THE SPATIO-TEMPORAL ANALYSIS OF THE SUPPLY PATTERNS OF PETROLEUM PRODUCTS IN LAGOS STATE

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Abstract

This study examines the spatial and temporal variations in the supply of petroleum products in Lagos state. Quota sampling was applied to choose 400 filling stations across 20 LGAs in Lagos State, based on proportionate-to-size sampling. The data on the fuel supplied to these sampled filling station from January 2023 to December 2023 was gathered with the use of questionnaire administered to the managers of these filling station. Descriptive Analysis of Charts, Hotspot Analysis and ANOVA were used. There is significant monthly variation in fuel distribution, with December recording the highest consumption spike ($F=18.722$, $p=0.000$). Spatial and temporal analysis of petroleum supply revealed pronounced concentration in LGAs such as Amuwo Odofin, Ikeja, Kosofe, Ajeromi-Ifelodun, Surulere, and Eti-Osa, driven by high population density, industrial activities, and strategic transport corridors. Temporal analysis revealed significant variations in the PMS distribution and consumption volumes across LGAs and the time periods variations highlighted significant monthly fluctuations, particularly during festive seasons. These findings emphasise the importance of adaptive logistical strategies, targeted infrastructure investments, and contingency planning to address seasonal fluctuations and ensure supply chain resilience. This study however recommended that temporal variations in fuel demand, particularly during festive seasons and economic peak periods, necessitate adaptive supply chain strategies. Distributors should implement flexible scheduling systems, optimise delivery routes, and establish contingency plans to address seasonal demand spikes. Government agencies should collaborate with stakeholders to forecast demand patterns accurately and proactively allocate resources.

Keywords: Hotspot Analysis, Lagos State, Petroleum products, Physical distribution, Spatial analysis.

JEL classification: R12

1. INTRODUCTION

The global petroleum industry serves as the backbone of economic development, facilitating energy supply, industrial production, and transportation (OPEC, 2013). Across the world, petroleum products serves as the primary energy source, powering industries, transportation networks, and households (OPEC, 2013; World Bank, 2023). The efficient physical distribution of petroleum products remain critical to global economic stability, industrial productivity, and energy access, while effective management of petroleum logistics ensures seamless product availability, reduces costs, minimises disruptions, and promotes energy security (Lisitsa et al., 2019; World Bank, 2023).

In Nigeria, petroleum logistics continue to face substantial and persistent challenges, including Inadequate infrastructure, infrastructural decay, over-reliance on road-based tanker transportation spatial mismatches in supply and demand, oil theft, and poor regulatory enforcement. These operational inefficiencies exacerbate fuel shortages, inflate distribution costs, and hinder economic stability. The 2023 World Bank's Logistics Performance Index ranks Nigeria and many other African countries poorly due to inadequate transport infrastructure, insufficient storage facilities, and limited adoption of digital technologies (World Bank, 2023). These challenges are not only complex, multiple but also are severe challenges, which reflect broader systemic issues in Nigeria's downstream petroleum sector. The Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA) reports that over 85% of petroleum products in Nigeria are transported by tanker trucks and this heavy reliance creates severe inefficiencies, where road infrastructure is overburdened, poorly maintained, and prone to congestion. Specifically in Lagos State where consumption is approximately 40% of the country’s petroleum products have its major routes for petroleum distribution frequently experiences gridlocks caused by tanker breakdowns and accidents, leading to delays, environmental hazards, and safety risks. Furthermore, tanker-related accidents have become a recurring issue, resulting in significant human and material losses and huge logistics bottlenecks that compromises distribution efficiency and create widespread fuel shortages.

Additional logistical challenges in Nigeria include inadequate storage facilities, poor inventory management, and supply chain disruptions. Limited depot capacities and inefficiencies in scheduling often lead to delays in product evacuation and delivery. The fuel scarcity episodes of 2022 and early 2023 emphasised these inefficiencies, as long queues at filling stations disrupted economic activities and caused hardships for businesses and households reliant on petroleum products. Moreover, the lack of real-time monitoring and digital tracking systems allows for product theft and diversion, further compounding the inefficiencies in the supply chain.

Despite the increasing severity of these distribution challenges, the application of spatial and geostatistical analysis to petroleum product distribution in Lagos State has received limited academic attention. Geostatistical methods allow for an assessment of the relationship between supply volumes and distances travelled from depots to filling stations. Such analyses are critical for identifying inefficiencies, optimising routes, and balancing supply and demand across spatial locations. However, existing studies including Ehinomen and Adeleke (2012); Badejo (2014); Nwachukwu and Chike, (2015); Badejo (2018); Bataiya (2018); Adewuyi, et al., (2021); Nwoloziri et al., (2021) and Ucheobi et al. (2024) on physical distribution challenges and petroleum logistics in Nigeria often fail to adopt spatial approaches or focus specifically on Lagos State, highlighting a significant gap in the literature.

A detailed analysis of the distributional pattern of these facilities is essential to understanding their influence on the efficiency of petroleum product transport in the state. Also, the differentiation in the locational characteristics of filling stations, such as their proximity to supply depots or high-demand areas, can create spatial inequalities in fuel supply patterns. Addressing these disparities requires understanding the geospatial analysis to optimise the placement of distribution facilities and improve logistical performance.

In that case, this study intends to investigate the spatial and temporal variations in the supply of petroleum products in Lagost state.

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1. SPATIAL INTERACTION CONCEPT OF ULLMAN

The Spatial Interaction concept, postulated and introduced by David Ullman in 1954, presents a theoretical framework to understand the flow of goods, services, and people between different locations. Ullman's theory identifies three critical factors that influence spatial interaction: complementarity, transferability, and intervening opportunities. Complementarity refers to the degree to which two places have a mutually beneficial relationship, such as the supply of products in one location meeting the demand in another. Transferability addresses the feasibility of moving goods between two places, considering the cost of transport, infrastructure, and time. The intervening opportunities relate to the alternative locations that may offer similar or better opportunities, often closer to the origin or destination, which may affect the flow of goods between locations (Rodrigue, 2013; Badejo, 2014; Oyesiku, 2021).

Globally, Ullman's Spatial Interaction theory has been widely applied to understand the complexities of goods distribution in various sectors. For instance, in the logistics of goods like petroleum, the concept helps explain why certain routes and distribution networks are more efficient than others. In countries like the United States, Canada, and the United Kingdom, where urbanization and economic activities are highly concentrated in particular regions, spatial interaction models have been applied to optimise logistics networks. A study by Rodrigue (2013) on fuel distribution in the UK emphasised that complementarity between supply and demand centres and the efficiency of transport routes can significantly reduce delivery times and improve the overall system's responsiveness to market needs. In the case of fuel, this is especially crucial, as delays and inefficiencies in the distribution process can result in fuel shortages, price hikes, and even socio-economic disruptions.

Intervening opportunities, the third component of Ullman’s theory, are particularly important in petroleum distribution, where a nearby alternative may reduce the need for long-distance transportation. In Lagos, for instance, the network of depots and filling stations may be influenced by the availability of closer alternatives or secondary suppliers that can intervene and reduce the transportation burden. According to the studies by Salisu et al, (2022); Etuk et al. (2024), the availability of alternative distribution centres, like smaller depots closer to high-demand areas in Lagos, significantly impacted the efficiency of the distribution network. This understanding of intervening opportunities highlights how changes in the location of depots, the emergence of new suppliers, or the addition of alternate routes can reshape logistics strategies in petroleum distribution.

2.2. ACCESSIBILITY CONCEPT

The accessibility concept refers to the ease of reaching a desired location or service, considering factors such as transportation infrastructure, geographic distance, and associated costs. In logistics and distribution, accessibility determines the efficiency with which goods, such as petroleum products, move through a region. The accessibility concept can be traced to the central place theory of Walter Christaller (1933) and the subsequent contributions of geographers like Brian Berry and Michael Gottdiener, who refined its application to spatial interaction and logistics (Christaller, 1966). The concept’s main focus lies in measuring how easily a certain location can be accessed from various other points within a transportation network. Accessibility is often quantified using methods like distance decay functions or gravity models, which assess how the ease of access to a location diminishes with distance or as other intervening factors, such as travel time or cost, become more pronounced.

Accessibility in Lagos is hindered by several factors, including congestion, road conditions, and spatial separation between depots and filling stations. Studies have shown that improving access to key locations, such as depots, through enhanced road networks or alternative transport modes like waterways can reduce delivery delays (Liu et al., 2016). Similarly, in cities of the Global North, enhancing accessibility in remote regions has improved logistics and fuel distribution (Holguín-Veras et al., 2020). To address these challenges in Lagos, the government is working to upgrade infrastructure and promote alternative transport methods. These measures aim to reduce congestion and improve access, ensuring efficient distribution of petroleum products and reducing costs for both suppliers and consumers. In other words, the accessibility concept is crucial for understanding physical distribution systems, particularly in urban areas like Lagos. By proper integrating and improving accessibility through better infrastructure, alternative transport modes, and spatial planning, the efficiency of petroleum product distribution can be significantly enhanced. These improvements would reduce logistical delays, lower transportation costs, and ensure a reliable supply of petroleum products to urban consumers.

2.3. LITERATURE REVIEW

The distribution of petroleum products in Nigeria has long been plagued by a range of systemic and infrastructural challenges. Ehinomen and Adeleke (2012) pointed out that factors such as low production output from government-owned refineries, widespread corruption in the oil sector, inconsistent pricing regulations, and disruptions due to industrial actions, oil bunkering, and smuggling have significantly hindered the smooth flow of petroleum products. These issues not only lead to product shortages and price volatility but also fuel public disputes over pump prices. Such inefficiencies strain both the economy and the public, while also complicating the broader task of ensuring energy security for the nation.

Further investigation into Nigeria's petroleum distribution system was conducted by Tata et al. (2016) using Geographic Information Systems (GIS). Their study revealed that the country's distribution infrastructure is grossly inadequate, with limited pipeline networks and unevenly distributed depots across the country. These inefficiencies lead to disruptions in supply chains and exacerbate fuel shortages in remote or underserved areas, hindering the overall accessibility of petroleum products. In a more specific study focused on the Federal Capital Territory (FCT) of Abuja, Aminu and Olawore (2014) explored the underlying causes of Premium Motor Spirit (PMS) scarcity. Their findings indicated that a variety of factors, including low refining capacity, poor pipeline infrastructure, pipeline vandalism, and the reliance on road transportation, were contributing to supply shortages. Notably, pipeline infrastructure was identified as the primary bottleneck, underlining the need for significant investments in enhancing the country's petroleum transportation network.

In the context of petroleum product distribution in Nigeria, although various studies have explored different aspects of the industry, a critical gap persists in understanding the spatio-temporal dynamics and regulatory challenges specific to Lagos State.

3. RESEARCH METHODOLOGY

3.1 STUDY AREA

Lagos State was created on May 27, 1967, by virtue of States (Creation and Transitional Provisions) Decree No. 14 of 1967 which restructured Nigeria's Federation into 12 States. Prior to this, Lagos Municipality was administered as a Federal Territory by the Federal Government through the Federal Ministry of Lagos Affairs as the regional authority, while the Lagos City Council governed the City of Lagos (Lagos State Government-LASG, 2024) . The State is located on the South–Western part of Nigeria, on the narrow plain of the Bight of Benin. Lying approximately on longitude 20 42'E and 32 2'E respectively, and between latitude 60 22'N and 60 2'N (Figure 1). Lagos State is bounded in the North and East by Ogun State of Nigeria, in the West by Republic of Benin, and stretches over 180 kilometers along the Guinea Coast of the Bight of Benin on the Atlantic Ocean (LASG 2024). Its territorial extent and political jurisdiction encompass the city of Lagos and the four administrative divisions of Ikeja, Ikorodu, Epe and Badagry collectively referred to as IBILE and covering an area of 358,862 hectares or 3,577 sq. km. which represents 0.4% of Nigeria's territorial land mass of 923,773 sq. km (LASG 2024).

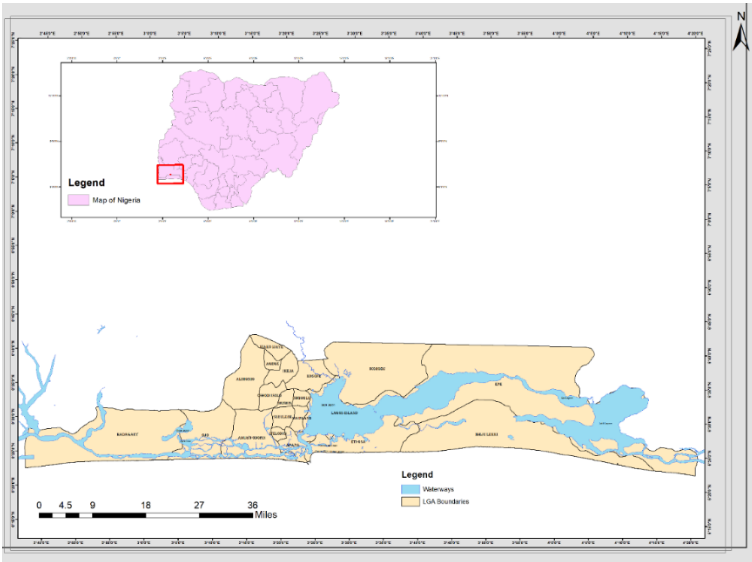

***Figure 1**: Lagos State Showing LGAs in the context of Nigeria*
Source: Author's GIS Analysis, (2024)

3.2 METHODS OF DATA COLLECTION

The data for the study were obtained both using primary and secondary data source. This study adopts a quantitative research approach to systematically analyse the spatial pattern of supply of petroleum products in Lagos state. The quantitative approach ensures objectivity, reliability, and replicability by employing standardised instruments, such as structured questionnaire survey and spatial data from GIS. This facilitates data-driven findings aligning with the study's objectives, such as analysing spatio temporal supply variations within the study area. The filling stations form a crucial component of the petroleum distribution network as the end points in the supply chain. This study leverages the total number of operational filling stations in Lagos State put at 1,747 (MOMAN, 2024). and optimization strategies within the supply chain. The quota sampling is used for the second sample unit, which consists of filling stations across Lagos State. This technique ensures that filling stations are adequately represented from all 20 local government areas. By selecting 20 filling stations from each local government area, the study ensures proportional representation across the entire state. Random sampling is then employed within each local government area to select the final set of filling stations. This final random selection guarantees that each facility has an equal chance of being included in the sample, allowing for an unbiased and comprehensive understanding of petroleum distribution points across the 20 local government areas in Lagos State, Nigeria. A total of 400 stations were sampled from the 1,747 registered stations in Lagos State, based on the Major Oil Marketers Association of Nigeria (MOMAN) 2023 report. Similarly, the sample represents 23% of the total population of filling stations. The sampling was carried out by selecting 20 stations from each of the 20 local government areas in Lagos, ensuring equitable representation across the state. Spatial variations in petroleum distribution facilities and temporal changes in the supply patterns were also analysed using ArcGIS software (Hotspot analysis). The hotspot analysis identify spatial patterns in the distribution of monthly Premium Motor Spirit (PMS) volumes received by filling stations across Lagos State. To investigate temporal variations in the supply of petroleum products, Analysis of Variance (ANOVA) was conducted to examine the variations in supply from January 2023- December 2023. This provided a clearer picture of how supply patterns varied both spatially and temporally. Hotspot analysis was conducted using the Getis-Ord Gi (Gi-star) statistic in ArcGIS. This statistical tool identifies clusters of high (hotspots) and low (cold spots) PMS volumes based on spatial dependencies. A spatial weights matrix was constructed using a fixed-distance band conceptualisation to model the spatial relationships and interactions among filling stations within a predefined radius. The monthly PMS volume attribute served as the input field for the analysis. The Gi* tool generated z-scores and p-values, which were used to statistically validate areas with significantly high or low PMS concentrations.

4. FINDINGS

The hotspot analysis results for understanding the spatial pattern of the annual PMS consumption in Lagos State reveal that hotspots are significantly concentrated in LGAs such as Amuwo Odofin, Ikeja, Kosofe, Ajeromi-Ifelodun, Surulere, Alimosho, Ojo and Eti-Osa. These areas demonstrate consistently high volumes of Premium Motor Spirit (PMS) consumption throughout the year, emphasising their strategic importance in Lagos State's fuel distribution network. The analysis shows that most filling stations in these LGAs recorded average monthly volumes ranging between 337,500 litres and 1,650,000 litres, reflecting sustained high demand across different months (Figure 2). It is worth knowing that this pattern can be attributed to several factors, including the high population density, commercial activities, industrial hubs, and strategic transport corridors present in these LGAs. Areas such as Ikeja and Amuwo Odofin serve as major commercial and industrial centres, while Surulere and Eti-Osa cater to significant residential and commercial populations. Furthermore, Ajeromi-Ifelodun and Kosofe act as key transit routes and logistics hubs, supporting fuel demand from both local commuters and inter-state transport networks.

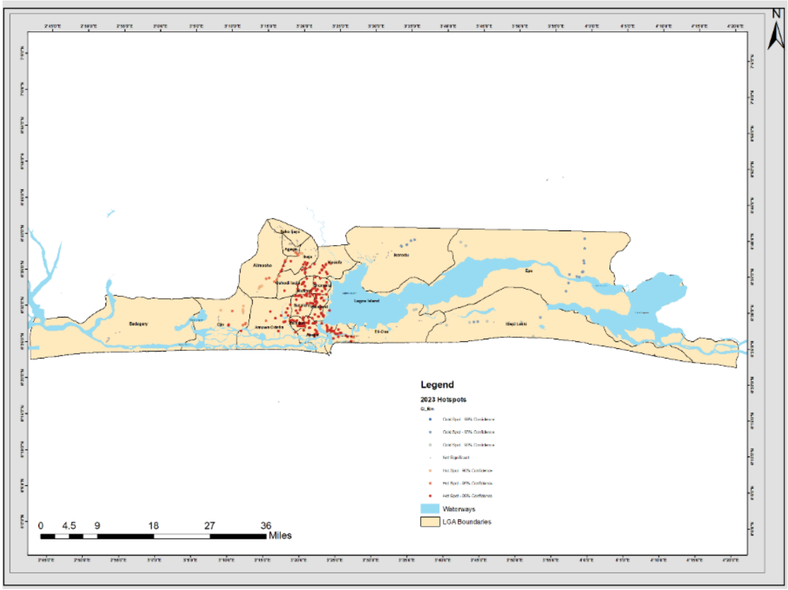

Figure 2: *Spatial Pattern of PMS Consumption in 2023 by Hotspot Analysis*
Source: Authors' Field Survey

In summarising the total volume of PMS collected by 396 filling stations in Lagos State throughout 2023, categorised into seven volume ranges. The 90,001–180,000-litre range is the most dominant, accounting for 158 stations (40.3%). These medium-capacity stations, primarily located in Ibeju-Lekki, Ifako-Ijaye, and Agege, are pivotal in serving residential, small commercial, and light industrial fuel needs, ensuring a stable supply network across diverse urban and suburban areas. The second most populated category is the 180,001–270,000-litre range includes 74 stations (20.2%), with significant representation in Ikorodu, Badagry, and Apapa. These stations cater to moderate-to-high demand areas, bridging the supply chain between smaller operations and high-capacity stations. The next is the category of less-than-90,000-litre, representing 56 stations (13.5%) with concentration in Ojo, Lagos Mainland, and Mushin. These smaller stations are essential for localised fuel access in lower-demand regions but face capacity challenges during high-consumption periods.

Higher volume ranges, including 270,001–360,000 litres (9.4%) and 360,001–450,000 litres (6.3%), are concentrated in Apapa, Amuwo-Odofin, and Eti-Osa. These stations serve high-demand economic hubs, sustaining fuel availability for industrial users and transport sectors. The highest categories, 450,001–540,000 litres (5.8%) and above 540,000 litres (5.5%), include 45 stations predominantly located in Ikeja and Lagos Mainland. These high-capacity stations are critical for stabilising supply in commercial and industrial zones, though their limited numbers highlight the need for operational expansion.

In order to assess whether there are significant differences in the volumes of petroleum products collected by filling stations across different months in 2023. The

ANOVA results in Table 4.1 show that there is a statistically significant variation in petroleum distribution across all months, with p-values consistently below the 0.05 threshold. This means that fluctuations in the volume of petroleum collected from month to month are not due to random chance, but rather reflect real changes in distribution patterns. The F-values associated with each month indicate the degree of variation, with higher values suggesting greater differences in petroleum volumes between months.

The F-values and corresponding p-values for each month show clear differences in the volume of petroleum distributed. In January, the F-value is 4.491 (p = 0.000), indicating moderate variation in fuel volumes compared to other months. February shows an F-value of 3.589 (p = 0.000), also reflecting significant variation, though slightly less than January. In March, the F-value rises to 4.643 (p = 0.000), showing a stronger variation in petroleum volumes than in February. April has a lower F-value of 3.496 (p = 0.000), suggesting that while there is still significant variation, it is less pronounced than in March. The months of May and June demonstrate particularly high variations, with F-values of 13.010 (p = 0.000) and 14.377 (p = 0.000) respectively. These months likely reflect increased fuel consumption, potentially due to seasonal demand and other economic reasons, which often leads to higher fuel consumption. Similarly, July follows with an F-value of 12.618 (p = 0.000), reinforcing the seasonal trend of increased demand during mid-year months. August shows an F-value of 11.974 (p = 0.000), with significant variation as well, although slightly less than in May and June (Table 4.1).

The trend of high variation continues into September, where the F-value is 12.615 (p = 0.000), indicating sustained fuel demand likely driven by economic activities. October has an F-value of 12.989 (p = 0.000), showing notable variation, similar to the months of peak demand. November demonstrates an even higher F-value of 14.566 (p = 0.000), reflecting increased fuel consumption, likely in preparation for the year-end holiday season. Finally, December sees the highest F-value at 18.722 (p = 0.000), which is consistent with the expected seasonal spike in fuel consumption due to increased travel, festivities, and economic activity. Overall, the results show that all months in the year exhibited significant temporal variation in fuel distribution, with December having the highest F-value (18.722) and p-value of 0.000, indicating a substantial spike in fuel demand, likely driven by the festive season. Other months with high F-values include June (14.377) and November (14.566), which also suggest periods of high fuel consumption, potentially linked to seasonal factors, holidays, and increased transportation activities. Conversely, months like January, March, and April exhibited more moderate F-values, indicating less dramatic fluctuations in fuel volumes. These findings suggest that while fuel distribution is generally stable throughout the year, certain months experience higher than usual demand, particularly during festive and summer periods, which requires filling stations and fuel distributors to plan for increased demand.

Table 1: *Significant Monthly Spatial Variation in Volume of Petroleum Product Distributed across the Study Area using ANOVA*

		Sum of Squares	Df	Mean Square	F	Sig.

Average Volume of PMS Collected January	Between Groups	4266773585323.752	19	224567030806.513	4.491	.000
	Within Groups	18850272379411.766	377	50000722491.808		
	Total	23117045964735.516	396			
Average Volume of PMS Collected Feb.	Between Groups	8639134496088.310	19	454691289267.806	3.589	.000
	Within Groups	47764922158823.520	377	126697406256.826		
	Total	56404056654911.836	396			
Average Volume of PMS Collected March	Between Groups	4390329264928.138	19	231069961312.007	4.643	.000
	Within Groups	18764217470588.234	377	49772460134.186		
	Total	23154546735516.370	396			
Average Volume of PMS Collected April	Between Groups	8927206235153.357	19	469852959744.914	3.496	.000
	Within Groups	50669955432352.940	377	134403064807.302		
	Total	59597161667506.300	396			
Average Volume of PMS Collected May	Between Groups	3552332646836.569	19	186964876149.293	13.010	.000
	Within Groups	5417860617647.059	377	14370983070.682		
	Total	8970193264483.627	396			
Average Volume of PMS Collected June	Between Groups	4458010540957.845	19	234632133734.623	14.377	.000
	Within Groups	6152716894205.883	377	16320203963.411		
	Total	10610727435163.727	396			
Average Volume of PMS Collected July	Between Groups	3724079938316.789	19	196004207279.831	12.618	.000
	Within Groups	5856102464705.883	377	15533428288.345		
	Total	9580182403022.672	396			
Average Volume of PMS Collected August	Between Groups	3963013874307.305	19	208579677595.121	11.974	.000
	Within Groups	6566878700000.000	377	17418776392.573		
	Total	10529892574307.305	396			
Average Volume of PMS Collected Sept.	Between Groups	3831776406482.442	19	201672442446.444	12.615	.000
	Within Groups	6026984379411.765	377	15986695966.609		
	Total	9858760785894.207	396			
Average Volume of PMS Collected Oct.	Between Groups	3912079618921.322	19	205898927311.649	12.989	.000
	Within Groups	5976170864705.882	377	15851912107.973		
	Total	9888250483627.203	396			
Average Volume of PMS Collected Nov.	Between Groups	4271574147999.202	19	224819691999.958	14.566	.000
	Within Groups	5818761752006.832	377	15434381305.058		
	Total	10090335900006.033	396			
Average Volume of PMS Collected Dec.	Between Groups	6284975320514.149	19	330788174763.903	18.722	.000
	Within Groups	6661141767647.059	377	17668811054.767		
	Total	12946117088161.207	396			

Source: Author's Analysis, (2024)

The results of a repeated measures ANOVA analysis, examining significant temporal variations in the volume of petroleum products collected by filling stations across Lagos State. The table includes multivariate test statistics, sphericity assumptions, tests of within-subjects effects, and tests of between-subjects effects. These metrics provide a detailed evaluation of how monthly collection volumes vary, reflecting temporal patterns and operational dynamics. The multivariate tests, which include Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root, indicate significant variation across the months. All these tests yielded an F-value of 17.947 and a significance level of $p = 0.000$. These results confirm the presence of statistically significant changes in PMS collection volumes over time, emphasising the impact of temporal factors such as seasonal demand, economic activities, and infrastructural capacity on petroleum distribution. Wilks' Lambda value of 0.662, in particular, revealed that about 33.8% of the variability in collection volumes can be attributed to temporal factors.

The Mauchly's Test of Sphericity shows a highly significant result ($\chi^2 = 5823.083$, $p = 0.000$), indicating that the assumption of sphericity was violated. Consequently, adjusted tests such as the Greenhouse-Geisser and Huynh-Feldt corrections were applied. The Greenhouse-Geisser epsilon value of 0.263 suggests substantial deviations from sphericity, requiring adjusted degrees of freedom to ensure valid conclusions (Table 4.2). The violation of sphericity assumptions and the significance of polynomial trends suggest that the factors influencing PMS collection volumes are complex and multidimensional. These could include market dynamics, regulatory interventions, infrastructural constraints, and consumer behaviour.

The within-subject effects further validate significant temporal variations. The type III sum of squares for the factor across months is 1,168,815,775,428.68, with an F-value of 4.596 under the sphericity assumption and $p = 0.000$. This implies that the differences in monthly PMS volumes are not due to random chance but are significant and impactful. Additionally, polynomial contrasts reveal that quadratic ($F = 17.200$, $p = 0.000$) and cubic ($F = 26.937$, $p = 0.000$) trends are particularly prominent, suggesting that changes in collection volumes over time are not linear but follow complex patterns influenced by multiple interacting factors. The tests of between-subjects effects show a highly significant intercept ($F = 683.640$, $p = 0.000$), reflecting consistent baseline differences in collection volumes among stations (Table 4.2). The error term for the intercept revealed substantial variability among individual filling stations, further corroborating the disparities observed in earlier presented descriptive results.

Table 2: *Significant Variation in the Petroleum Products Collected by Filling Stations using Repeated Measures of ANOVA*

Multivariate Tests[a]

		Value	F	Hypothesis df	Error df	Sig.
factor1	Pillai's Trace	.338	17.947[b]	11.000	386.000	.000
	Wilks' Lambda	.662	17.947[b]	11.000	386.000	.000
	Hotelling's Trace	.511	17.947[b]	11.000	386.000	.000
	Roy's Largest Root	.511	17.947[b]	11.000	386.000	.000

a. Design: Intercept
Within Subjects Design: factor1 b. Exact statistic

Mauchly's Test of Sphericity[a]

Mauchly's W	Approx. Chi-Square	Df	Sig.	Greenhouse-Geisser	Epsilon[b] Huynh-Feldt	Lower-bound
.000	5823.083	65	.000	.263	.265	.091

Tests the null hypothesis that the error covariance matrix of the orthonormalised transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept Within Subjects Design: factor1
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

		Type III Sum of Squares	Df	Mean Square	F	Sig.
Factor1	Sphericity Assumed	1168815775428.678	11	106255979584.425	4.596	.000
	Greenhouse-Geisser	1168815775428.678	2.890	404484062431.217	4.596	.004
	Huynh-Feldt	1168815775428.678	2.913	401220574949.212	4.596	.004
	Lower-bound	1168815775428.678	1.000	1168815775428.678	4.596	.033
Error(factor1)	Sphericity Assumed	100713689757405.530	4356	23120681762.490		
	Greenhouse-Geisser	100713689757405.530	1144.300	88013374137.130		
	Huynh-Feldt	100713689757405.530	1153.607	87303258284.804		
	Lower-bound	100713689757405.530	396.000	254327499387.388		

Tests of Within-Subjects Contrasts

factor1	Linear	85942028260.078	1	85942028260.078	1.151	.284
	Quadratic	325035213057.809	1	325035213057.809	17.200	.000
	Cubic	410711655408.566	1	410711655408.566	26.937	.000
	Order 4	80910059554.152	1	80910059554.152	4.353	.038

	Order 5	21899673273.930	1	21899673273.930	.978	.323
	Order 6	7284155938.801	1	7284155938.801	.238	.626
	Order 7	56886163340.242	1	56886163340.242	3.646	.057
	Order 8	1720533427.441	1	1720533427.441	.143	.706
	Order 9	7800108773.293	1	7800108773.293	.339	.561
	Order 10	61366606732.598	1	61366606732.598	3.542	.061
	Order 11	109259577661.777	1	109259577661.777	18.377	.000
Error(factor1)	Linear	29575394736233.066	396	74685340243.013		
	Quadratic	7483578202805.531	396	18897924754.559		
	Cubic	6037891241563.078	396	15247200104.957		
	Order 4	7360572722533.110	396	18587304854.882		
	Order 5	8866321403318.918	396	22389700513.432		
	Order 6	12124733664397.860	396	30618014304.035		
	Order 7	6178278776605.152	396	15601714082.336		
	Order 8	4768440974629.441	396	12041517612.701		
	Order 9	9103016108274.895	396	22987414414.836		
	Order 10	6861105284757.067	396	17326023446.356		
	Order 11	2354356642287.537	396	5945345056.282		

Tests of Between-Subjects Effects

	Type III Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Intercept	248654209497236.380	1	248654209497236.380	683.640	.000
Error	144033581199930.500	396	363721164646.289		

Source: Author's Analysis

5. CONCLUSIONS

Geographically, regional disparities persist, with peripheral LGAs like Epe and Badagry dominated by lower-capacity stations due to lower demand and infrastructure gaps. In contrast, central LGAs such as Ikeja and Surulere exhibit a more balanced station distribution, reflecting diverse and higher demand from residential, commercial, and industrial activities. The total annual distribution emphasised the central role of medium-capacity stations in stabilising Lagos's fuel supply. Investments in storage capacity, streamlined logistics, and supply chain enhancements for these stations would improve operational efficiency. Smaller stations require infrastructure upgrades and better connectivity to manage local demand and mitigate shortages during peak periods. The limited representation of high-capacity stations reveals a need for strategic investments in these operations, particularly in underserved or rapidly developing industrial zones. By addressing capacity disparities and improving infrastructure, Lagos State can strengthen its petroleum supply network, ensuring equitable and reliable fuel access for all areas while enhancing the system's resilience and long-term sustainability.

Furthermore, the hotspot analysis results for understanding the spatial pattern of the annual PMS consumption in Lagos State reveal that hotspots are significantly concentrated in LGAs such as Amuwo Odofin, Ikeja, Kosofe, Ajeromi-Ifelodun, Surulere, Alimosho, Ojo and Eti-Osa. These areas demonstrate consistently high volumes of Premium Motor Spirit (PMS) consumption throughout the year, emphasising their strategic importance in Lagos State's fuel distribution network. The analysis shows that most filling stations in these LGAs recorded average monthly volumes ranging between 337,500 litres and 1,650,000 litres, reflecting sustained high demand across different months (Figure 2). It is worth knowing that this pattern can be attributed to several factors, including the high population density, commercial activities, industrial hubs, and strategic transport corridors present in these LGAs. Areas such as Ikeja and Amuwo Odofin serve as major commercial and industrial centres, while Surulere and Eti-Osa cater to significant residential and commercial populations. Furthermore, Ajeromi-Ifelodun and Kosofe act as key transit routes and logistics hubs, supporting fuel demand from both local commuters and inter-state transport networks.

The implications of these findings highlight the need for enhanced fuel supply chain management and infrastructure improvements in these LGAs to ensure consistent availability and distribution efficiency. Authorities and stakeholders should consider prioritising these areas for investment in storage facilities, improved logistics, and monitoring mechanisms to prevent disruptions in supply. Additionally, strategies should include robust contingency planning to address seasonal demand surges and mitigate potential supply bottlenecks. By focusing on these high-demand regions, Lagos State can enhance fuel distribution efficiency, reduce supply shortages, and support economic and social stability across its key urban centres.

The statistical significance of the monthly differences also indicates that filling stations and distribution companies need to continuously monitor and adjust to these seasonal variations in fuel demand. Planning for peak months, such as the end-of-year festive season, is crucial to ensure that adequate supplies are available. The results further suggest that external factors like holidays, economic activity, and possibly policy changes contribute to these fluctuations. Thus, the analysis not only provides understanding into the operational realities of petroleum distribution in Lagos State but also emphasised the importance of dynamic and flexible logistical strategies to maintain a reliable and responsive supply chain throughout the year.

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