservation and waste minimization (Gungor & Gupta, 1999; Jabbour et al., 2020). Within this paradigm, the management of products at the End-of-Life (EoL) stage has become an important determinant of environmental and economic performance. According to Kiritsis, Bufardi, and Xirouchakis (2003), an EoL product refers to an item that has been retired from functional use due to technical, economic, social, or regulatory reasons, yet retains residual value embedded in its components or materials. Earlier, Zussman, Zhou, and Caudill (1994) emphasized that such products still contain recoverable economic and ecological value, which underscores the objective of EoL product recovery which geared towards the restoration of latent value through reuse, remanufacturing, or recycling processes. This notion emerged from concerns over the unsustainable pace of energy and resource consumption (Naser et al., 2006) and the growing need to close material loops in industrial production systems (Deniz, 2002).

2.3 Empirical Review

Nnorom and Osibanjo (2010) examined electronic waste management and practices in the electronics sector in Nigeria. The study examined e-waste management challenges in developing economies, emphasizing collection efficiency and recycling practices. Collection efficiency, recycling rate, environmental risk, and regulatory compliance were the dimensions of the study. Findings revealed that inadequate collection systems and weak

recycling infrastructure hinder sustainable supply chain practices in developing countries.

Vanalle, Ganga, Godinho Filho, and Lucato, (2017) investigated green supply chain management: An investigation of pressures, practices, and performance within the Brazilian automotive supply chain. The paper aimed to explore the GSCM pressures, practices, and performance observed in suppliers of a Brazilian automotive supply chain. The data were treated using partial least squares structural equation modeling (PLS-SEM) provided by SmartPLS software. The results showed that the economic and environmental performance of the studied supply chain is positively related to the adoption of GSCM practices. In addition, the present research also identified the institutional pressures that influence this supply chain to pursue green supply chain management practices. Eco-design, green design, and green R&D were useful in this current study.

Vijayvargy, Thakkar, and Agarwal, (2017) examined green supply chain management practices and performance: the role of firm-size for emerging economies. The purpose of the paper was to investigate the impact of organizational size on the adoption of green supply chain management (GSCM) practices for the Indian industry. It also evaluated the impact of GSCM practices on organizational performance. The statistical inferences were drawn using the data provided by 161 Indian firms and were analyzed using regression. The study revealed that Indian organizations have shown a satisfactory implementation of the majority of

the environmental practices, except for supplier ISO:14001 certification and Tier-II supplier evaluation. Out of 21 practices, medium-sized organizations have adopted GSCM practices at a similar level compared with large organizations, with three exceptions: existing environmental management systems, support from mid-level and top management, and supplier evaluation for environmental practice. Eco-design and green design were adopted in this study.

Longoni, and Cagliano, (2018) studied inclusive environmental disclosure practices and firm performance: The role of green supply chain management. The paper aimed to discuss the positive effects of inclusive environmental disclosure practices that enhance GSCM practices. To test these relationships a combination of primary data on environmental disclosure practices, GSCM practices and environmental performance, and secondary data on financial performance was used. A series of hierarchical regression models were performed to test the disclosure-outcome relationships and the moderation of GSCM practices. Results provide empirical support for the impact of inclusive environmental disclosure practices on financial performance but no support for the impact on environmental performance. Specifically, the more inclusive the environmental disclosure practices the greater and positive the impact on financial performance in the presence of GSCM practices. Green manufacturing and green purchasing were adopted in the current study

2.4 Summary of Literature and Gap Analysis

Table 2.1: Empirical Literature Gap on End-of-Life Product Recovery Practices and Supply Chain Performance

S/N	Author(s) / Year of Research	Title of Work	Source of Gap: Green Training Dimension
1	Subramoniam, Huisin, & Chinnam, (2010)	Aftermarket remanufacturing strategic framework: An analysis of drivers, challenges and enablers	Strategic drivers, cost efficiency, product life extension, environmental performance
2	Nnorom, & Osibanjo, (2010)	Electronic waste management and practices in developing countries	Collection efficiency, recycling rate, environmental risk, regulatory compliance
3	Srivastava, (2011)	Green supply-chain management: A state-of-the-art literature review	Reverse logistics, recycling, eco-design, sustainable operations
4	Govindan, Palaniappan, Zhu, & Kannan, (2012)	Analysis of third party reverse logistics provider using interpretive structural modeling	Reverse logistics, outsourcing, sustainability, performance
5	Agrawal, Singh, & Murtaza, (2012)	A literature review and perspectives in reverse logistics	Product recovery, waste minimization, performance improvement, sustainability
6	Senthil, Srirangacharyulu, & Ramesh, (2013)	A decision-making model for selection of reverse logistics options using fuzzy logic	Decision-making, recycling, remanufacturing, cost-benefit analysis

3.0 Methodology

3.1 Research Design

This study focuses on examining the relationship between End-Of-Life Products Recovery Practices and Supply Chain Performance in Oil and Gas Industry in South-South geopolitical zone of Nigeria. Research design has been described as being at the very heart of scientific methodology and useful in answering practical questions or testing theoretical propositions/hypothesis. The cross-sectional design survey design was adopted in this study; which involves the systematic gathering of information from respondents for the purpose of understanding and/ or predicting some aspects of the behavior of population of interest through the use of statistical control and appropriate test statistic (Tull & Albaum 1973).

3.2 Population of the Study

The population of the study comprises all registered and operational oil and gas firms located within the South-South geopolitical zone of Nigeria. The South-South region, commonly referred to as the Niger Delta, consists of six states, namely Rivers State, Delta State, Bayelsa State, Akwa Ibom State, Edo State, and Cross River State. Major operators in the region include Nigerian National Petroleum Company Limited, Renaissance Africa Energy Company, Chevron Nigeria Limited, ExxonMobil Nigeria, TotalEnergies EP Nigeria, and Agip Oil Company, alongside numerous indigenous and multinational servicing firms. However, beyond these flagship operators, the region hosts hundreds of registered oil servicing, logistics, marine, fabrication, waste management, and engineering support firms that form the broader petroleum value chain. Accordingly, the estimated distribution of oil and gas firms across the South-South states is presented in Table 3.1.

Table 3.1: Estimated Population Distribution and Proportional Sample Allocation of Oil and Gas Firms in South-South Nigeria

State	Estimated Number of Oil & Gas Firms	Percentage of Total Population (%)	Proportional Sample Allocation (%)	Remarks
Rivers State	360	35.3%	35%	Highest concentration; operational hub
Delta State	220	21.6%	22%	Major upstream & offshore activities
Akwa Ibom State	180	17.6%	18%	Offshore production dominance
Bayelsa State	140	13.7%	14%	Core crude oil producing state
Edo State	70	6.9%	7%	Servicing & marginal fields
Cross River State	50	4.9%	4%	Emerging and servicing operations
Total	1,020	100%	100%	-

Source: Compiled from CAC (2024), NUPRC (2024), NMDPRA (2024), NCDMB Vendor Directory (2024), and NEITI Industry Reports (2023)

3.3 Sample Size Determination

Given that the estimated population of oil and gas firms in the South-South region is 1,020 firms, as established in Section 3.2, a scientific approach to sample size determination is required. For studies involving finite populations and structured questionnaires, the Taro Yamane (1967) formula is widely regarded as suitable because it provides a simplified but statistically valid method for determining sample size at a specified level of precision.

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = Sample size

N = Population size

e = Level of precision (sampling error), typically 0.05 for 95% confidence level

Since this study adopts a 95% confidence level and a margin of error of 5% (0.05), the sample size is computed as follows:

$$n = \frac{1,020}{1 + 1,020(0.05)^2}$$

$$n = \frac{1,020}{1 + 1,020(0.0025)}$$

$$n = \frac{1,020}{1 + 2.55}$$

$$n = \frac{1,020}{3.55}$$

$$n = 287.32$$

$$n \approx 287$$

Therefore, the statistically appropriate minimum sample size for this study is 287 oil and gas firms. Using a 10% non-response adjustment:

$$= 10\% \text{ of } 287 = 29$$

$$= 287 + 29 = 316$$

Thus, the adjusted sample size becomes:

$$n = 316$$

Table 3.2: Proportional Distribution of Selected Oil and Gas Firms across South-South Nigeria

State	Estimated Population of Firms	Percentage of Total Population (%)	Allocated Sample Size (Firms)
Rivers State	360	35.3%	112
Delta State	220	21.6%	68
Akwa Ibom State	180	17.6%	56
Bayelsa State	140	13.7%	43
Edo State	70	6.9%	22
Cross River State	50	4.9%	15
Total	1,020	100%	316

Source: Researcher's Computation (2026) based on CAC, NUPRC, NMDPRA, NCDMB, and NEITI records.

4.1 Results and Analysis

4.1: Presentation of Data

This section presents the data collected from respondents across selected oil and gas firms in the South-South region of Nigeria. The presentation is structured to reflect the objectives of the study, and it begins with the analysis of the

response rate, followed by the demographic characteristics of respondents, and subsequently the descriptive statistics of the study variables. The data were coded and analyzed using SPSS software for descriptive statistics, while further inferential analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM).

4.1.1 Field Work

Table 4.1: Questionnaire Distribution and Collection

	Frequency	Percentage (%)
Copies of Questionnaire Distributed	316	100
Copies of Questionnaire Retrieved	281	0.89
Copies of Questionnaire Not Retrieved	30	0.09
Copies of Questionnaire Invalid	5	0.02
Copies of Questionnaire Valid	276	0.98

Source: Author's Compilation (2026)

Table 4.1 presents the distribution and collection of questionnaires administered to respondents across the selected oil and gas firms in the South-South region of Nigeria. A total of 316 copies of the questionnaire were distributed, representing 100 percent of the intended sample size. Out of this number, 281 copies were successfully retrieved, which indicates a retrieval rate of approximately 89 percent. This high retrieval rate suggests a strong level of participation and engagement from respondents, and it reflects the effectiveness of the Google Form survey method adopted for data collection.

However, 30 copies of the questionnaire were not retrieved, representing about 9 percent of the total distributed instruments. This non-retrieval may be attributed to factors

such as respondents' busy schedules, organizational constraints, or limited follow-up compliance. Despite this, the non-response rate remains relatively low and does not significantly threaten the representativeness of the sample.

Furthermore, out of the 281 retrieved questionnaires, 5 copies were found to be invalid, accounting for approximately 2 percent. These invalid responses may have resulted from incomplete submissions, inconsistent answers, or failure to meet required response criteria. After excluding the invalid responses, 276 questionnaires were confirmed valid and suitable for analysis, representing approximately 98 percent of the retrieved copies and about 87 percent of the total distributed questionnaires.

4.2 Descriptive Data Analysis

Descriptive Statistics on the Latent Variables

Descriptive Statistics									
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
REMANUFACTURING DESIGN (RD)	276	8	70	20.51	4.692	3.785	.147	44.565	.292
PRODUCT RECONFIGURATION (PRN)	276	5	25	17.07	2.938	-1.040	.147	3.163	.292
PRODUCT RECYCLING (PRC)	276	12	25	19.33	3.722	-.429	.147	-.816	.292
PRODUCT REDESIGN (PRD)	276	12	25	19.74	3.379	-.520	.147	-.198	.292
DELIVERY LEAD TIME	276	8	25	19.75	3.451	-.843	.147	.590	.292
DELIVERY RELIABILITY (DRL)	276	7.00	25.00	19.6667	3.32557	-.889	.147	.910	.292
CUSTOMER SATISFACTION (CSN)	276	8	25	19.53	3.347	-.844	.147	.861	.292
ORGANIZATIONAL POLICY (OP)	276	7	73	19.29	5.677	5.169	.147	47.431	.292
Valid N (listwise)	276								

Source: Author's Computation (2026)

Table 4.7 presents the descriptive statistics for the latent variables examined in the study, including End-of-Life Product Recovery Practices dimensions, Supply Chain Performance dimensions, and Organizational Policy. The table reports the number of observations, minimum and maximum values, mean scores, standard deviations, as well as skewness and kurtosis statistics, and these indicators collectively provide insight into the distributional characteristics of the data.

The results show that all variables have a valid sample size of 276, which indicates that there were no missing values in the dataset for the variables included in the analysis. This strengthens the reliability of subsequent multivariate analysis.

For Remanufacturing Design (RD), the mean score is 20.51 with a standard deviation of 4.692, ($M = 20.51$, $SD = 4.692$) which suggests a moderate level of agreement among respondents regarding remanufacturing practices, although there is some variability in responses. However, the skewness value of 3.785 and kurtosis value of 44.565 indicate a highly positively skewed and leptokurtic distribution, suggesting that responses are clustered toward one end of the scale and that extreme values may be present.

Product Reconfiguration (PRN) recorded a mean of 17.07 and a standard deviation of 2.938, ($M = 17.07$, $SD = 2.938$) indicating relatively consistent responses with moderate dispersion. The skewness value of -1.040 suggests a slight negative skew, meaning responses are somewhat concentrated toward higher values, while the kurtosis value of 3.163 indicates a distribution that is more peaked than normal.

Product Recycling (PRC) has a mean of 19.33 and a standard deviation of 3.722 ($M = 19.33$, $SD = 3.722$), indicating a relatively high level of agreement and moderate

variability. The skewness value of -0.429 and kurtosis of -0.816 suggest that the distribution is fairly symmetrical and slightly platykurtic, meaning it is flatter than a normal distribution.

Similarly, Product Redesign (PRD) shows a mean of 19.74 with a standard deviation of 3.379 ($M = 19.74$, $SD = 3.379$), which reflects a generally positive perception of redesign practices among respondents. The skewness (-0.520) and kurtosis (-0.198) values indicate a fairly normal distribution with slight negative skewness.

For the Supply Chain Performance dimensions, Delivery Lead Time recorded a mean of 19.75 and a standard deviation of 3.451 ($M = 19.75$, $SD = 3.451$), while Delivery Reliability (DRL) recorded a mean of 19.67 and a standard deviation of 3.326 ($M = 19.67$, $SD = 3.326$). Customer Satisfaction (CSN) recorded a mean of 19.53 with a standard deviation of 3.347 ($M = 19.53$, $SD = 3.347$). These relatively high mean scores suggest that respondents generally perceive their firms' supply chain performance to be favorable. Additionally, the skewness values for these variables range between -0.843 and -0.889, indicating mild negative skewness, while kurtosis values remain within acceptable ranges, suggesting distributions that are approximately normal.

Organizational Policy (OP) recorded a mean of 19.29 and a standard deviation of 5.677 ($M = 19.29$, $SD = 5.677$), indicating moderate agreement but with comparatively higher variability in responses. However, the skewness value of 5.169 and kurtosis value of 47.431 indicate a highly positively skewed and extremely leptokurtic distribution, suggesting that responses are heavily concentrated at one end and that extreme values may be influencing the distribution

Measurement Model Evaluation

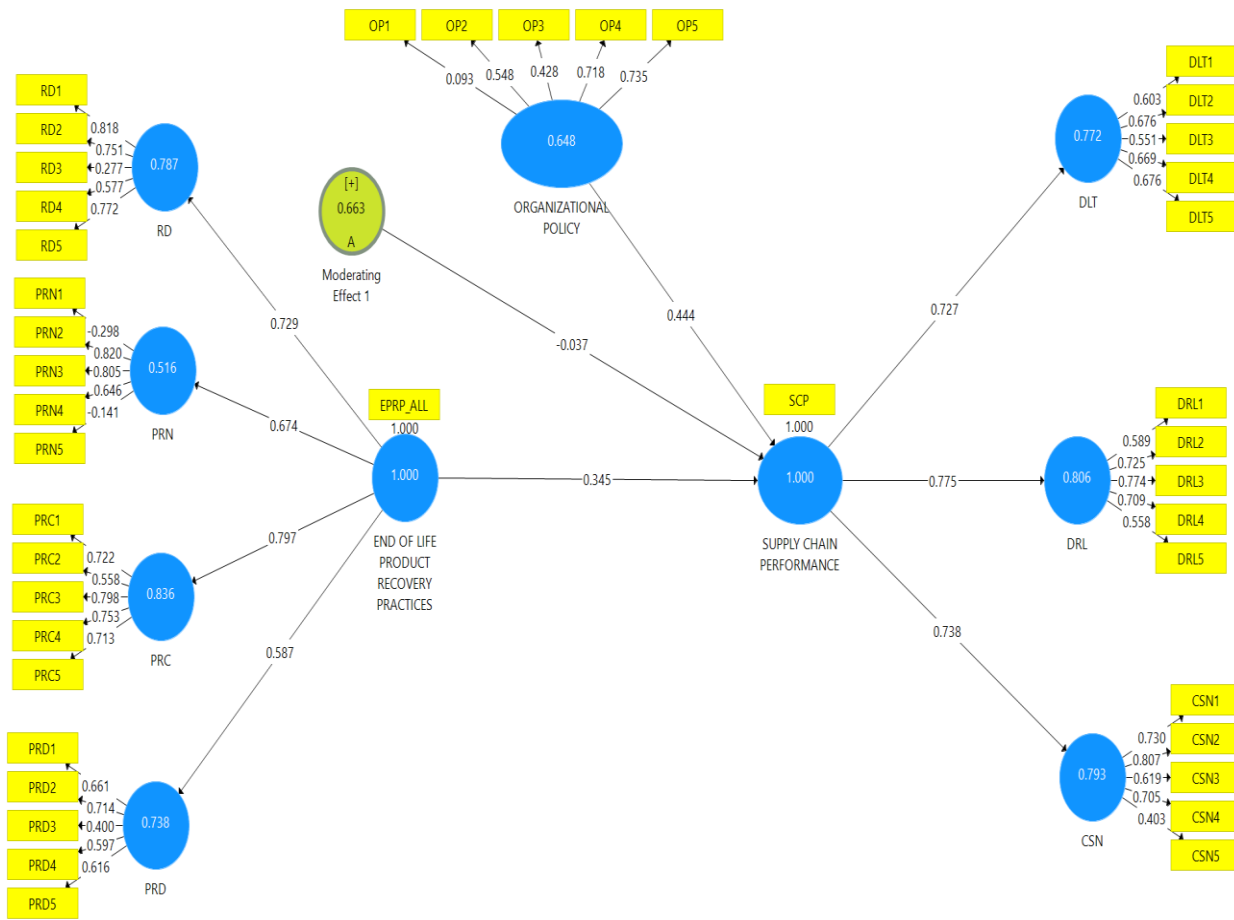


Table 4.16 presents the pre-structural diagnostics analysis using the Variance Inflation Factor (VIF) to assess multicollinearity among the measurement items and constructs prior to estimating the structural model in PLS-SEM. Multicollinearity occurs when predictor variables are highly correlated, and it can distort estimates result and weaken the stability of path coefficients. In PLS-SEM analysis, VIF values below 5.0 are generally considered acceptable, while more conservative thresholds recommend values below 3.3 to confirm the absence of critical collinearity issues.

The results in Table 4.16 show that all VIF values fall well below the critical threshold of 5.0, and most values are even below the stricter benchmark of 3.3, thereby indicating no serious multicollinearity concerns within the model. For the Customer Satisfaction (CSN) indicators, VIF values range from 1.097 to 1.519, which demonstrates low inter-item collinearity and confirms that each indicator contributes uniquely to the construct. Similarly, the Delivery Lead Time (DLT) items recorded VIF values between 1.171 and 1.351, while Delivery Reliability (DRL) items range from 1.232 to

1.503, and these values indicate that the items are sufficiently independent of one another.

The Organizational Policy (OP) indicators show VIF values between 1.008 and 1.162, which are very close to 1.0, and this suggests minimal collinearity among policy-related measures. Additionally, the interaction term “End of Life Product Recovery Practices * OP” recorded a VIF of 1.000, indicating no collinearity problem in the moderation construct. The composite constructs EPRP_ALL and SCP also recorded VIF values of 1.000, further confirming that the higher-order constructs are not affected by multicollinearity.

For the Product Recycling (PRC) items, VIF values range from 1.830 to 2.386, while Product Reconfiguration (PRN) items range from 1.033 to 2.262. Although these values are relatively higher compared to other constructs, they remain comfortably below the conservative threshold of 3.3, and therefore they do not indicate problematic collinearity. Similarly, the Remanufacturing Design (RD) indicators recorded VIF values between 1.051 and 1.653, and Product Redesign (PRD) indicators ranged from 1.174 to 1.446, all of which are within acceptable limits.

Table 4.18: Result Summary for Reflective Measurement Model of End-of-Life Product Recovery Practices

Constructs	Indicators	Convergent Validity			Internal Consistency Reliability	
		Loadings (β) (I_k)	Indicator Reliability (I_k^2)	AVE	Composite Reliability (ρ_c)	Cronbach's Alpha (α)
	Thresholds	>0.70	>0.50	>0.50	>0.70	0.70 - 0.90
Remanufacturing Design	RD01	0.886	0.759	0.500	0.81	0.790
	RD1	0.781	0.706			
	RD2	0.724	0.514			
	RD3	0.427	0.687			
	RD4	0.571	0.717			
	RD5	0.757	0.824			
Product Reconfiguration	PRN02	0.821	0.709	0.527	0.725	0.701
	PRN1	-0.142	0.821			
	PRN2	0.849	0.634			
	PRN3	0.841	0.845			
	PRN4	0.660	0.736			
	PRN5	- 0.019	0.632			
Product Recycling	PRC03	0.994	0.702	0.589	0.893	0.850
	PRC1	0.695	0.729			
	PRC2	0.532	0.766			
	PRC3	0.813	0.755			
	PRC4	0.761	0.333			
	PRC 5	0.737	0.636			
Product Redesign	PRD04	0.991	0.702			
	PRD1	0.619	0.729			
	PRD2	0.684	0.766	0.575	0.836	0.763
	PRD3	0.438	0.755			
	PRD4	0.640	0.333			
	PRD5	0.643	0.636			

Source: SmartPLS 4.1 Output of Research Data, 2026

Table 4.18 presents the result summary for the reflective measurement model of End-of-Life Product Recovery Practices (EPRP), and it evaluates the constructs in terms of convergent validity and internal consistency reliability. The assessment is based on outer loadings (β or λ_k), indicator reliability (λ_k^2), Average Variance Extracted (AVE), Composite Reliability (ρ_c), and Cronbach's Alpha (α), and the interpretation is guided by the recommended thresholds where outer loadings should be greater than 0.70, AVE should exceed 0.50, Composite Reliability should be above 0.70, and Cronbach's Alpha should fall between 0.70 and 0.90.

For Remanufacturing Design, the AVE is reported as 0.500, which meets the minimum threshold of 0.50, thereby

confirming adequate convergent validity. The Composite Reliability ($\rho_c = 0.81$) exceeds the recommended threshold of 0.70, and Cronbach's Alpha ($\alpha = 0.790$) falls within the acceptable range of 0.70 – 0.90, indicating satisfactory internal consistency reliability. Although some indicators such as RD01 ($\beta = 0.886$) and RD1 ($\beta = 0.781$) demonstrate strong loadings, others such as RD3 ($\beta = 0.427$) fall below the 0.70 threshold, suggesting weaker individual indicator contribution. However, since the overall AVE and reliability measures meet acceptable criteria, the construct demonstrates adequate measurement properties.

For Product Reconfiguration, the AVE is 0.527, which exceeds the 0.50 benchmark and confirms convergent validity. The Composite Reliability ($\rho_c = 0.725$) and

Cronbach's Alpha ($\alpha = 0.701$) both exceed the minimum acceptable threshold of 0.70, indicating acceptable internal consistency. While indicators such as PRN2 ($\beta = 0.849$) and PRN3 ($\beta = 0.841$) show strong loadings, some indicators such as PRN1 ($\beta = -0.142$) and PRN5 ($\beta = -0.019$) exhibit weak or negative loadings, which may indicate measurement inconsistencies or reverse coding issues. Nevertheless, the overall construct meets the required reliability and validity criteria.

For Product Recycling, the AVE is 0.589, which is above the required threshold of 0.50, thereby demonstrating strong convergent validity. The Composite Reliability ($\rho_c = 0.893$) and Cronbach's Alpha ($\alpha = 0.850$) both indicate high internal consistency reliability. Indicators such as PRC03 ($\beta = 0.994$) and PRC3 ($\beta = 0.813$) show very strong loadings, while other indicators also maintain acceptable values. Although some squared loadings vary, the construct overall demonstrates robust measurement quality.

For Product Redesign, the AVE is 0.575, which exceeds the minimum threshold and confirms convergent validity.

The Composite Reliability ($\rho_c = 0.836$) and Cronbach's Alpha ($\alpha = 0.763$) are both within acceptable ranges, indicating satisfactory internal consistency reliability. While indicators such as PRD04 ($\beta = 0.991$) exhibit very high loadings, others such as PRD3 ($\beta = 0.438$) show weaker contributions. However, since the AVE and reliability coefficients meet recommended standards, the construct is considered statistically reliable and valid.

Therefore, the reflective measurement model for End-of-Life Product Recovery Practices demonstrates adequate convergent validity, as all constructs report AVE values greater than 0.50, and acceptable internal consistency reliability, as Composite Reliability and Cronbach's Alpha values exceed 0.70. Although a few individual indicators display lower loadings, the aggregate construct-level statistics confirm that the measurement model satisfies the required thresholds ($\beta > 0.70$, AVE > 0.50 , $\rho_c > 0.70$, α between 0.70 and 0.90). Consequently, the EPRP constructs are deemed suitable for inclusion in the structural model analysis.

Table 4.24: Summary of the Results for the Tested Hypotheses

S/N	Hypotheses	Outcome	Extent of Relationship	Decision
1	H₀₁ : There is no significant relationship between remanufacturing design (RD) and delivery lead-time (DLT) of oil and gas firms in South-South.	$\beta = -0.082$, $t = 0.963$, $p > 0.05$	Very weak negative	Accepted
2	H₀₂ : There is no significant relationship between remanufacturing design (RD) and delivery reliability (DRL) of oil and gas firms in South-South.	$\beta = 0.122$, $t = 1.784$, $p < 0.05$	Weak positive	Rejected
3	H₀₃ : There is no significant relationship between remanufacturing design (RD) and customer satisfaction (CSN) of oil and gas firms in South-South.	$\beta = 0.063$, $t = 0.354$, $p > 0.05$	Very weak positive	Accepted
4	H₀₄ : There is no significant relationship between product reconfiguration (PRN) and delivery lead-time (DLT) of oil and gas firms in South-South.	$\beta = -0.087$, $t = 1.873$, $p < 0.05$	Weak negative	Rejected
5	H₀₅ : There is no significant relationship between product reconfiguration (PRN) and delivery reliability (DRL) of oil and gas firms in South-South.	$\beta = 0.033$, $t = 0.059$, $p > 0.05$	Very weak positive	Accepted
6	H₀₆ : There is no significant relationship between product reconfiguration (PRN) and customer satisfaction (CSN) of oil and gas firms in South-South.	$\beta = 0.045$, $t = 1.933$, $p < 0.05$	Very weak positive	Rejected
7	H₀₇ : There is no significant relationship between product recycling (PRC) and delivery lead time (DLT) of oil and gas firms in South-South.	$\beta = -0.148$, $t = 2.350$, $p < 0.05$	Weak negative	Rejected
8	H₀₈ : There is significant relationship between product recycling (PRC) and delivery reliability (DRL) of oil and gas firms in South-South.	$\beta = 0.013$, $t = 0.234$, $p > 0.05$	Very weak positive	Not Rejected
9	H₀₉ : There is significant relationship between product recycling (PRC) and customer satisfaction (CSN) of oil and gas firms in South-South.	$\beta = 0.104$, $t = 1.591$, $p < 0.05$	Weak positive	Rejected
10	H₀₁₀ : There is significant relationship between product redesign (PRD) and delivery lead time (DLT) of oil and gas firms in South-South.	$\beta = -0.003$, $t = 0.043$, $p > 0.05$	Very weak negative	Not Rejected
11	H₀₁₁ : There is significant relationship between product redesign (PRD) and delivery reliability (DRL) of oil and gas firms in South-South.	$\beta = 0.148$, $t = 2.683$, $p < 0.05$	Weak positive	Rejected
12	H₀₁₂ : There is significant relationship between product redesign (PRD) and customer satisfaction (CSN) of oil and gas firms in South-South.	$\beta = -0.057$, $t = 1.192$, $p < 0.05$	Very weak negative	Rejected
13	H₀₁₃ : Organizational policy does not moderate the relationship between End-of-Life Product Recovery Practices (EPRP) and Supply Chain Performance (SCP).	$\beta = 0.043$	Very weak positive moderation	Rejected

Source: SmartPLS 4.1 Output of Research Data (2026).

Summary of Findings

1. Remanufacturing Design and Delivery Lead Time (RD → DLT)

The study found that remanufacturing design has a weak negative and statistically insignificant relationship with delivery lead-time ($\beta = -0.082$, $t = 0.963$, $p > 0.05$). This indicates that remanufacturing design practices do not significantly influence delivery lead-time among oil and gas firms in the South-South region. Consequently, the null hypothesis was accepted.

2. Remanufacturing Design and Delivery Reliability (RD → DRL)

The results revealed a weak positive relationship between remanufacturing design and delivery reliability ($\beta = 0.122$), indicating that improved remanufacturing design practices may slightly enhance delivery reliability. However, the relationship was relatively weak, suggesting limited influence of remanufacturing design on delivery reliability in the oil and gas sector.

3. Remanufacturing Design and Customer Satisfaction (RD → CSN)

The findings showed that remanufacturing design has a very weak and statistically insignificant positive relationship with customer satisfaction ($\beta = 0.063$, $t = 0.354$, $p > 0.05$). This implies that remanufacturing design practices do not significantly improve customer satisfaction among oil and gas firms in the region.

4. Product Reconfiguration and Delivery Lead Time (PRN → DLT)

The results indicated a weak negative but statistically significant relationship between product reconfiguration and delivery lead-time ($\beta = -0.087$, $t = 1.873$, $p < 0.05$). This suggests that product reconfiguration slightly reduces delivery lead-time, indicating that flexible product structures can marginally improve operational speed.

5. Product Reconfiguration and Delivery Reliability (PRN → DRL)

The study found a very weak positive and statistically insignificant relationship between product reconfiguration and delivery reliability ($\beta = 0.033$, $t = 0.059$, $p > 0.05$). This indicates that product reconfiguration does not significantly influence delivery reliability among oil and gas firms.

6. Product Reconfiguration and Customer Satisfaction (PRN → CSN)

The results revealed a weak positive and statistically significant relationship between product reconfiguration and customer satisfaction ($\beta = 0.045$, $t = 1.933$, $p < 0.05$). This

suggests that the ability to adjust product configurations slightly improves customer satisfaction level

7. Product Recycling and Delivery Lead Time (PRC → DLT)

The findings showed a weak negative and statistically significant relationship between product recycling and delivery lead-time ($\beta = -0.148$, $t = 2.350$, $p < 0.05$). This indicates that effective recycling practices can contribute to reducing delivery lead-time by improving material availability and production continuity.

8. Product Recycling and Delivery Reliability (PRC → DRL)

The study revealed a very weak positive and statistically insignificant relationship between product recycling and delivery reliability ($\beta = 0.013$, $t = 0.234$, $p > 0.05$). This implies that recycling practices do not significantly influence delivery reliability among oil and gas firms.

9. Product Recycling and Customer Satisfaction (PRC → CSN)

The findings indicated a weak positive and statistically significant relationship between product recycling and customer satisfaction ($\beta = 0.104$, $t = 1.591$, $p < 0.05$). This suggests that firms engaging in recycling practices may experience slight improvements in customer satisfaction, possibly due to improved corporate environmental reputation.

10. Product Redesign and Delivery Lead Time (PRD → DLT)

The results showed that product redesign has a very weak negative and statistically insignificant relationship with delivery lead-time ($\beta = -0.003$, $t = 0.043$, $p > 0.05$). This indicates that redesign initiatives do not significantly influence delivery lead-time among oil and gas firms.

11. Product Redesign and Delivery Reliability (PRD → DRL)

The findings revealed a weak positive and statistically significant relationship between product redesign and delivery reliability ($\beta = 0.148$, $t = 2.683$, $p < 0.05$). This suggests that redesigning products to improve operational efficiency contributes slightly to more reliable delivery performance.

12. Product Redesign and Customer Satisfaction (PRD → CSN)

The study found a very weak negative but statistically significant relationship between product redesign and customer satisfaction ($\beta = -0.057$, $t = 1.192$, $p < 0.05$). This indicates that while redesign initiatives may improve

operational efficiency, they may slightly reduce customer satisfaction during implementation phases.

13. Moderating Effect of Organizational Policy (EPRP × OP → SCP)

The analysis further revealed that organizational policy plays a moderating role in the relationship between End-of-Life Product Recovery Practices and Supply Chain Performance ($\beta = 0.043$). Although the moderating effect is relatively weak, it indicates that supportive organizational policies enhance the effectiveness of recovery practices in improving supply chain performance outcomes such as delivery reliability, lead-time, and customer satisfaction.

5.1 Summary of Findings

This study examined the relationship between End-of-Life Product Recovery Practices (EPRP) and Supply Chain Performance (SCP) among oil and gas firms operating in the South-South region of Nigeria, with particular emphasis on the moderating role of organizational policy (OP). The study focused on four key dimensions of end-of-life product recovery practices: remanufacturing design (RD), product reconfiguration (PRN), product recycling (PRC), and product redesign (PRD) and assessed how these practices influence three major supply chain performance indicators: delivery lead-time (DLT), delivery reliability (DRL), and customer satisfaction (CSN). In addition, the study examined whether organizational policy strengthens or weakens the relationship between end-of-life product recovery practices and supply chain performance within the oil and gas industry.

The findings of the study revealed that the influence of end-of-life product recovery practices on supply chain performance varies across the different operational dimensions. In the case of remanufacturing design (RD), the results showed that remanufacturing design has a weak negative but statistically insignificant relationship with delivery lead time. This indicates that although remanufacturing design practices may contribute to operational efficiency, they do not significantly reduce delivery lead-time among oil and gas firms in the South-South region. The finding suggests that delivery speed in the oil and gas sector is more strongly influenced by logistics coordination, transportation systems, and supply chain integration than by remanufacturing design practices alone.

5.2 Conclusions

1. Specifically, Remanufacturing design does not significantly improve delivery lead time. The findings indicate that remanufacturing design has a weak negative and statistically insignificant relationship with delivery lead time. This suggests that remanufacturing-oriented design practices alone are not sufficient to reduce delivery lead time in the oil and gas sector,

where delivery speed is largely influenced by logistics coordination, transportation infrastructure, and supply chain integration.

2. Remanufacturing design contributes slightly to improving delivery reliability. The study concludes that remanufacturing design has a weak positive relationship with delivery reliability. Although the influence is relatively small, firms that adopt remanufacturing-oriented product design may experience slight improvements in the consistency and stability of delivery operations.

5.3 Recommendations

Based on the findings and conclusions of this study, the following recommendations are made:

1. Oil and gas firms should integrate remanufacturing design practices with broader supply chain management strategies such as logistics optimization, supplier coordination, and digital supply chain technologies. This integration should ensure that remanufacturing design contributes more effectively to operational efficiency and delivery performance.
2. Managers in oil and gas firms should strengthen product reconfiguration capabilities by adopting flexible manufacturing systems, modular product structures, and adaptive production processes. Such flexibility should enable firms to respond quickly to operational changes and customer demands, thereby reducing delivery lead time and improving responsiveness.
3. Oil and gas firms should invest in efficient product recycling systems and reverse logistics infrastructure in order to improve material recovery and resource utilization. Establishing effective recycling processes should help reduce dependency on external raw materials, improve production continuity, and enhance environmental sustainability.
4. Firms should incorporate product redesign strategies that emphasize standardization, modularity, and component compatibility in order to enhance delivery reliability. Redesign initiatives should be implemented carefully to ensure that operational adjustments do not disrupt production processes or negatively affect customer experiences.

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