

# **INTELLIGENT TRANSPORT ROUTE DETERMINATION FOR SOLID WASTE COLLECTION IN PORT HARCOURT METROPOLITAN CITY, RIVERS STATE, NIGERIA, USING REMOTE SENSING AND GIS**

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## **Abstract**

The research was necessitated by the need to determine an optimal transport route for solid waste collection in the metropolitan city of Port Harcourt, Rivers State, Nigeria, with the aim of improving waste management practice in the city once known as the ‘garden city’ of Nigeria. The methodology involves the acquisition of relevant road network and transportation infrastructure data, as well as the collection of spatial data of approved solid waste collection points within the study area. Overlay operation was performed on the aforementioned data using ArcGIS 10.5 software. The study applied an intelligent transport system to optimize a waste collection route in the study area. The resulting waste collection route was reduced from 15.5km to 14.5km with a travel time of 3.5 hours to 2.9 hours; marking a gain of 36 minutes of an hour. The optimized route resulted in a more efficient waste collection process, with the waste collection vehicle able to cover a significant distance and pick up waste from multiple locations. The results highlight the effectiveness of an Intelligent Transport System (ITS) route optimization in reducing travel distance and time, while still covering all necessary pick-up points. The optimized waste collection route has been highly effective, covering a significant distance and collecting waste from multiple locations. This approach can potentially result in cost savings and improved waste management practice in urban areas. It was recommended that the Rivers State Waste Management Agency employ this system to optimize their waste collection routes in the future, reducing travel time and increasing efficiency.

**Keywords:** Collection, Intelligent Transport, Network Analysis, Optimal Route, Solid Waste

## **Introduction**

The World Health Organization (WHO) refers to waste as something which the owner no longer wants at a given time and space and which has no current or perceived market value. However, waste may be gaseous, liquid, or solid. Whereas gaseous and liquid wastes are free flowing and can easily migrate from one place to another, solid waste is not free flowing. Solid waste

management is defined as the application of techniques to ensure an orderly execution of various functions of collection, transportation, procession treatment and disposal of solid materials (Ayotamuno, 1997). It is a practice associated with the control of the generation, collection, storage, action transfer and transport, procession and disposal of solid waste in a manner that is in accordance with the best principle of public health, economics, engineering,

conservation, aesthetics, and other environmental considerations, and is also responsive to public attribute (Falomo, 1995).

Waste handling according to the master plan of Port Harcourt developed in 1975 involves container collection service with a maximum collection time of one week. But after about 25 years when this was implemented, the nature and the objectives of this master plan was unsustainable because of the meteoric rise in population of the city. Refuse compacting trucks and the location of containers at strategic places were proposed. Also on the plan, the establishment of one or more treatment plants, establishment of area for this purpose, the use of landfill technique and composition method due to available technologies at that time was also drawn. However, the plan failed to state in its land use proposal the size or magnitude of expected refuse in the future due to the increase in population. The master plan also did not state categorically the method(s) of disposing this waste in a more sustainable sense, (Ajie, Frank, and Ukeame, 2016).

On 27<sup>th</sup> May, 1967 Rivers State was created from the Eastern Nigeria Government, and Port Harcourt became the capital. The metropolitan city noticed a complexity in solid waste management due primarily to increased population of the city. In 1986, the Rivers State Environmental Sanitation Edict was enacted aimed at facilitating environmental sustainability. The Rivers State Government in continuation of her quest of maintaining the quality of the Earth's environment and achieve environmentally sound and sustainable development promulgated the Rivers State Refuse Collection and Disposal Law of 1991 as well as the Rivers State Environmental Protection Agency law of 1991. The River State Environmental Sanitation Authority (RSESA), a parastatal under the Rivers State Ministry of Environment was established by the Edict to manage the solid waste generated within the metropolis and its environments. One of the major works of the

RSESA is to supervise the contractors appointed by the State Government to collect and dispose municipal solid waste. The government provided places and/ or large bins at market places and at street corners and road junctions for residents to dump their household waste. The Authority contracted the supply of truck equipment and their maintenance and technical advice to a West German firm called Sulo. The initiative was good, but its implementation generated more problems. Garbage/waste from the exercise was dumped along roadsides instead of at the collection site designed by the local authorities for the purpose, (Ajie and Dienye, 2014).

The Rivers State Government in July, 2014 established by law the Rivers State Waste Management Agency (RIWAMA), a parastatal under the State Ministry of Environment. The agency is to be responsible for the enhancement of the environment with the aim of achieving positive and substantial change in living conditions as well as reducing diseases or health problems in the state. RIWAMA adopted the household bagging of waste and deposition at median of roads and/or streets of Port Harcourt from 7pm to 6am daily and subsequent collection at night. This did not give the desired result, which gave rise to the setting up of a Special Taskforce on sanitation by the Rivers State Government in 2022 to oversee the clearing of refuse in Port Harcourt and its environs. The Task-force reviewed the existing road median waste dumping approach and re-introduced the curb side method. Curbs were designated at approved locations, solid waste bagged and dumped from 7pm-6am each day. Solid waste collection and haulage from the curbs were done mainly at night using compactors. This has reduced the environmental impact of the waste on the people and tends to be more acceptable approach by the Rivers State Government, (Ajie and Dienye, 2014).

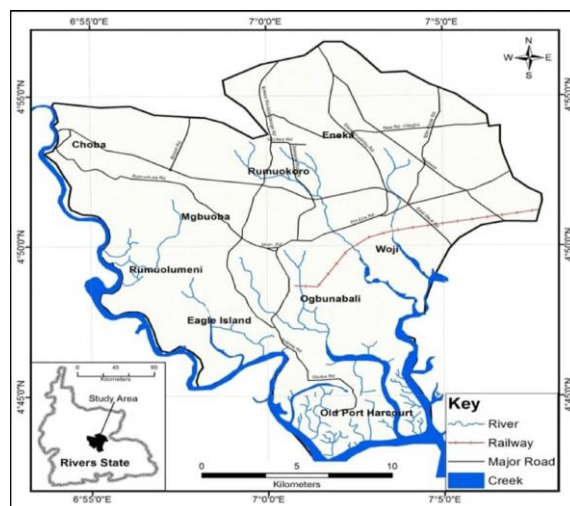
Intrinsically, there is need for the determination of an optimal route for the collection of solid waste from the designated

curb sides and their haulage to approved dump sites. An Intelligent Transport System (ITS) can play a significant role in optimizing waste collection routes to minimize costs related to waste collection. By utilizing real-time data and advanced analytics, an ITS can design efficient waste collection routes while distinguishing between the collection of residential and industrial waste. Since the study area is majorly residential and commercial areas, an ITS becomes indispensable tool to establish fixed frequencies for emptying waste bins, ensuring waste collection is carried out efficiently.

Waste collection is a vital municipal service that involves significant expenditures. However, it is a challenging operational issue to solve. An ITS can aid in waste collection by providing garbage disposal trucks with real-time data on waste bin locations, thus eliminating the tedious task of keeping track of all waste bins without a map or GPS tracker. The study optimized the initial routes being used by Rivers State waste management agency by factoring in the distance and time travelled from the starting point to the end point, with the aid of an intelligent transport system. By optimizing routes, an ITS can reduce the time and costs associated with waste collection, resulting in a more efficient waste management system.

### The Study Area

Port Harcourt is capital city of Rivers State and the headquarters of the Niger Delta Region of Nigeria. It is located within latitudes longitude  $6^{\circ} 58'$  and  $7^{\circ} 06'$  East of the Greenwich Meridian and longitude  $4^{\circ} 40'00''$  and  $4^{\circ} 55'$  North of the equator. It is bounded by Etche and Ikwerre Local Government Areas in the north, Eleme Local Government Area in the east, Emohua Local Government Areas in the west and in the south it lies along the Bonny River. The city is made of several towns, as shown in Figure 1.



**Figure 1:** Map of Port Harcourt City

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### Historical background of Solid Waste Management in Port Harcourt

From 1913 when waste generation commenced in a notable nature in Port Harcourt, standard dustbins were provided to each household with collection being disposal by vehicles. There were adequate sanitary inspectors and labourers, with the cities councils responsible for waste disposal, the final disposal was by incineration plant. The effectiveness of the Municipal Solid Waste (MSW) Management as of this period can be tagged to be a function of the little population of people (only 5,000) within the city (1915). As at this

period the environs of the city were characterized and renowned for its cleanliness and beauty and were christened as the Garden city. (Ajie, *et al*, 2016).

After the independence of Nigeria in 1960, the city of Port Harcourt was under the administration of the then Eastern Nigeria Government. The population rate noticed meteoric rise in fame as new areas were built up, some were planned and some not planned, thereby lacking access road. This led to difficulties in organizing an effective primary collection of refuse throughout the city by the usual vehicle collection strategy. Numbers of sanitation workers become minimal and inadequate to cope with increasing population and unplanned development reducing the much labelled set standard.

After the creation of the state on 27<sup>th</sup> May, 1967 from the Eastern Nigeria Government, and consequent upon the pronouncement of Port Harcourt as the capital, the populations of the city increased to about 103,000, the consumption activities that breed waste also increase as more problem on how to manage these waste were also noticed. In 1973, the proposed Diobu was prepared by Nicksons and Borys partners. So far, nothing has been done to implement this plan for the physical development of the area. According to a survey of the then prepared master plan, the approved dumpsites were very far away from residential/commercial households and most of the residents prefer dumping the waste at designated centres. But with the advent of the oil boom, the area noticed influx of population, which altered the original settings of the area, more domestic and commercial waste were produced, creating difficulties in managing them by the local authorities, (Ajie and Dienne, 2014).

During second republic (1979-1983), the management of solid waste in Port Harcourt assumed greater complexity and management imperfection as a result of rapid population increase. The government in an attempt to manage MSW appointed (5) five

environmental contractors to help manage the heap of municipal waste indiscriminate dumping. The contractors adopted management strategy of households, providing plastic dustbins in low density areas and mobile trucks in high density areas at designated locations in order to clear the waste. Collection was done three times a week costing about Eight Million Naira per (N8,000,000) annum, (Falomo, 1995). The services of the contractors were poor and so they were relieved of their responsibility in 1982, bringing back city council districts to manage waste. These councils individually were asked to set up an environmental sanitation task force to manage waste in each of their councils using mostly tippers and pay loaders for collection, transportation and disposal (Falomo, 1995).

In 1985, the Federal Government of Nigeria introduced the Environmental Sanitation Authority, whereby all residents in the country were expected to carry out a compulsory environmental clean-up from 7am to 10am at every last Saturday of each month. The War Against Indiscipline (WAI) was launched to discipline defaulters of the law. In 1986, the Rivers State Environmental Sanitation Edict was enacted and the five districts and their contractors hitherto inaugurated were dissolved and city management returned back to Port Harcourt City Council. The Rivers State Government in the course of maintaining the quality of the Earth's environment and especially achieve environmentally sound and sustainable development promulgated the Rivers State Refuse Collection and Disposal Law of 1991, as well as the Rivers State Environmental Protection Agency Law of 1991. These gave power to the State Government to create particular parastatal to manage MSW, thus eroding the functions of Local Government Council in conflict with Paragraph (h) of the Fourth Schedule of the Nigerian 1999 Constitution which maintains the status quo of management of MSW to local government authorities.

Inherently, the Edict gave rise to the establishment of the River State Environmental Sanitation Authority (RSESA), to manage the solid waste generated within the city. The RSESA provided places and/or large bins at market places and at street corners and road junctions for residents to dump their household waste. The authority contracted the supply of truck equipment and their maintenance and technical advice to a West German firm called Sulo. The outcome of this initiative generated more problems, as garbage/waste from the exercise was dumped along roadsides instead of at the designated collection site. (Ajie and Dienne, 2014).

In consonance with the failures noticed, the government thereafter adopted the “task force” approach. This approach involves- the designation of solid waste collection centres on major and public markets, and the use of local contractors/ agencies to evacuate the waste generated. This approach was later found to be counter-productive as it created more problems due to lack of coordination on the part of government and inadequate solid waste management knowledge of the responsible agencies. Littering of solid waste was noticed along roadsides and street corners, creating health concerns. (Ajie, *et al*, 2016).

Consequent upon the above, The Rivers State Government established by law the Rivers State Waste Management Agency (RIWAMA) 2014, charged with the primary responsibility of enhancing a better and sustainable environment. Thirty-Five (35) Contractors were engaged by RIWAMA to clear waste from the indiscriminate collection points along roads/streets corners in the City of Port Harcourt (see Plate 1), disposing it at either the Elioizu or the Boskel dumpsite; the only two (2) dumpsites legally approved by the Government (Ajie and Dienne, 2014).



**Plate 1:** Indiscriminate solid waste collection points at corners of roads/streets

Source: Ajie and Dienne (2014)

Contractors responsible for the collection of solid waste sometime allowed it to heap for days; blocking drains, obstructing free flow of traffic and posing great health challenges as shown in figure 10 above. Tippers and pay loaders were used for haulage of waste from the collection points to the dumpsites. Wastes were hauled along transport routes in open vehicles, thereby creating environmental hazards, as well as diminishing the aesthetical value of the city. Waste management in Port Harcourt during this period can be best described as waste transfer from area of generation to area of suffering, (Ajie and Dienne, 2014).

In 2017, RIWAMA diversified their strategy and adopted the household bagging of waste and deposition at median of roads and/or streets of Port Harcourt from 7pm to 6am daily and subsequent collection at night. Presence of piles of refuse was seen dotting medians of roads, creating environmental problems and transportation challenges. Solid waste collection and haulage were carried out mainly at night using compactors. Waste haulage still poses health hazard to the general public. Aesthetical nature of Port Harcourt deteriorates at night as a result of presence of heaps of refuse along street/road medians. This is as illustrated in Plate 2.



**Plate 2:** Waste deposition at median of roads/streets

Source: Researcher’s field work (2017)

The Rivers State Government in 2022 set up a five-man Taskforce on sanitation to oversee the clearing of refuse in Port Harcourt and its environs. The Task force reviewed the existing road median waste dumping approach and re-introduced the curb side method (see Plate 3). Curbs were designated at approved locations, solid waste bagged and dumped from 7pm-6am each day. Collection of the waste from the curbs is done by designated contractors, using compactors, (see plate 4).

In enforcing this, municipal inspectors are appointed to issue ensure compliance.



**Plate 3:** Solid waste curbs

Source: Researcher’s field work (2023)



**Plate 4:** Solid waste haulage using compactors.

Source: Researcher’s field work (2023)

### Materials and Methods

The list and locations of the solid waste collection points were received from the Rivers State Waste Management Agency (RIWAMA). Coordinates of these points were observed and abstracted using Garmin 76 Handheld GPS configure in Universal Traverse Mercator (UTM) System of World Geodetic System of 1984 (WGS-84) Datum under zone 32N. The observations were done with clear air visibility to ensure obtaining GPS observations with good accuracy (Dilute of Precisions). The Easting and Northing coordinates observed were carefully recorded and automatically saved in the waybill of the GPS. The data requirement for the research also includes road network data and digital globe imagery. An overlay operation, using ArcGIS 10.5 software was performed on the abstracted data.

### Route optimization

Route optimization was achieved through the steps as shown in Figure 2.

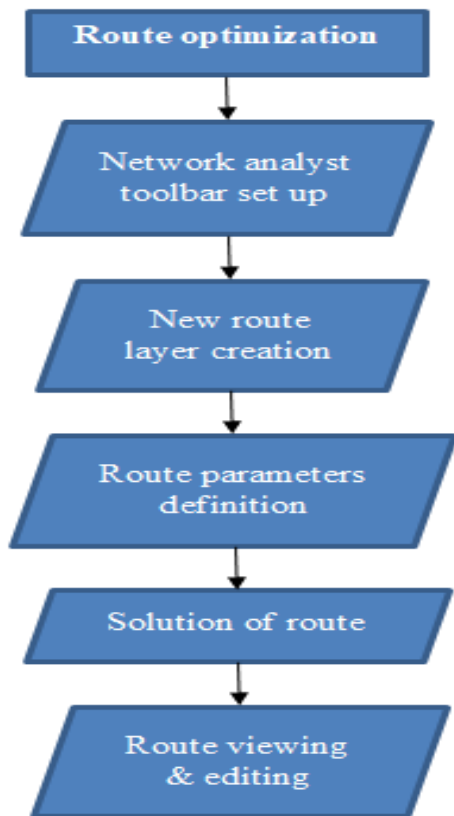


Figure 2: Route optimization flowchart.

Results and Discussion

The study optimized the initial routes being used by Rivers State waste management agency by factoring in the distance and time travelled from the starting point to the end point, with the aid of an intelligent transport system. By optimizing routes, an ITS can reduce the time and costs associated with waste collection, resulting in a more efficient waste management system. The results are shown in Figures 3 and 4.

The initial waste collection route covered four pick up points with a total travel distance of 15.5km and a time travel of 3.5hours. Covering Aba Expressway, Market Road, Rumuola Road, Ikwerre Road, Orazi Road, Tombia Road, and terminating 201.9m off Sani Abacha Road. This is illustrated in Figure 3.

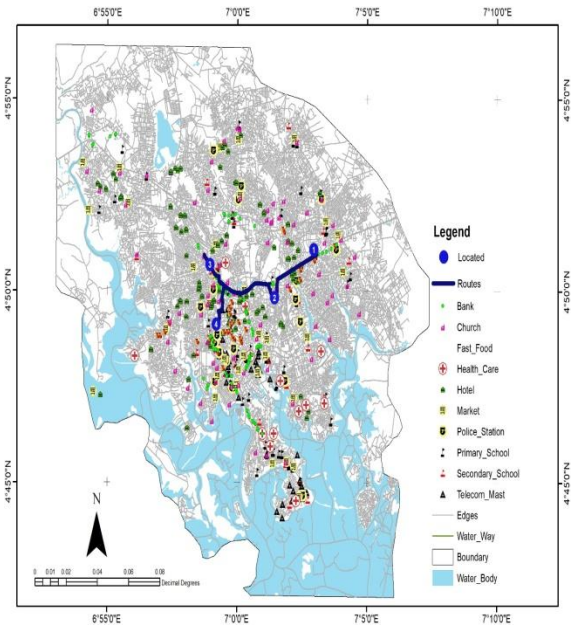


Figure 3: Initial Waste Transportation Route

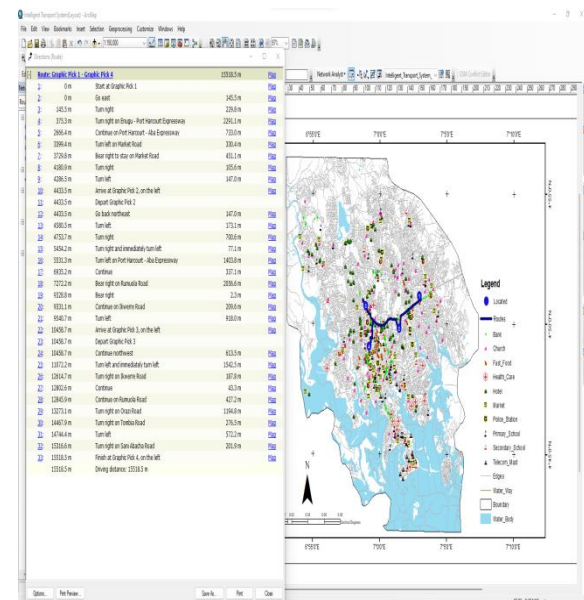


Figure 4: Initial Driving Distance

Based on the optimized waste collection route presented in Figure 5, the waste collection vehicle was able to cover a total travel distance of 14.5km and complete the task in 2.9 hours. The collection route comprised of four pick-up points, along the Port Harcourt – Aba Expressway, and Market Road. However, the vehicle deviated from the main route by taking Uyo Street and turning left on Stadium Road before reconnecting with Port Harcourt – Aba Expressway. From there, it made a right turn on Rumuola Road, went right and continued

on Ikwerre Road, Orazi Road, Tombia Road, and finally terminated 842.3 meters off Sani Tombia Road. Overall, the waste collection vehicle was able to cover a significant distance and pick up waste from multiple locations, highlighting the effectiveness of the optimized collection route. This is illustrated in Figure 5.

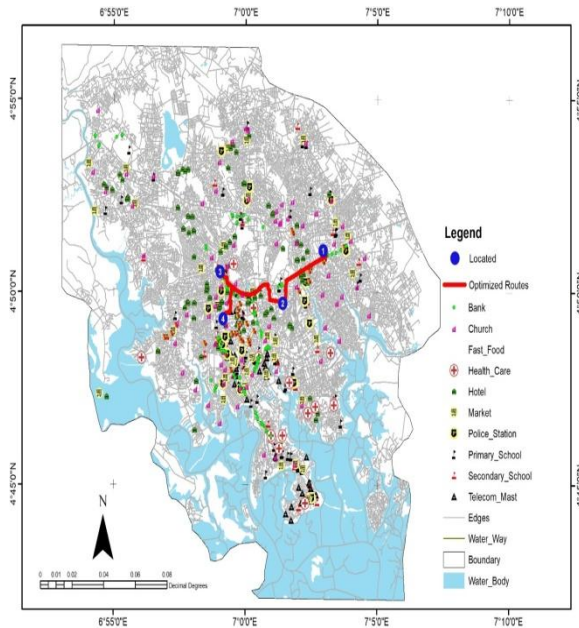


Figure 5: Optimized waste transportation route

The study conducted an analysis of the waste collection route in Port Harcourt and compared the results before and after the implementation of an intelligent transport system (ITS) route optimization. The initial waste collection route covered four pick-up points, which resulted in a total travel distance of 15.5km and a time travel of 3.5 hours. This route covered several major roads, Port Harcourt – Aba Expressway, Market Road, Rumuola Road, Ikwerre Road, Orazi Road, Tombia Road, and terminated 201.9m off Sani Abacha Road.

However, after the implementation of the optimized waste collection route, the waste collection vehicle was able to cover a shorter distance of 14.5km and complete the task in a shorter time of 2.9 hours. The optimized collection route also included four pick-up points, including Port Harcourt – Aba Expressway, and Market Road. The route deviation involved taking Uyo Street and turning left on Stadium Road before reconnecting with Port Harcourt – Aba Expressway. From there, it made a right turn on Rumuola Road, went right and continued on Ikwerre Road, Orazi Road, Tombia Road, and finally terminated 842.3 meters off Sani Tombia Road. This is illustrated in Figure 6.

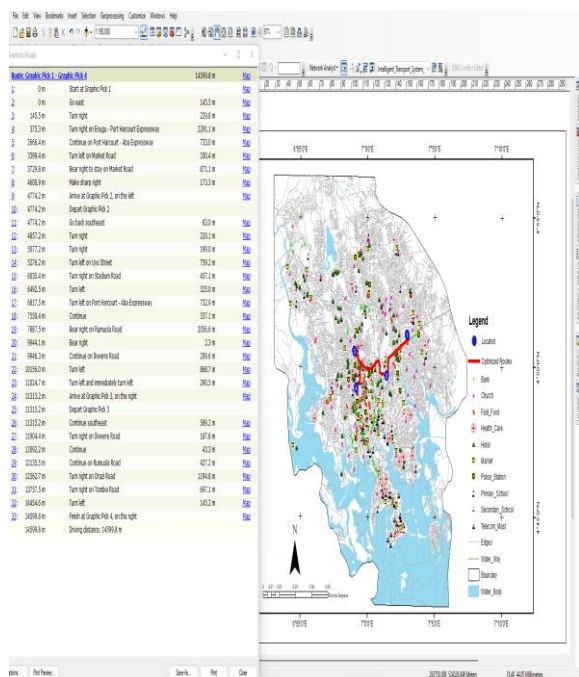


Figure 6: Optimized Driving Distance

## Conclusion and Recommendation

### Conclusion

The deployment of intelligent transport system for route optimization has resulted in a more efficient waste collection process, with the waste collection vehicle able to cover a significant distance and pick up waste from multiple locations. The results highlight the effectiveness of an ITS route optimization in reducing travel distance and time, while still covering all necessary pick-up points. This approach can potentially result in cost savings and improved waste management practices in urban areas. The results have demonstrated that the intelligent transport system can significantly improve the efficiency and effectiveness of transportation services in the city. It can help to minimize travel distances, reduce travel



time, and increase service quality, resulting in cost savings, and improved customer satisfaction.

Conclusively, the development of an intelligent transport system using remote sensing and GIS has the potential to revolutionize transportation services in Port Harcourt City, making it more efficient, effective, and sustainable

### **Recommendation**

The study reveals that the optimized waste collection route has been highly effective, covering a significant distance and collecting waste from multiple locations. It is recommended that the Rivers State Waste Management Agency (RIWAMA) can use this system to optimize their waste collection routes in the future, reducing travel time and increasing efficiency.

### **Reference**

- Ajie, U. E, Frank, B. M. and Ajie, V. U. (2016). Solid Waste Management System of Port Harcourt Metropolis from the experience of ages to the realities of the presence and the hope for tomorrow. *Proceeding of the Maiden Conference of the School of Environmental Sciences, Captain Elechi Amadi Polytechnic, Rumuola, Port Harcourt.* pp 26-42.
- Ajie U. E and Dienye A. S. (2014). Spatial data analysis of Solid Waste Management System in Port Harcourt Metropolis after 100 years of its existence. *A peer reviewed paper presented during the XXV FIG Working Week/Conference, Kuala Lumpur, Malaysia.*
- Ayotamuno M. J. (1997). Housing situation in Port Harcourt with reference to waterfront settlements. *Journal of the Environmental Education & Information, 16(2), 151-8.*
- Falomo, A. A. (1995). City waste as a public nuisance. *Presented at the Annual Conference of the Nigerian Society of Environment, Lagos.*